FINAL REPORT

Evaluation of Service Life of Noise Barrier Walls in Illinois

Project IIB-H1, FY 1997

Report No. ITRC FR 97-3

Prepared by

D.H. Kay, S.M. Morgan, and S.N. Bodapati
School of Engineering
Southern Illinois University at Edwardsville
Edwardsville, Illinois

November 1999

Illinois Transportation Research Center
Illinois Department of Transportation

ILLINOIS TRANSPORTATION RESEARCH CENTER

This research project was sponsored by the State of Illinois, acting by and through its Department of Transportation, according to the terms of the Memorandum of Understanding established with the Illinois Transportation Research Center. The Illinois Transportation Research Center is a joint Public-Private-University cooperative transportation research unit underwritten by the Illinois Department of Transportation. The purpose of the Center is the conduct of research in all modes of transportation to provide the knowledge and technology base to improve the capacity to meet the present and future mobility needs of individuals, industry and commerce of the State of Illinois.

Illinois Transportation Research Center Members

Reports may be obtained by writing to the administrative offices of the Illinois Transportation Research Center at 200 University Park, Edwardsville, IL 62025 [telephone (618) 650-2972], or you may contact the Engineer of Physical Research, Illinois Department of Transportation, at (217) 782-6732.

Technical Report Documentation Page

1. Report No. ITRC FR 97-3	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of Service Life of Noise Barrier Walls in Illinois		5. Report Date November 1999
		6. Performing Organization Code
		8. Performing Organization Report No.
7. Author(s) Dianne H. Kay, Susan M. Morgan, and S.N. Bodapati		
9. Performing Organization Name and Address Southern Illinois University Edwardsville School of Engineering Campus Box 1800 Edwardsville, IL 62026-1800		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. IIB-H1, FY 97
12. Sponsoring Agency Name and Address Illinois Transportation Research Center 200 University Park Drive Edwardsville, IL 62025		13. Type of Report and Period Covered Final Report September 1997 through January 1999
		14. Sponsoring Agency Code

15. Supplementary Notes

16.

The scope of this project included: development of a means to quantify the service lives of materials used for construction of noise barriers in Illinois; development of a life cycle cost model for the evaluation of alternative materials; and evaluation of the need for potential changes to the Special Provisions for noise barrier construction currently used in Illinois. The project included a survey of all state DOTs to develop information on experiences with noise barrier materials and products, which showed that nationwide, less than 1% of noise barriers by length have been repaired or replaced, and that few DOTs use life cycle cost analysis (LCCA) for selection of noise barriers. A comprehensive list of the materials currently approved for use in Illinois by the Illinois Highway Development Council was developed. The current condition of existing Illinois noise barriers was assessed by field observation, and Illinois Department of Transportation (IDOT) maintenance personnel were surveyed to develop information on maintenance histories, costs of repairs, scheduled repair or replacement of barriers, and estimated service lives of barriers in place. Service life criteria was developed considering the structural, acoustical, and aesthetic functions of noise barriers. A life cycle cost model was developed and the relative life cycle costs of existing Illinois noise barriers were computed. Noise barrier specifications supplied by IDOT and the Illinois State Toll Highway Authority (ISTHA) were reviewed, and recommendations for improving the organization and content of the specifications were made.

17. Key Words noise barrier service life life cycle cost analysis	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 307	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

FINAL REPORT

Evaluation of Service Life of Noise Barrier Walls in Illinois

Project IIB-H1, FY 1997

Report No. ITRC FR 97-3

Prepared by

D.H. Kay, S.M. Morgan, and S.N. Bodapati
School of Engineering
Southern Illinois University at Edwardsville
Edwardsville, Illinois

November 1999

Illinois Transportation Research Center
Illinois Department of Transportation

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

ACKNOWLEDGEMENTS

The research described in this report was performed for the Illinois Transportation Research Center (ITRC), a joint public-private university cooperative research unit underwritten by the Illinois Department of Transportation (IDOT). The assistance of ITRC Center Administrator, Steven J. Hanna of Southern Illinois University Edwardsville is gratefully acknowledged.

The research was conducted by personnel from the Departments of Construction and Civil Engineering at Southern Illinois University Edwardsville. Assistant Professor Dianne H. Kay was the project director. Associate Professor S. Narayan Bodapati and Assistant Professor Susan M. Morgan were co-investigators. Daniel Wilson, a graduate student in the Department of Civil Engineering, assisted for one semester. Lorry Bannes, who served as a consultant to the research team in the area of construction cost estimating and life cycle cost analysis, provided invaluable input.

IDOT personnel who served as the Project Technical Review Panel (TRP) guided the research. Michael Bruns, of the Bureau of Design and Environment chaired the TRP and assisted the researchers in many ways. Prem Suri and Michelle Mahoney of IDOT District 1, John C. "Chet" Herne of the Illinois State Toll Highway Authority, Salah Khayyat of the Bureau of Bridges and Structures, Richard Hahn of the Bureau of Materials & Physical Research, and Arlene Kocher of the Bureau of Design and Environment served as TRP members. The TRP met with the researchers, responded to requests for information and assistance, and reviewed the final report. Michelle Mahoney, Prem Suri and Michael Bruns guided the researchers on a field tour of noise barriers in the Chicago area. In addition, James DuBose of the Bureau of Materials & Physical Research, David Johnson of the Bureau of Operations, William Barbel of IDOT District 1, Allan Guttmann of IDOT District 8, and Gisela Motzkus, IDOT librarian, each contributed to this research effort by providing timely assistance.

EXECUTIVE SUMMARY

Evaluation of Service Life of Noise Barrier Walls in Illinois

Project IIB-H1, FY 1997
Report No. ITRC FR 97-3

November 1999

In Illinois, the Illinois Department of Transportation (IDOT) and the Illinois State Toll Highway Authority (ISTHA) have constructed over 96 km (60 miles) of highway noise barriers since 1978. The total cost of these barriers is over $61.5 million in 1995 dollars (FHWA 1996), or slightly more than $1 million per mile. Recent IDOT construction of new noise barriers has averaged over $1.3 million annually, and new noise barrier projects are currently planned by both IDOT and ISTHA.

The Illinois Transportation Research Center, a cooperative research unit of IDOT and twelve public and private Illinois universities, requested this research to assist IDOT in determining the service lives of the various noise barrier materials and products currently in use in Illinois. The scope of this project included:

- development of a means to quantify the service lives of materials used for construction of noise barriers in Illinois
- development of a life cycle cost model for the evaluation of alternative materials
- evaluation of the need for potential changes to the Special Provisions for noise barrier construction currently used by IDOT.

The project included the following specific tasks:

- a review of literature
- a survey of state DOTs to develop information on experiences and histories with noise barrier products
- a review of materials approved by the Illinois Highway Development Council and used in Illinois
- a survey of IDOT and ISTHA maintenance personnel to obtain information on maintenance and replacement histories of Illinois noise barriers, and a field study to observe and evaluate current conditions of Illinois noise barriers
- development of service life criteria considering structural, functional, and aesthetic conditions
- development of a life cycle cost model to evaluate alternative materials or products
- review of specifications used for construction of Illinois noise barriers
- preparation of the final report.

A review of materials used and approved for use in Illinois showed that although ten noise barrier products have been approved for use by the Highway Development Council, the majority of IDOT noise barriers (60%) have been constructed of wood or concrete. IDOT has used 11 different materials to construct over 38 km (24 miles) of noise barriers, while ISTHA has used only 4 materials for its 59 km (36 miles) of barriers. The majority (97%) of ISTHA barriers are either wood or concrete.

Replacement of aged or deteriorated barriers will become an increasingly important issue in Illinois and across the nation within the next decade. Field observations and discussions with IDOT personnel indicated that most Illinois highway noise barriers have performed their intended function with minimal maintenance. However, two materials exhibited significant, rapid deterioration after installation. The current conditions of Illinois noise barriers was determined by field observation of noise barriers by the researchers and a survey of maintenance personnel in IDOT Districts 1,2,4,6, and 8. The maintenance survey gave new information regarding the maintenance and replacement histories and costs, and the observations and opinions of maintenance personnel regarding expected service life of the noise barrier materials currently in use in the state. Two barrier sections were rated "failed, needs replacement" by the maintenance survey: a tropical hardwood barrier in District 1, and a steel barrier in District 8.

The 40 states having noise barriers (FHWA 1996) were surveyed regarding their experiences with noise barriers and noise barrier materials; 30 states (75%) completed the survey. The information obtained showed that nationally, less than 1% of noise barriers (by length) have been repaired or replaced, although one material, metal, had been repaired or replaced by 20% of the states responding to the survey. There was no consensus among survey respondents on the average service life of noise barriers, although 20 years was considered a minimum. Routine inspection of noise barriers for structural integrity or acoustical performance is not being performed by most states responding to those questions.

The information obtained through review of the literature, surveys of other state DOTs, surveys of IDOT maintenance personnel and the field observation of barriers provided data for the researchers to estimate the service lives of the materials and products in service in Illinois. These estimates, which varied from a low of 25 years for wood and metal products to a high of 50 years for earth berms, concrete, and fiberglass, were subsequently used in developing a life cycle cost model to evaluate alternative materials.

It was found that, for the assumptions used in the analysis, earth berms represented the lowest cost alternative among the materials currently in service in Illinois. Metal barriers with absorptive panels were estimated to have the highest life cycle cost. The life cycle costs of all other materials currently in use in Illinois fell within a narrow range of $28.00 to $32.00 per sq. ft. Based on the assumptions used in this analysis, the life cycle costs of 8 of the 11 materials currently in use by IDOT are sufficiently similar that economically justifiable choices can be made from any of these materials. However, due to the importance of costs associated with the frequency of repairs and replacement, and the difficulty in obtaining reliable data on which to estimate such costs, it is recommended that life cycle cost analysis not be used as the sole criterion for selecting noise barrier materials.

A review of specifications was conducted since adequate specifications are an important factor in the service life of a noise barrier. Based on a limited number of specifications provided by Districts 1 and 8, and ISTHA, it is recommended that noise barrier specifications be standardized and incorporate a number of specific topics synthesized from the literature. It is expected that these changes will improve the performance of future noise barriers constructed in Illinois.

CHAPTER 1

INTRODUCTION

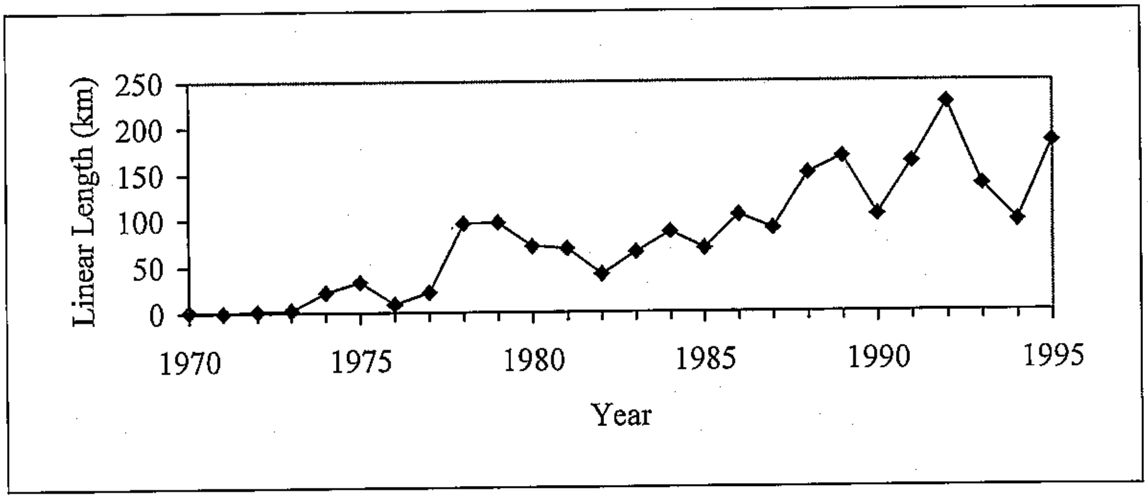
In the past three decades, highway noise has been recognized as a problem affecting many Americans living close to high-speed, high-volume roadways. Federal legislation addressing the issue of highway noise culminated in the United States Code of Federal Regulations Part 772 (23 CFR 772), "Procedures for Abatement of Highway Traffic Noise and Construction Noise". This regulation and subsequent federal policies give the states latitude in determining the need for and type of highway noise abatement. However, most noise abatement projects nationwide have involved the construction of a physical barrier between the noise generator and noise receptors (FHWA 1989). The most recent data show that over 2121 km (1318 miles) of noise barriers have been built in the United States since the early 1970s, at a total cost of over $1.4 billion (1995 dollars) (FHWA 1996).

In Illinois, the Illinois Department of Transportation and the Illinois State Toll Highway Authority have constructed over 96 km (60 miles) of noise barriers on highways in their respective jurisdictions; the total cost of Illinois noise barriers is over $61.5 million (1995 dollars) (FHWA 1996). Illinois' noise barrier construction began in 1978 with an earth berm along Illinois Route 4 in Springfield. Other early walls include additional earth berms in Springfield (1979), two types of precast concrete walls in the Rockford area (1979-1980), and glue-laminated wood walls in Bolingbrook (1980) and Highland Park (1982). A total of thirteen different materials or products have been used for noise barriers in Illinois. While the majority of these noise barriers have performed well, some have exhibited significant deterioration within a short period of time. In addition, there are many new products being introduced into the noise barrier market that are not typical in highway construction, the long-term durability of which is unproven in field tests.

It is important for designers to have information with which to make rational choices between the materials available. Recent noise barrier construction by IDOT has averaged $1.3 million per year, and construction of new noise barriers is expected to continue. Currently IDOT is studying four new noise barrier sections on new alignment in District 8. In District 1, one mile of barriers is scheduled for construction on I-55 (Stevenson Expressway), and existing barriers on IL 83 are being extended between 55th and 58th Streets. New noise barriers are being planned on Business Route 55 in Bloomington (District 3). The ISTHA is also currently planning construction of additional noise barriers in Downer's Grove.

In addition to planned new construction of noise barriers, replacement of existing barriers will become an increasingly important issue in the next decade, in Illinois and across the country. Figure 1-1 shows the national trend in annual noise barrier construction by length based on data reported to the FHWA through 1995; 2121 km of barrier had been built as of the end of 1995 (FHWA 1996). Although there have been substantial fluctuations from year to year, the general trend is increasing annual length constructed. Figure 1-2 shows the cumulative percent of length constructed annually. As of 1996, 37% of the barriers are at least 10 years old; however, only 3% are at least 20 years old, a common design and service life criterion (Chapter 3). If each barrier's service life were 20 years, then 20% of the U.S. noise barriers (425 km) will require replacement by 2001; approximately 33% (687 km) will require replacement by 2005, and nearly 50% (1032 km) will require replacement by 2008; by 2015, all the barrier length constructed through 1995 (2121 km) will require replacement (Figure 1-3). If the barriers have a 50-year service life, then replacement will begin in 2020 (0.05%, or 1 km, of barrier). (All these calculations neglect 9 km of barrier, which is 0.42% of the length constructed as of 1995, that cannot be assigned a construction year (FHWA 1996).)

Figure 1-1. Noise barrier length constructed annually.



Source: FHWA 1996

Figure 1-2. Cumulative percent of noise barrier length constructed annually.

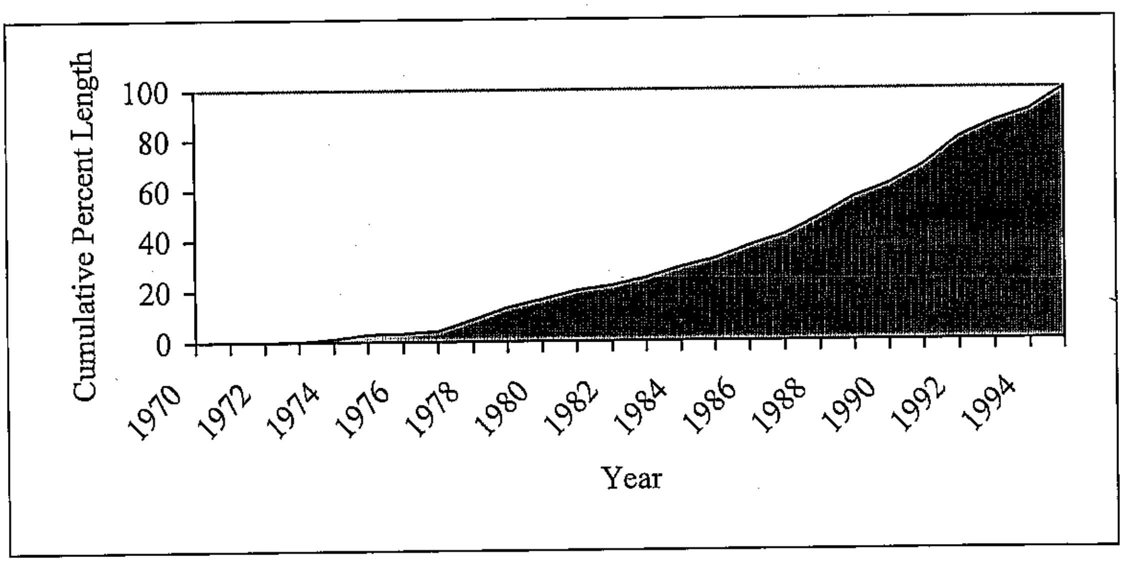
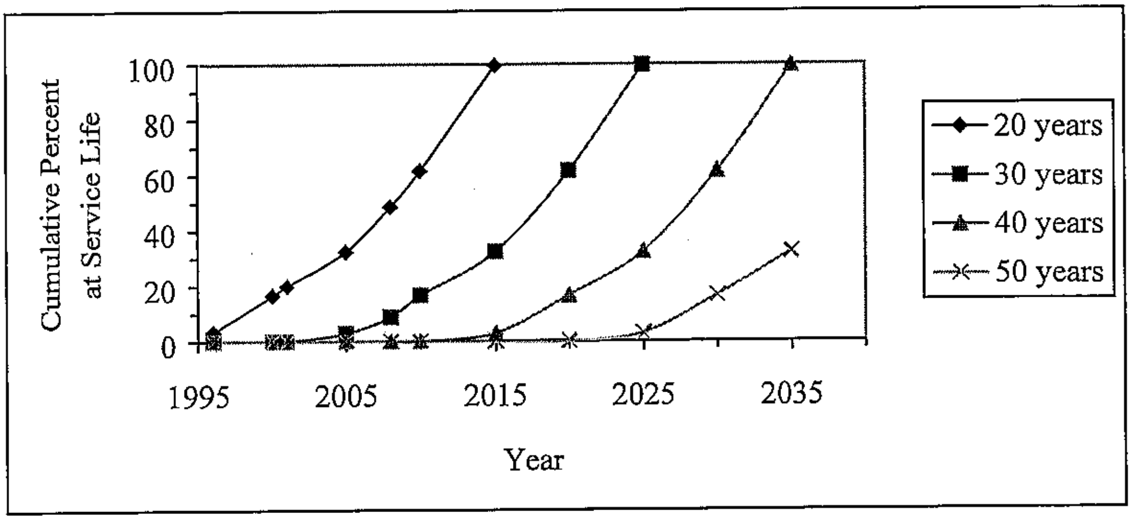
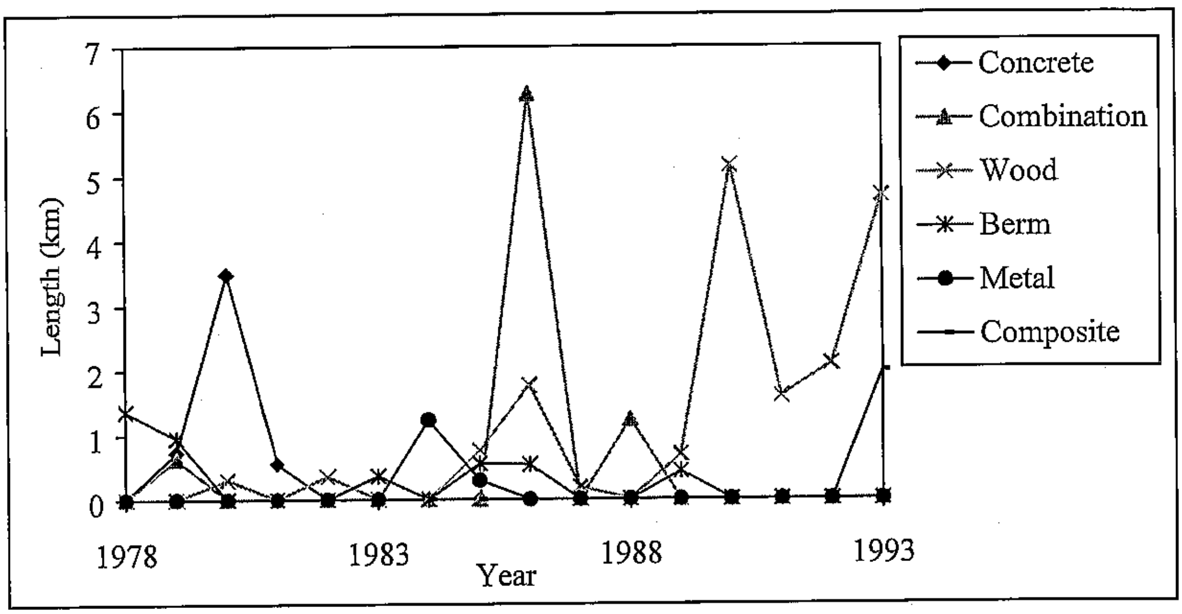


Figure 1-3. Cumulative percent of barrier length requiring replacement for service lives of 20 to 50 years.



Source: FHWA 1996

Figure 1-4. Illinois noise barrier walls constructed annually.



In November 1995, the Illinois Transportation Research Center (ITRC), a cooperative research unit of the Illinois Department of Transportation (IDOT) and twelve public and private Illinois universities, held a seminar on environmental issues in transportation. The roundtable discussions at that seminar yielded a number of research problem statements in the areas of highway noise abatement, air quality, and water quality. One of the problem statements developed dealt with the issue of the evaluation of the service life of the materials and products that had been used, or were approved for use, by IDOT.

life of the materials and products that had been used, or were approved for use, by IDOT. Development of that problem statement into a Request for Proposals ultimately led to the initiation of this research project in September 1997. The Illinois State Toll Highway Authority (ISTHA), although not a member of ITRC, is cooperating in this study.

The purpose of this research is to assist the IDOT in determining the service life of the various materials and products already in service in Illinois. The scope of the project included:

- development of a means to quantify the service lives of materials used for construction of noise barrier walls in Illinois
- development of a life cycle cost model for the evaluation of alternative materials
- evaluation of the need for potential changes to the Special Provisions for noise wall construction currently used by the IDOT.

In order to complete the project, work was divided into eight distinct tasks, as follows:

Task A: Literature Review—Review of published information about noise barrier maintenance and service life for various materials, as well as literature dealing with methods to evaluate service life and model life cycle costs, from technical journals, popular media, and vendor literature.

Task B: Maintenance Survey—Develop and administer a survey of state DOTs, manufacturers and industry representatives to obtain information on experiences and histories with various noise wall materials and products.

Task C: Materials List—Develop a comprehensive list of materials used for noise barrier walls by IDOT, ISTHA, and states with climates similar to Illinois and a list of products pre-approved by the Illinois Highway Development Council.

Task D: Current Conditions Survey—Survey IDOT maintenance personnel in Districts 1, 2, 4, 6, and 8 and the ISHTA to obtain their assessment of current conditions of the noise barriers, including information on replacements, maintenance histories, and other pertinent information; observe and evaluate current conditions in the field.

Task E: Service Life Criteria—Develop a checklist of factors that determine the serviceability of a noise barrier wall, considering structural, functional, and aesthetic conditions.

Task F: Life Cycle Cost Model—Develop a life cycle cost model using the information collected in the previous tasks.

Task G: Specification Review—Determine whether improvements in the specifications used for the construction of noise barrier walls would yield benefits in terms of reduced construction and maintenance costs.

Task H: Final Report—Prepare a final report that includes a summary of the findings of the above-named tasks, conclusions drawn from those findings, specific recommendations for improving specifications, if needed, and recommendations for the use of life cycle costing as a criteria for material selection for noise barrier walls in Illinois.

This report is a summary of the findings of the research project, which began on September 26, 1997, and concluded on January 31, 1999. The report arrangement will follow the outline of tasks listed above. Chapter 2 contains the review of literature the findings are given in Chapter 3. The material approval process and listing of IDOT-approved materials is given in Chapter 4. The current condition of noise barrier walls in Illinois is discussed in Chapter 5. Service life criteria for noise barriers are developed in Chapter 6. The use of life cycle costing for Illinois noise barriers is discussed in Chapter 7, and a model for comparing different materials is developed. The specifications used for Illinois walls are discussed in Chapter 8 and compared to problems observed in the field or noted in the current condition survey. The report is summarized and conclusions drawn in Chapter 9.

Appendix A contains copies of the two surveys used to obtain data for this project. Appendix B contains the data and computations used in the life cycle cost analysis.

Appendix C is a photographic index of noise barriers observed by the researchers in Illinois, Michigan, and Missouri during the course of the study.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Background

Because the history of highway noise barriers in the U.S. spans fewer than 30 years, the issue of the service life of the materials and products used in barrier construction has not been a research priority; the majority of noise barriers are relatively new and have not exhibited significant deterioration. The focus has instead been on developing computer models of noise propagation, models to optimize the placement, length and height of noise barriers, and models to analyze the acoustical effectiveness of noise barriers. An analysis of past studies indicates that the research to date has focused on four basic areas (Bowlby 1992):

- improving noise prediction modeling
- evaluating noise barrier (acoustical) performance
- analyzing multiple refractions between parallel noise barriers
- investigating meteorological effects on traffic noise propagation.

In a 1983 Federal Highway Administration (FHWA) workshop to identify research needs in the area of highway traffic noise, participants identified and ranked 51 items. Of these 51, only one, "National Physical Design Criteria Based on Risk Analysis and Life Cycle Costing," appears to address the issue of life cycle cost; the topic placed 16th in the rankings. Of the top eleven research needs identified by the workshop participants, seven were related to computer modeling. None of the remaining four topics included a study of material durability or service life issues (Hatano et al. 1987). In subsequent updates of this list of research needs (TRB 1992; TRB 1997), the issue of service life of noise barrier walls has not been rated as a priority issue. Klinger et al., in a 1996 report for the Texas Department of Transportation (TxDOT), found during their literature review that maintenance and construction issues have not been well-studied, in part because of the difficulty of obtaining data on construction and maintenance costs.

The researchers reviewed over 100 published reports on highway noise barriers and found no study devoted solely to the topic of determining the service life of highway noise barriers. However, a number of studies have examined problems related to the present study. These include life cycle cost analysis, highway maintenance, and material selection process, which covers the comparative study of material cost, aesthetics, and durability.

2.2 Service Life

Defining the term "service life" is a necessary first step in comparing the performance of various noise barrier wall materials and products. Although it would perhaps seem intuitive that the service life of a material is the length of time it remains in useful service, a precise and comprehensive definition has not been found in the context of noise barriers, which must function acoustically, aesthetically and structurally. In the literature, the term is often used without definition.

Bowlby (1992), in a comprehensive survey of state highway agencies' experiences with noise barriers, called service life a very important issue that is often overlooked in comparing the costs of different barrier systems. Bowlby did not define service life, but uses the term interchangeably with "expected life".

Klinger et al. (1996) make reference to service life but do not explicitly define the term. The implication of the reference is that service life is synonymous with durability with regard to resistance to weathering and to vehicle impact. The authors developed performance criteria for noise barrier design, including aesthetic, acoustic, traffic safety and structural performance, but did not establish any criteria for determining the point at which a barrier is no longer serviceable.

A technical evaluation of the performance of noise barriers was reported by the Highway Innovative Technology Evaluation Center (HITEC), which published guidelines for the evaluation of highway noise barriers (HITEC 1996). The report addresses the standard tests that can be used to evaluate the following key performance issues:

- mechanical connection of panel to post
- system durability
- repairability
- drainage
- access
- erection
- aesthetics
- panel cap
- panel strength
- cost
- acoustical properties

Although the report does not use the terminology "service life," its description of system durability concludes that materials used for noise barriers must "exhibit a minimum predicted maintenance-free life span of 20 years under the expected service conditions." In this context, service life is equated with the maintenance-free life span.

A definition of the term "service life" was found in a study of highway culverts and drainage pipe. Although the product itself is unrelated to noise barriers, the definition of service life is applicable. Gabriel (1998) defined the service life of drainage pipe as the projected years of reliable, low-maintenance service measured from the time of installation. Durability of a material was described as a means of stating and comparing service lives, not as a synonym for service life.

Flodine (1991), performing an analysis and comparison of various noise barrier alternatives for the Colorado DOT, assumed unequal design lives for the eight materials studied. Although the term service life is not used in the report, and the term design life is not defined, it can be inferred that the design life is the length of time the noise barrier is expected to remain in service before replacement. Bowlby (1992), referring to the Flodine report, interprets design life to mean service life.

Some studies have considered the acoustic properties of a noise barrier as a component of the service life, in addition to the durability of the material of which the barrier is constructed. Because noise reduction is the initial and principal justification for constructing noise barriers and holes or openings in a wall can significantly reduce acoustical effectiveness (Cohn 1981), it would seem reasonable that continued acoustical effectiveness over time should be a consideration in determining service life.

Anday (1978), in an early review of Virginia DOTs material selection process for noise barriers, discussed potential durability and maintenance problems for wood, steel and concrete noise barriers. Warpage of wood panels, which according to Anday would "render the entire barrier acoustically ineffective," would necessitate replacement of the affected panels. Although the author does not use the term service life, the implication is that acoustic function is an important consideration in determining the end of a barrier's life.

Flodine (1991) also reported that shrinkage cracks in wooden noise barriers significantly reduce the acoustical effectiveness by allowing up to 8% of the barrier surface area to become sources of potential sound leaks. The report does not attempt to relate a minimum acceptable level of noise reduction to a barrier's service life.

Aesthetics may also be an important consideration in the determination of the service lives of noise barriers because of the importance of public perception of barriers. Anday (1978) noted that the broader definition of barrier performance places significant emphasis on public choice and aesthetics. Bowlby (1992) stated that appearance plays a critical role in the public acceptance of noise barriers. Billera et al. (1997) rated a noise barrier's positive aesthetic impact on a community's built environment second in importance only to acoustic effectiveness. Herman, Finney et al. (1997) found that public perception of the acoustical effectiveness of a barrier was linked to perception of the appearance of the barrier. Public input, which in some states plays heavily in the initial choice of noise barrier materials, may also play into the determination of the end of a noise barrier's useful life. However, nothing was found in the literature to substantiate this assumption.

In summary, the literature tends to regard the service life of noise barriers as a function of the durability of the material, although references to other considerations such as the acoustic effectiveness and aesthetics are made. It does not appear that criteria have been developed for quantifying a minimally acceptable level of service for noise barrier performance.

2.3 Life Cycle Cost Analysis

Life cycle cost analysis (LCCA) is the process by which the total cost of constructing, operating, and maintaining a structure throughout its life is accounted. Using compound interest factors based on a chosen interest rate and a given time period for the economic analysis, future costs such as annual maintenance, rehabilitation, and eventual replacement of a structure can be brought to an equivalent present value and added to the initial construction cost. Alternatively, the present value of the construction cost and any future rehabilitation and replacement costs can be converted into equivalent uniform annual costs and added to the anticipated annual maintenance costs. Using the concepts of engineering economics, it is therefore possible to compare products that have different anticipated life spans or maintenance requirements. Life cycle cost analysis is commonly used as a decision-making tool in studying and evaluating the cost of alternatives and may be required for some projects. Under the National Highway System Designation Act of 1995, states are required to conduct LCCA of each usable project segment on the National Highway System with a cost of $25 million or more (FHWA 1996a).

However, in order to be meaningful, life cycle cost analysis must be based on reliable historical cost data (Dhillon 1989), including initial construction cost as well as operation and maintenance costs. An accurate value for the useful life of the material and a reasonable interest rate for the economic analysis are also required. The literature review indicates that this type of reliable historical data is largely unavailable for noise barrier walls and that the life cycle cost analyses that have been performed rely on assumptions regarding noise barrier life spans, maintenance requirements, and even the initial construction cost.

2.3.1 Initial Construction Cost

The most comprehensive data on noise barrier cost is found in the Federal Highway Administration (FHWA) summaries published approximately every two years. This database of noise barrier costs is collected from the individual state highway agencies (SHAs) and summarizes the noise barrier location, height, length, cost per unit length, date of construction, and total construction cost of all noise barriers constructed to date by SHAs in the U.S. and Puerto Rico (FHWA 1996). The construction costs are indexed biennially to account for highway construction cost inflation (Armstrong 1998). Weiss (1988) reported that the construction cost information contained in the FHWA summaries must be considered "estimates" due to the many differences in noise barrier cost reporting among SHAs. It is not possible to tell whether the reported costs include or exclude foundations, earthwork, drainage, landscaping, or other costs that may be related to noise barrier construction. Bowlby (1992) also addressed the inconsistencies in the SHAs' reporting of noise barrier costs, as well as the many variables in determining the cost of noise barriers. The costs of labor, transportation, and foundations, and the manner in which a contractor prices noise barriers in a bid package, and other factors may affect the cost.

2.3.2 Maintenance Requirements

Klinger et al. (1996) called maintenance a major component of the life cycle cost of noise barriers but noted that data on maintenance costs was lacking. The cost of maintenance can include upkeep of landscaping and mowing, snow and trash removal, graffiti removal, repair of barriers damaged by vandalism, vehicle crashes, and the actions of weather, application of paint, stain or water sealer, and washing or steam-cleaning (Ceran 1992). A review of several studies showed that maintenance costs are often left out of comparative analyses of noise barrier walls.

A recent study performed for the Pennsylvania Department of Transportation (Lin 1997) evaluated the cost-effective alternatives for highway noise barriers, developed a comprehensive comparison of barrier performance and costs, and proposed field testing methodology for evaluating new noise barrier materials. The study provides a recent comparison of the initial construction cost of a wide variety of proprietary and non-proprietary noise barrier products and does contain some elements of a life cycle cost comparison of these products. Seven criteria for evaluating noise barriers were identified:

- noise abatement efficiency
- cost
- structural integrity
- safety
- constructability
- aesthetics
- use of recycled materials.

The researchers used a panel of highway noise experts to rank 22 proprietary and five non-proprietary noise barriers on the basis of these seven criteria. A comprehensive study of the construction costs for each barrier type was also performed. The components of the total cost of noise barrier construction were identified as the costs of materials, installation, transportation, and maintenance. However, it was found that including transportation and maintenance costs was impractical. The transportation cost for each noise barrier is a function of several variables, including the project location, weight and size of noise barrier panels, and distance of the haul from the manufacturer to the construction site. Data on each of these variables was not available, making accurate computation of transportation cost impossible. Maintenance costs were also dropped from the cost computation due to lack of data. The researchers contacted six state DOTs and got similar responses from each; there is no maintenance cost data because preventive maintenance is seldom done on noise barrier walls. Manufacturers contacted for maintenance data typically responded that their respective products were maintenance free.

After computing the construction cost on the basis of material and installation costs, the researchers converted these present value costs to equivalent uniform annual costs. The conversion was made in order to compare on an equivalent basis the costs of noise barriers having different initial construction costs and unequal anticipated life spans. This is similar to the concept of life cycle cost analysis but differs in two important ways. First, the life spans used for the noise barriers analyzed were those given by the manufacturers. In the case of one product, the manufacturer reported an anticipated life span of 100 years. Second, the analysis did not include future costs, such as periodic maintenance or repair. The analysis did allow the relative ranking of the noise barriers, based on the stated assumptions.

Flodine (1991) performed a life cycle cost analysis (LCCA) of eight materials in an effort to show whether the use of products with low initial cost was cost effective for the Colorado DOT when the unequal lives of various products was considered. The analysis compared wood, precast concrete, masonry, aluminum, steel, Durisol, cast-in-place concrete, and plastic. The LCCA considered only two variables: the initial construction cost of a barrier 10 feet high and the estimated design life of the barrier. An interest rate of 4% and an analysis period of 40 years were chosen. The initial construction cost was obtained from actual projects for two barriers, from manufacturers' quotes for three barriers, and from published information on costs from other state DOTs for the remaining three barriers. The estimated design life of each material varied from 15 years for wood to a maximum of 40 years for concrete, masonry, and two proprietary products. The report contains no explanation of the values used for the estimated design lives of the eight materials analyzed, but it may be inferred that the values reflect the experience and perceptions of the Colorado DOT. Colorado made heavy use of wood noise barriers during the early years of its barrier construction (FHWA 1996), with disappointing results (Flodine 1998). The analysis included no numerical values for future costs of maintenance but made subjective comments on the advantages and disadvantages of each material. The results of this simplified analysis can be interpreted to show that even with a greatly reduced expected life span, wood walls were cost competitive with masonry and precast concrete walls.

In summary, the literature indicates that some states have considered life cycle cost analysis in the selection of noise barrier products and in comparing the cost effectiveness of past selections. However, the analysis is hampered by the lack of reliable historical data on initial construction and maintenance costs.

CHAPTER 3

MAINTENANCE SURVEY

3.1 Introduction

To obtain an indication of in-field performance and actual service lives of various noise barrier materials as well as life cycle cost analysis (LCCA) data, a mail survey was distributed to state DOTs. The survey is reproduced in Appendix A. Methods recommended by Salant and Dillman (1994) were used to develop and distribute the survey. Originally only a limited number of states with climates similar to Illinois were going to receive the survey. However, due to the limited field experience with noise barriers in many of these states, all states with noise barriers in the 1996 FHWA report (FHWA 1996) received the survey in the summer of 1998.

3.2 Survey Results

Of the 40 surveys mailed, 30 were returned either partially or entirely completed, resulting in a response rate of 75%. In addition, one state responded by telephone that there was only one barrier (a gravel berm) in the state; therefore, they felt the survey was not applicable. Including this state, the overall response rate was 77.5%. Illinois did not complete this survey but did complete a similar current condition survey discussed in Chapter 5. Unless otherwise indicated, the percentages reported below are based on the 30 responses.

3.2.1 Policies

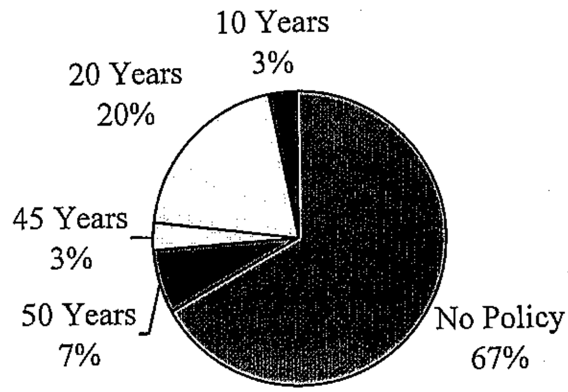
Part I of the survey dealt with policies concerning noise barrier service life, LCCA, design, and use of recycled materials. These questions were designed to assist the researchers in developing service life criteria and the LCCA model as well as to obtain information pertinent to potential specification revisions required in Illinois.

3.2.1.1 Service Life

Question: What is your design life policy for noise barrier walls?

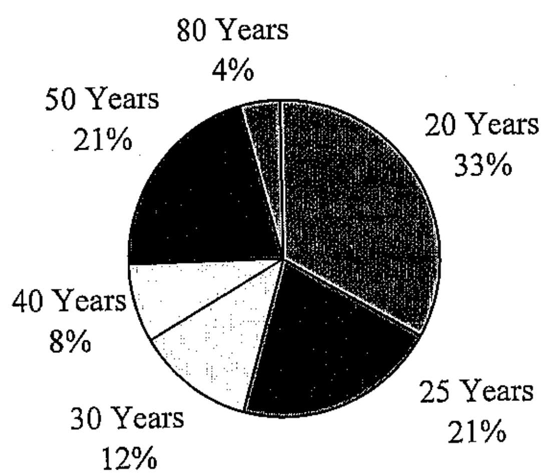
The majority of states (20, or 67%) do not have a design life policy for noise barrier walls (Figure 3-1). (One of these states did comment that it has a practice of using 20 years as the design life.) For the ten states with policies, the design life ranges from 10 plus to 50 years. However, over half (six of ten, or 60%) of these states use 20 years.

Figure 3-1. Design life policies for noise barriers.



Question: What do you consider to be the average service life of a noise barrier wall? States consider the average service life of a noise barrier wall to be between 20 and 80 years (Figure 3-2). The highest percentage of respondents (eight of 24, or 33%) reported 20 years, but 21% (five of 24) reported 25 years and 21% reported 50 years. Nine of the ten states that have design life policies also estimated an average service life. Of these states, 44% (four of nine) consider the average service life to be the same as the design life policy while 33% (three of nine) consider the average service life to be greater and 22% (two of nine) consider it to be less than the design life. In the latter case, the design life policy is at least twice the estimated service life.

Figure 3-2. Estimated average service life of barriers. [1]



[1] Based on 24 responses. Percentages do not add to 100 due to rounding.

Question: Please rank these factors in determining the service life of noise barriers.

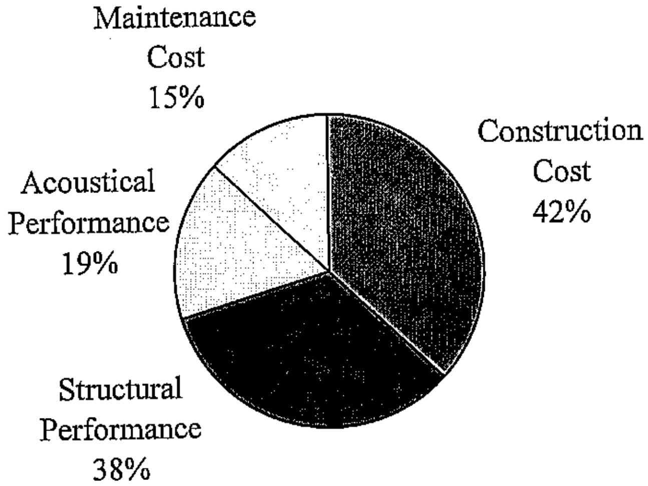
The most important factors considered when determining service life are construction cost and structural performance; 42% of respondents (11 of 26) ranked construction cost as the most important factor while 38% of respondents (10 of 26) ranked structural performance as the most important (Figure 3-3). In decreasing order of importance, other factors considered are acoustical performance, maintenance cost, and aesthetics. None of the respondents ranked aesthetics as the most important factor; however, 19% (five of 26) and 15% (four of 26) ranked acoustical performance and maintenance cost, respectively, as most important.

3.2.1.2 Life Cycle Cost Analysis

Question: Does your state use LCCA in selecting materials for noise barriers?

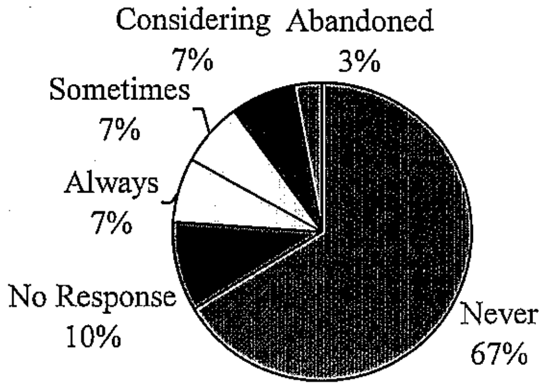
Twenty (67%) of the respondents have never used LCCA in selecting materials for noise barrier walls (Figure 3-4).

Figure 3-3. Factors considered important in determining service life of noise barriers. [1]



[1] Based on 26 responses. Percentages do not add to 100 because more than one response could be given.

Figure 3-4. Use of LCCA in selecting materials for noise barriers. [1]



[1] Percentages do not add to 100 due to rounding.

One state commented that LCCA had not been considered, and another stated that "only block, concrete or earth" is used. On the other hand, two states always use LCCA, although one commented that LCCA is "at least considered" but that they are "not using a specific LCCA 'menu.' " Two states sometimes use LCCA, one of which cited insufficient data as the reason it is not used more frequently. One state formerly used but abandoned LCCA because "public preferences often precluded [its] use." Two states are considering using LCCA in the future. One state "uses maintenance history of like structures of given materials" rather than LCCA.

Question: Please rank your primary reasons for not using or abandoning LCCA.

The primary reason given by the respondents for not using LCCA is insufficient data. In decreasing order of importance, other reasons are unfamiliarity with the analysis method, pressure to keep initial cost low, and unclear benefits of the method. Two states commented that they did not build enough barriers to justify using LCCA; another precertifies barrier materials through ASTM testing.

Question: What inputs do you use, plan to use, or did use in computing life cycle cost?

The most common input considered for LCCA is construction cost. Maintenance and material costs are also commonly used. Labor, periodic rehabilitation, replacement, and design costs are used less often. Relocation and disposal costs are rarely considered, and it appears that discount and inflation rates are generally not considered.

Questions: Do you have a policy regarding rehabilitation and replacement of existing noise barriers? What is the strategy(ies) for funding replacement and rehabilitation of walls?

None of the states responding to the survey have a policy regarding rehabilitation and replacement of existing noise barriers. The majority of states (19 of 26, or 73%) also do not have a strategy for funding these activities. All the states reporting a strategy (seven) use their annual maintenance funds. One state also reported stockpiling replacement materials. No states reported strategies of considering these activities as a Type II project, expecting local jurisdictions to undertake these activities, or establishing a special fund to finance these activities.

3.2.1.3 Design

Question: Who most often designs the noise barrier walls?

Over half the states often use consultants to design noise barrier walls (Table 3-1). However, 70% of states most often use in-house staff, either at the state or district level. Personnel at state headquarters are used over 1.5 times as much as district personnel. Only one state often used contractors to design barriers. Another state also commented that they use vendors or manufacturers as well as consultants. Thirty percent of the respondents listed more than one designer.

Table 3-1. Most frequent noise barrier designer.

Most Frequent Designer	States Using [1]
Consultants	18 (60%)
In-house staff at state headquarters	13 (43%)
In-house staff at district (or similar) level	8 (27%)
Contractors	1 (3%)
Other	1 (3%)

[1] Percentages do not add to 100 because some respondents chose more than one category.

Questions: Please indicate the type of design specifications you use for noise barrier walls. Have you developed standard noise barrier designs for various materials?

Over half the states use AASHTO design guidelines, although one state commented that walls were designed with the AASHTO specifications for highway bridges, signs and luminaires (Table 3-2). Similarly, 63% of states indicated that they use state specifications, distributed almost evenly between standard specifications and job-specific specifications. However, an additional 17% of the states (five of 30) indicated that they have developed standard noise barrier designs for various materials. If they also use these standard designs, then 50% of the states (15 of 30) use standard specifications, which means that 80% of the states (24 of 30) rather than 63% use state specifications. In addition, one state developed a design manual, and one state commented that the design specifications are "created by [the] Bridge Division." Few states use vendor specifications, American Society of Civil Engineers' (ASCE) guidelines, or Uniform Building Code requirements; none of the states use Naval Facilities Engineering Command (NAVFAC) requirements. One third (ten) of the respondents indicated that more than one type of design specification is used. The majority of these states (seven of ten, or 70%) use two types, generally AASHTO and state specifications.

Table 3-2. Types of design specifications used for noise barrier walls.

Design Specification [2]	States Using [1]
AASHTO design guidelines	18 (60%)
Standard specifications	10 (33%)
Job-specific specifications	9 (30%)
Vendor specifications	3 (10%)
Uniform Building Code requirements	1 (3%)
ASCE guidelines	1 (3%)
NAVFAC requirements	0 (0%)

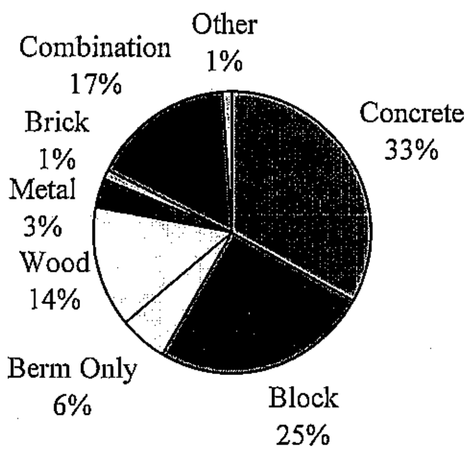
[1] Percentages do not add to 100 because more than one answer could be given.
[2] ASCE stands for American Society of Civil Engineers, and NAVFAC stands for Naval Facilities Engineering Command.

3.2.1.4 Recycled Materials

Question: Do you have a policy promoting the use of recycled materials in noise barrier walls?

Although recycled material is not reported as a separate category to the FHWA, barriers made of such material would likely be listed in the category "other." This category accounts for only 1.0% of the total length of single material barriers constructed between 1970 and 1992 (Figure 3-5), or 2.3% if "other combination" barriers are included. Therefore, it is not surprising that only two states (7%) have policies promoting the use of recycled materials in noise barrier walls. (Another state commented that, while they do not have a policy, they "do have a Department initiative.")

Figure 3-5. Percent of total noise barrier length by material type 1970 - 1992.
Source: FHWA 1994



3.2.2 Material Selection

Part II of the survey dealt with material selection for noise barriers. These questions were designed to assist the researchers in developing service life criteria as well as to obtain information pertinent to potential specification revisions required in Illinois.

3.2.2.1 Selection Criteria

Question: What criteria influence the choice of materials for noise barrier walls?
The most important criteria reported in the selection of noise barrier wall materials were construction cost and durability; over three-quarters of the states are influenced by each of these issues (Table 3-3 and Figure 3-6). In-state experience with the material closely follows. Also important are the initial appearance and ability to reduce noise. Adjacent sites (e.g., neighborhood themes) and maintenance cost are used by almost two-thirds of the states. Over half are influenced by public requests. Safety issues are an important influence to only 37% of the states (11 of 30). Fewer than one quarter of the states consider local availability of material and other states' experiences. Even fewer states are influenced by the life cycle cost analysis, proximity of material production, local availability of skilled labor, or using a local labor force. One state commented that multiple reflections from parallel walls are also a consideration in material selection. Another state commented that "local contractors [are] unwilling to use proprietary products [and] skilled concrete workers [are] available, resulting in cast-in-place construction."

3.2.2.2 Material Evaluation

Questions: How does your state evaluate new materials for noise barrier walls? Are your current evaluation methods adequate indicators of the long-term performance of noise barriers? Please list additional evaluation methods you recommend.
While other state's experiences were not cited as an important criteria in choosing noise barrier wall materials, their experiences and data were the most common method used to evaluate new materials; 63% (or 19) of the states rely on this information (Table 3-4). This apparent contradiction may be explained by limited budgets and time constraints making sharing evaluation information attractive while differences between climates, site conditions, and state policies as well as limited field performance data make it impractical to use other states' experiences when choosing materials. The other common method of evaluation (used by 57%, or 17, of the states) is using manufacturer's literature. Less than one third of states use independent laboratories or trial and error. Twenty percent (six) use full-scale field demonstrations or in-house laboratory testing. Other methods used to evaluate materials include plant inspections, Transportation Research Board A1FO4 papers and meetings, and consultant recommendations.

Table 3-3. Criteria that influence the choice of noise barrier wall material.

Criterion	States Using [1]
1. Construction cost	23 (77%)
2. Durability	23 (77%)
3. In-state experience	22 (73%)
4. Initial appearance	21 (70%)
5. Noise reduction	21 (70%)
6. Adjacent sites	19 (63%)
7. Maintenance cost	19 (63%)
8. Public request	17 (57%)
9. Safety issues	11 (37%)
10. Local availability of material	6 (20%)
11. Other state's experiences	5 (17%)
12. Life cycle cost analysis	2 (7%)
13. Local availability of skilled	2 (7%)
14. Locally produced material	2 (7%)
15. Multiple use or function	2 (7%)
16. Utilizes local labor force	1 (3%)

[1] Percentages do not add to 100 because more than category could be chosen.

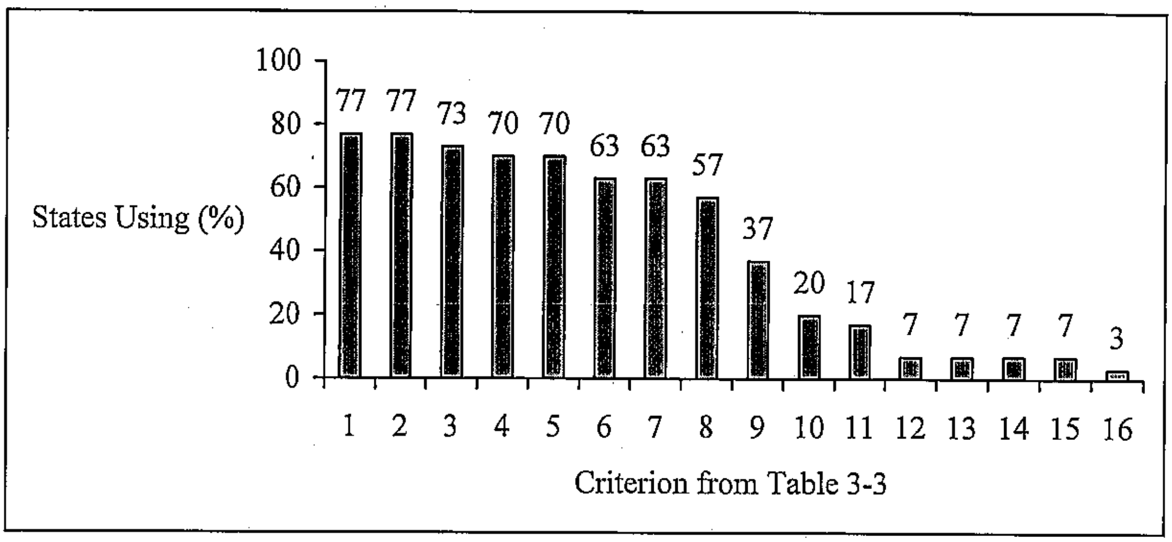


Figure 3-6. Criteria that influence the choice of noise barrier wall material. [1]

[1]Percentages do not add to 100 because more than one category could be chosen.

Table 3-4. Evaluation methods for new noise barrier wall materials.

Evaluation Method	States Using [1]
Experience of or data from other states	19 (63%)
Manufacturers' literature	17 (57%)
Independent laboratory testing	10 (33%)
Trial and error	8 (27%)
Full-scale field demonstrations	6 (20%)
In-house laboratory testing	6 (20%)

[1] Percentages do not add to 100 because more than one response could be given.

More than half the states (18 of 26, or 69%) believe their current evaluation methods are adequate indicators of the long-term performance of noise barriers. One respondent commented that the evaluation methods are adequate "if construction and manufacturing process [are] done properly." Several additional evaluation methods were recommended, including constructing demonstration projects and monitoring for at least two years, measuring long-term maintenance and effectiveness, and reviewing and evaluating warranties (especially to ensure the repair and replacement responsibility is properly addressed). One state evaluates in-field performance through "structural observations and public response."

3.2.2.3 Pre-approval of Materials

Questions: Does your state have a pre-approved list of materials for noise barrier walls? Do you plan to add to the list of approved materials for noise barriers as new products become available? Which products have been approved?

Less than half the states (14, or 47%) have a pre-approved list of materials. Of these states, 79% (11 of 14) plan to add to their lists as new products become available; the rest (three of 14, or 21%) do not know if they will add materials. All states with lists have pre-approved precast concrete products (Table 3-5). Almost two-thirds have pre-approved berms while half have pre-approved block and metal products. None of the states have pre-approved plastic or recycled products. One respondent commented that "any material is approved if it stands up and looks decent."

Question: Do you use absorptive noise barrier walls?

Only one state uses absorptive barriers for all new construction. Approximately half (15 of 29, or 52%) of the states do not use absorptive barriers while 45% (13 of 29) have used them at least once as indicated by acoustical requirements. Several states that have not used absorptive barriers (five of 15, or 33%) believed they were unnecessary. In addition, respondents commented that they had freeze-thaw concerns, did not have an approved material as yet, believed "reflection problems [are] greatly over-stated," or were still evaluating the cost versus the benefits. One state commented that "reflective steel is a better material for the life of a barrier."

Table 3-5. Products on pre-approved lists of materials.

Product[1]	States with Product on List
Berm	9 (64%)
Block	7 (50%)
Faddis	
Brick	3 (21%)
Composite	4 (29%)
Carsonite, Crane Cortec, Durisol, Fiberplank, Sound Zero	
Cast-in-place concrete	7 (50%)
Precast concrete	14 (100%)
Boxco/Soundtrap, Brickcrete, Faddis, Fanwall, LSE 1000/2000, Monowall, Sidley, Soundcore, Spancrete	
Metal	7 (50%)
Armco, Industrial Acoustics, Soundscreen	
Plastic	0 (0%)
Recycled	0 (0%)
Hardwood	6 (43%)
Soft wood	5 (36%)
Timbrtech	

[1] Trade names do not account for all the pre-approved materials in a particular category.

3.2.2.3 Absorptive Barriers

3.2.3 Material Performance

Part II of the survey also dealt with in-field performance of noise barriers. Similarly, these questions were designed to assist the researchers in developing service life criteria as well as to obtain information pertinent to the LCCA modeling and potential specification revisions required in Illinois.

3.2.3.1 General Performance

Questions: Based on your state's experiences, check all that apply regarding the negative (positive) performance of noise barriers made of these materials.

Respondents reported on the performance of 11 noise barrier materials in the following categories—construction cost, maintenance cost, acoustics, aesthetics, and structural performance. The percent of states reporting positive performance of specific materials ranged from zero to 67 while the percent reporting negative performance ranged from 13 to 43 (Table 3-6). Two-thirds (20) of the states reported positive performance of precast concrete products, and over half the states (17, or 57%) reported positive performance of berms. No states reported positive attributes of recycled products, and only one state reported a positive performance for a plastic product. In three of the five categories (construction cost, maintenance cost, and aesthetics), berms received the highest percentage of favorable comments (Table 3-7 and Figure 3-7).

Table 3-6. Performance of noise barrier wall materials.

Material	States Reporting Performance		Ratio of Positive to Negative Comments
	Positive	Negative	
Berm	17 (57%)	13 (43%)	1.3
Block	9 (30%)	7 (23%)	1.3
Brick	5 (17%)	6 (20%)	0.8
Composite	4 (13%)	4 (13%)	1.0
Cast-in-place Concrete	11 (37%)	5 (17%)	2.2
Precast Concrete	20 (67%)	6 (20%)	3.3
Metal	7 (23%)	11 (37%)	0.6
Plastic	1 (3%)	7 (23%)	0.1
Recycled	0 (0%)	4 (13%)	0.0
Hardwood	6 (20%)	9 (30%)	0.7
Softwood	4 (13%)	8 (27%)	0.5

Precast concrete received the highest percentage of favorable comments in the other two categories (acoustics and structural performance); however, berms were a close second in terms of acoustics. There was less variation among responses in terms of negative performance (Table 3-8 and Figure 3-8), although metal walls received the highest percentage of negative comments for maintenance costs and hardwood barriers received the highest percentage of negative comments for acoustics. Precast concrete and cast-in-place concrete received the highest ratios of positive to negative comments (Table 3-6). The only other ratios over 1.0 were for berms and block walls.

Table 3-7. Areas of positive performance.

Material	Cost [1] (Percent)		Performance [1] (Percent)		
	Construction	Maintenance	Acoustic	Aesthetic	Structural
Berm	71 (40)	71 (40)	76 (43)	65 (37)	29 (17)
Block	22 (7)	44 (13)	56 (17)	44 (13)	56 (17)
Brick	0 (0)	20 (3)	40 (7)	100 (17)	60 (10)
Composite	25 (3)	75 (10)	75 (10)	100 (13)	75 (10)
Cast-in-place Concrete	18 (7)	64 (23)	55 (20)	36 (13)	73 (27)
Precast Concrete	35 (23)	50 (33)	70 (47)	40 (27)	75 (50)
Metal	57 (13)	57 (13)	57 (13)	43 (10)	43 (10)
Plastic	0 (0)	0 (0)	100 (3)	0 (0)	0 (0)
Hardwood	67 (13)	50 (10)	67 (13)	67 (13)	67 (13)
Softwood	75 (10)	25 (3)	75 (10)	50 (7)	50 (7)

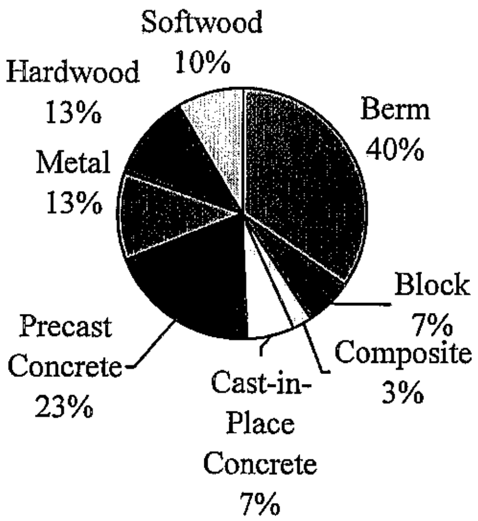
[1] Percentages within parentheses are percents based on 30 responses. Other percentages are based on the number of states reporting a positive performance of a material (Table 3-6). For example, 17 states reported positive performance associated with berms; 71% (12) of these 17 states reported low construction costs.

Table 3-8. Areas of negative performance.

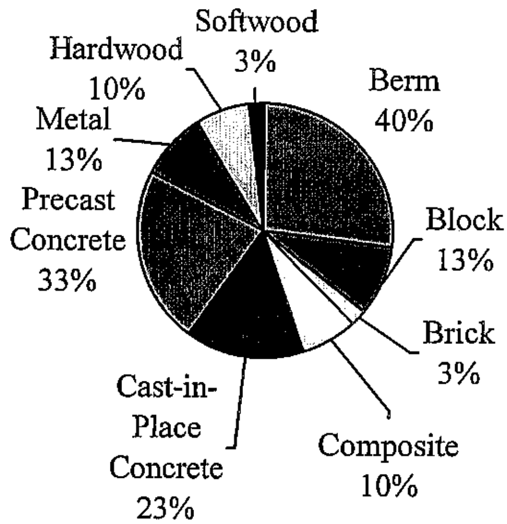
Material	Cost [1] (Percent)		Performance [1] (Percent)		
	Construction	Maintenance	Acoustic	Aesthetic	Structural
Berm	15 (7)	15 (7)	0 (0)	15 (7)	8 (3)
Block	71 (17)	57 (13)	0 (0)	0 (0)	14 (3)
Brick	100 (20)	33 (7)	0 (0)	0 (0)	0 (0)
Composite	50 (7)	25 (3)	0 (0)	25 (3)	100 (13)
Cast-in-place Concrete	80 (13)	0 (0)	0 (0)	20 (3)	0 (0)
Precast Concrete	33 (7)	17 (3)	0 (0)	50 (10)	0 (0)
Metal	27 (10)	64 (23)	9 (3)	55 (20)	27 (10)
Plastic	43 (10)	57 (13)	0 (0)	86 (20)	29 (7)
Recycled	25 (3)	25 (3)	0 (0)	50 (7)	100 (13)
Hardwood	22 (7)	22 (7)	56 (17)	67 (20)	44 (13)
Softwood	25 (7)	25 (7)	37 (10)	50 (13)	37 (10)

[1] Percentages within parentheses are based on 30 responses. Other percentages are based on the number of states reporting a negative performance of a material (Table 3-6.). For example, 13 states reported negative performance associated with berms; 15% (2) of these states reported high construction costs.

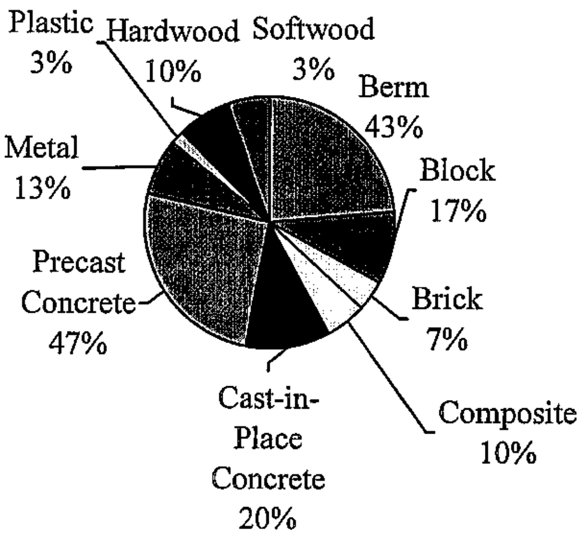
Figure 3-7. Percent of states indicating positive performance of barrier materials. [1]



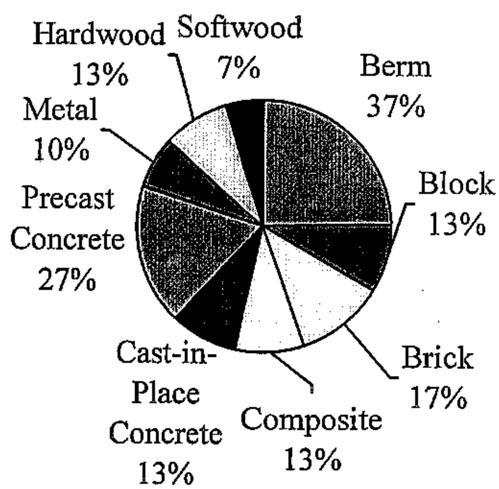
a. Low construction cost



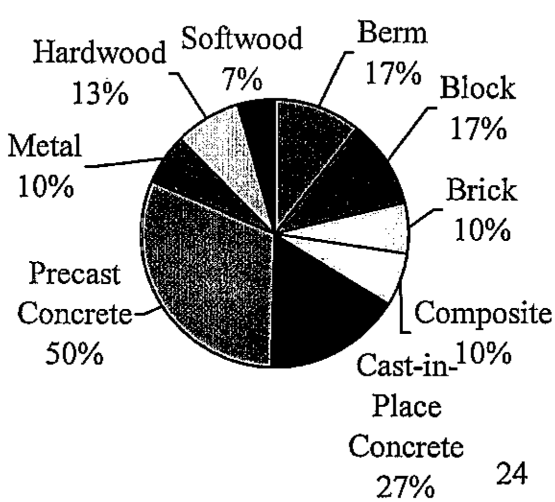
b. Low maintenance cost



c. Positive acoustical performance



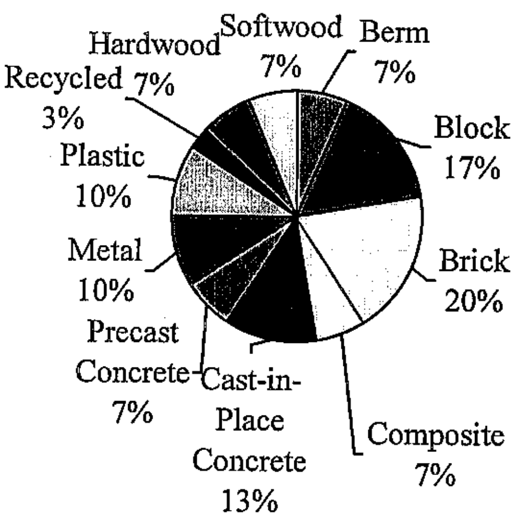
d. Positive aesthetic performance



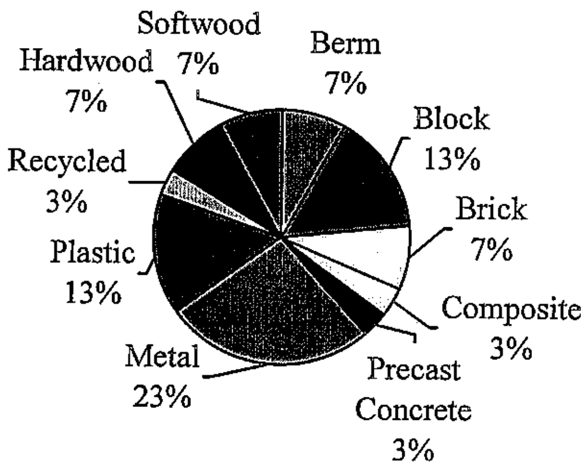
e. Positive structural performance

[1] Percentages do not add to 100 because multiple responses could be given.

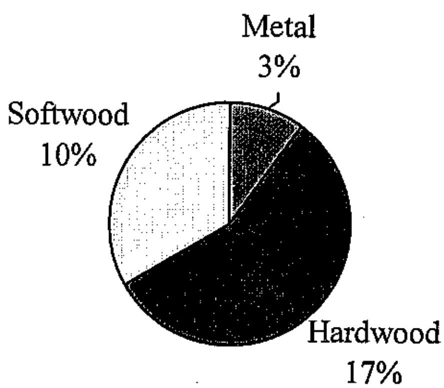
Figure 3-8. Percent of states indicating negative performance of barrier materials. [1]



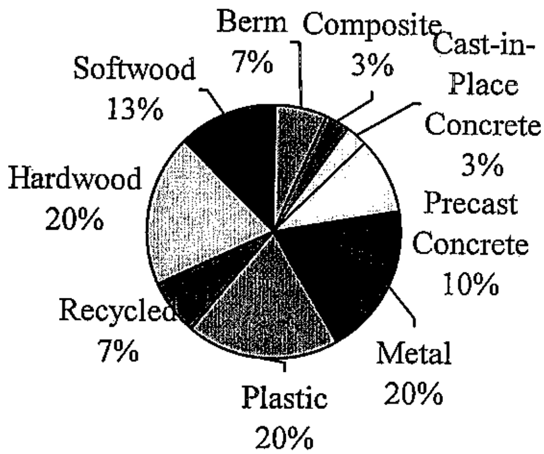
a. High construction cost



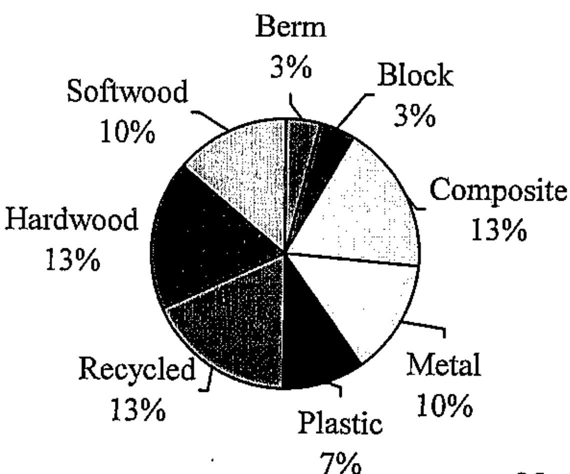
b. High maintenance cost



c. Negative acoustical performance



d. Negative aesthetic performance



e. Negative structural performance

[1] Percentages do not add to 100 because multiple responses could be given.

3.2.3.2 Berm Performance

While berms were ranked second-highest in positive performance, they also received the highest percent (43%) of states reporting negative performance (Table 3-6). Right-of-way availability is the major constraint associated with berms; 69% of the respondents reporting negative performance noted this characteristic. In fact, 54% of the respondents reporting negative performance noted only this negative characteristic. One state reported poor aesthetic performance due to erosion and landscaping problems. Another state commented that "berms are best, when adequate space [is] available." In support of this comment, berms have performed well in most categories investigated (Table 3-7 and Figure 3-7); good structural performance may be the only exception. Fewer than one-third of the respondents reporting positive performance noted good structural performance; however, only one respondent actually reported poor structural performance (Table 3-8 and Figure 3-8). Positive comments included "blends well with local environment" and "well accepted by near residents." One state commented that "berms are used whenever space allows due to costs, acoustic absorption, and aesthetics."

3.2.3.2 Block Performance

While 30% (nine) of the states reported positive performances of block walls, 23% (seven) reported negative performances (Table 3-6). This material performs well acoustically and structurally according to five of the nine states reporting positive performance (Table 3-7 and Figure 3-7). However, one state commented that a wall cracked from settling. Four respondents on positive performance listed good aesthetic performance. One state commented that block has "very high public approval." The main negative criterion is the construction cost (Table 3-8 and Figure 3-8), but four respondents also noted high maintenance costs, although an equal number reported low maintenance costs. Two states commented on the high cost of labor for installation while another commented that these types of walls are "easy to install with local labor."

3.2.3.3 Brick Performance

Five states reported positive and six reported negative performance of brick (Table 3-6). The walls have performed well aesthetically according to all the respondents reporting positive performance (Table 3-7 and Figure 3-7), and three of these respondents reported good structural performance. One respondent commented that there "have been many good comments on [their] brick walls from residents and [they] have also performed well structurally." However, brick walls are expensive to construct according to all six respondents reporting negative performance (Table 3-8 and Figure 3-8). Two states commented on the high cost of labor for installation. The only other negative performance noted was maintenance cost. Although it was not reported in the survey, structural failure has occurred on a brick wall in Michigan, as reported in Chapter 5.

3.2.3.4 Composite Performance

Four states reported positive performance while four others reported negative performance of composite walls (Table 3-6). Two states commented on the lightweight nature of composites and ease of maintenance, including the ease of removing paint. All the states reporting positive performance noted good aesthetics of the walls, and three of these states reported low maintenance costs as well as good acoustical and structural performance (Table 3-7 and Figure 3-7). However, all the respondents reporting negative performance noted poor structural performance (Table 3-8 and Figure 3-8). One state reported a framing and connection failure while another reported that the "acoustic panels debonded from the precast concrete panels."

3.2.3.5 Cast-in-Place Concrete Performance

Eleven states reported positive performance of cast-in-place concrete while only five reported negative performance (Table 3-6). Barriers from this material were reported to perform well structurally and have low maintenance cost according to 73% (eight) and 64% (seven) respectively of the states reporting positive performance (Table 3-7 and Figure 3-7). One state commented that this material is "useful where safety and use as a retaining wall are important." Another state commented that maintenance is easy. The major drawback, according to the states reporting negative performance, is the construction cost (Table 3-8 and Figure 3-8). One state commented that the "labor to form and pour cast-in-place concrete is [the] most expensive process." Another state reported that, in general, "concrete [is] very durable but 'stark' in appearance if not heavily vegetated [but it has] no maintenance cost."

3.2.3.6 Precast Concrete Performance

Over three times the number of states reported on the positive performance of precast concrete as reported on its negative performance (20, or 67%, versus six, or 20%) (Table 3-6). According to the states reporting positive performance, precast concrete performs well structurally and acoustically (Table 3-7 and Figure 3-7). While fewer states reported low construction cost, one state commented that all the materials included in the survey have high construction cost except precast concrete. Another state commented that precast concrete "has been used frequently due to [low construction] cost." Two states commented on the ease or speed of installation. For those states reporting negative performance, aesthetics was the most common problem (Table 3-8 and Figure 3-8). One state commented that "concrete color was inconsistent throughout a project," and another commented that it is "hard to form both sides to provide aesthetics." Another state commented, in general, that "concrete [is] very durable but 'stark' in appearance if not heavily vegetated [but it has] no maintenance cost."

3.2.3.7 Metal Performance

For metal barriers, 23% (seven) of the states reported positive performance while 37% (11) reported negative performance (Table 3-6). For those states reporting positive performance, the same number (four, or 57%) reported low construction, low maintenance cost, and good acoustical performance for metal barriers (Table 3-7 and Figure 3-7). Comments received include that metal walls "can be relocated if necessary" and that they are "relatively easy to clean." In addition, one state commented that a wall built in 1980 "still looks good." While there was consistency among the reports on positive performance, there was less consistency among the reports on negative performance (Table 3-8 and Figure 3-8). The main complaints were the high cost of maintenance (64%) and poor aesthetics (55%). One state reported "deteriorating connections [due to] expansion-contraction forces at [the] connections]" resulting in poor structural performance and flaking surface treatment resulting in high maintenance costs. Another state reported "corrosion problems due to deicing agents." One state commented that "metal imparts an 'industrial' appearance and has demonstrated structural problems but is effective, with no real complaints from [the] public."

Metal has been rejected by 27% (three) of the states reporting negative performance, or 10% of all the states participating in the survey. One state that rejected metal only reported high construction cost. The other two states reported high maintenance costs and poor aesthetic performance. In addition, one of these states reported poor structural performance.

3.2.3.8 Plastic Performance

Only one state (3%) reported positive performance of plastic noise barriers (Table 3-6); this state reported good acoustical performance (Table 3-7 and Figure 3-7). However, seven states (23%) reported negative performance (Table 3-6). Six of these seven states (86%) reported poor aesthetic performance (Table 3-8 and Figure 3-8). One state reported that the plastic barrier was "susceptible to plastic 'creep' under ultraviolet" light. Another reported that a "plastic barrier had engineering problems from the start."

Plastic has been rejected by 29% (two) of the states reporting negative performance, or 7% of all the states participating in the survey. Both states reported poor aesthetic performance. One of the states also reported poor structural performance; the other state also reported high maintenance costs.

3.2.3.9 Recycled Material Performance

No states reported positive performance of noise barriers made of recycled materials, but four states (13%) reported negative performance (Table 3-6.) All the states reporting negative performance indicated poor structural performance (Table 3-8 and Figure 3-8). Two (50%) of these states also reported aesthetic problems.

One state (3% of all the states participating in the survey) has rejected a recycled noise barrier wall. The state reported poor aesthetic and structural performance. Another state commented that a "wall failed and collapsed" but did not indicate that recycled materials had been rejected.

3.2.3.10 Hardwood Performance

Nine states reported negative performance while six reported positive performance with hardwood barriers (Table 3-6). There was consistency among the states reporting positive performance, with most of the states reporting good acoustic, aesthetic, and structural performance as well as low construction cost (Table 3-7 and Figure 3-7). Half the states (three) also reported low maintenance cost. There was less consistency among the states reporting negative performance (Table 3-8 and Figure 3-8). Five states reported poor acoustic performance, and six states reported poor aesthetic performance. One state reported that the "heat dries and dulls wood." Another state reported that a wall had a "faded appearance but [had] no complaints" with the wall. A state commented that "wood looks real good early but its eventual 'weathered' appearance is not universally accepted." However, almost half the states (four, or 44%) reported structural problems, including warping, splitting, and cracking. In addition, one state commented that "wooden walls, unless landscaped, are unattractive." A state that does not have any wood walls commented that "wood walls have proven to be poor performers in other states due to deterioration as well as poor dimensional stability (warping)." A south central state commented that wood walls are "perceived as [having] high maintenance and short life in [their] region" while a southwestern state commented that their state is "too dry."

One state (11% of those reporting negative performance, or 3% of all states participating in the survey) has rejected hardwood "as originally designed" for noise walls. This state reported acoustical and structural problems with hardwood barriers.

3.2.3.11 Softwood Performance

Twice as many states reported negative performance of softwood barriers as reported positive performances (eight, or 27%, versus four, or 13%) (Table 3-6). Three states reporting positive performance reported good acoustical performance or low construction cost (Table 3-7 and Figure 3-7). Two states reported good aesthetic and structural performance. However, four of the eight states reporting poor performance reported poor aesthetics (Table 3-8 and Figure 3-8). Comments were the same as for hardwood performance. In addition, one state commented that softwood walls are "susceptible to surface fire damage," and another noted that "poor quality control at [the] job site...[and] moisture control" were problems.

One state (12% of those reporting negative performance, or 3% of all states participating in the survey) has rejected softwood for noise barriers. (This state is not the same state that has rejected hardwood.) The state only reported poor acoustical performance.

3.2.4 Maintenance

Part III of the survey dealt specifically with the maintenance of noise barriers, including repairs to and replacements of barriers. These questions were designed to assist the researchers in developing service life criteria as well as to obtain information pertinent to LCCA modeling and potential specification revisions required in Illinois.

3.2.4.1 Responsibilities

Questions: Please indicate the portion of the walls for which the state is responsible. How long is the state responsible for the noise barriers?

Twenty-nine (97%) of the states responding to the survey say the state is responsible for maintaining at least one side of the noise barriers. (One state did not respond to the question.) Almost 90% (26) of these states are responsible for both sides while the remaining states are responsible only for the highway side. One state commented that they maintain the "structural integrity for the life of [the] wall [and the] aesthetics on [the] freeway side only" of Type I walls but that a "local agency assumes ownership" of Type II walls. All 29 states (100%) reported that they are responsible for maintenance for more than 20 years. One state added that their responsibility extended "for the design life of the material."

3.2.4.2 Program

Questions: Does your state have a maintenance program for noise barrier walls? What is the maintenance program?

Less than half the states have a maintenance program (12 of 29, or 41%). Of those states with programs, the majority include activities related to aesthetics; 75% (nine) maintain landscaping (through, for example, mowing and pruning) while 67% (eight) clean or coat the walls (Table 3-9). Several states commented that the latter activity is in response to graffiti. Half the states (six) include section replacement in their maintenance programs. (The reasons for the replacements were not requested in the survey, but based on other information in the surveys, it is likely generally due to structural damage caused by vehicles.) Despite the importance of durability and acoustical performance to the states when selecting noise barrier materials (Table 3-3), less than half (five, or 42% of those with maintenance programs, or 17% of all states responding to the survey) conduct structural or visual inspections of the barriers, and none conduct acoustic testing as part of their maintenance programs.

Table 3-9. Maintenance programs.

Maintenance Activity	States Performing [1]
Landscaping upkeep	9 (75%)
Cleaning	8 (67%)
Coating, painting, or staining	8 (67%)
Repair of minor cracks	7 (58%)
Vegetation removal	7 (58%)
Replacement of wall sections	6 (50%)
Structural inspections	5 (42%)
Visual inspections	5 (42%)
Acoustic testing	0 (0%)
Interviews of homeowners	0 (0%)

[1] Percentages do not add to 100 since more than one response could be given.

Questions: What is the annual maintenance budget for noise barrier walls? What portion of the funding is used for routine maintenance and major repairs?

Consistent with the states' lack of policy and funding strategies reported regarding rehabilitation and replacement of walls, little data was obtained from the survey on maintenance costs. Only one state reported an annual maintenance budget for noise walls ($300,000). Comments received ranged from "no idea" and "no data" to "as needed" and "not specific." Similarly, only two states reported the breakdown of funding into routine maintenance and major repairs; one reported 75% and the other reported 100% goes toward routine maintenance.

3.2.4.3 Acoustic Testing

Questions: Do you consider failure to meet insertion loss and/or noise level criteria to be reason to replace a barrier? Has the acoustical performance of existing walls ever been tested? What is the testing procedure?

While one-third (ten) of the states consider failure to meet insertion loss and/or noise level criteria to be reason to replace a barrier, half (15) do not. This result is in contradiction to the reported importance of acoustical performance in the selection of noise barrier materials (Table 3-3). (Except for one respondent who indicated that the question was not applicable, the remaining four respondents did not answer the question.) Two-thirds (20) of the states have acoustically tested existing walls, generally following either ANSI or FHWA procedures. Of these 20 states, four, or 20%, have had walls fail to meet their testing criteria.

Questions: How frequently is testing conducted?

The frequency of the testing ranges from "often" to "once." Twenty percent (four of 20) routinely or frequently conduct testing. These states do not consider this testing to be part of a maintenance program (Table 3-9) apparently because the testing is performed at construction rather than during the barrier's life. One state reported that "every barrier has before and after measurements to prove effectiveness," and another reported that testing is conducted "routinely...on each wall if time and equipment is available." Thirty percent (six of 20) of the states performing acoustic tests do so infrequently while 45% (nine of 20) test rarely or have tested only once.

Question: What prompted the testing?

The reported reasons for testing are varied. Twenty percent (four of 20) conduct testing out of curiosity; another 20% (four of 20) test due to community requests or complaints, and 30% (six of 20) have tested for research or demonstration projects. In addition, one state reported a legislative mandate caused testing while another reported testing in response to a potential legal challenge.

3.2.4.4 Repair and Replacement

Questions: Have you had to repair or replace any walls or are you considering repairing or replacing any walls? What percent of the walls by length have had to be repaired or replaced? Please mark why the repairs or replacements were needed.

Over half the states (18 or 30, or 60%) have repaired or replaced noise walls or are considering repairing or replacing walls. Most of these states (12 of 18, or 67%) have repaired or replaced 1% or less of their noise walls by length. Of the remaining six states, only one reported repairing or replacing more than 10% of the length; this state reported repairing approximately 50% (or approximately 27 km). For all materials, the main reasons that walls have been repaired or replaced are damage due to traffic accidents and poor aesthetic or structural performance (Table 3-10). Only one state reported performing repairs or replacements due to normal aging. (Note that these figures do not reflect walls that may require repair but are not currently being considered for repair or replacement.)

Table 3-10. Reasons for repair or replacement of noise barriers.

Reason	States That Have Repaired or Replaced Walls [1]
Traffic accidents	10 (56%)
Poor performance	9 (50%)
Normal aging	2 (11%)
Natural disaster	1 (5%)

[1] Percentages are based on 18 responses and do not add to 100 because more than one reason could be given.

Questions: Were future construction or design specifications changed as a result of the repair(s) or replacement(s)?

One-third (six, or 33%) of the states that have repaired or replaced walls changed construction specifications as a result of the repairs or replacements. However, 50% (nine) of these states have changed design specifications. One state reported that a "product is no longer used." Another state reported that they "adopted an absorptive noise wall policy." This state retrofitted 100% of a reflective wall with absorptive panels. A third state commented the specifications were changed to ensure that the walls "better withstand vehicular impact."

Questions: Please complete the following tables for walls that have been repaired or replaced and for walls being considered for repair or replacement (concerning the reason(s) for repair or replacement and the age, replacement cost, and replacement system used).

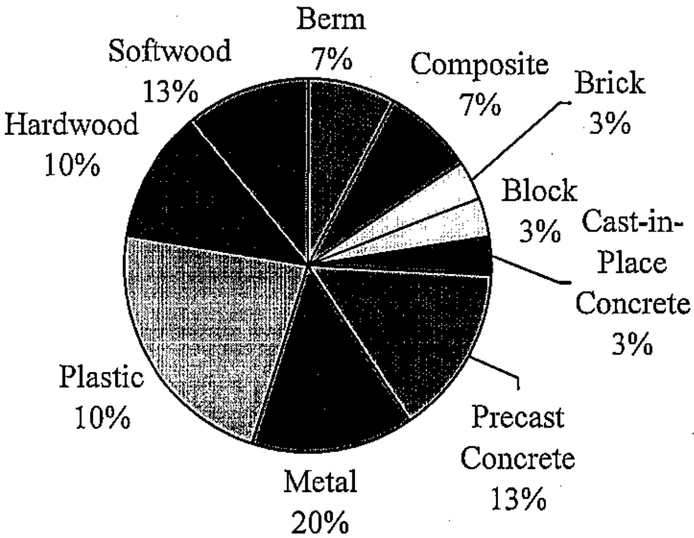
Of the 11 materials included in the survey, metal has been repaired or replaced the most often (Table 3-11 and Figure 3-9), despite the small amount of metal barrier by length constructed (Figure 3-5). No states reported repairing or replacing barriers made of recycled materials; however, as stated earlier, at most 2.3% of barriers are constructed of recycled material. More barriers have been constructed of concrete than any other single material (Figure 3-5), but only 13% of the states (four of 30) have repaired or replaced concrete barriers (Table 3-11). (One state reported repairing or replacing both cast-in-place and precast concrete barriers.) Wood makes up approximately 14% of the length of barriers constructed (excluding wood barriers used in combination with other materials), but 20% of the states (six of 30) have repaired or replaced wood barriers.

Table 3-11. Repairs or replacement of noise barrier materials.

Material	Ages (years)	Percent of States Reporting Repairs or Replacements [1]
Berm	5 - 15	11 (7)
Block	15	5 (3)
Brick		5 (3)
Composite	10	11 (7)
Cast-in-place Concrete	19	5 (3)
Precast Concrete	1 - 10	22 (13)
Metal	<1 - 15	33 (20)
Plastic	1.5 - 10	17 (10)
Recycled		0 (0)
Hardwood	<1 - 3	17 (10)
Softwood	0 - >10	22 (13)

[1] Percentages within parentheses are based on 30 responses. Other percentages are based on the 18 states reporting a repair or replacement of a particular material. For example, two states reported repairing or replacing berms, which represents 11% of those states repairing or replacing walls or 7% of all states responding to the survey.

Figure 3-9. States reporting repairs or replacements of noise barrier materials. [1]



[1] Percentages do not add to 100 because various numbers of responses were given.

Berm. Two states reported repairs or replacements of berms (Table 3-11). Both states reported public complaints (Table 3-12). One of the states commented that erosion was a problem on a 5-year-old berm; this state "reduced the height and side slopes" of the berm to solve the problem. The other state placed a precast concrete wall on an existing 15-year-old berm.

Table 3-12. Reasons for repair or replacement of walls by material type.

Material	Reasons for Repair or Replacement (Percent of States Reporting) [1]					
	Appearance	Installation Errors	Reduced IL [2]	Complaints	Safety	Structural Failure
Berm	50 (5)	50 (5)		100 (11)		
Block	100 (5)					
Brick	100 (5)					100 (5)
Composite					50 (5)	100 (11)
Cast Concrete [3]	100 (5)					
Precast Concrete	50 (11)		25 (5)		50	25 (5)
Metal	50 (17)		33 (11)	17 (5)	17 (5)	33 (11)
Plastic	33 (5)		33 (5)	33 (5)		33 (5)
Hardwood	67 (11)	33 (5)	67 (11)	67 (11)		
Softwood	50 (11)	25 (5)	75 (17)			25 (5)

[1] Percentages within parentheses are based on the 18 states reporting repairs to and replacements of walls. Other percentages are based on the number of states reporting a repair or replacement of a particular material. For example, two states reported repairing or replacing berms; 50% (one) of these states reported appearance was the cause, which equates to 5% of the states repairing or replacing walls (one of 18).

[2] IL stands for insertion loss.

3 Cast stands for cast-in-place.

Block. Only one state reported repairing or replacing a block wall (Table 3-11), although block walls make up 25% of the walls by length (Figure 3-5). The wall was 15 years old and developed an appearance problem (Table 3-12).

Brick. Likewise, only one state reported repairing or replacing a brick wall (Table 3-11). A traffic accident resulted in appearance and structural problems (Table 3-12).

Composite. Two states reported repairing or replacing composite walls (Table 3-11). Both states reported structural failures (Table 3-12). One of the states replaced a 10-year-old composite wall with a precast concrete barrier.

Cast-in-Place Concrete. One state reported repairing or replacing a 19-year-old cast-in-place concrete wall that developed appearance problems (Tables 3-11 and 3-12).

Precast Concrete. Precast concrete barriers have been repaired or replaced by 22% (four) of the states repairing or replacing walls (Table 3-11 and Figure 3-9). The walls ranged in age from 1 year to 10 years. One state reported a loss of noise reduction as the

Metal. More states (six) have repaired or replaced metal walls than walls made of other materials (Table 3-11 and Figure 3-9). Half these states (three) did so due to the appearance of the walls (Table 3-12). Other reasons given include car accidents, a fallen tree, and public complaints about the performance of a new wall that resulted in absorptive panels being added less than a year after installation. Appearance problems seem to appear on older walls, those eight to 15 years old (although Illinois had a problem with a new wall as discussed in Chapter 5). Loss of noise reduction occurred on a three-year-old wall as well as on an eight-year-old wall. One state reported replacing a metal wall that experienced structural failure due to "wrecks" with the same system. (Not included in these figures is a metal wall used for three years as a temporary wall during roadway construction.)

Plastic. One state reported that a 1.5-year-old plastic wall structurally failed and "fell down" (Table 3-12). Another state reported that a 10-year-old barrier's "clear plastic panels yellowed and cracked," resulting in appearance problems, loss of noise reduction, and public complaints. The third state (Table 3-11) reported that a traffic accident caused the repair or replacement. Two of the states reported replacing the plastic barriers with different systems; one state used a "small berm" while the other used a composite.

Recycled. No states reported repairing or replacing walls made of recycled material. However, the 1.5-year-old plastic wall discussed above was made of recycled plastic.

Hardwood. The hardwood barriers repaired or replaced ranged in age from new to 3 years old (Table 3-11). A new hardwood barrier lost noise reduction capabilities after "separation due to moisture" (Table 3-12). A 3-year-old barrier had appearance problems, installation errors, lost noise reduction, and public complaints likely due to "manufacturing errors." The state reported that the same system is being used to replace "pieces of panels." Public complaints and appearance problems led to the repair or replacement of a 2-year-old wall.

Softwood. The problem most often reported for softwood barriers was loss of noise reduction (three of four, or 75%, of states) (Table 3-12). One softwood barrier had appearance problems, installation errors, loss of noise reduction, and structural failure at construction (Tables 3-11 and 3-12). The state reported that the "plywood sheathing of [the] plank wall mount opened up severely;" the contractor replaced the wall. A new wall lost noise reduction capabilities after "separation due to moisture." Another wall had appearance problems and loss of noise reduction after the "wood rotted." A wall at least 10 years old was repaired or replaced due to "traffic strikes."

3.2.5 Summary

There was no consensus among the respondents on the average service life of noise barriers, although 75% (18 of 24) respondents listed at least 20 years. However, it appears that the majority of barriers built to date have performed well. While repairs and replacements of noise barrier walls appear to have generally been due to vehicle damage or poor performance structurally or aesthetically, less than 1% of walls by length have been repaired or replaced or were being considered for repair or replacement. Metal barriers may be an exception; barriers constructed of metal have been repaired or replaced by 20% (six) of the states responding to the survey—more than any of the other materials. Precast concrete, cast-in-place concrete, block walls, and berms received been repaired or replaced or were being considered for repair or replacement. Metal barriers may be an exception; barriers constructed of metal have been repaired or replaced by 20% (six) of the states responding to the survey—more than any of the other materials. Precast concrete, cast-in-place concrete, block walls, and berms received generally favorable comments from the respondents. Precast concrete received the most comments about positive acoustical and structural performance while berms received the most comments about positive economic and aesthetic performance. The main negative comment received about berms was the need for large amounts of right-of-way.

The most important factors for the respondents when choosing noise barrier materials are construction cost and durability. However, in-state experience, initial appearance, noise reduction, adjacent sites, maintenance cost, and public requests are also important. State staff and consultants most often design the noise barriers, generally using AASHTO or state design specifications. One-third of the states that have repaired or replaced walls (six of 18) changed construction specifications as a result of the repairs or replacements, and half (nine) have changed design specifications.

All but one state responding to the survey reported maintaining only the highway side of the barriers. All reported being responsible for the walls for more than 20 years. However, 67% (20) of the states do not have a design life policy for noise barriers. For those states with policies, over half use 20 years, less than the responsible maintenance period. In addition, 59% of the respondents (17 of 29) do not have a maintenance program for their walls. Those states that have programs generally maintain landscaping or conduct cleaning or coating. Only 17% (five) of the respondents conduct structural or visual inspections of the walls. Despite the reported importance of acoustical performance in the selection of noise barrier materials, none of the respondents conduct acoustic testing as part of a maintenance program and half (15) do not consider failure to meet insertion loss and/or noise level criteria to be reason to replace a barrier.

CHAPTER 4

MATERIALS SELECTION PROCESS FOR NOISE BARRIERS IN ILLINOIS

4.1 Introduction

The Illinois Department of Transportation (IDOT) and the Illinois State Toll Highway Authority (ISTHA) have constructed a total of over 97 km (60 miles) of noise barriers on Illinois highways. The construction of noise barriers has been concentrated in IDOT districts containing urban areas (Districts 1, 2, 4, 6, and 8) (Figure 4-1). All noise barriers constructed by ISTHA are in the greater Chicago metropolitan area.

A total of 13 different products have been used by IDOT and ISTHA in the construction of noise barriers (Table 4-1). However, wood and concrete have been the preferred materials both in Illinois and nationally, accounting for 90% of all highway noise barriers built in this country through 1995. In Illinois, these two materials account for 60% of the IDOT and 97% of the ISTHA barriers built to date. Table 4-2 compares the percent of area in each material throughout the U.S. with the percent in Illinois.

The IDOT and ISTHA have made different choices in the selection of products and materials for the construction of noise barriers. While IDOT has used 11 different materials to construct 38 km (24 miles) of barriers, ISTHA has used only 4 different materials for over 59 km (36 miles) of noise barrier construction. Only two materials, precast concrete and glue-laminated softwood, have been used by both agencies. A summary of the materials used by each agency is given in Tables 4-3 and 4-4.

A listing of noise barriers constructed in Illinois to date, by location, is given in Table 4-5. The listing is broken down by material type in Table 4-6 (a-l). All data shown in Tables 4-3 through 4-6 is adapted from the 1996 FHWA summary report. This summary shows noise barrier quantities and costs in each state by generic categories (concrete/precast, block, berm, wood/post & plank, wood/unspecified, concrete/unspecified, metal/unspecified, wood/glue laminated, brick, and other) rather than by specific material or by brand names. This data has been restructured and presented in Tables 4-3 to 4-6, using more specific product information.

The costs presented in Tables 4-3 through 4-6 are taken without modification from the FHWA summary and are given for information only. These costs represent estimates of the costs of noise barrier construction from projects over the past 20 years, as reported to the FHWA by IDOT and ISTHA. The accuracy of the original data supplied to FHWA cannot by verified. In some cases, the reported costs of noise barrier construction may have included costs associated with other items such as earthwork, foundations, guardrail, landscaping, or other work items. In addition, the reported costs have been periodically indexed by FHWA to reflect construction cost inflation.

Figure 4-1. IDOT district map.

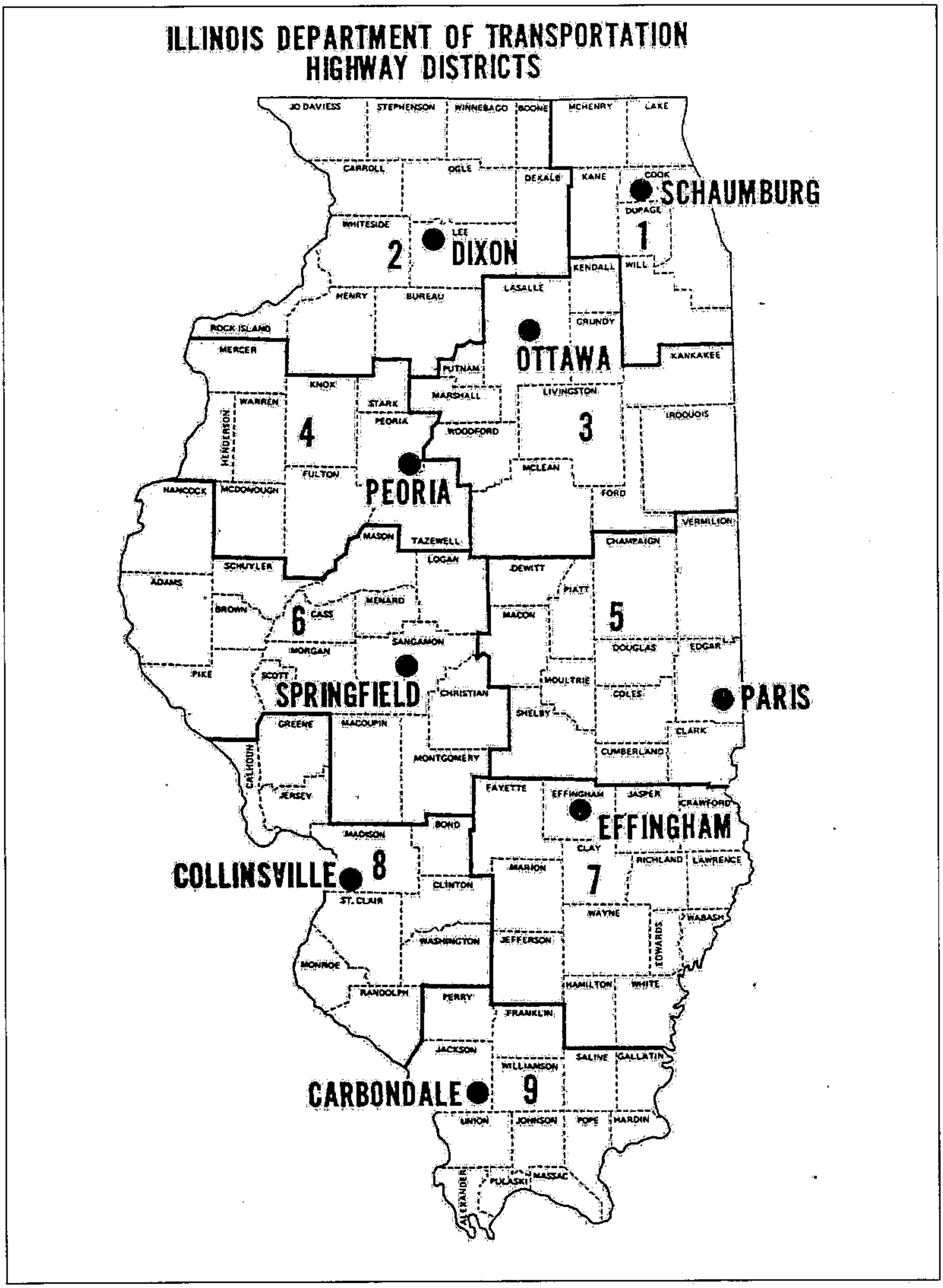


Table 4-1. Illinois Noise Barriers by Material

Material	Description
Berm Only	Compacted earth with 3:1 (maximum) side slopes
Berm/Retaining Wall	Combination noise and retaining structure
Combination Berm and Wood	Compacted earth topped by short wood barrier
Carsonite®	Fiberglass casing and recycled rubber core
Durisol™	Composite sandwich (concrete core covered with compressed, cemented wood shavings)
Fanwall® Concrete	Footingless, free-standing wall on prepared granular base
Noishield®: Steel	Steel casing with mineral wool fill
Noishield®: Aluminum	Aluminum casing with mineral wool fill
Precast/Prestressed Concrete	Cantilever wall (full-height panels, no posts)
Precast Concrete	Post and Panel (full-height panels with monolithic posts)
Softwood	Post and Panel (tongue-and-groove boards)
Glue-laminated Softwood	Glue-laminated pressure treated softwood post and panel
Tropical Hardwood	Post and panel (tongue-and-groove boards)

Table 4-2. Comparison of U.S. and Illinois noise barriers by material.

Material	U.S. Area (%)	Illinois Area (%)
Concrete	38	14
Block	28	0
Combination	14	23
Wood	11	45
Berm Only	3	9
Metal	3	3
Brick	1	0

Source: FHWA (1996)

Table 4-3. Summary of IDOT Noise Barriers (through Dec. 31, 1995)

Wall Type	Area (sq. m.)	Percent of Total Area
Tropical Hardwood	48,715	32.9%
Combination Berm and Wood	33,062	22.3%
Glue-laminated Softwood	18,786	12.7%
Precast/Prestressed Concrete (Cantilever)	16,469	11.0%
Durisol™	10,652	7.2%
Berm Only	9,659	6.5%
Fanwall® (Precast Concrete)	4,459	3.0%
Metal: Noishield® (Steel)	3,690	2.5%
Berm/Retaining Wall	1,902	1.3%
Metal: Noishield® (Aluminum)	622	0.4%
Total Area	148,016	100%
Total Length	38.3 km (23.8 miles)	
Total Cost (1995 Dollars)	$20,744,709	
Cost (by area)	$140/sq. m. ($ 13/sq.ft.)	
Cost (by length)	$542,300/km ($871,600/mile)	

Source: FHWA (1996)

Table 4-4. Summary of ISTHA Noise Barriers (through Dec. 31, 1995)

Wall Type	Area (sq. m.)	Percent of Total Area
Precast Concrete (Post and Panel)	109,743	58%
Glue-laminated Softwood	53,095	28%
Softwood (Post and Panel)	19,791	11%
Carsonite®	5,698	3%
Total Area	188,327	100%
Total Length	58.6 km (36.4 miles)	
Total Cost (1995 Dollars)	$40,800,000	
Cost (by area)	$217/sq. m. ($20/sq. ft.)	
Cost (by length)	$696,100/km ($1.12 million/mile)	

Source: FHWA 1996

Table 4-5. Summary of Illinois Noise Barrier Construction Through Dec. 31, 1995
(Source: FHWA, 1996)

ILLINOIS NOISE WALL BARRIERS LISTED BY LOCATION

State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost
Illinois	Addison	I-290	I	Comb/Berm/Wood	1986	2,286	6.10	1,614,027
Illinois	Addison/ DuPage	I-355/290	I	Tropical Hardwood	1990	1,332	5.50	869,949
Illinois	Cook	IL 53	I	Tropical Hardwood	1990	3,827	4.60	2,347,568
Illinois	DuPage	IL 83	I	Glue Laminated	1991	1,595	2.10	737,947
Illinois	DuPage	I-290	I	Glue Laminated	1992	104	2.10	39,479
Illinois	DuPage	IL 83 @ I-290	I	Glue Laminated Softwood	1992	1,991	1.80	545,642
Illinois	Elmhurst	I-290 (ramp)	I	Berm Only	1985	561	2.10	257,018
Illinois	Elmhurst	I-290 (ramp)	I	Glue Laminated Softwood	1985	757	4.90	665,171
Illinois	Elmhurst	I-290	I	Comb/Berm/Wood	1986	853	4.00	532,371
Illinois	Elmhurst	I-290	I	Comb/Berm/Wood	1986	1,387	3.00	544,910
Illinois	Elmhurst	I-290	I	Comb/Berm/Wood	1986	1,741	4.00	709,088
Illinois	Elmhurst/Villa Park	SR 83	I	Glue Laminated Softwood	1986	1,770	2.10	296,460
Illinois	West Chicago, Bartlett	IL 59	I	Durisol	1993	1,489	5.50	932,729
Illinois		I-355	T	Glue Laminated Softwood	1988	21,238	2.50	8,600,000
Illinois		I-294	T	Concrete/Precast Post/Panel	1994	29,139	3.69	20,500,000
Illinois		I-294	T	Softwood Post/Panel	1994	6,597	3.00	5,700,000
Illinois		I-294	T	Carsonite	1994	1,036	5.50	3,300,000
Illinois		I-94	T	Concrete/Precast Post/Panel	1996	600	3.70	2,700,000
Illinois	Schaumburg	IL 19	I	Durisol	1993	226	5.50	510,500
Illinois	Schaumburg, Elk Grove, Roselle	Elgin-O'Hare	I	Tropical Hardwood	1993	4,691	5.00	3,186,120
Illinois	Monroe Center	US 51	I	Fanwall Precast Concrete	1979	731	6.10	656,501
Illinois	Highland Park	US 41	I	Glue Laminated Softwood	1982	363	3.00	197,044

Table 4-5. (continued)

State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost
Illinois	Highland Park	US 41	S	Berm Only	1983	366	3.00	213,518
Illinois	Highland Park	US 41	I	Glue Laminated Softwood	1989	389	3.00	140,616
Illinois	Highland Park	US 41	I	Glue Laminated Softwood	1989	305	4.30	153,688
Illinois	Bartlett	IL 59	I	Durisol	1993	265	4.60	197,392
Illinois	Bolingbrook	SR 53	I	Glue Laminated Softwood	1980	305	2.10	129,518
Illinois	Rockford	US 51	I	Precast Concrete (cantilever)	1980	384	4.00	203,009
Illinois	Rockford	US 51	I	Precast Concrete (cantilever)	1980	1,217	4.00	774,448
Illinois	Rockford	US 51	I	Precast Concrete	1980	932	4.90	604,493
Illinois	Rockford	US 51	I	Precast Concrete	1980	956	4.00	483,178
Illinois	Peoria	I-474	I	Tropical Hardwood	1987	183	1.80	52,896
Illinois	Springfield	SR 4	I	Berm Only	1978	1,370	4.90	631,598
Illinois	Springfield	SR 4	I	Berm Only	1979	319	2.10	26,839
Illinois	Springfield	SR 4	I	Berm Only	1979	634	3.00	53,739
Illinois	Springfield	SR 4	I	Combination Berm/Retaining Wall	1979	634	3.00	508,313
Illinois	Springfield	SR 4	I	Berm Only	1986	539	3.00	68,926
Illinois	Springfield	SR 4	I	Berm Only	1989	305	3.00	39,454
Illinois	Springfield	SR 4	I	Berm Only	1989	125	3.00	16,170
Illinois	Moline	SR 5	S	Comb/Berm/Wood	1988	1,238	3.70	332,211
Illinois	Centerville	I-255	I	Noishield steel	1984	1,230	3.00	819,389
Illinois	Collinsville	I-255	I	Noishield aluminum	1985	296	2.10	259,549
Illinois	East St. Louis	I-255	I	Precast Concrete (cantilever)	1981	558	3.00	393,241
					TOTAL	96,864		61,544,709

Table 4-6 (a through ℓ). Summary of Illinois Noise Barriers by Material Type

(Source: FHWA 1996)

Table 4-6a. Berm only.

BERM ONLY

State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois	Elmhurst	I-290	I	Berm Only	1985	561	2.10	$ 257,018.00	1178.1
Illinois	Highland Park	US 41	S	Berm Only	1983	366	3.00	$ 213,518.00	1098
Illinois	Springfield	SR 4	I	Berm Only	1978	1,370	4.90	$ 631,598.00	6713
Illinois	Springfield	SR 4	I	Berm Only	1979	319	2.10	$ 26,839.00	669.9
Illinois	Springfield	SR 4	I	Berm Only	1979	634	3.00	$ 53,739.00	1902
Illinois	Springfield	SR 4	I	Berm Only	1986	539	3.00	$ 68,926.00	1617
Illinois	Springfield	SR 4	I	Berm Only	1989	305	3.00	$ 39,454.00	915
Illinois	Springfield	SR 4	I	Berm Only	1989	125	3.00	$ 16,170.00	375
					SUM	4,219		$ 1,307,262.00	9659

AVERAGE COST PER LINEAR METER	$ 309.85
AVERAGE COST PER SQ. METER	$ 135.34
AVERAGE COST PER SQ. FOOT	$ 12.57

Table 4-6b. Berm/ retaining wall.

Berm/Retaining Wall									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois	Springfield	SR 4	I	Berm/Retaining Wall	1979	634	3.00	$ 508,313.00	1902
					SUM	634		$ 508,313.00	1902
					AVERAGE COST PER LINEAR METER			$ 801.76	
					AVERAGE COST PER SQ. METER			$ 267.25	
					AVERAGE COST PER SQ. FOOT			$ 24.83	

Table 4-6c. Combination berm/wood.

COMBINATION BERM AND WOOD									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois	Addison	I-290	I	Comb/Berm/Wood	1986	2,286	6.10	$ 1,614,027.00	13944.6
Illinois	Elmhurst	I-290	I	Comb/Berm/Wood	1986	853	4.00	$ 532,371.00	3412
Illinois	Elmhurst	I-290	I	Comb/Berm/Wood	1986	1,387	3.00	$ 544,910.00	4161
Illinois	Elmhurst	I-290	I	Comb/Berm/Wood	1986	1,741	4.00	$ 709,088.00	6964
Illinois	Moline	SR 5	S	Comb/Berm/Wood	1988	1,238	3.70	$ 332,211.00	4580.6
					SUM	7,505		$ 3,732,607.00	33062.2
					AVERAGE COST PER LINEAR METER			$ 497.35	
					AVERAGE COST PER SQ. METER			$ 112.90	
					AVERAGE COST PER SQ. FOOT			$ 10.49	

Table 4-6d. Carsonite.

Carsonite									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois		I-294	T	Carsonite	1994	1,036	5.50	$ 3,300,000.00	5698
					SUM	1,036		$ 3,300,000.00	5698
					AVERAGE COST PER LINEAR METER			$ 3,185.33	
					AVERAGE COST PER SQ. METER			$ 579.15	
					AVERAGE COST PER SQ. FOOT			$ 53.80	

Table 4-6e. Durisol.

Durisol									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois	West Chicago, Bartlett	IL 59	I	Other, Composite	1993	1,489	5.50	$ 932,729.00	8189.5
Illinois	Schaumburg	IL 19	I	Other/Composite	1993	226	5.50	$ 510,500.00	1243
Illinois	Bartlett	IL 59	I	Other/Composite	1993	265	4.60	$ 197,392.00	1219
					SUM	1,980		$ 1,640,621.00	10651.5
					AVERAGE COST PER LINEAR METER			$ 828.60	
					AVERAGE COST PER SQ. METER			$ 154.03	
					AVERAGE COST PER SQ. FOOT			$ 14.31	

Table 4-6f. Fanwall.

PRECAST CONCRETE (Fanwall)									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois	Monroe Center	US 51	I	Concrete/Precast	1979	731	6.10	$ 656,501.00	4459.1
					SUM	731		$ 656,501.00	4459.1
					AVERAGE COST PER LINEAR METER			$ 898.09	
					AVERAGE COST PER SQ. METER			$ 147.23	
					AVERAGE COST PER SQ. FOOT			$ 13.68	

Table 4-6g. Noishield.

Metal									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois	Centerville	I-255	I	Noishield Steel	1984	1,230	3.00	819,389	3690
Illinois	Collinsville	I-255	I	Noishield Aluminum	1985	296	2.10	259,549	621.6
					SUM	1,526		$ 1,078,938.00	4311.6
					AVERAGE COST PER LINEAR METER			$ 707.04	
					AVERAGE COST PER SQ. METER			$ 250.24	
					AVERAGE COST PER SQ. FOOT			$ 23.25	

Table 4-6h. Precast/prestressed concrete cantilever.

PRECAST CONCRETE (Cantilever)									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois	Monroe Center	US 51	I	Concrete/Precast	1979	731	6.10	$ 656,501.00	4459.1
Illinois	Rockford	US 51	I	Concrete/Precast	1980	384	4.00	$ 203,009.00	1536
Illinois	Rockford	US 51	I	Concrete/Precast	1980	1,217	4.00	$ 774,448.00	4868
Illinois	Rockford	US 51	I	Concrete/Precast	1980	932	4.90	$ 604,493.00	4566.8
Illinois	Rockford	US 51	I	Concrete/Precast	1980	956	4.00	$ 483,178.00	3824
Illinois	East St. Louis	I-255	I	Concrete/Precast	1981	558	3.00	$ 393,241.00	1674
					SUM	4,778		$ 3,114,870.00	20927.9
				AVERAGE COST PER LINEAR METER				$ 651.92	
				AVERAGE COST PER SQ. METER				$ 148.84	
				AVERAGE COST PER SQ. FOOT				$ 13.83	

Table 4-6i. Precast concrete monolithic post and panel.

PRECAST CONCRETE Post/Panel									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois		I-294	T	Precast Concrete Post/Panel	1994	29,139	3.69	$ 20,500,000.00	107522.91
Illinois		I-94	T	Precast Concrete Post/Panel	1996	600	3.70	$ 2,700,000.00	2220
					SUM	29,739		$23,200,000.00	109742.91
					AVERAGE COST PER LINEAR METER			$ 780.12	
					AVERAGE COST PER SQ. METER			$ 211.40	
					AVERAGE COST PER SQ. FOOT			$ 19.64	

Table 4-6j. Softwood post and panel.

Softwood Post/Panel									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois		I-294	T	Softwood Post/Panel	1994	6,597	3.00	$ 5,700,000.00	19791
					SUM	6,597		$ 5,700,000.00	19791
					AVERAGE COST PER LINEAR METER			$ 864.03	
					AVERAGE COST PER SQ. METER			$ 288.01	
					AVERAGE COST PER SQ.FOOT			$ 26.76	

Table 4-6k. Glue-laminated softwood.

Glue Laminated Softwood									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois	Elmhurst	I-290 (ramp)	I	Glue Laminated Softwood	1985	757	4.90	$ 665,171.00	3709.3
Illinois	Elmhurst/Villa Park	SR 83	I	Glue Laminated Softwood	1986	1,770	2.10	$ 296,460.00	3717
Illinois		I-355	T	Glue Laminated Softwood	1988	21,238	2.50	$ 8,600,000.00	53095
Illinois	Highland Park	US 41	I	Glue Laminated Softwood	1982	363	3.00	$ 197,044.00	1089
Illinois	Highland Park	US 41	I	Glue Laminated Softwood	1989	389	3.00	$ 140,616.00	1167
Illinois	Highland Park	US 41	I	Glue Laminated Softwood	1989	305	4.30	$ 153,688.00	1311.5
Illinois	Bolingbrook	SR 53	I	Glue Laminated Softwood	1980	305	2.10	$ 129,518.00	640.5
Illinois	DuPage	IL 83	I	Softwood Post/Panel	1991	1,595	2.10	$ 737,947.00	3349.5
Illinois	DuPage	I-290	I	Softwood Post/Panel	1992	104	2.10	$ 39,479.00	218.4
Illinois	DuPage	IL 83	I	Softwood Post/Panel	1992	1,991	1.80	$ 545,642.00	3583.8
					SUM	28,817		$11,505,565.00	71881

AVERAGE COST PER LINEAR METER	$	399.26
AVERAGE COST PER SQ. METER	$	160.06
AVERAGE COST PER SQ. FOOT	$	14.87

Table 4-6*l*. Tropical hardwood.

Tropical Hardwood									
State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost	TOTAL AREA IN METERS SQUARED
Illinois	Cook	IL 53	I	Tropical Hardwood	1990	3,827	4.60	$ 2,347,568.00	17604.2
Illinois	Schaumburg, Elk Grove, Roselle	Elgin-O'Hare	I	Tropical Hardwood	1993	4,691	5.00	$ 3,186,120.00	23455
Illinois	Peoria	I-474	I	Tropical Hardwood	1987	183	1.80	$ 52,896.00	329.4
Illinois	Addison/DuPage	I-355/290	I	Tropical Hardwood	1990	1,332	5.50	$869,949.00	7326
					SUM	10,033		$ 6,456,533.00	48714.6

AVERAGE COST PER LINEAR METER	$ 643.53

AVERAGE COST PER SQ. METER	$ 132.54
AVERAGE COST PER SQ. FOOT	$ 12.31

4.2. Materials and Products Approved by the Illinois Highway Development Council

IDOT and ISTHA have operated separately in the evaluation and approval of materials and products for noise barrier walls. Each agency has used materials and products that the other has not. The Highway Development Council (HDC) acts on behalf of IDOT in evaluating and approving noise barrier products.

The HDC (established on September 18, 1963) provides the Director of Highways with advice on the value of new products, materials, and procedures that are offered or developed for use in the highway field. The group, through its recommendations, also guides further evaluation and development of new items. The Council acts as a clearinghouse where proposals of manufacturers, producers, and others promoting new items for highway use can be reviewed and given proper consideration.

The organizations comprising the HDC are given in Table 4-7, although other Bureau Chiefs and District Engineers are called upon for advice as the need arises.

Table 4-7. Composition of Illinois Highway Development Council

Organization	Representative
Division of Highways	Deputy Director of Program Implementation
District 1	District Engineer
District Engineer	from one of the remaining districts
Bureau of Bridges and Structures	
Bureau of Construction	
Bureau of Design and Environment	
Bureau of Local Roads and Streets	
Bureau of Materials and Physical Research	
Bureau of Operations	
Division of Aeronautics	Engineer of Materials

The Products Evaluation Engineer in the Bureau of Materials and Physical Research acts as the Chairman of the Council and also performs the duties of Secretary. The Council, consisting of 13 members from the representative organizations, meets at least three times a year and evaluates new products for highway use.

To date, HDC has approved ten proprietary noise barrier products. Of the ten products approved, two products (Evercrete and Sound Off) have been withdrawn without prejudice by the manufacturers and two products (Armco and Koppers) are no longer marketed. Of the six remaining, two products (Fence Crete and Soundcore) were approved in December 1994 and April 1995 respectively and have not been used to date. Of the four remaining, three products have been used by IDOT (Bongossi, Durisol™ and Noishield®), and one product (Carsonite®) has been used by ISTHA but not by IDOT.

Of the three products used by IDOT, one (Noishield® steel) is no longer approved for further use based on poor performance in the field. A second product (tropical hardwood) has not been formally disapproved by HDC but is no longer recommended based on its performance in the field. Of the 11 different noise barrier products used by IDOT, four walls were built using HDC approved materials (Durisol™ and two types of Noishield® walls), six walls were built using non-proprietary materials (wood, concrete, and earth berm), and one (Fanwall®) was built using a proprietary product without specific HDC review and approval. A detailed listing of the approved products is shown in Table 4-8.

Table 4-8. Noise Barrier Products Approved by the Illinois Highway Development Council

		EVALUATION IN PROGRESS			EVALUATION COMPLETE		
PRODUCT NAME, MANUFACTURER	DESCRIPTION	FIELD TEST	LAB TEST	OTHER	ACCEPT	REJECT	REMARKS
Armco Noise Barrier Armco, Inc. 703 Curtis St. Middletown, OH (513) 425-5000	Prefinished steel panel noise barrier				9/9/79		No use of this product by IDOT. Company now AK Steel, does not market a noise barrier
Noishield Industrial Acoustics 1160 Commerce Ave. Bronx, NY 10462 (718) 430-4515 Mr. Gary Figallo	Prefinished steel or aluminum acoustic panel noise barrier				7/80	8/24/90	Trials installed in District 8, 1984, 1985.
Koppers Sound Barrier Koppers Company, Inc. Pittsburgh, PA 15219 (412) 227-2419	Non-proprietary V-groove wood plank noise barrier						No use of this product by IDOT. Company no longer markets this product.
Evercrete Noise Barrier Evercrete Limited Maple, Ontario	Precast concrete noise barrier			12/4/92			Withdrawn by vendor without prejudice; now marketed as "Fence-Crete"
Soundcore Advanced Storage Tech Amherst, NY (716) 833-6212	Precast concrete noise barrier				4/7/95		No use of this product by IDOT to date.

Table 4-8 (continued)

		EVALUATION IN PROGRESS			EVALUATION COMPLETE		
PRODUCT NAME, MANUFACTURER	DESCRIPTION	FIELD TEST	LAB TEST	OTHER	ACCEPT	REJECT	REMARKS
Bongossi North American Hacon Doylestown, PA rep: Timber Holdings Milwaukee, WI (414) 445-8989	Tropical hardwood for bridge, marine structures, and noise barriers				12/8/88		Trials installed 9/87 (District 4); 10/89 and 5/90 (District 1).
SoundOff Crane/COR TECH Co. Wash. Court Hse., OH (800) 879-4377	Prefabricated sound barrier						Withdrawn by vendor without prejudice.
Carsonite Sound Barrier Carsonite International Early Branch, SC (800 648-7916	Fiber-reinforced composite surface with polyolefin and recycled rubber core				5/6/93		No use of this product by IDOT to date. Approved by letter from Ralph Wehner instead of HDC action. Used on I-294 (tollway) 1994.
Durisol Durisol, Inc. 95 Frid Street Hamilton, Ontario (905) 521-0999	Sound absorptive panels of cemented wood shavings				10/29/93		Field trials 1986 (District 8); 1991 (District 1).
Fence-Crete Faddis Conc. Products Ddownington, PA (800) 777-7973	Precast concrete noise barrier				12/2/94		No use of this product by IDOT to date.

4.3. IDOT Product Approval Process for Noise Barrier Walls

The product evaluation process begins with a manufacturer or vendor submitting product evaluation data on prescribed forms (Figure 4-2) with enclosures that include trade literature, test results, specifications, drawings, data from actual and/or test installations, installation instructions, and guarantees. HDC relies heavily on the manufacturer-furnished literature and data in the evaluation process. For concrete-based products, testing by HDC is limited to freeze/thaw resistance and compressive strength tests; other materials are not tested. The vendors are required to furnish all other data, including acoustical test results through approved testing laboratories. In addition to approving or rejecting the product, HDC may also recommend field testing to determine highway user and resident reactions at a selected site. The review process and recommendation of a product by HDC can take up to 6 months.

4.4. Description of Proprietary Noise Barrier Walls Built in Illinois

The vendor-furnished literature on proprietary wall systems used in the construction of noise barriers in Illinois was reviewed and summarized below. The barriers are grouped into two categories, reflective and absorptive, according to their acoustic properties. Absorptive barriers are those with a Noise Reduction Coefficient (NRC) of at least 0.80 when tested in accordance with ASTM C 423. (Refer to Chapter 5.)

4.4.1. Reflective Barriers

4.4.1.1 Carsonite® Noise Barrier wall

Carsonite is a reflective barrier manufactured by Carsonite International. This company has been a manufacturer of highway safety products for more than 24 years. The development of the Carsonite noise barrier began in 1990 and the first walls using this system were built in late 1993. The structural element is a fiberglass-reinforced polymer outer casing and recycled tire core. The panels (2 inches thick, 6 inches high and 10 feet long) can be stacked on top of each other to reach the required height. The ends are anchored in "H" shaped steel or concrete supports. The fiberglass is manufactured with a variety of integral colors and contains flame-retardants and UV inhibitors to prevent solar degradation. A wall panel 10 feet by 10 feet weighs only about 800 lbs (or 8 lbs/sft). The manufacturer claims this product is easy to install, repair and relocate without large construction equipment. The product has been in use or approved for use in several states, including Illinois, Nevada, Maryland, Ohio and California. Product data abstracted from vendor literature is summarized in Table 4-9.

Figure 4-2. HDC Product Evaluation Form.

State of Illinois
DEPARTMENT OF TRANSPORTATION
Division of Highways

PRELIMINARY INFORMATION FOR PRODUCT EVALUATION

Product Trade Name ________________________________ Date

Manufacturer ________________________________ Phone No.

Address____
Street City State Zip

Representative ________________________________ Phone No.

Address____
Street City State Zip

Product Identification

____

Recommended uses – Primary

____

____

Recommended uses – Alternate

____

____

Outstanding features or advantages claimed

____

____

____

Material composition

____

____

Patented? Yes __________No __________ Applied for

Material specifications furnished by mfr.? Yes ________ No ________
Copy attached

Meets requirements of following specifications: AASHTO ______________________ ASTM

Fed. Spec. ________________________________ Cml. Std Others.

Use by highway authorities or other agencies in other states

Agency	**Years in Use**	**Remarks**

(Can be continued on page 3)

Are instructions or directions for installation, application, or use available? Yes No
Copy attached ______________________ Will a demonstration be provided?

Are educational courses or movies available? Yes _________________________ No

Availability: Seasonal __________Nonseasonal ____________ Delivery at site
weeks after receipt or order

Are quantities limited? Yes _______ No ________ Will free sample be furnished upon
request? Yes ____ No

Will laboratory analysis be furnished? Yes __________________ No _____________ Attached

Approximate cost – Material only

____

____

Approximate cost – Complete in place

____

____

Royalty costs

____

New on market? Yes _______ No ______ It was in 19_____. Alternate for
what existing product(s)?

PRELIMINARY INFORMATION FOR PRODUCT EVALUATION
Page 3

Background description of company and its product

Who recommended that the Department of Transportation be contacted?

Who directed you to the Bureau of Materials and Physical Research?

Has another office of the Department of Transportation been contacted? Yes
No

Which?

Additional Information

(Attach additional sheets as necessary)

Please attach applicable trade literature, test results, specifications, instructions, guarantee, etc.

Interview by

Person furnishing information

Title

For consideration by the Illinois Highway Development Council submit <u>original</u> of this form to:

Engineer of Physical Research
Illinois Department of Transportation
Division of Highways
126 East Ash Street
Springfield, Illinois 62704

4.4.1.2 Fanwall® Precast Concrete

Fanwall® is a proprietary noise barrier manufactured by Picket Wall Systems, Inc. This product is currently marketed as Monowall™ system. The barrier section used near Monroe Center, Illinois consists of precast concrete panels placed directly on a prepared base in a "zig-zag" pattern. No below-ground foundations were required.

Each Monowall™ module includes both panel and monolithic post. The panels are 5.5 inches thick and are available as wide panels (maximum length of 20 feet) or as tall panels (maximum length of 13.5 feet) and can be oriented vertically or horizontally. These modules can be installed in a straight line, requiring a caisson foundation, or as a curving or undulating wall. Post sections are designed to allow up to 45° bends to avoid obstacles. All modules' posts can be off-centered to provide a flat surface on one side. The manufacturer claims that combining the post, panel and vertically off-settable joint system in one module eliminates many crane and crew expenses, resulting in savings in installation costs. Monowall™ panels can readily incorporate all available concrete textures, colors, patterns and noise absorptive surfaces. The product has been in use in several states, including Massachusetts (1970), Maryland, California, Illinois and Vermont. The Fanwall noise barrier at Los Angeles Airport received a national award for design excellence. Product data abstracted from the vendor literature is summarized in Table 4-9.

4.4.1.3 Precast/Prestressed (Cantilever) Barrier

The barrier consists of precast prestressed concrete panels 8 feet wide and 5.5 inches thick. Panel lengths are variable to conform to required barrier height. Design data for the cantilever barrier in East St. Louis shows that panel lengths of 12 and 15 feet were used; the panels were embedded in the ground a minimum of 4 feet, giving a barrier height of 8 to 11 feet. The barriers constructed in Illinois have used a vertical broomed finish on one side, and a rope textured face on the other. Panels are installed with the textures alternating on every second panel. Adjacent panels are connected with a galvanized steel plate located approximately 9 inches below finish grade, and a steel key plate (5 1/2 inches by 4 inches by 1/4 inch in size) grouted into a key slot at the top of adjacent panels. Panels are formed with L-shaped ends that overlap with adjacent panels, forming a 1/2 inch joint that is sealed with caulk. Specially formed ends and modified connection plates are required to accommodate bends in the barrier. The panels are placed in a trench excavation, the bottom of which has been smoothed and leveled with compacted earth or sand. In Illinois, barriers of this design have been constructed by at least two precast concrete companies. Product data abstracted from IDOT plans is given in Table 4-9.

4.4.1.4 Precast/Prestressed Concrete Soundwall System (Post and Panel)

The wall system consists of precast reinforced concrete panels 5 inches thick ranging in height from 6 feet to 28 feet and 15-inch square monolithic posts. Each panel measures 12 foot 9 inches in width and is joined by a vertical tongue and groove design. Panels are formed vertically and can be designed with a different pattern on each side. To reduce traffic noise, panel designs feature highly textured surface mass to provide optimum sound abatement. Panels are formed to replicate a wide choice of building materials, including stone, brick, and wood, and can be produced in a variety of textures and colors. Some panel faces are similar to popular split-faced concrete masonry walls. Simulated mortar joints are formed in the panel to duplicate the traditional stacked bond pattern of block walls. The vendor literature claims that the system is capable of providing over 60 years of service with minimal maintenance. The ISTHA used this system to build nearly 30 km (19 miles) of walls in 1994. Product data abstracted from the vendor literature is given in Table 4-9.

4.4.1.5 Softwood (Post and Panel)

This product is a non-proprietary product used by ISTHA. No plans or specifications were made available to the researchers.

4.4.1.6 Glue-laminated Softwood

The glue-laminated wall system is a non-proprietary reflective barrier manufactured by Sentinel Structures, Inc., Peshtigo, Wisconsin. The wall system consists of glue-laminated pressure-treated softwood, with post and panel construction. The barrier modules are 1 foot 10-3/4 inches wide and fabricated in either 2-11/16 inch 3-15/16 inch thickness. Four of these modules are pre-assembled to create a unit 8 feet wide. Vertical 2 inch by 6 inch battens cover both sides of the 1-¾ inch gaps between the modules. Assembled panel units can be embedded in the ground for cantilevered support or attached to posts with A-307 bolts and A-36 angles. The posts can be used on one side of the wall or on alternate sides of the wall for better appearance. The lightweight panels (10 to 12 lbs/sft depending on the panel thickness) facilitate easy erection. The panel units can be easily attached to Jersey barriers, concrete retaining walls, and bridge abutments. The first noise walls using this system were built in 1982 and the system has been in use in several states, including Illinois, New Jersey, Wisconsin and Minnesota. Product data summarized from vendor literature is summarized in Table 4-9.

4.4.1.7 Tropical Hardwood

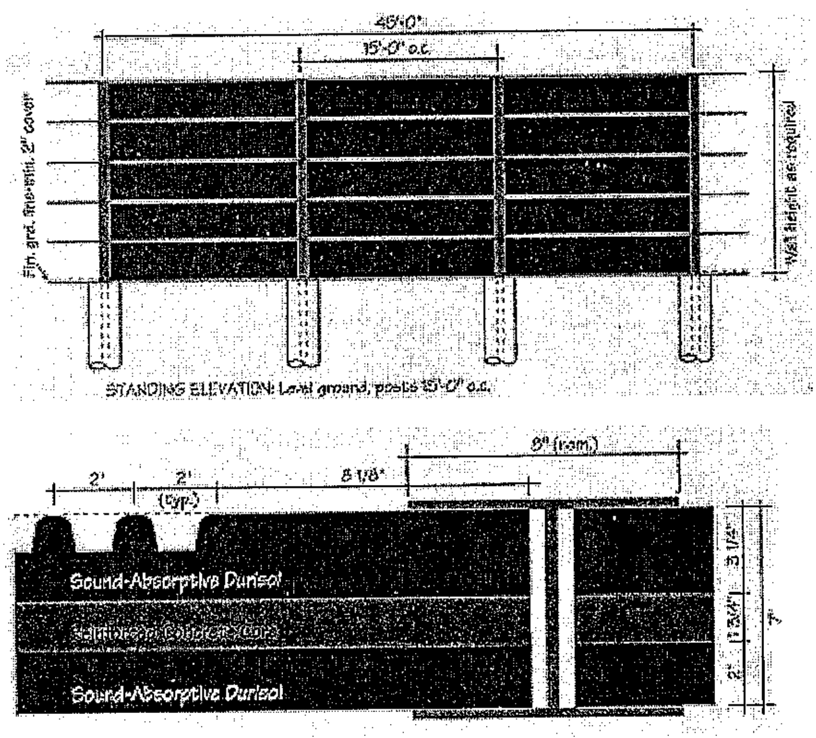
Bongossi is a dense (specific gravity of 1.05 versus 0.7 for kiln-dried oak), naturally fire-, insect- and rot-resistant East African wood. The principal claim made for Bongossi is its aesthetically pleasing appearance and superior durability. The wall system typically consists of single-ply 2 inch by 8 inch lumber with tongue-and-groove construction attached to posts spaced at 8 to 12 foot centers. The posts vary in size from 8 inches by 15 inches to 15 inches square.

4.4.2. Absorptive Barriers

4.4.2.1 Durisol™

Durisol™ is a proprietary absorptive noise barrier system manufactured by the Reinforced Earth Company. It consists of a composite sandwich panel with a 2-inch concrete core covered with compressed, cemented wood shavings. The outer layers may be shaped with various textures and integrally pigmented to give a variety of colors. The thickness of the panels range from 5 to 7 inches depending on the exterior treatments. The tongue-and-groove panels are typically 15 feet long and are installed between posts consisting of wide flange beams (Figure 4-3). Thin Durisol™ surface panels 2 inches to 3 inches thick are also available to retrofit walls. The vendor literature claims that as a building material, Durisol™has performed well in all kinds of environments for more than 50 years. Durisol™ noise barriers were first constructed in 1979 near Toronto, Canada, by the Ontario Ministry of Transportation. Subsequently, some 51 km of Durisol™ two-sided sound absorptive barriers were constructed throughout the province of Ontario. "These barriers appear to have endured the elements of harsh climates for nearly two decades with no apparent loss of acoustical effectiveness and no significant weather damage" (Bischoff 1997). Durisol™ barriers have been widely used in Wisconsin, and have also been constructed in Illinois and Indiana. Product data abstracted from vendor literature is summarized in Table 4-9.

Figure 4-3. Elevation and cross-section of Durisol barrier.



Source: The Reinforced Earth Company

4.4.2.2 Noishield®

Noishield® is a proprietary absorptive system manufactured by Industrial Acoustics Company, Inc. This product is available in two materials, stainless steel and aluminum. The steel barrier system consists of modular panels (4 inches thick) constructed of cold-rolled galvanized steel sheets, minimum 16 gauge solid side and 20 gauge perforated side. The barrier incorporates absorptive fiberglass as acoustic fill material. Each panel is 2 feet wide and 12 feet long. The modules are coated in the factory with a polyester powder coating applied through an electrostatic charge and thermally bonded to the surface of the galvanized steel sheets. The vendor literature claims that harsh cleaning chemicals used in the removal of spray painted graffiti do not damage the treated surfaces. The system can also provide a wide variety of standard colors and optional facings, including brick, stone, stucco, wood, and slate. The panels are oriented horizontally and are held in place by galvanized steel wide flange beams (W 5 X 16) acting as posts. Noishield® barriers were built along I-255 in Illinois in 1984 and 1985. Noishield® was also used as sound absorptive cladding on two bridge-mounted reflective concrete walls in Mechanicsburg, PA.

The Noishield wall system is also available in aluminum instead of stainless steel with panels oriented vertically rather than horizontally. Product data abstracted from vendor literature is summarized in Table 4-9.

4.2.3 Summary

The information shown in Table 4-9 as taken from vendor literature highlights the lack of consistent reporting of pertinent of acoustic information, service life estimates and structural properties of noise barrier products. The product evaluation form used by the HDC for reviewing new highway products is not specific in requesting acoustic performance and service life estimates or documentation from vendors. Minor revision of the form or creation of a form specific to noise barriers could result in more consistent and comparable information from noise barrier vendors.

Table 4-9. Product Data on Noise Barrier Walls Built by IDOT and ISTHA.

Wall Type, Description	Wall Thickness	Density lbs/cft	Weight per sft	STC	NRC	Claimed Service Life	Remarks
Berm Only Material Type: Soil	---	---	---	---	---	---	---
Berm/Retaining Wall Material Type: Soil & Concrete	---	---	---	---	---	---	---
Combination Berm & Wood Material Type: Soil & Wood	---	---	---	---	---	---	---
Carsonite Material Type: 2" thick panels with fiberglass outer casing and recycled tire core	2"	48	8 lbs/sft	36	0.15	50	
Durisol Material type: composite sandwich panel, reinf. conc. core, outer layer cemented wood shavings	7" (varies)	47	27	40	0.9	-	

Table 4-9 (continued)

Wall Type, Description	Wall Thickness	Density lbs/cft	Weight per sft	STC	NRC	Claimed Service Life	Remarks
Fanwall now marketed as Monowall Material: Precast Concrete	5.5"	150	69	-	-	-	
Noishield (steel) Sound absorptive panels with steel	4"		6		0.95		Disapproved for further use
Noishield (aluminum)	5"		6				
Precast Concrete (cantilever)	5.5"	150	69	-	-	-	
Precast Concrete (post & panel)	5"	150	63			60	
Softwood (post & panel) No data available							
Glue Laminated Softwood	2 11/16"; 3 15/16"	36	8 12	34 35	0.1		
Tropical Hardwood Bongossi No Data Available							No longer recommended for use

CHAPTER 5

CURRENT CONDITIONS OF ILLINOIS NOISE BARRIERS

5.1 Methodology

Determination of the current condition of noise barriers in Illinois was key to assessing the potential service life of each material or product. The researchers made this assessment by personally observing noise barriers in neighboring states and a majority of the noise barriers in Illinois, and by surveying IDOT and ISTHA maintenance personnel regarding their observations and experiences with noise barriers in their jurisdictions.

5.2 Field Survey

Over the course of the research project, the investigators observed highway noise barriers in Illinois, Missouri, Michigan, Maryland, Florida and Tennessee. This report will summarize only the close observations made of noise barriers in Michigan and Missouri, neighboring states with climates similar to Illinois.

5.2.1 Michigan Noise Barriers

Noise barriers in the greater Detroit area were observed in a one-day trip in November 1997. This visit, made while the researchers were in the area for an unrelated conference, was complemented by a two-hour interview with Mr. Leo DeFrain of Michigan DOT. Although the climate of Michigan is similar to that of northern Illinois, the experiences of Michigan DOT in regard to noise abatement are quite different from those of IDOT. Michigan used home insulation, window replacement and air conditioning for a group of 150 homes as an alternative to noise barrier construction, one of the only abatement projects of its kind in the U.S. The design of I-696 in Detroit's northern suburbs introduced long stretches of depressed roadway for noise abatement. Community input on aesthetics and a desire to employ local skilled labor also led to widespread use of brick noise barriers, a material not used for Illinois noise barriers.

The visit to Michigan was instructive, however. In particular, several sections of brick and brick/concrete noise barrier constructed in the late 1980s on I-696 were observed to have failed. In both cases, the cause of the observed distress was not a failure of the materials used to construct the barrier (brick and cast-in-place concrete), but rather a failure of the connection of these two materials. In all the observed cases of distress or failure, control joints in the poured concrete footing and in the brick were not aligned with each other. Differential movement at the joints in the concrete wall supporting the brick could not be transferred to corresponding joints in the brick. The resulting differential movement appears to have caused stresses in the brick resulting in cracking, spalling of the brick facing, and in one case complete failure of the barrier (Figures 5-1 and 5-2).

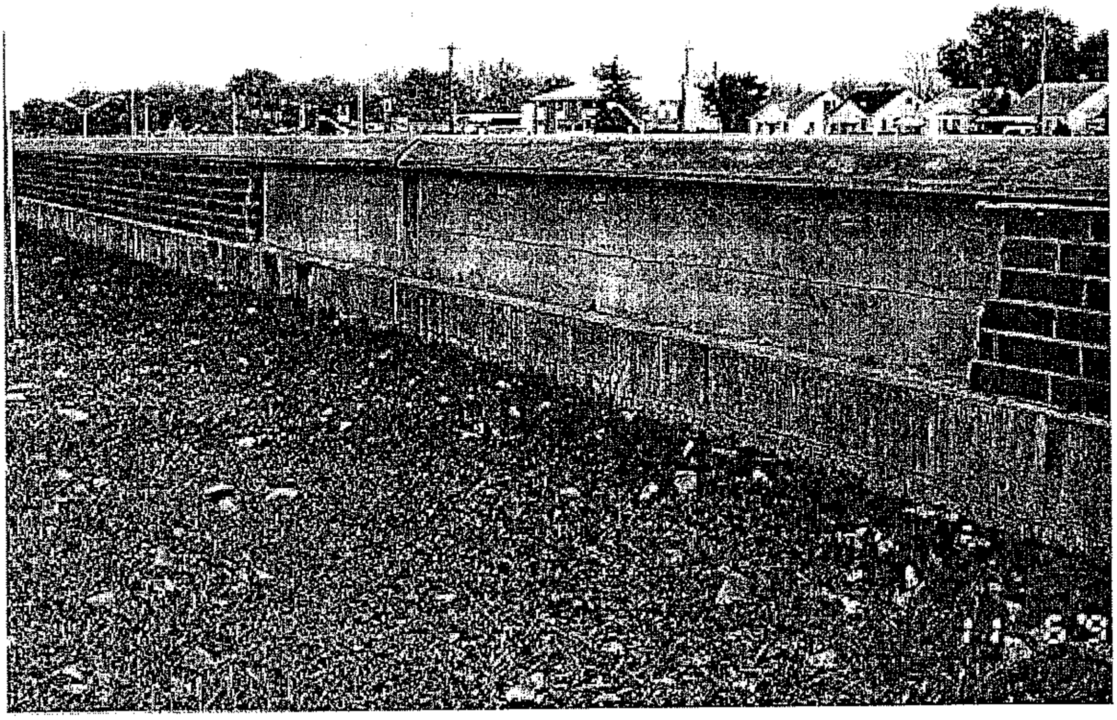


Figure 5-1. Spalling of brick-faced barrier. I-696, Detroit MI.

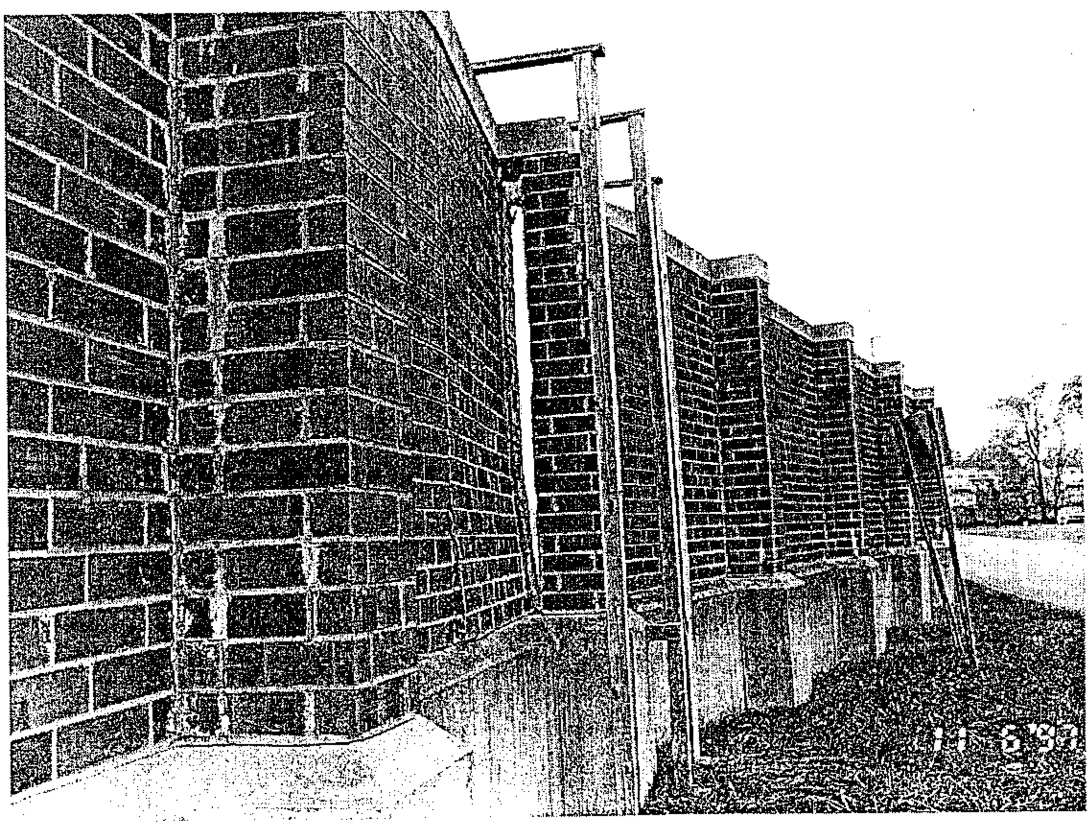


Figure 5-2. Failure of brick barrier, I-696, Detroit, MI.

5.2.2 Missouri Noise Barriers

Noise barriers in the St. Louis, Missouri area were also observed due to the similarity of St. Louis climate to that of downstate Illinois and the similarity of materials used. The oldest barrier in St. Louis was constructed on I-170 in north St. Louis County in 1980 of precast/prestressed concrete. Wall panels are imbedded into the ground to a depth approximately one-half of the wall height for support. The panels are approximately 2.5 inches thick and 8 feet wide. Each panel is notched on the ends to fit together with adjacent panels without posts (Fig. 5-3). This wall type, also used in Illinois, is hereafter referred to as a "cantilever" wall because the wall section itself is used for foundation support. The condition of this type of wall at 18 years was generally good, although one section was observed to be out of plumb, leaning visibly toward the roadway. Another section appeared to be leaning due to the growth of sapling trees along the wall on the residents' side (Fig. 5-4), pushing the wall panel out of alignment. This section also showed minor movement at the joints with open cracks up to 6 mm (1/4 inch) wide. The condition of the concrete itself appears to be good, with no evidence of cracking or spalling.

Precast concrete full-height panels with monolithic posts are located along I-170 in west St. Louis County. These barriers were constructed in 1988, and are of the same design and manufacture as those used by ISTHA in later projects. The barriers are stained dark brown, and are textured on both sides to resemble masonry block. Much of the barrier length is covered with ivy and vines from the residents' side. Sections visible to the researchers were examined and no structural defects were noted. Some fading and staining of the surface is visible in some locations.

5.2.3 Illinois Noise Barriers

Of the 43 noise barrier sections in Illinois, the researchers visited 36 sites (84%), and saw representative sections of each type of noise barrier currently in use in the state. The researchers conducted a two-day field tour of noise barriers in IDOT District 1 and along the tollway system in northern Illinois in addition to day trips to Springfield, Rockford, Collinsville, and East St. Louis. TRP chairman Michael Bruns visited and took current photographs of the noise barrier in Peoria in June 1998. In addition, the researchers made survey measurements of a noise barrier scheduled for replacement in the East St. Louis vicinity in an effort to quantify the parameters that define the failure of that barrier.

Figure 5-3. Precast/prestressed concrete cantilever, detail end of panel.

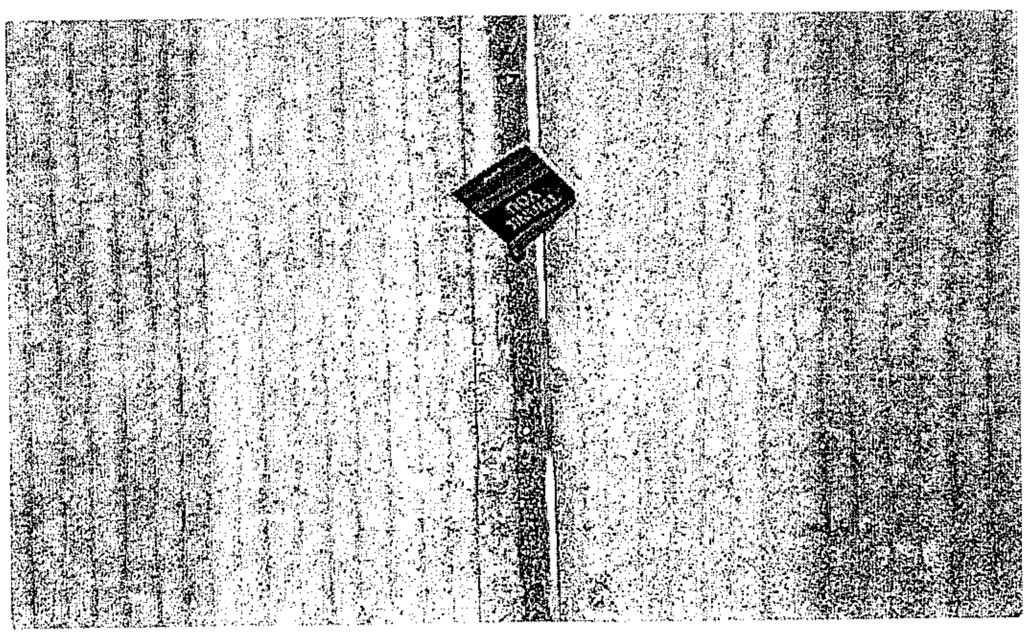


Figure 5-4. Precast/prestressed concrete barrier, opening of joint.

5.2.3.1 IDOT District 1

Twenty-one noise barrier sections, 55% of the IDOT total listed in the December 1996 FHWA summary, are located in District 1. Five additional noise barrier sections are located on toll expressways in the Chicago area. The researchers toured noise barriers in the Chicago metropolitan area on May 14-15, 1998, accompanied by members of the project TRP. The field tour included both "windshield surveys" and close observation from both the highway side and residents' side. During the tour, all of the noise barriers in IDOT District 1 and along the tollways were observed, with the exception of wooden barriers and an earth berm located on US 41 in Highland Park, and one section of concrete barrier on the North-South Tollway (I-94). The tour allowed the researchers to see the field condition of noise barriers of various materials and ages and to discuss some of the observed problems with IDOT District 1 consultant services engineer Prem Suri.

5.2.3.1.1 Glue-laminated wood

District 1 has used a wide variety of materials, colors, textures, and foundation types for noise barriers. The earliest barrier in the district is a glue-laminated wood wall along IL 59 in Bolingbrook (Fig. 5-5). At the time this noise barrier was being designed, in the late 1970s, material selection for noise barriers was influenced heavily by public input, and wood was a popular choice. In addition, the variety of noise barrier products from which to choose was still limited, and no Illinois manufacturers were in the market. Glue-laminated wood, which had been used for indoor and outdoor structural applications in bridges and buildings since the 1930s, was a product that was appealing to the public, commercially available, and economically feasible. The condition of this barrier at age 18 years is still remarkably good. The wall is landscaped on the road side as well as the residents' side, and blends into the neighborhood well. The barrier is approximately 5 feet tall, of glue-laminated pressure-treated softwood, with post and panel construction. Although the short barrier was designed primarily as a sight screen, noise level measurements made by IDOT District 1 at the time of construction reportedly indicated the barrier provided a 9 dB insertion loss. No more recent noise measurements are known to have been made. The barrier shows no evidence of ground-level rot, sagging, deviation from plumb, or other structural defect. It does not appear that the barrier has had maintenance in the form of staining or waterproofing. Based on the current structural and aesthetic conditions of this wall, the researchers would not anticipate that this barrier is near the end of its useful service, and estimate a service life of at least 25 years.

Other glue-laminated wood walls in the Chicago area (both IDOT and IHSTA barriers) also appeared to be in good condition, based on the observations of the researchers.

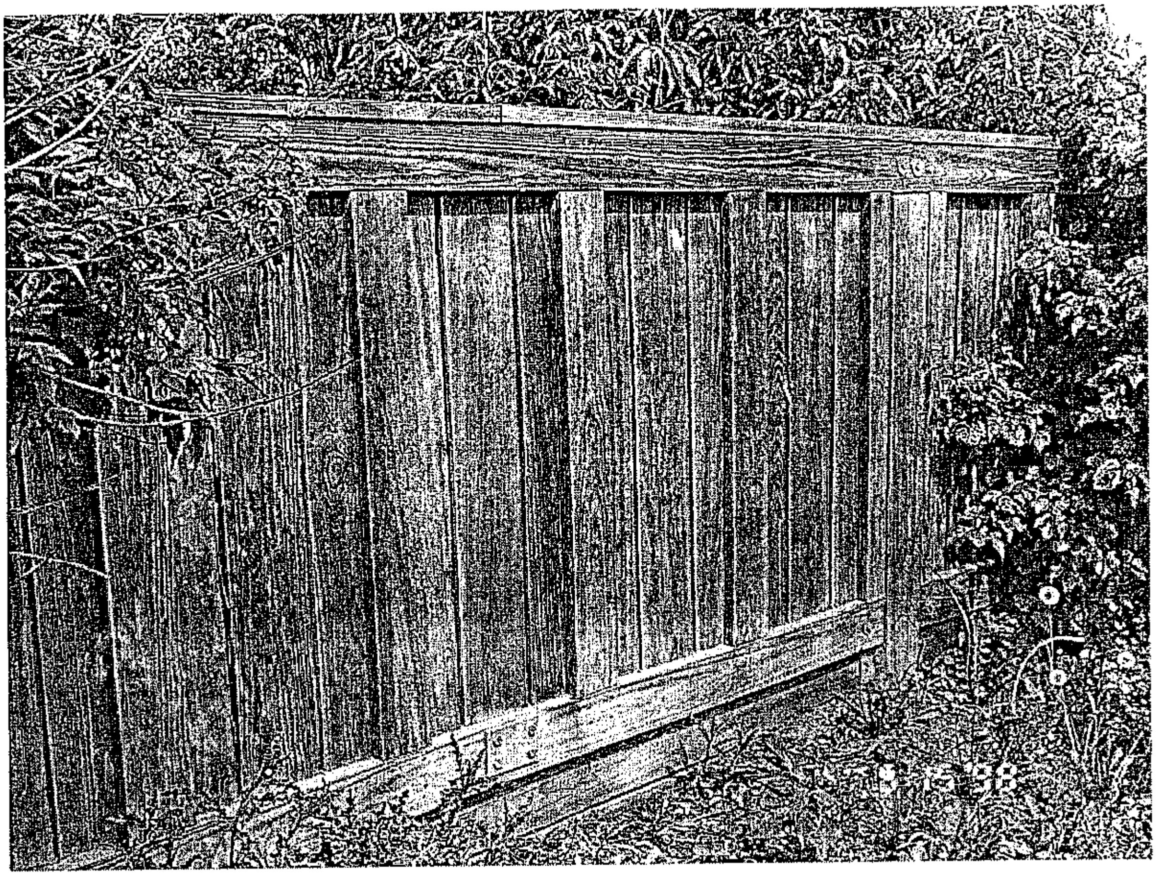


Figure 5-5. Glue-laminated Wood Noise Barrier, IL 53.

5.2.3.1.2 Tropical Hardwood

In contrast to the overall good condition of glue-laminated wood barriers, tropical hardwood barriers constructed of tongue-and-groove boards in District 1 were observed to show more warpage, gaps at the joints, movement of the panels, and discoloration. Tongue-and-groove wood barriers are typically single-ply 2 by 8 lumber (nominal thickness). For a typical panel 12 feet high by 12 feet long, this type of barrier has 216 linear feet of horizontal joints between boards and 24 feet of vertical joints, all potential sources of open cracks. In contrast, the glue-laminated wood walls are multi-ply (Fig. 5-6), have no horizontal joints, and vertical joints are covered with battens.

The tropical hardwoods bongossi (*Lophira alata* or *Lophira procera)* and bonalin (*Dinizia exclesa)* were first used in District 1 in October 1989 on IL 53 in DuPage County. Bongossi is a dense (specific gravity = 1.05 vs. 0.7 for kiln-dried oak), naturally fire, insect and rot-resistant East African wood, used for the vertical support posts. Bonalim is used for the barrier panels. Records provided by the IDOT Bureau of Materials and Physical Research indicate that the initial project consisted of approximately 24,260 square feet of ground-mounted and 1,013 square feet of Jersey barrier-mounted tropical hardwood barriers. A larger section of tropical hardwood barrier, over 186,000 square feet, was installed on IL 53 at the Lake County/Cook County line. An additional 78,780 square feet was installed in 1990 on IL 53. Finally, tropical hardwood barriers were used on the Elgin-O'Hare Expressway in the Schaumburg area in 1993. The specifications for each wall were incrementally changed in response to problems noted on the Lake/Cook barriers on IL 53. Some of the changes reportedly made included:

- post spacing was reduced from 12 feet to 8 feet
- a 2 X 6 cap board was added to protect the top panel and end grain of posts
- butt joints in the cap board were flashed to keep moisture out
- vertical battens on the residents' side of the barrier were fastened with screws rather than nails
- vertical 2 X 2 battens were made continuous for the entire height of the wall with no joints.

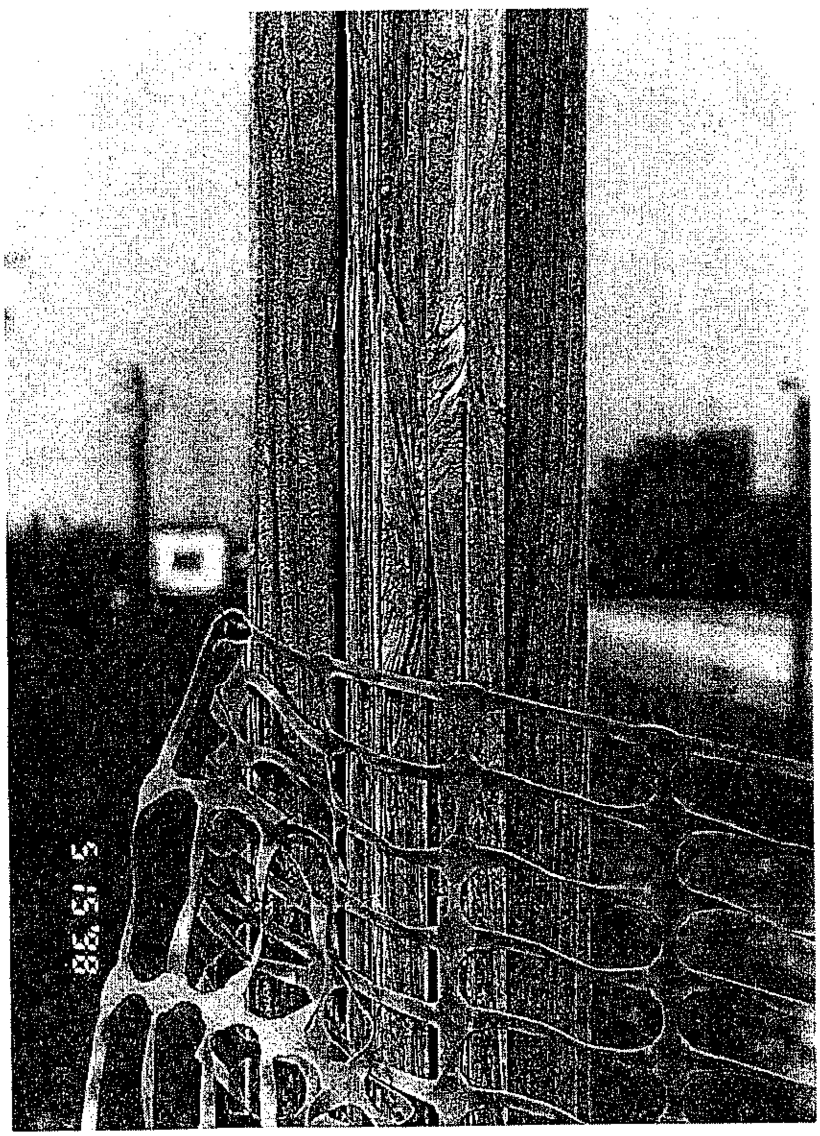


Figure 5-6. Glue-laminated wood, cross-sectional view Bolingbrook, IL.

One section of tropical hardwood barrier on IL 53 north of Army Trail Road appears to have benefited from these design improvements (Fig. 5-7). However, the other tropical hardwood barriers have significant defects (Figures 5-8 and 5-9). The primary cause of problems appears to be shrinkage of the material, resulting in warpage along joints, movement of the panels between posts, differential settlement of panels, and panels falling out of the posts. Gaps between boards in the panel sections sometimes exceed 6 inches (Figure 5-10) and at night, headlights are reportedly visible through the barrier from the residents' side. The posts vary in cross section from 8 inches square to 8 by 15 inches and have a 2-inch deep groove to hold the panels. The posts are generally intact although some twisting of posts was observed on the Elgin-O'Hare Expressway section.

The acoustical effectiveness of the barrier sections containing large gaps or numerous small gaps must also be questioned. Qualitative observation behind sections of the compromised barrier seemed to indicate that the barrier is still providing some level of noise reduction. No acoustic measurements were included as part of this research project.

The remaining life of this type of barrier is difficult to speculate upon. Sections of barrier at Lake/Cook appear to be currently unserviceable after approximately 8 years. Numerous panels appear unsafe, and the barrier is unsightly. It is likely that given the inherent density and rot-resistance of this wood, and the massive cross section of the posts, the material itself will last beyond the time this barrier must be removed for structural or aesthetic reasons. Some of the redesigned barriers on IL 53 are performing well after 8 years, and should have a service life at least equal to that of glue-laminated wood barriers, 25 years or more.

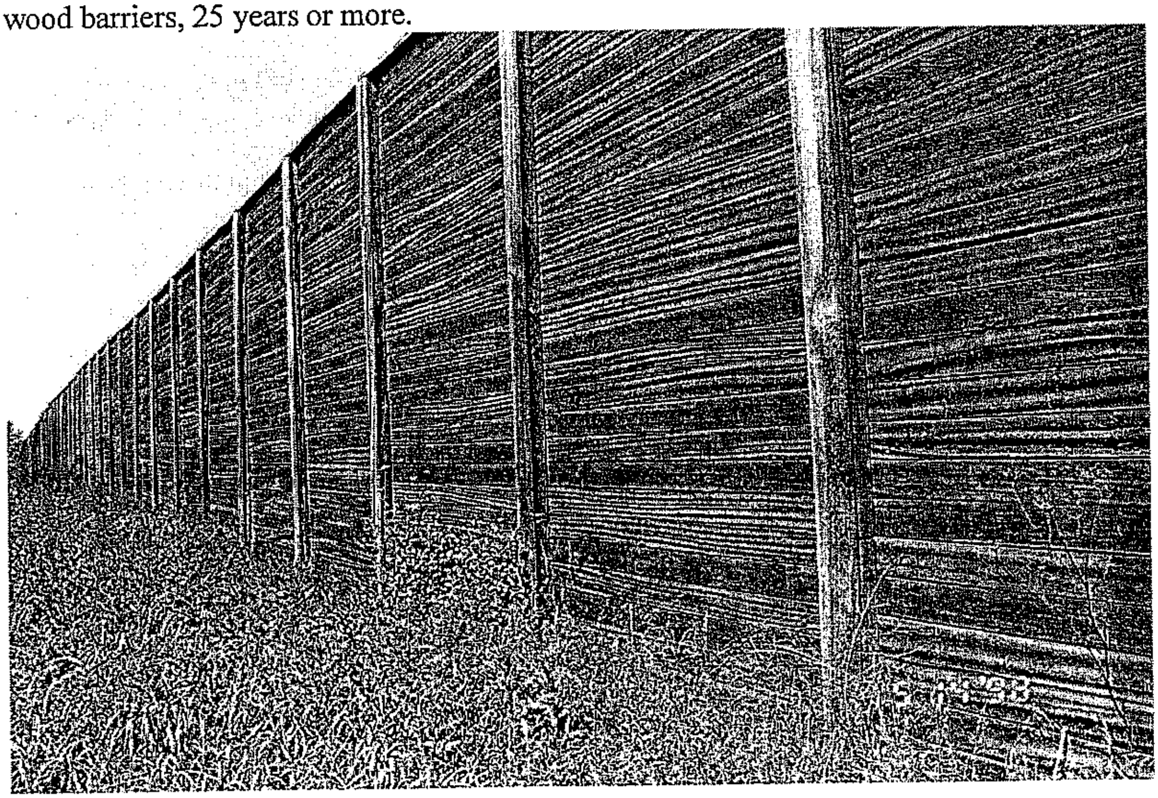


Figure 5-7. Tropical hardwood barrier IL 53 near Army Trail Road.

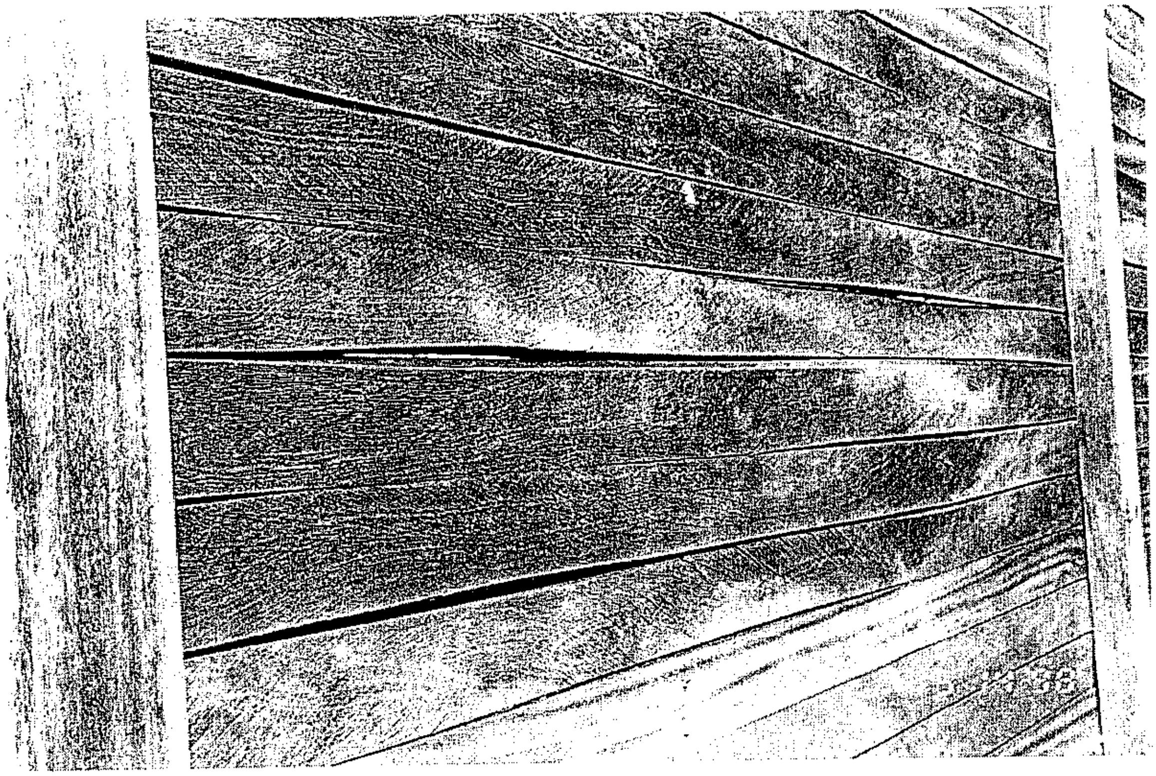


Figure 5-8. Tropical hardwood barrier, IL 53, warping of boards.

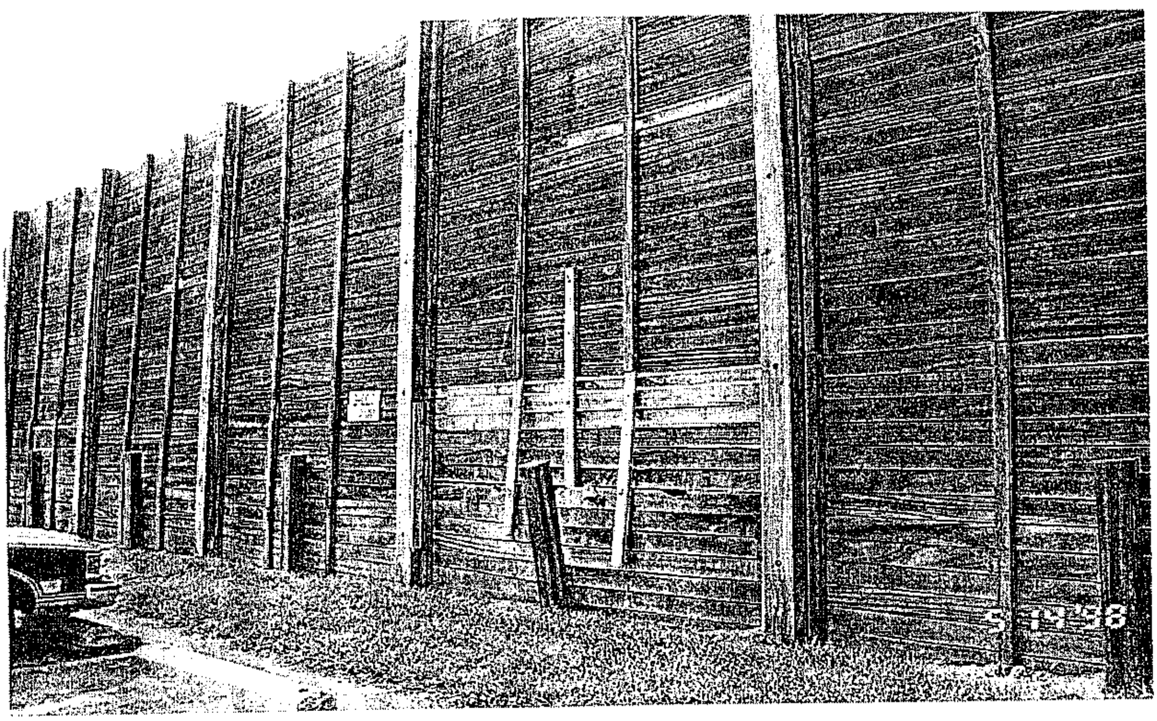


Figure 5-9. Tropical hardwood barrier, IL 53 at Lake Cook Road.

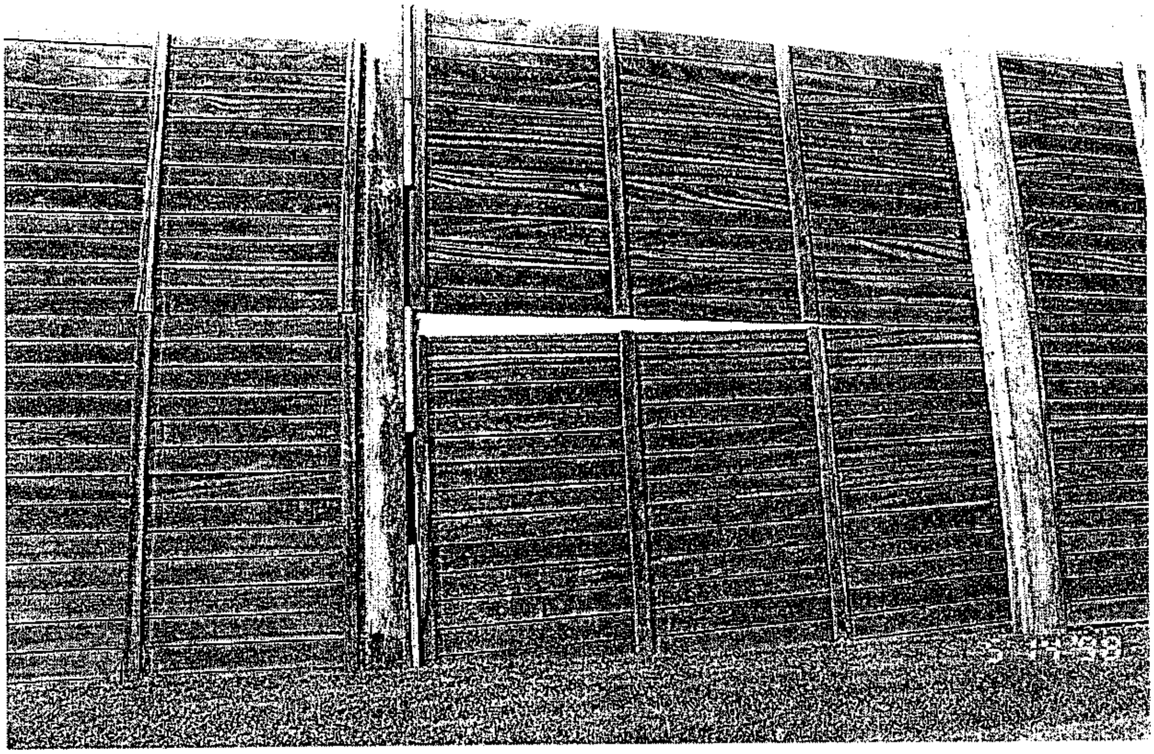


Figure 5-10. Tropical hardwood barrier, gap between panels.

5.2.3.1.3 Durisol™

District 1 has also used an absorptive noise barrier system, marketed under the trade name Durisol™. Durisol is a composite sandwich panel composed of a 2 inch concrete core covered with compressed, cemented wood shavings. The outer layer may be shaped in various textures, and the thickness varies from approximately 5 inches to more than 7 inches. The outer surface can be integrally pigmented, or surface stained to give a variety of colors. Durisol has been used in a number of sections along IL 59, for one section on IL 19, and as a facing for a retaining wall along IL 83. Typically, a fluted texture has been used for the highway side (Fig. 5-11). A smooth or patterned surface can be used for the residents' side (Figure 5-12). Posts are typically galvanized steel, but for the IL 19 project, custom Durisol covers were made to cover the posts.

The earliest Durisol noise barrier in Illinois was constructed in 1993. The condition of the Durisol barriers was found to be generally good. On several sections, the fluted surface has been marred by vehicle or snowplow strikes. Although the coloration of the panels is continuous through the outer layer, damage to the surface of individual panels creates a visible gash that is not reparable in the field. Correction of panels damaged by vehicle strikes would most likely require replacement of the affected panel.

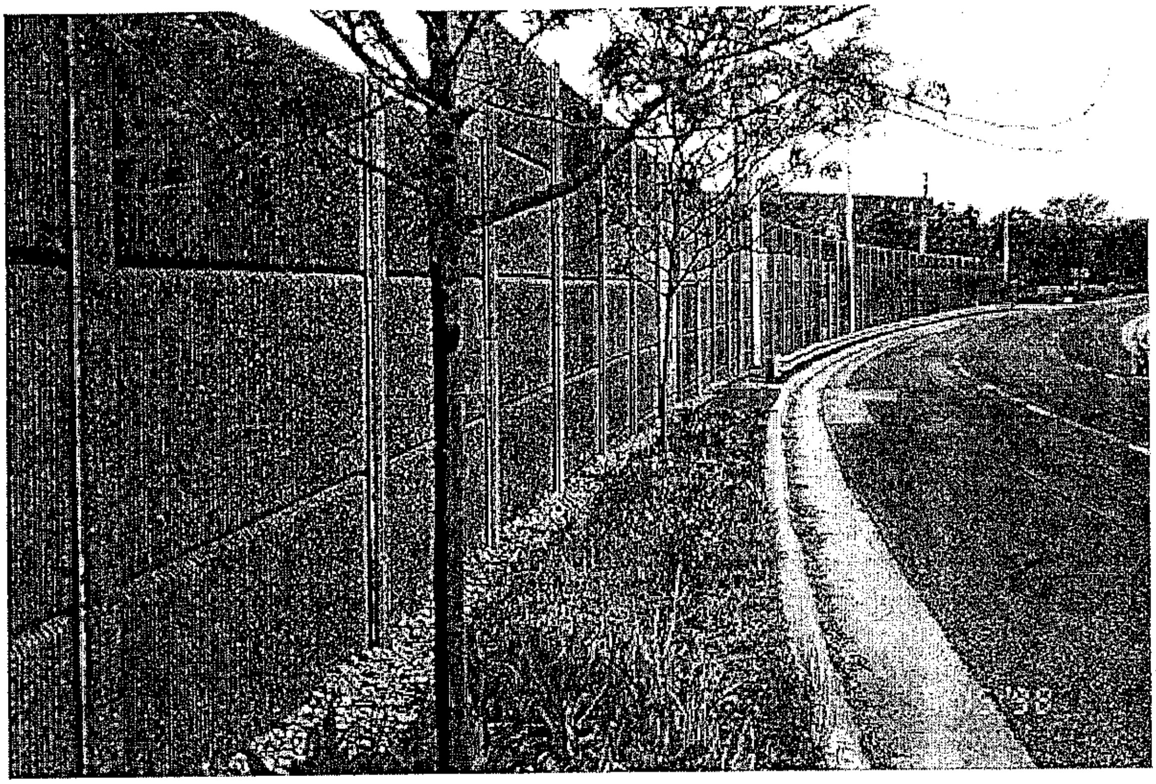


Figure 5-11 Durisol barrier, IL 19 Schaumburg 1993-1998.

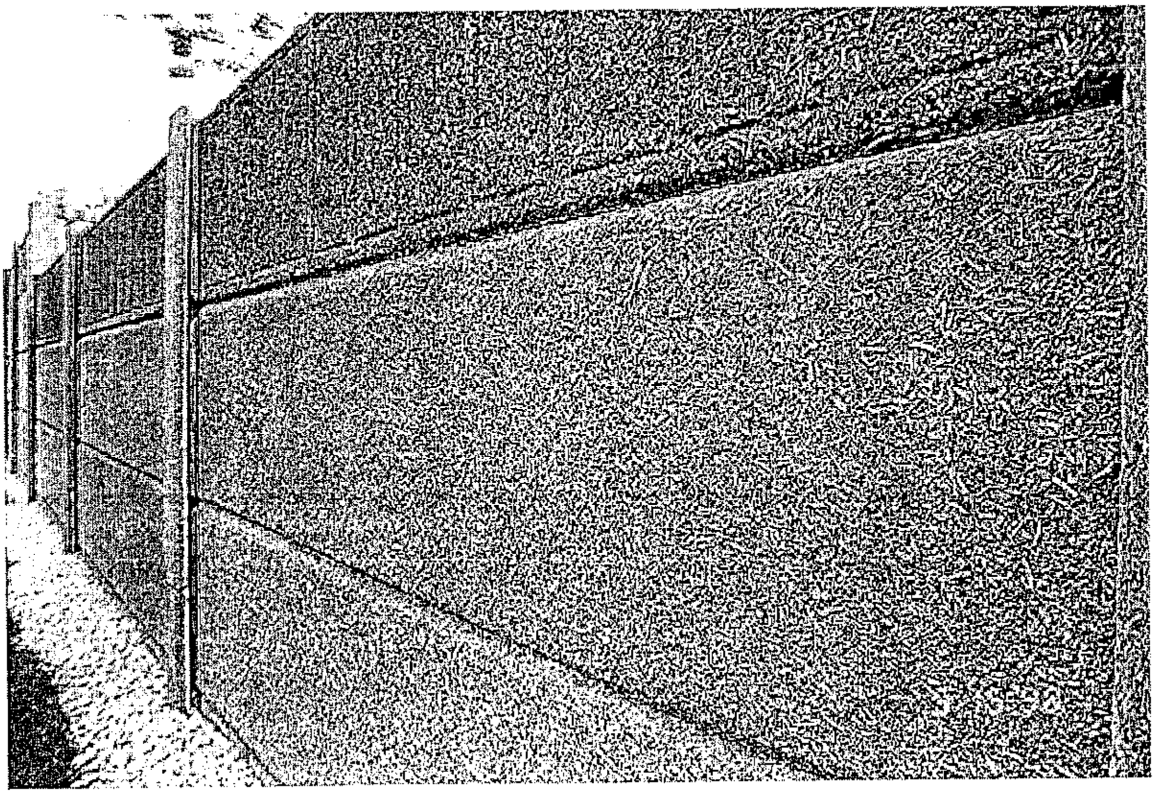


Figure 5-12. Durisol barrier, IL 19 Schaumburg, residents' side.

The long-term performance of Durisol would be difficult to predict based on only 5 years' experience on Illinois projects. Published reports from other highway agencies, including Wisconsin DOT and Ontario, indicate that Durisol is performing well in harsh winter highway conditions (Pedeson 1996, Bischoff 1997). Some barriers have been in service since 1978, reportedly without significant deterioration. In Illinois, the researchers noted no evidence of structural failure, and the observed defects were cosmetic and should not affect the durability of the material. The service life of Durisol in Illinois could therefore be expected to approach the estimate of 25 years used by Lin, et al. (1997).

5.2.3.2 IDOT District 2

Noise barriers in the Rockford, Illinois area were observed in May 1998. Two types of concrete wall were used along I-39/US 51 in the late 1970s and 1980.

5.2.3.2.1 Fanwall precast concrete

In Monroe Center, approximately 5 miles south of Rockford, a Fanwall® precast concrete wall was used on US 51/I-39. This wall is the only one of its kind in Illinois, although it has been used in other states, including Florida, Texas, Massachusetts, Vermont and California. The unpainted precast concrete wall panels comprising the barrier are placed directly on the ground surface in a "zig-zag" pattern on a prepared base. The undulating pattern of the wall gives this type of barrier inherent stability, and no below-ground foundations are required.

The barrier in Monroe Center, approximately 2.4 m (8 feet) in height and 731 m (2,400 feet) in length, appears to be in very good condition after nearly 20 years in service. Based on the current condition of the barrier, the researchers estimate that the service life may approach the life of concrete, approximately 50 years.

5.3.2.2.2 Precast concrete cantilever barrier

Other noise barriers in Rockford are precast/prestressed "cantilever" walls. These barriers are 4 to 4.9 m (13 to 16 ft) in height, and have a total length of over 3500 m (2 miles). The barriers were examined by means of a "windshield survey" for their entire length, and were closely observed from the residents' side in two locations. The condition of the barriers was very good, with no observed serious defects. No significant leaning or opening of joints was noted, although minor misalignment of adjacent panels was noted in one location (Fig. 5- 13). Some vertical joints between panels were caulked, but it was unclear from the field observation whether the caulking was original to the barrier or recently applied. Graffiti had been painted out in several locations, one of the few instances of graffiti noted on any Illinois noise barriers. The concrete barrier itself is unpainted, with panels that alternate between smooth and fluted finish. The view of this barrier from the highway side emphasizes the alternating panels, presumably to reduce monotony for drivers (Fig. 5-14). The pattern when viewed from the residents' side seemed less dominant (Fig. 5-15). Based on the current structural condition of this barrier, the researchers estimate a service life of the barrier could equal the life of the concrete, approximately 50 years.

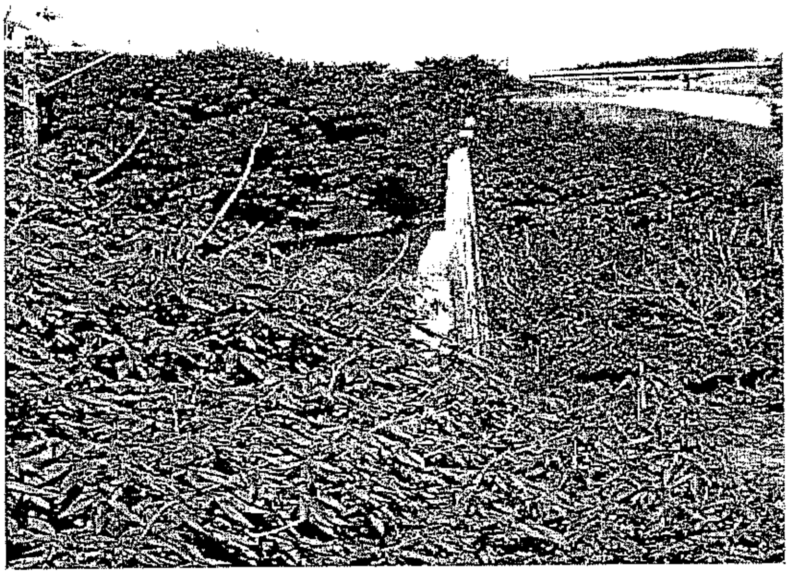


Figure 5-13. Misalignment of panels, precast/prestressed concrete barrier.

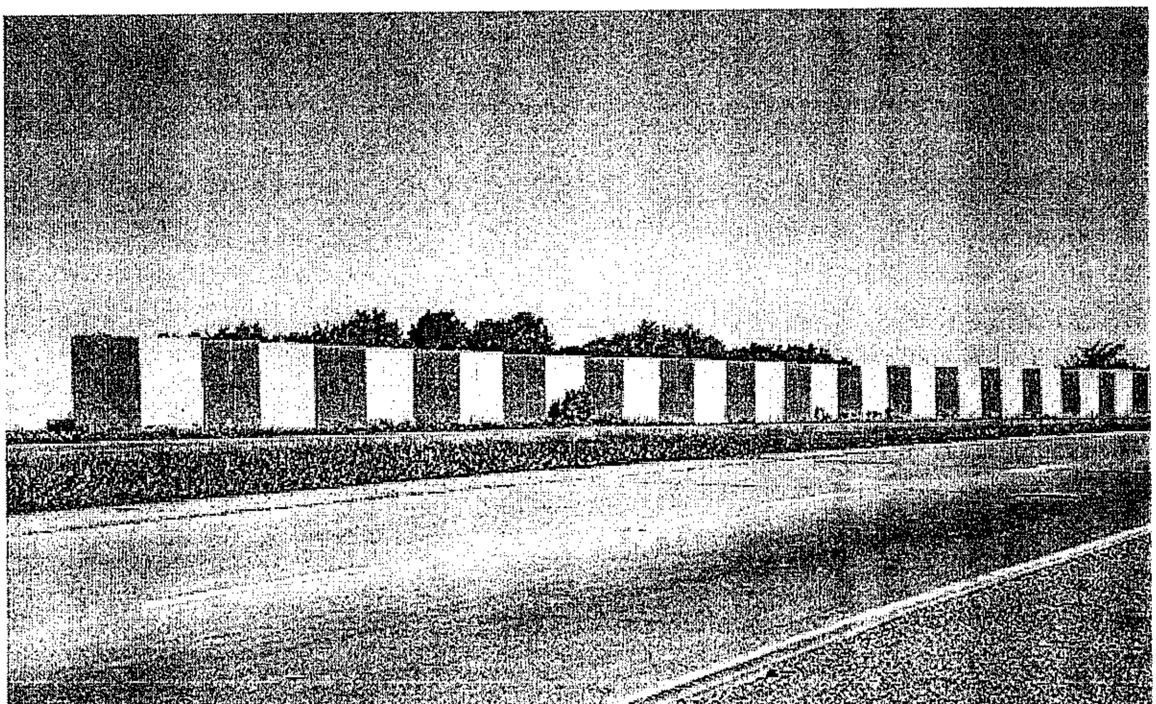


Figure 5-14. Precast/prestressed concrete barrier, I-39, Rockford.

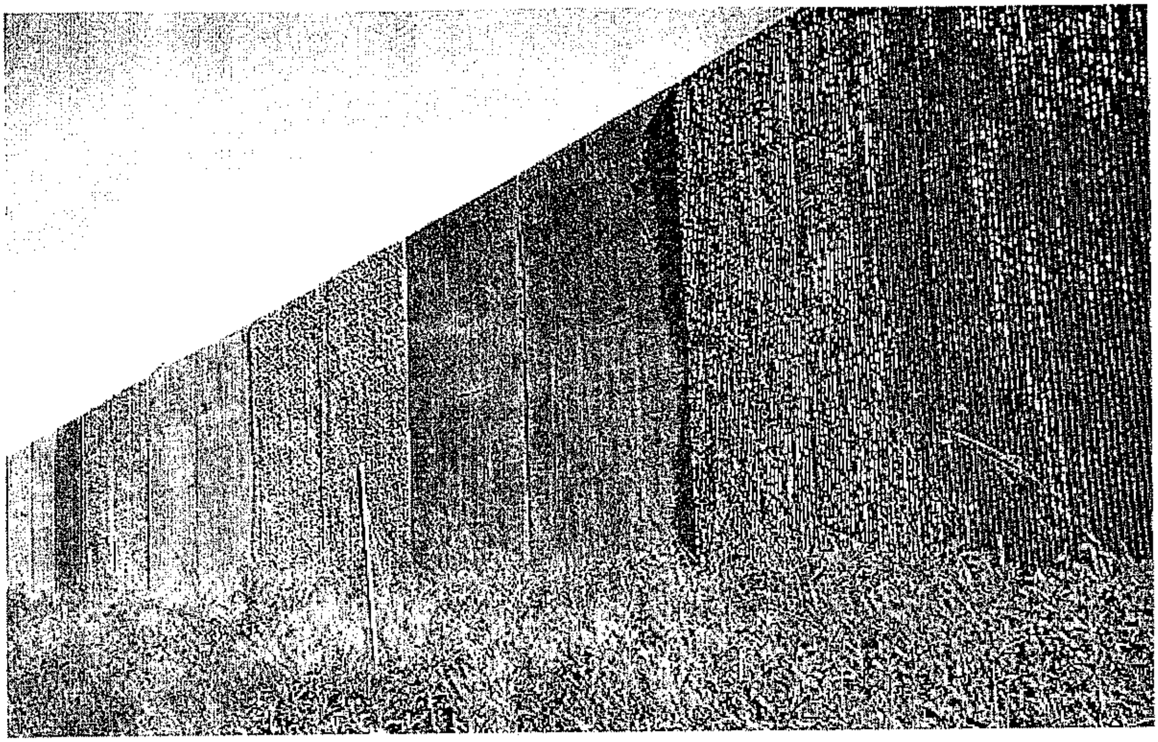


Figure 5-15. Residents' side, precast/prestressed concrete barrier, I-39, Rockford.

A section of earth berm/wood barrier built in Moline, Illinois in 1988 was not personally viewed by the researchers due to the relative remoteness of the site and the existence of similar barriers in other locations.

5.2.3.3 IDOT District 4

One noise barrier was constructed in the Peoria area in 1987 along I-474. This small section remains the only highway noise barrier in the district.

5.2.3.3.1 Tropical Hardwood

This short 183 m (600 ft) section of tropical hardwood barrier is 1.8 m (6 ft) in height, located at the top of an embankment (Fig. 5-16). The site was visited by TRP chairman Michael Bruns and photographed in June 1998. This section of tropical hardwood barrier is the oldest of its kind in Illinois, and the initial good experience of the district with this barrier led to the further use of the material in the Chicago area on larger projects.

The barrier, which due to its short height has more of the appearance of a simple fence, appears at a distance to be in good condition (Fig. 5-17). There is no evidence of maintenance or repair to any of the panels. However, on closer inspection, there is minor differential movement of panels at the posts, resulting in an uneven profile along the top of the barrier. The joints appear to be generally tight, with little evidence of the warping and twisting seen in barriers constructed of this material in District 1.

Residents living adjacent to the barrier are reportedly pleased with its appearance and noise reduction. Based on the current condition of the barrier, the researchers estimate that its service life could exceed 30 years.

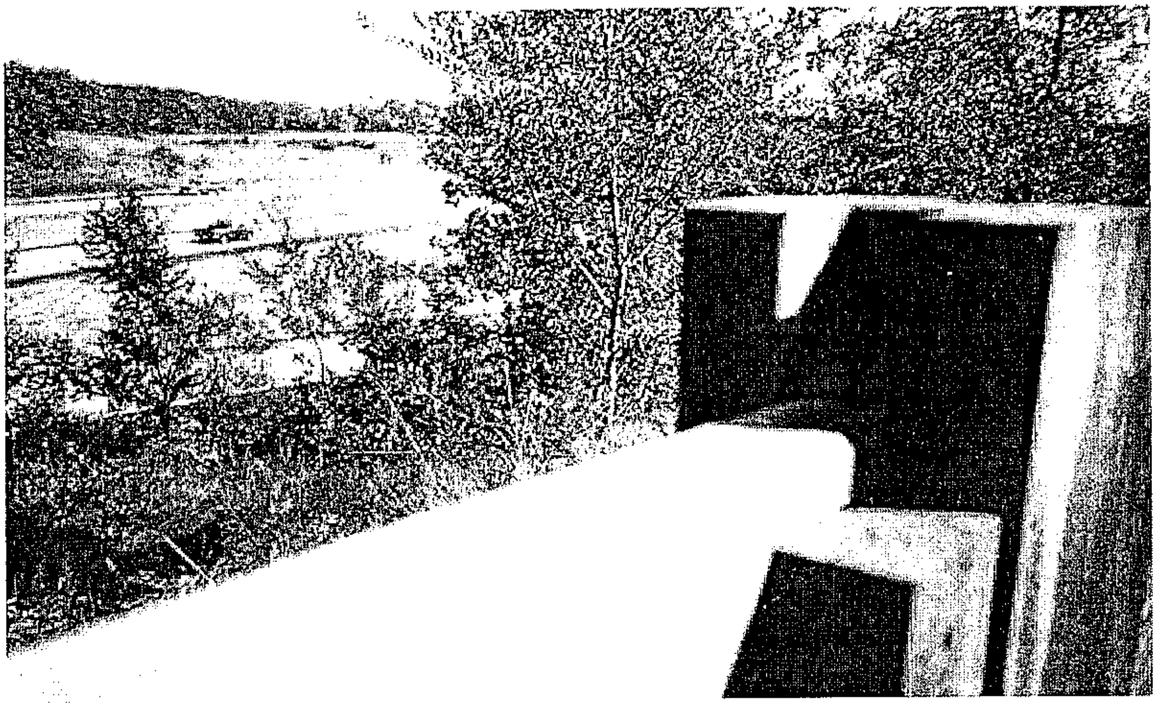


Figure 5-16. Tropical hardwood barrier, I-474, Peoria.

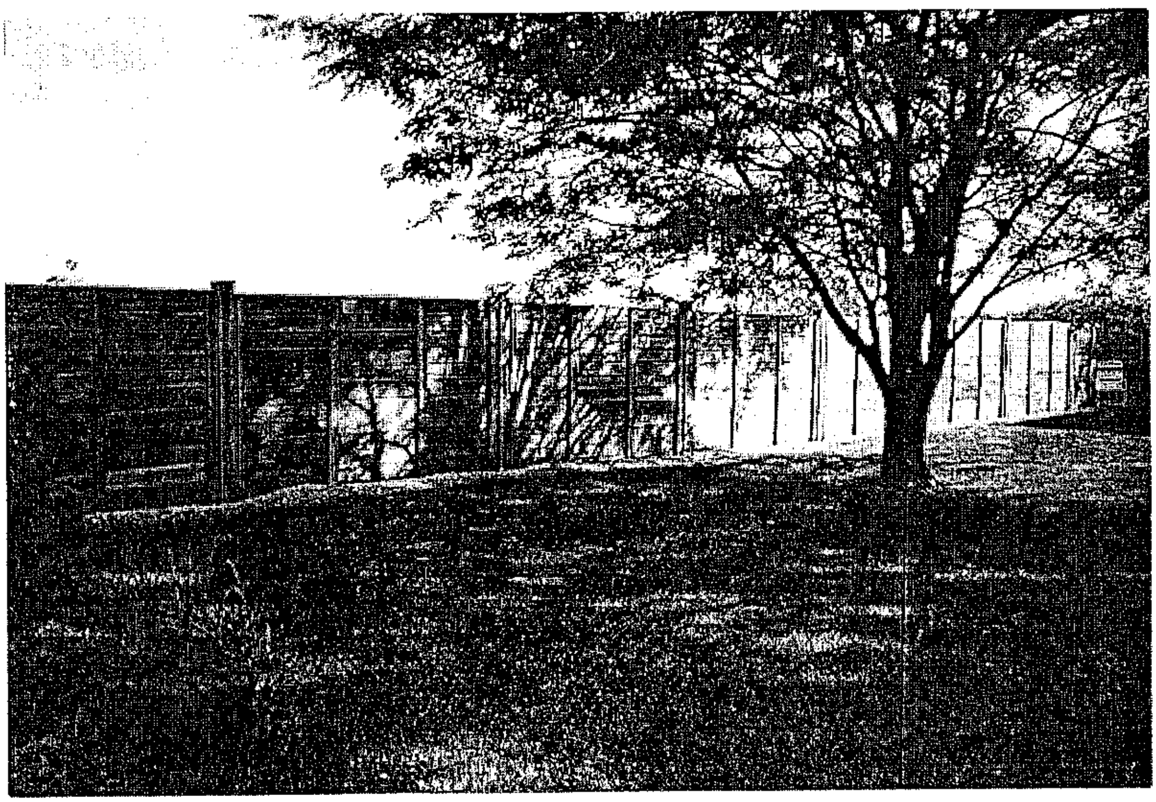


Figure 5-17. Tropical hardwood barrier, I-474, Peoria.

5.2.3.4 IDOT District 6

Nearly 4 km (2.4 miles) of noise barrier are constructed in 7 sections in the Springfield area. These barriers are among the oldest in Illinois.

5.2.3.4.1 Earth Berm and Combination Berm/Retaining Wall

The noise barriers in Springfield were constructed in the late 1970s and late 1980s along a new alignment of IL 4. The route at the time of its construction was along the developing western edge of the city of Springfield. In this instance, sufficient right of way was purchased to allow the use of earth berms for noise abatement. In one section, the earth berms were combined with a precast concrete retaining wall on the residents' side to reduce the width of the noise barrier (Fig. 5-18). The earth berms have sideslopes of 3:1, the maximum allowed for mowing, and vary from 2.1 to 4.9 m (7 to 16 ft) in height. The berms are planted in native wildflowers, shrubs and trees (Fig. 5-19). Mowing is limited to the lower portions of the slopes during the growing months, with one complete mowing of the berms in the fall to spread the seeds of the native grasses and wildflowers. No evidence of slope failure or other structural distress was noted in either the berm-only or combination berm/retaining wall sections.

In general, the use of earth berms will be limited to new highway construction in suburban areas where sufficient right-of-way can be obtained to accommodate the substantial width of a berm. However, where the opportunity exists, the use of earth berms has many potential service life advantages over other materials. Some service life advantages of earth berms include:

- potential for maintenance-free or low maintenance operation
- no graffiti potential
- no fire damage potential
- no footings or foundations
- no connections or joints for potential movement or corrosion
- no damage potential from vehicle strikes
- no damage potential from high winds
- positive salvage value (as borrow material) at end of service life
- excellent acoustic properties
- positive aesthetic properties for drivers and residents

Based on these positive factors and the current condition of the earth berms observed, the service life of the berm could be expected to equal the life of the highway facility.

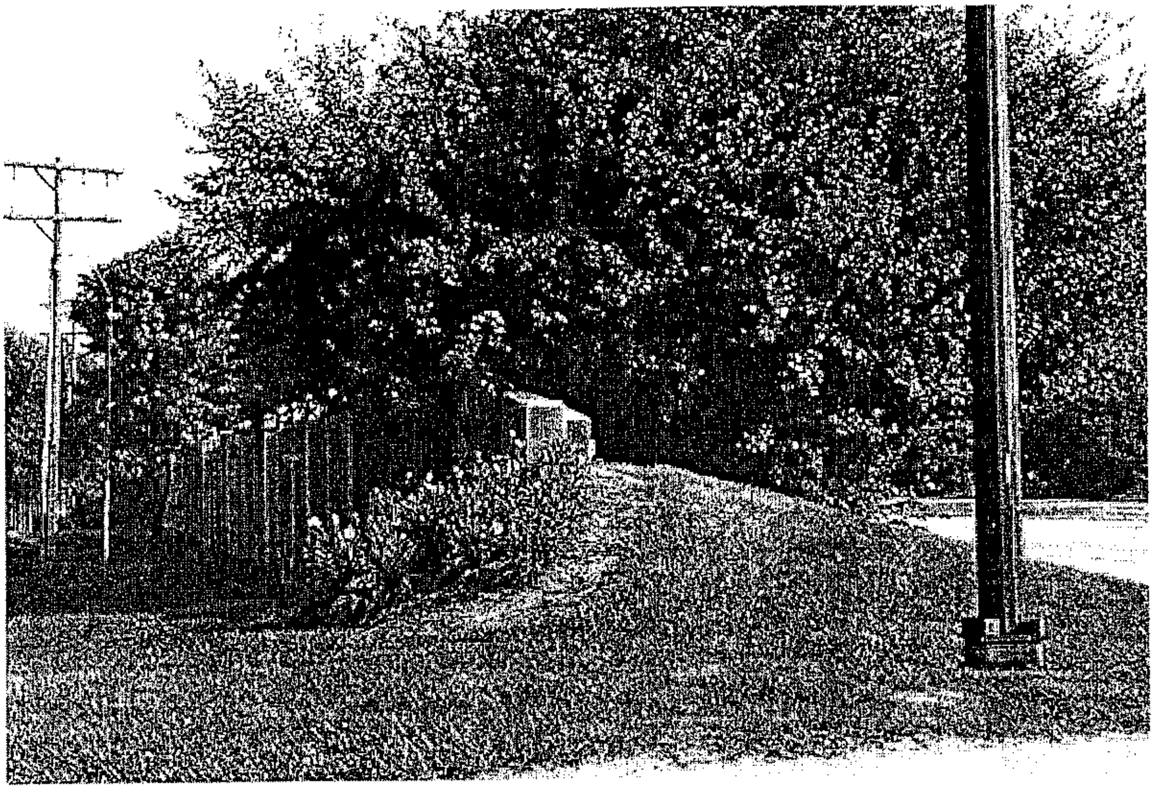


Figure 5-18. Earth berm/retaining wall, IL 4, Springfield.

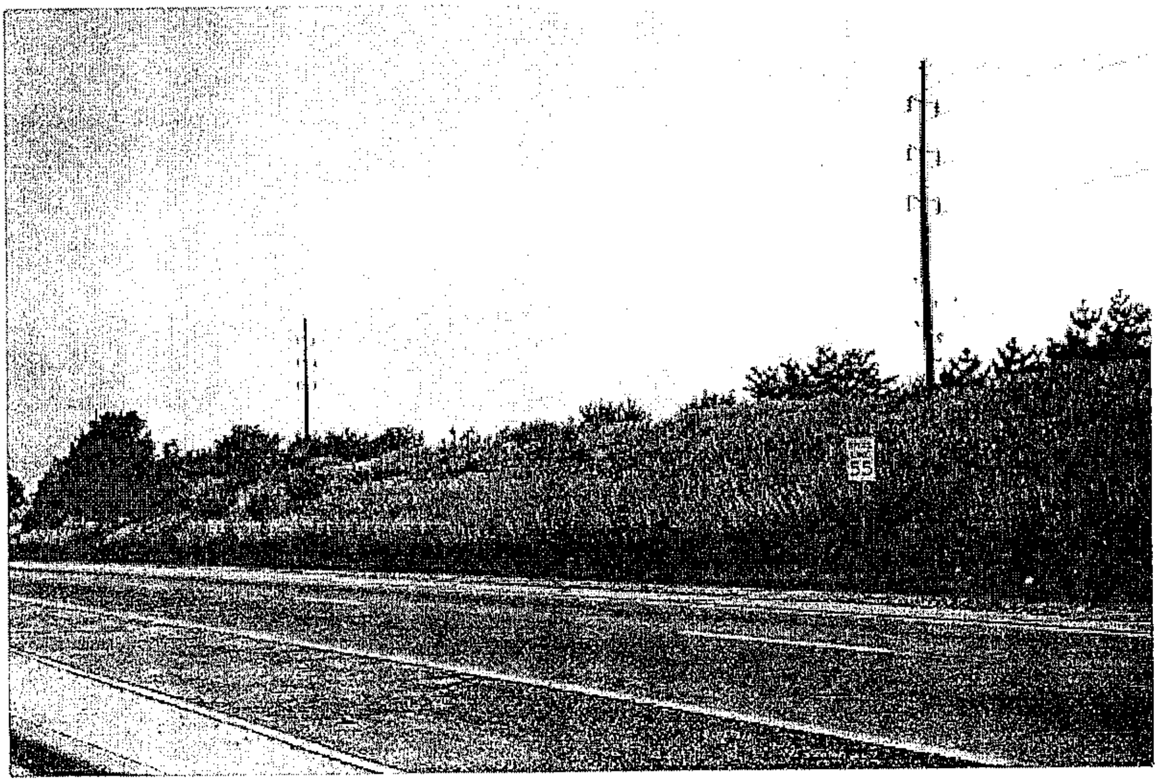


Figure 5-19. Earth berm, IL 4, Springfield.

5.2.3.5 IDOT District 8

Three noise barrier sections are currently located in this district, with additional barriers planned for a section of IL 255 (new alignment). The three barriers are located along I-255, and each is of a different material.

5.2.3.5.1 Precast/prestressed concrete cantilever barrier

The earliest barrier was constructed near East St. Louis in 1981 of precast/prestressed concrete, using the "cantilever" wall design. The barrier is 3 m (10 ft) in height and 558 m (1830 ft) long. Researchers visited the site in January 1998 and found the barrier to be in very good condition, with no observable evidence of movement (Fig. 5-20). Based on the condition of this barrier and ones of similar design elsewhere, the service life of this barrier is estimated to be 40 to 50 years.

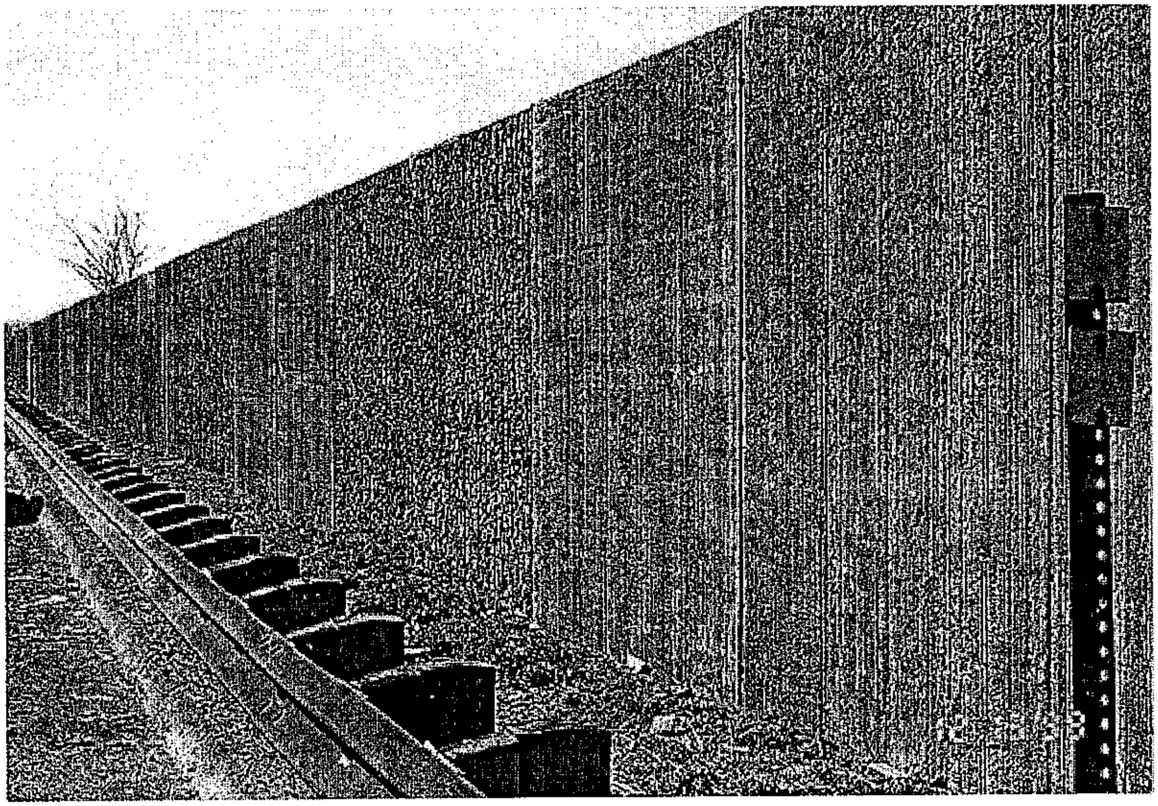


Figure 5-20. Precast/prestressed concrete, I-255, East St. Louis.

5.2.3.5.2 Noishield® Aluminum

A second barrier is located several miles north of the first, near the town of Collinsville. This barrier section was constructed along the north-bound lanes of I-255 in 1985. The barrier height averages 2.1 m (7 ft). The barrier material is Noishield® aluminum 5052 type H32 (Figallo 1998), a proprietary absorptive barrier consisting of perforated aluminum panels on the roadside, aluminum panels on the residents' side, and a mineral wool filling. The vertically oriented panels are 2 feet wide and 12 feet high, at each end by galvanized steel wide flange beams acting as posts and by steel channels along the top and bottom edges (Fig. 5-21 – 5-22). The panels are joined with a non-welded connection, and are perforated along the bottom to allow drainage. The condition of this barrier, which has been in service approximately 13 years, is good. There is no evidence of movement of the panels or posts and no deterioration of the panels. The coating on the posts and the panels appears to have faded from the original colors, but the coating has not peeled or flaked. There are no signs of corrosion or rusting of the steel components, but the barrier will have to be painted periodically to protect the metals from weathering. Based on the current condition of this barrier, the researchers estimate its service life to be approximately 25 years.

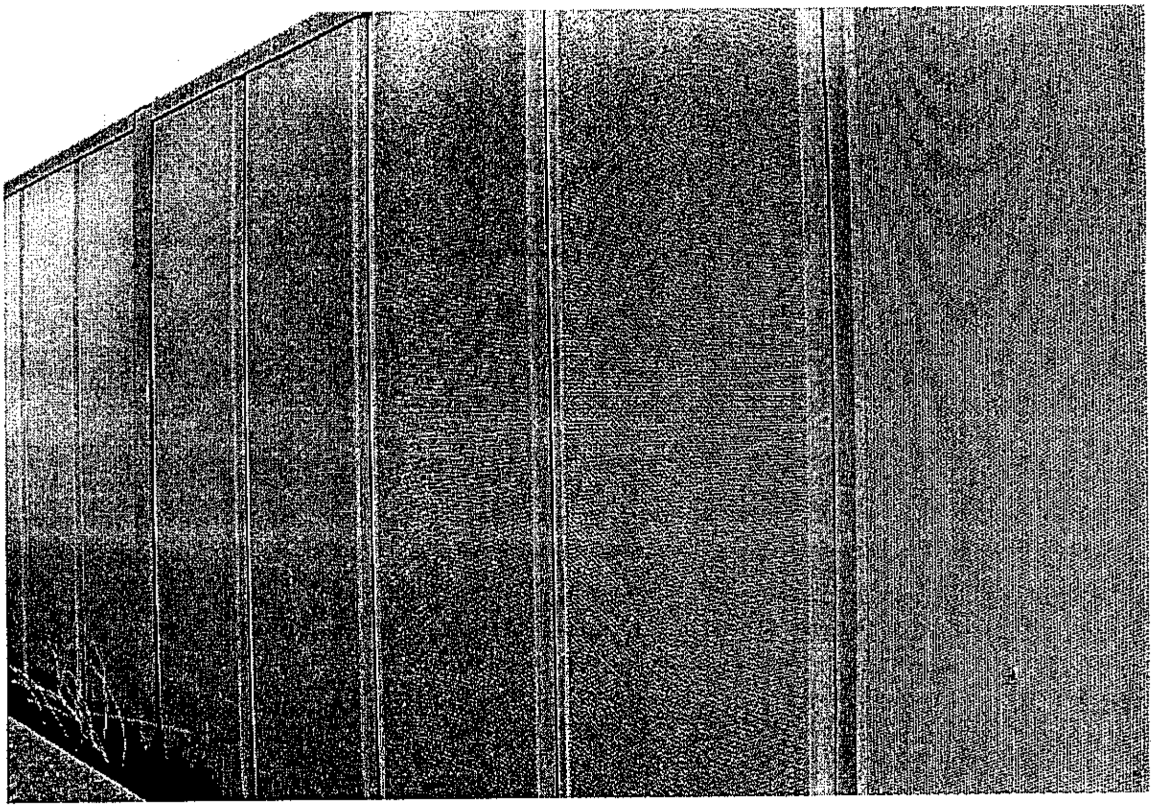


Figure 5-21. Noishield® aluminum barrier, I-255, Collinsville.

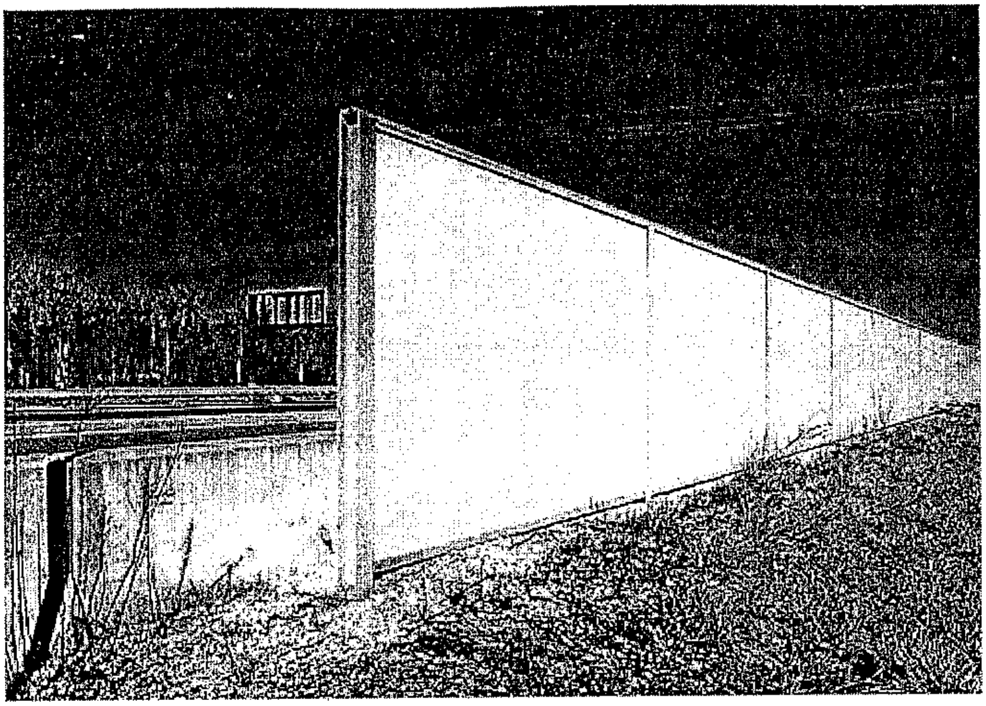


Figure 5-22. Noishield® aluminum, I-255, Collinsville.

5.2.3.5.3 Noishield Steel

A second metal wall, also supplied by Industrial Acoustics Company, Inc., is located on I-255 near the town of Centreville. This barrier is constructed of a perforated stainless steel face, a solid galvanized steel back, with a mineral wool filling. The panels are coated with an epoxy-based primer and are oriented horizontally. Each panel is 2 feet high and 12 feet long; individual panels are stacked to reach the required barrier height. The panels are held in place by galvanized steel wide flange beams (W 5 X 16) acting as posts. According to IDOT District 8 personnel, the barrier began to deteriorate soon after installation in 1984. The supplier determined that the "detail of the panel allowed entrapment of water in a pocket which was intended to drain out at the end of the panel. The presence of water which acted as an electrolyte created a corrosive environment which destroyed the integrity of the barrier" (Figallo 1998). The painted coating on the face (highway side) of the panels peeled off, and the steel corroded. IDOT maintenance personnel later covered the perforated surface with solid fiberglass panels (Fig. 5-23). On the back side, the solid steel panels also corroded and buckled, with some panels bowing out of the plane of the wall by more than 2 inches in the 12 foot length of the panel (Fig. 5-24).

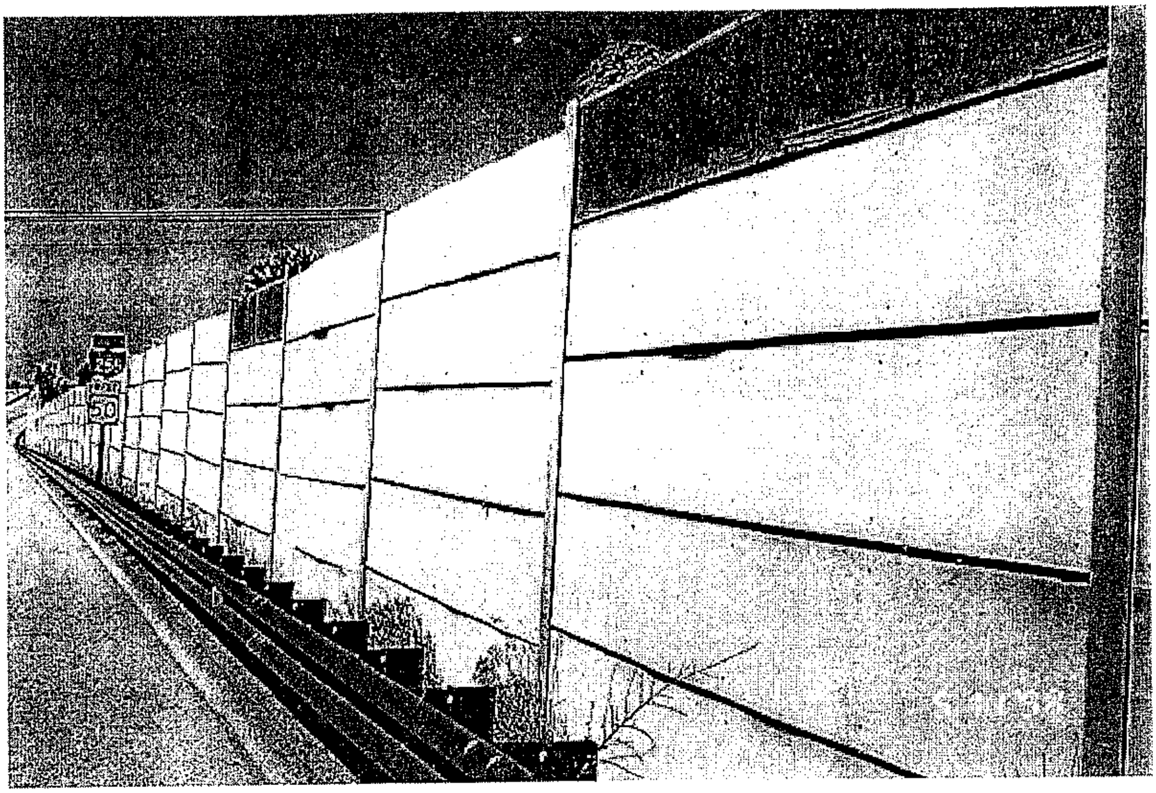


Figure 5-23. Noishield® steel, I-255, Centreville.

Three sections of corroded steel barrier on the north-bound lanes were replaced with Durisol panels in 1988 as a demonstration project. It was intended that the panels would be used as a field test to evaluate Durisol for future use. It is not known whether any formal evaluation was done by District 8. The researchers observed that the Durisol panels appear to be structurally sound after 10 years' service.

IDOT District 8 is currently considering the replacement of the steel noise barrier. Because this barrier has been determined by the district to be at the end of its useful life, the researchers requested permission to study this barrier in some detail in an effort to quantify some of the physical characteristics that define service life. The researchers met to discuss the proposed field work at IDOT District 8 headquarters on April 20, 1998 with Allan Guttmann, John Dhermy, Paul Bauer, and Bernie Fahey of District 8 and TRP members Michelle Mahoney and Michael Bruns. The district gave permission for the work, provided access to the site, and coordinated the necessary traffic control when the researchers were on IDOT right-of-way. The field work was performed on May 11, 1998. Measurements were taken along a 500-foot section of barrier on the south-bound lanes of I-255, beginning at the northern end of the barrier.

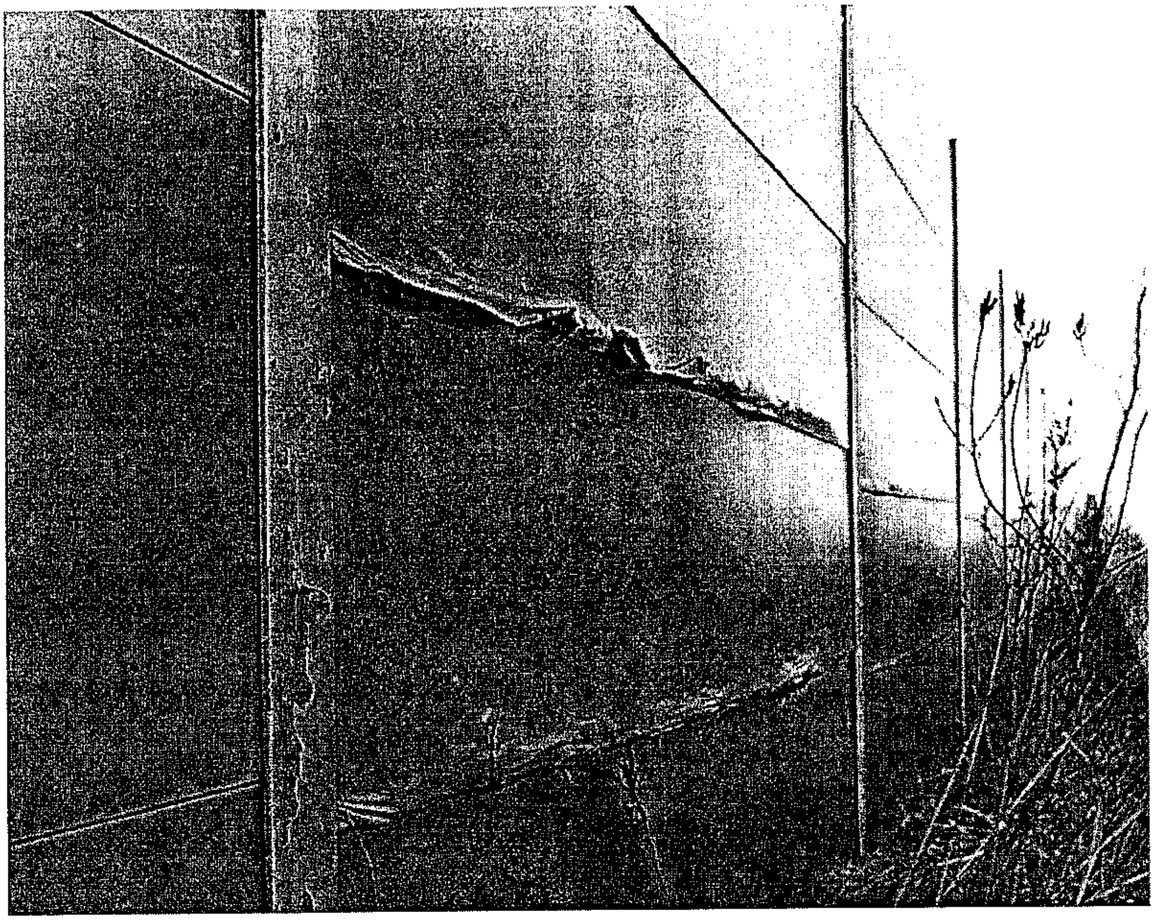


Figure 5-24. Noishield®steel, corrosion visible on residents' side.

Four types of measurements were made:

- vertical plumb of posts
- count of corroded panels
- buckling of panels
- differential settlement of panels between posts.

The equipment used for the tests consisted of a four-foot carpenter's level for measurement of vertical plumb, a string line, two carpenter's triangles, a six-inch rule, and a surveyor's level and tripod. The measurements were taken on the back side of the barrier in order to interfere as little as possible with traffic and because the fiberglass panels added to the front of the barrier obscure the condition of the underlying material.

Each of 40 posts in the test section was measured for vertical plumb in two directions using the carpenter's level. Beginning at the north end of the test section, posts were numbered to the south. The results show that only 2 posts (# 20 and #27) were slightly out of plumb (less than 1/4 inch in 4 feet).

Each of the 190 panels in the test section was observed for signs of corrosion. Panels at ground level were referenced as panel "A." The tallest section at the southern end of the test section consisted of 6 panels. Over two-thirds of the panels in the test section showed at least some signs of corrosion. Over half (57%) were heavily corroded while 18% were beginning to show signs of corrosion. The most heavily corroded panels were located at the "B" and "C" levels. Panels nearer the top of the barrier were generally only beginning to show signs of corrosion (Table 5-1).

Each section between adjacent posts was measured for buckling out of the plane of the wall. A string line and a pair of carpenter's triangles with inch graduations along one edge were used to determine a line parallel to each section. The triangles were placed perpendicular to the face of adjacent posts at the bottom of panel "B" and a string stretched taut between the triangles. Measurements were typically taken at the base of panel "B", except in cases where the corrosion of this panel was so severe that it was not practical to judge the location of the edge of the panel. The string was held on the 1-inch graduation mark, approximately two inches from the face of the panel. A six-inch ruler was used to measure the distance from the string line to the panel at four points--near each post and at the 1/3 points. In cases where the panels were severely buckled, the string was held on the 2-inch or 3-inch graduation mark. Results of this survey show that the maximum deflection measured at the base of panel "B" was over 2 inches in 12 feet. Survey data are given in Table 5-2.

The final survey measurement was the differential settlement of the panels within each section. A surveyor's level was set up and readings were taken at the base of panel "B" for each of 38 sections (two panels were measured at the base of "C" due to corrosion). Each panel was measured at the face of the two posts supporting that panel. Maximum differential settlement of panels was over 5.5 inches in 12 feet (Table 5-3). A discussion of the results and their implication for service life criteria is found in Chapter 6.

Table 5-1. Survey notes on plumbing of posts and panel corrosion.

Post Numbers for Section	Posts Plumb (Y/N)	Number of Panels in Section	Panels Showing Severe Corrosion[1]	Panels Showing Slight Corrosion
1-2	Y	2	B	
2-3	Y	3	B,C	
3-4	Y	4	B,C	
4-5	Y	5	B	
5-6	Y	5	A,B	
6-7	Y	5	B,D	C
7-8	Y	5	A-C	D
8-9	Y	5	A,B	C
9-10	Y	5	A-C	D
10-11	Y	5	B,C	
11-12	Y	5	B,C	D
12-13	Y	5	A-D	
13-14	Y	5	A-C	D
14-15	Y	5	B	C,D
15-16	Y	5	B,C	D
16-17	Y	5	A-C	
17-18	Y	5	A-C	D
18-19	Y	5	A,B	C
19-20	N (#20)	5	B,C	D
20-21	N (#20)	5	B,C	
21-22	Y	5	B,C	D
22-23	Y	5	A-D	E
23-24	Y	5	A-C	D
24-25	Y	5	B,C	E
25-26	Y	5	A-C	D
26-27	N (#27)	5	A-D	
27-28	N (#27)	5	B,C	
28-29	Y	5	B-E	
29-30	Y	5	B,C	E
30-31	Y	5	B,C	
31-32	Y	5	A-D	E
32-33	Y	5	B,C	D,E
33-34	Y	5	A-C	D,E
34-35	Y	5	A-C	D,E
35-36	Y	5	B,C	D,E
36-37	Y	5	B,C,E	D
37-38	Y	5	A-C	D
38-39	Y	5	B,C	D,E
39-40	Y	6	A-C	F
TOTAL		190	97 (51%)	34 (18%)

[1]Panels labeled upward from "A" at ground level.

Table 5-2. Survey notes for measurement of panel bowing.

Panel btwn. posts numbered	Offset @ N. Post (in.)	Offset @ 4' (in.)	Offset @ 8' (in.)	O.S @ S. Post (in.)	Max. Bowing	
					in.	cm
1-2*	1.63	1.13		1.25	0.5	1.27
2-3	1.63	1.13	1.25	1.5	0.5	1.27
3-4	1.75	1.5	1.38	1.5	0.38	0.95
4-5	1.63	1.38	1.38	1.63	.025	0.64
5-6	1.44	0.5	0.69	1.56	1.06	2.7
6-7	1.56	1.13	1.5	1.63	0.44	1.11
7-8	2.94	0.81	0.81	2.88	2.13	5.4
8-9	1.44	1.19	1.38	1.5	0.25	0.64
9-10	1.25	1.31	1.38	1.63	0.38	0.94
10-11	2.63	1.13	0.75	2.19	2.0	5.1
11-12	1.5	0.31	0.13	1.5	1.38	3.5
12-13	1.56	1.0	1.13	1.63	0.56	1.43
13-14	1.5	1.44	1.75	1.5	0.25	0.64
14-15	2.38	0.5	0.63	2.5	2.0	5.1
15-16	1.5	1.5	1.38	1.5	0.13	0.32
16-17	1.44	0.93	1.5	1.5	0.19	0.48
17-18	1.44	0.5	0.5	1.5	1.0	2.54
18-19	1.44	1.38	1.5	1.56	0.19	0.48
19-20	1.5	0.63	1.19	1.63	1.0	2.54
20-21	1.5	1.38	1.38	1.63	0.25	0.64
21-22	2.5	0.63	0.63	2.38	1.88	4.76
22-23	1.56	1.56	1.56	1.56	0	0
23-24	2.5	0.88	0.13	2.5	2.38	6.03
24-25	2.5	1.38	0.75	2.69	2.13	5.40
25-26	2.63	1.69	1.5	2.56	0.93	2.38
26-27	2.5	1.38	1.38	2.63	1.25	3.18
27-28	2.5	1.13	1.25	2.5	1.38	3.49
28-29	1.5	1.38	1.44	1.5	0.13	0.32
29-30	1.63	1.63	1.63	1.63	0	0
30-31	1.5	1.44	1.25	1.63	0.38	0.95
31-32	1.44	1.5	1.5	1.63	0.13	0.32
32-33	3.44	1.5	1.88	3.25	1.93	4.92
33-34	2.5	1.88	1.38	2.5	1.13	2.86
34-35	1.5	1.0	1.0	1.5	0.5	1.27
35-36	1.5	0.69	0.63	1.56	0.93	2.38
36-37	1.5	0.13	0.5	1.56	1.44	3.65
37-38	2.5	0.75	1.25	2.5	1.75	4.45
38-39	2.56	1.0	1.0	2.44	1.56	3.97

*Panel 1-2 is 5 feet long; all other panels 12 feet long.

Table 5-3. Survey notes for differential settlement of panels.

@ Post #	Rod Rdg. (ft.)	Diff. (ft.)	Diff. per 12' (ft. / ft.)	@ Post	Rod Rdg. (ft.)	Diff. (ft.)	Diff. per 12' (ft. / ft.)
2	0.72			21	1.22	0.02	0.002
3	0.26	0.46	0.038	21	1.39		
3	0.85			22	1.49	0.10	0.008
4	0.93	0.08	0.007	22	1.75		
4	1.32			23	1.85	0.10	0.008
5	1.22	0.10	0.008	23	0.30		
5	1.54			24	0.06	0.24	0.020
6	1.59	0.05	0.004	24	0.30		
6	1.82			25	0.37	0.07	0.006
7	2.14	0.32	0.027	25	0.84		
7	0.00			26	0.88	0.04	0.003
8	0.07	0.07	0.006	26	1.13		
8	0.42			27	1.18	0.05	0.004
9	0.40	0.02	0.002	27	1.17		
9	0.73			28	1.21	0.04	0.003
10	0.63	0.10	0.008	28	1.36		
10	1.01			29	1.52	0.16	0.013
11	1.03	0.02	0.002	29	1.75		
11	1.08			30	1.88	0.13	0.011
12	1.18	0.10	0.008	30	2.06		
12	1.37			31	2.19	0.13	0.011
13	1.41	0.04	0.004	31	2.62		
13	1.88			32	2.56	0.06	0.005
14	1.83	0.05	0.004	32	2.86		
14	1.75			33	2.94	0.08	0.007
15	1.84	0.09	0.008	33	2.5		
15	2.20			34	0.18	0.32	0.027
16	2.25	0.05	0.004	34	0.22		
16	2.51			35	0.24	0.02	0.002
17	2.80	0.29	0.024	35	0.30		
17	2.67			36	0.50	0.20	0.017
18	0.31	0.36	0.030	36	0.86		
18	0.60			37	0.79	0.07	0.006
19	0.61	0.01	0.001	37	1.34		
19	0.80			38	1.31	0.03	0.003
20	0.84	0.04	0.003	38	1.53		
20	1.20			39	1.52	0.01	0.001
Average deflection 0.11 ft. (0.035m)							

5.2.3.6 Illinois Tollway

Noise barriers along toll ex1.31pressways were surveyed during a two-day field tour May 14-15, 1998. The Tollway ha1.53s made extensive use of glue-laminated wood barriers and precast concrete post and panel barriers. Carsonite®, a proprietary product consisting of fiberglass boards filled with shredded rubber, was also used for one barrier section.

5.2.3.6.1 Glue-laminated wood barrier

The researchers examined a section of glue-laminated wood wall on I-355 at Boughton Road. Lane additions at the toll plaza at this location have required the removal of some sections of the wooden barriers that were erected in 1988. The remaining portions were examined and found to be in good condition at an age of ten years, with no evidence of deterioration (Fig. 5-25). An additional glue-laminated wood section was examined on I-294. This section, constructed in 1994, had no evidence of deterioration. Based on the current condition of glue-laminated wood barriers used by both IDOT and ISTHA, the service life is estimated to be at least 25 years.

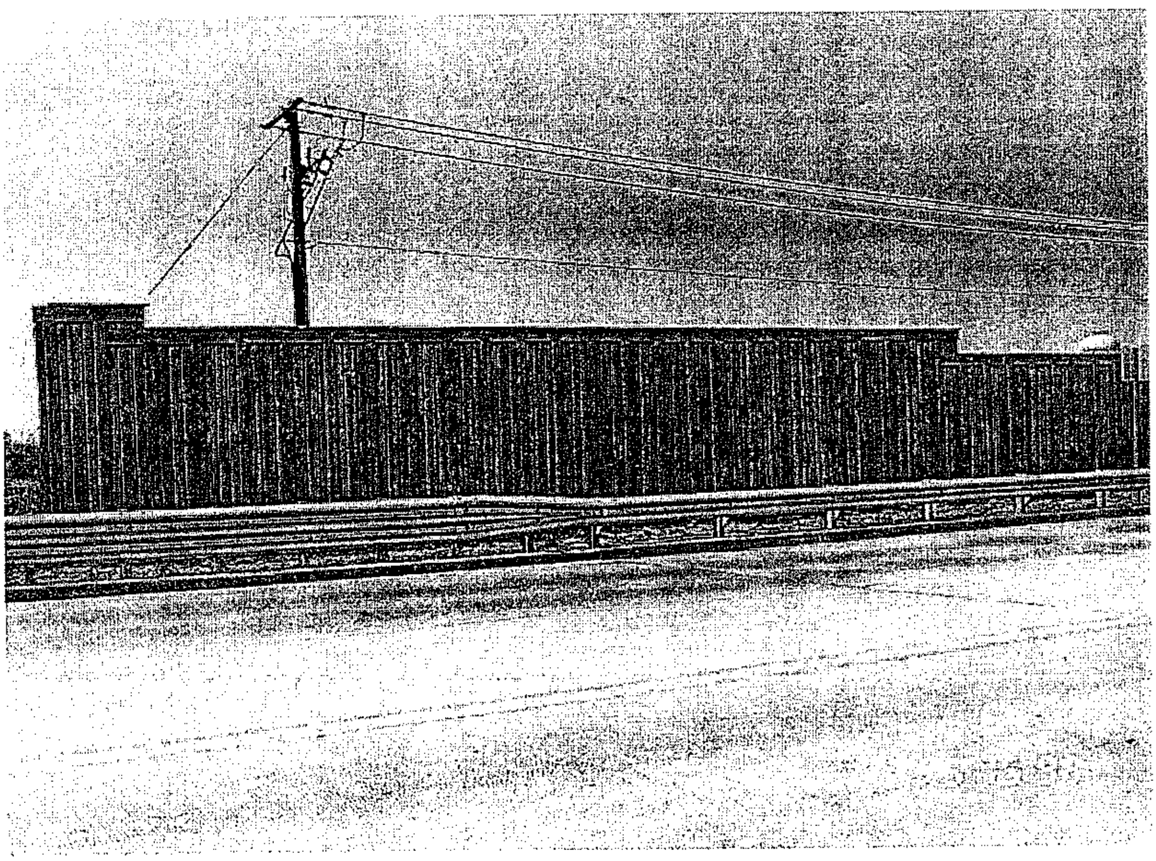


Figure 5-25. Glue-laminated wood barrier, I-355 at Boughton Road.

5.2.3.6.2 Precast Concrete Post and Panel Barrier

The precast concrete post and panel barrier used by the Tollway consists of full-height panels that have an integral post cast into one end, slotted to fit the adjacent panel section. Formliners are used to allow a wide variety of textures on both the road side and the residents' side. Panels are spray-coated at the plant with an acrylic resin coating, available in a number of colors. The Tollway has specified a light cream-colored finish for its concrete barriers.

Only a portion of the over 29,000 meters of precast concrete panels built in 1994 were examined, but no significant defects in the barriers were noted in the four-year old barriers. Panels are attached to pre-installed drilled piers by means of two anchor bolts. The design was later amended to include four bolts per post, although no failures of the two-bolt design have been reported. Spacing of the drilled piers varies up to a maximum of about 12.75 feet, the maximum panel width.

Recent lane additions on I-355 at the south toll plaza (near Boughton Road) necessitated the construction of a retaining wall near the toll plaza, and the existing glue-laminated wood ground-mounted barrier was replaced with a precast concrete combination retaining wall/barrier (Fig. 5-26) in the spring of 1998. A portion of the new construction is ground-mounted barrier. The barrier is constructed of precast concrete panels typically 12 feet wide and 4 inches thick (post spacing on the combination barrier/retaining wall section was as little as 6 feet). The panels are attached to drilled pier foundations by four anchor bolts. The four-bolt design speeds construction of the barrier: because each successive panel is self-supporting, installation can be suspended for the day without the use of a temporary post to stabilize the last panel.

The researchers observed several construction defects in the newly constructed section near Boughton Road. Several sections were installed unpainted, wood leveling shims were left in place, and the joints between the post and panel were large and unfinished on the residents' side of the barrier (Fig. 5-27). The panels were later field-painted, but the other conditions were not changed. The open joints would appear to be susceptible to ice accumulation, possibly damaging the panels. The manufacturer believes the joints are free to drain, and the potential for freeze damage is non-existent. Acoustical testing of the gaps at the joints appears to show no significant effect. The Tollway plans to amend its requirements for this type of barrier in the future to place the panels tight against the posts on the more visible residents' side, and any "play" in the panel fit toward the road side.

The long-term performance of this type of barrier is difficult to judge based on the present experience in Illinois. Other barriers of the same design exist in the St. Louis, Missouri area, but are only approximately 10 years old. The condition of these barriers is not easily determined due to the heavy growth of ivy and other vines planted on the residents' side of the barrier. The manufacturer estimates a life of 60 years. There is no evidence at present that would contradict this claim.

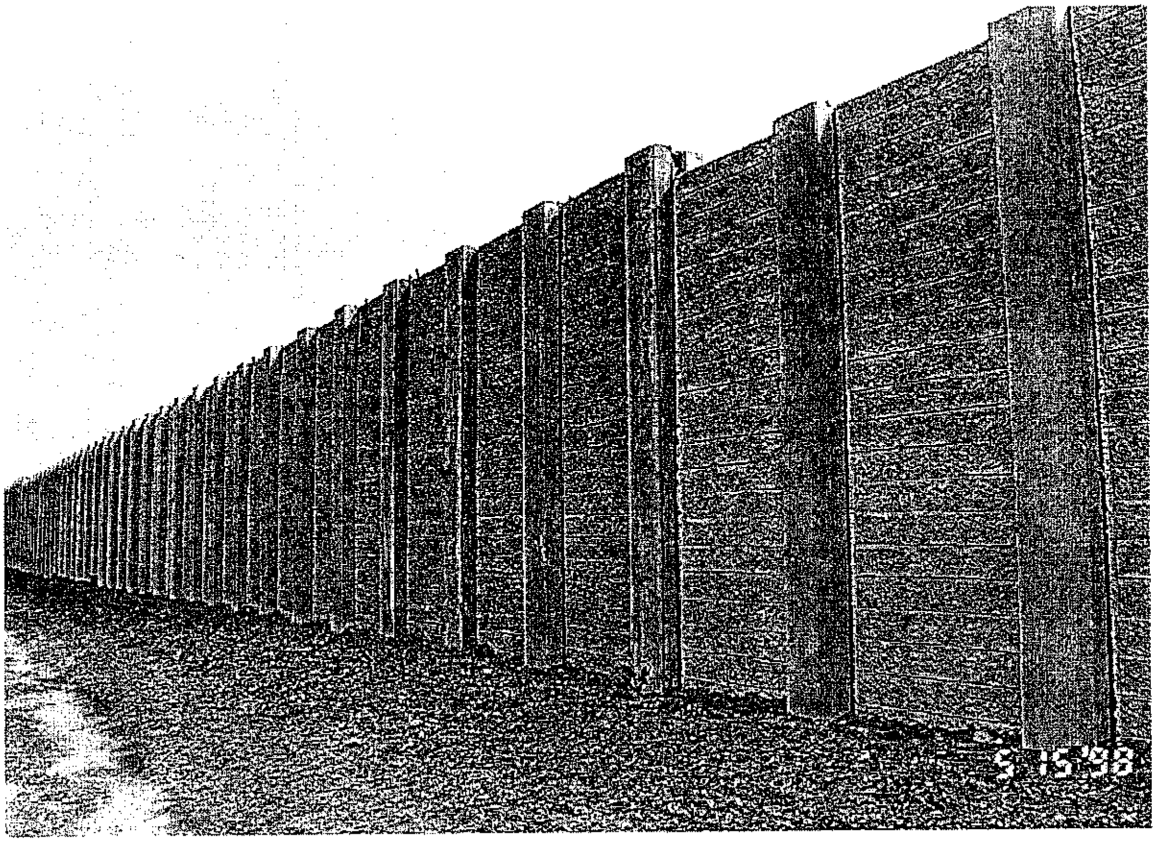


Figure 5-26. Precast concrete barrier, I-355 at Boughton Road.

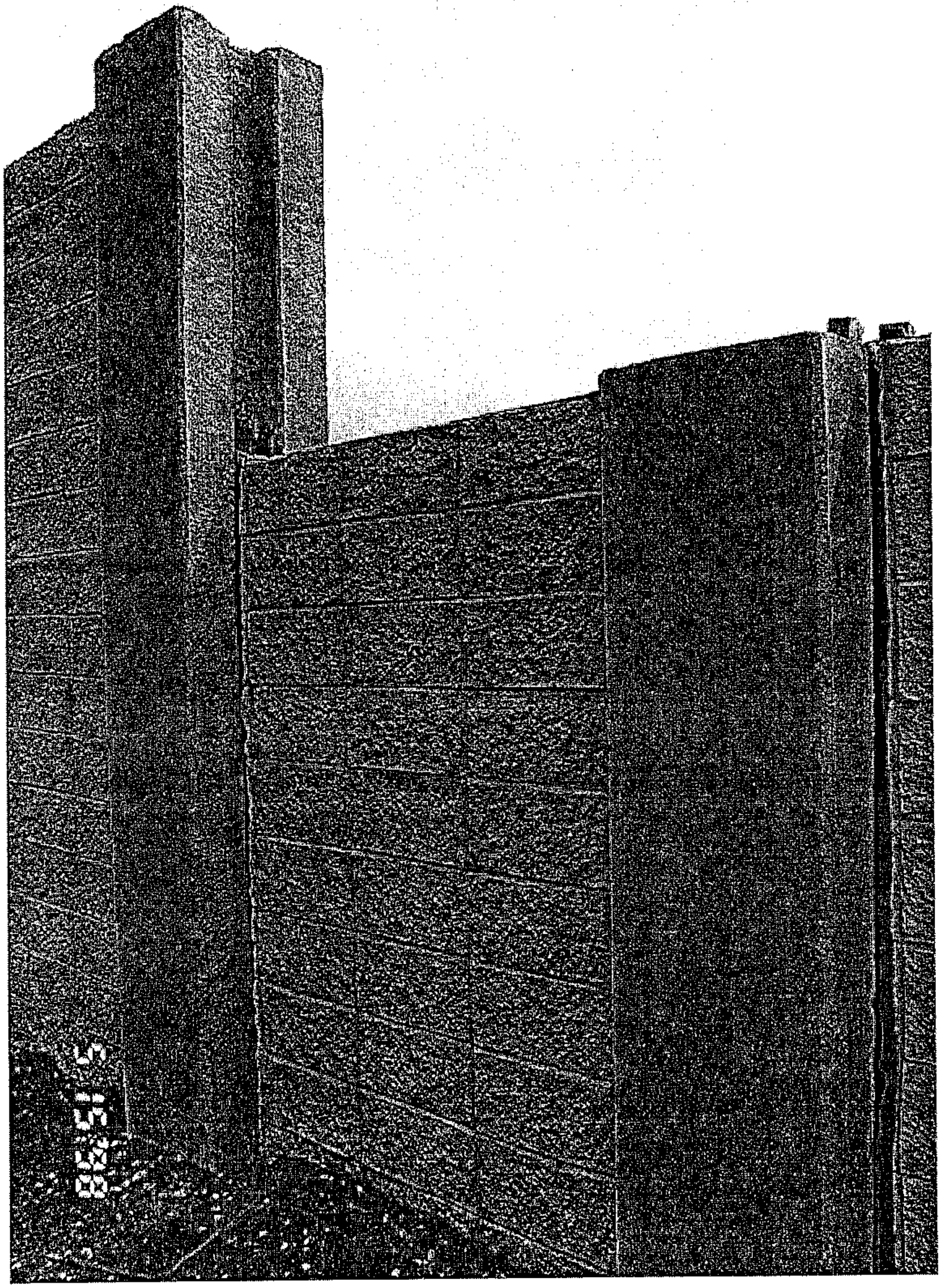


Figure 5-27. Precast concrete barrier, new construction, I-355.

5.2.3.6.2.3 Carsonite barrier

Finally, a Carsonite® barrier was examined at the toll plaza near the I-294/I-55 interchange. The Carsonite barrier is 5.5 m (18 ft) high, and is supported by steel wide flange beams on 15 foot centers. The posts are set in a concrete drilled pier. The panels are composed of tongue and groove planks, pre-assembled in 4-foot sections and lowered into place between the posts. The panels are integrally colored, and require no additional coating.

The condition of this barrier at an age of 4 years was generally good. Close examination of the barrier showed excellent attention to construction details such as the sealing of joints and horizontal alignment of the panels (Fig. 5-28). There does not appear to be any deterioration of the fiberglass surface of the panels. However, the Tollway has objected to the appearance of the panels from a distance (Fig. 5-29). The researchers noted that when viewed from a distance, the panels had random color differences between planks in some areas, while other panels seemed relatively color-consistent. This color variation was not noticeable when the barrier was viewed at close range. The cause of the discoloration is reportedly a manufacturing process, and not the result of weathering in the field. Painting the barrier to mask this color difference is not considered a viable option by the Tollway. Another defect noted in the Carsonite wall was a panel that had dropped several inches, creating a gap of approximately 1.5 inches. The cause of this appeared to be the slight misalignment of the post. Repair of this panel movement will require the addition of an angle or other support at the base of the post. Finally, the painted posts were beginning to show signs of weathering after only 4 years.

The long-term performance of this type of barrier is difficult to judge based on the present experience in Illinois. No other barriers of the same design were observed as part of this research. The manufacturer estimates a life of 50 years for the fiberglass panels. There is no evidence at present that would contradict this claim, although regular maintenance of the steel posts will be required.

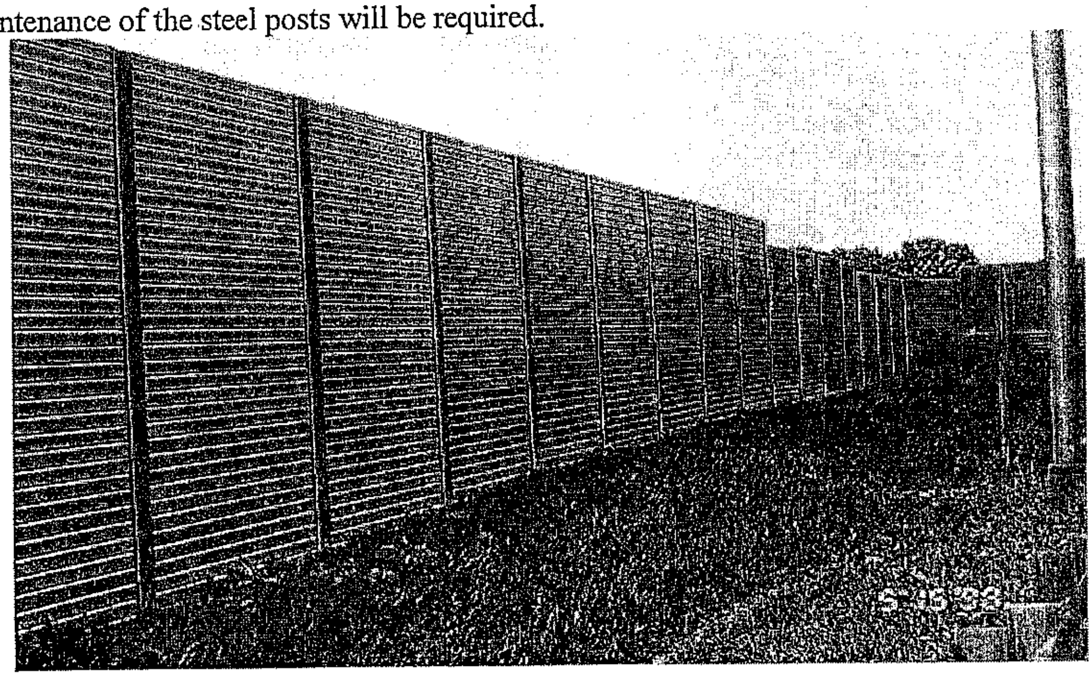


Figure 5-28. Carsonite Barrier, I-294, view of construction details.

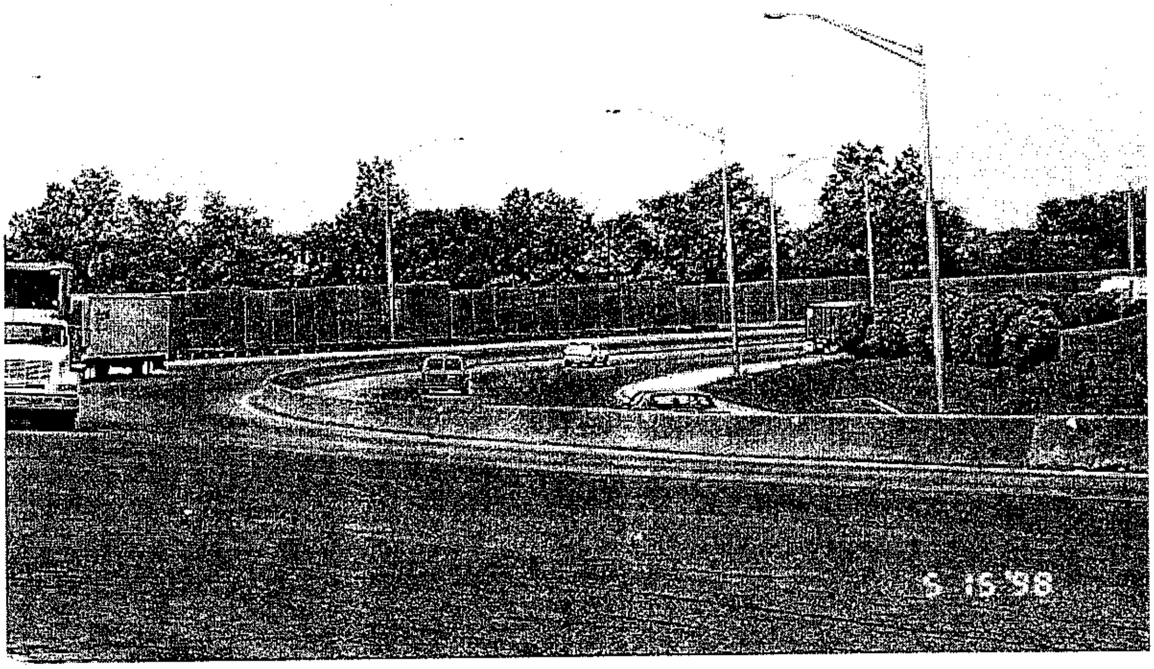


Figure 5-29. Carsonite Barrier, I-294, view of color variation among boards.

5.3 Survey of IDOT and ISTHA Maintenance Personnel

The project scope of work included a survey of IDOT districts to solicit information on the current (physical) condition of noise barriers, replacements, maintenance histories and costs, wall lengths, ages, and materials used. During the course of the project, the ISTHA expressed an interest and was added to the survey. The form of this survey was adapted from the maintenance survey sent to other state DOTs but was reworded to include only those materials currently in use in Illinois and to ask for more specific information on actual repairs performed, routine maintenance, and related costs. A form of the IDOT survey is included in Appendix A. The ISTHA version was revised slightly to remove references to districts and to include the correct contact for return of the survey; it is not reproduced in the appendix. The survey was transmitted to the appropriate IDOT maintenance yards in the five districts (Districts 1,2,4,6 and 8) that currently have noise barriers through Mr. David Johnson, Maintenance Operations Engineer, Bureau of Operations. Mr. Chet Herne distributed the surveys to ISTHA maintenance personnel. All IDOT districts responded to the survey. The results of the survey are summarized below.

5.3.1 Survey Questions

The survey was limited to 9 questions, worded to allow respondents to check appropriate responses. Respondents were provided space to comment or expand on their answers where needed. A summary of all Illinois noise barriers, as adapted from the 1996 FHWA Summary, was provided, with noise barriers in each respective district highlighted. Districts 1 and 2 had multiple maintenance yards respond to the survey, each commenting on the noise barriers in their maintenance area. A total of 10 surveys were returned.

5.3.1.1 Earth berm

Berms received uniformly favorable ratings. The current condition of 20-year old berms in District 6 was rated "like new". Berms were rated highly for low maintenance effort, low maintenance cost, good appearance over time, and for having no structural problems. The landscaped surface of the berms was rated as a positive attribute.

5.3.1.2 Carsonite

There were no comments returned on the performance of Carsonite on the Tollway.

5.3.1.3 Durisol

There were no comments returned on the performance of Durisol in District 1.

5.3.1.4 Fanwall precast concrete barrier

The single section of Fanwall received favorable ratings. Its current condition of the 20-year old section was rated "maintenance-free." District 2 reported no negative experiences with this product, and no planned or completed repairs. Graffiti removal from the unpainted concrete surface was reported as a negative feature of this barrier. However, the barrier was reported to require low maintenance effort, and to look good over time. The service life of this barrier was estimated as 30 years.

5.3.1.5 Precast/prestressed concrete cantilever barrier

Responses on the performance of this barrier were positive. Both Districts 2 and 8 rated the barrier as maintenance-free (no maintenance required since installation). However, District 2 reported that some panels have tilted, and joints separated 1 to 3 inches. Two panels have been replaced due to car crashes, but no estimate of the repair cost was provided. The reported tilting of the barriers has not resulted in any completed or planned repairs. Graffiti removal from the unpainted concrete surface was reported as a negative feature of this barrier. Estimates of service life of this type of barrier varied from 20 to 25 years.

5.3.1.6 Precast concrete post and panel

There were no comments on the performance of this type of barrier.

5.3.1.7 Tropical Hardwood

District 4 reported positive experience with this barrier, while District 1 was strongly negative. The current condition of the Peoria barrier was rated as "maintenance-free," and the District reported that they have been pleased with the barrier's ease of construction, low maintenance cost and effort, good noise reduction, good appearance over time, and absence of structural problems. The service life of this barrier was estimated as 25 to 30 years.

In contrast, the current condition of the tropical hardwood barrier on IL 53 from IL 68 to Lake/Cook Road was rated as "failed (needs replacement)." The negative experience of the district with this barrier includes high maintenance cost (approximately $6600 for panel replacement), high maintenance effort, poor structural performance, and poor appearance. The barrier reportedly began to require repair at an age of 1 year due to poor appearance, loss of noise reduction, public complaints, structural performance and crash damage. Maintenance issues that are perceived as negative features of this barrier include mowing and landscaping upkeep, crack repair, graffiti removal, surface cleaning and vegetation removal. The estimated service life of this barrier is "unknown."

5.3.1.8 Glue-laminated wood barrier

Glue-laminated wood barriers received mostly favorable ratings. Three maintenance yards in District 1 that reported on these barriers in their areas each had different experiences. A 1991 section was rated "trouble-free (routine maintenance only)." One 1982 barrier was rated "maintenance-free (no maintenance required since installation)," but another was "deteriorating (needs repair)." Needed repairs were limited to renailing the top cap board, and reported costs were minimal ("6 boxes of nails"). The repairs were linked to public complaints, and were made when the barrier was 16 years old. Glue-laminated walls were rated positively for low maintenance effort and cost, and two yards reported "no structural problems." Service life for this barrier was estimated at 20 years by the two respondents to this question.

5.3.1.9 Noishield steel barrier

District 8 rated this barrier as both "deteriorating (needs repair)" and "failed (needs replacement)." The barrier was repaired at one year of age because of poor appearance, public complaints, and structural failure due to "poor material." The cost of adding fiberglass panels to reface the surface of this barrier was estimated at $80,000. The barrier is currently being considered for replacement. The service life of this barrier was estimated to be 1 year.

5.3.1.10 Noishield aluminum

This barrier received favorable ratings. The current condition was rated "maintenance free" and no repairs or negative features of this barrier were reported. The service life was estimated to be 13 years, which is the current age of the barrier. The barrier is not currently being considered for replacement.

5.3.1.11 Combination earth berm/wood barrier

Districts 1 and 2 reported favorable performance of this type of barrier, although barriers in both districts have suffered crash damage. Both rated the barrier as "trouble-free (routine maintenance only)." Crash damage to the wood barrier required repairs to one barrier when it was 10 years old, and to the other at 13 years. A single repair cost of $600 was reported. No estimates of service life of this type of barrier were given.

5.3.2 Summary of Survey Responses

The survey of IDOT maintenance personnel revealed some new facts regarding the histories of barriers, giving the most complete picture to date of the maintenance effort and costs associated with Illinois noise barriers. The survey tends to confirm that noise barriers are not subject to any routine inspection and maintenance, but are repaired in response to discrete events such as vehicle crashes. Public complaints regarding the appearance of noise barriers has prompted repairs on several barriers. Graffiti was mentioned in only one case, confirming the researchers observations that this type of vandalism is not prevalent. The total reported repair cost was just over $87,200. The single largest expenditure, estimated to be $80,000, was required on a steel barrier only one year old. That repair was only a temporary measure, and the barrier, now 13 years old, is in need of complete replacement. The next largest repair expenditure, $6,600, was required on a tropical hardwood barrier, again after only one year of service. The hardwood barrier, now 8 years old, is also in need of complete replacement. No serious maintenance concerns were reported aside from these two failed barriers.

Crash damage was reported for three barriers. It is believed that this may not be the complete inventory of crashes involving noise barriers. Fire damage noted by the researchers, and a recent crash on I-290 involving a glue-laminated wood barrier were not reported: older crashes such as one involving another glue-laminated wood barrier on IL 59 were also not reported.

Maintenance personnel expressed positive experience with earth berms, precast/prestressed concrete cantilever walls, and the Fanwall precast concrete barrier. Generally positive comments were received for glue-laminated wood barriers, and the single repair concern was minor. In an interesting contrast, barriers similar to the two failed sections were rated very favorably: a tropical hardwood barrier in Peoria and an aluminum barrier in Collinsville have performed well.

The projected service lives of noise barriers as estimated by the survey respondents are in general lower than the estimates of the researchers for concrete products. In no case did the estimated service life of concrete barriers exceed 25 years, even though the barriers were reported to be maintenance-free. For wood walls, the range of projected service lives was 20 to 30 years, similar to the estimates of the researchers.

5.3 Discussion of Results

The observation of field conditions of noise barriers throughout Illinois clearly indicates that the designs used to date have been sound. Of the more than 96 km (60 miles) of barriers built in Illinois to date, only a small number of observable defects were noted by the researchers or reported by IDOT maintenance personnel. Only two barriers (the Noishield steel barrier near Centreville and the tropical hardwood barrier on IL 53 at Lake Cook Road) were observed to have undergone deterioration serious enough to potentially warrant removal and replacement. The failure of these two barriers appears to be primarily related to the material supplied and the specifications for that material. Other factors related to design including sizing of foundations, structural design of panels, sizing and placement of posts, and drainage under and around barriers did not appear to be major factors in noise barrier defects. The researchers also concluded, based on their observations, that any of the materials or products used to date in Illinois could be used successfully in the future if proper attention is given to specifications. This conclusion is underscored by the successful performance of the Noishield aluminum barrier, which was designed to remedy the design defects that caused the failure of the Noishield steel barrier. The successful performance of tropical hardwood on a small project in Peoria also would suggest that the material can be used with good result on similar projects if construction details and moisture content of the material delivered are closely monitored during erection of the barrier.

The minor defects noted in Illinois barriers, aside from the two failed barriers, were primarily related to movement at joints and connections. It would appear that noise barrier designs that minimize joints would reduce the potential number of defects and give better service. Of the materials or products used by Illinois to date, precast/prestressed concrete "cantilever" barriers, glue-laminated wood barriers, precast concrete post and panel barriers and earth berms (alone or in combination with other materials) have given similarly good service. No walls of these types have shown evidence of significant defect or appear near the end of serviceable life. Minor problems noted with the two proprietary barriers, Durisol and Carsonite, are related to aesthetics, not to structural or acoustic performance.

CHAPTER 6

SERVICE LIFE CRITERIA

6.1 Introduction

The performance of a highway noise barrier must be judged in at least three ways, each related to the intended function of the barrier. First, the barrier must perform its function acoustically, reducing highway noise for sensitive receivers located along the roadway. In order to carry out this function, the noise barrier must also perform structurally as a free-standing wall, carrying its own weight and specified live loads including wind and seismic loads. Finally, the noise barrier must function as an aesthetic feature of the community. The aesthetic aspect of a highway noise barrier must be considered from the perspective of the residents living behind the barrier, as well as the drivers viewing it from the roadway.

This multi-level performance criteria, in particular the involvement of the public in judging appearance, make highway noise barriers unique in the highway environment. Most highway elements are judged solely on structural performance, and criteria for determining minimum acceptable performance are well established. These criteria are often subjective and dependent on the evaluation of experienced observers, as in the determination of pavement distresses using the Condition Rating System (CRS). This pavement management system assigns pavement ratings of 1 to 9 based on district reviews of video logs of pavement condition and information on rutting and roughness. In this rating system, a CRS value of 9 corresponds to new pavements, and rehabilitation is programmed when the rating falls to a value of 5 (Buttlar et al, 1999). These determinations, although subjective, can be used to rate the serviceability of pavements.

A similar rating system does not yet exist for determining the serviceability of noise barriers, and in fact may be impossible to create. Whereas highway pavements are constructed of either of two basic materials, Portland cement concrete or bituminous concrete, noise barriers can be constructed of any one of dozens of materials or proprietary products. Highway pavement mileage exceeds noise barrier mileage by a factor of many thousands, and the experience in evaluating pavement performance exceeds that of evaluating noise barrier performance by several decades. Assessment of the acoustical performance of miles of highway noise barrier cannot be accomplished as easily as the appearance of highway pavement can be videotaped from a specially equipped van. Finally, the assessment of the aesthetics of highway noise barriers is a matter of personal taste, including the taste not only of highway officials but the public at large. An aesthetic rating system representing a diversity of personal opinions would be difficult to devise.

This report does not attempt to create a comprehensive serviceability rating system for noise barriers, but represents a first step in assembling the opinions of highway noise experts throughout the U.S. and highway maintenance personnel in Illinois regarding the long-term performance of noise barriers in their jurisdictions. The end product is a checklist of factors that influence the serviceability of noise barriers in terms of structural, acoustical, and aesthetic performance. Criteria for judging the continued serviceability of noise barriers are developed.

6.2 Service Life Definition

The service life of a noise barrier can be defined as the period of trouble-free performance with no discernible change in barrier insertion loss or appearance. During a barrier's service life, routine maintenance activities will be required to keep the barrier in a serviceable condition. Such activities will differ depending on barrier material. For example, earth berms may require periodic mowing, replacement of landscaping, and tree trimming. Post and panel systems with steel posts will require periodic painting of the posts to inhibit rust. Barriers of all types will require periodic repair of incidental damage due to vehicle crashes, vandalism or other causes.

Maintenance costs are expected to increase as a barrier approaches the end of its service life. At the end of barrier service life, the barrier will require major structural repairs or replacement. A benefit-cost analysis should be performed to assess whether repair of the existing barrier is more cost-effective than complete replacement.

Periodic inspections of a noise barrier's sturctural, acoustical and aesthetic performance, as described in subsequent sections, are recommended to determine the end of barrier service life. A barrier inspection report form containing a checklist of service life criteria is given in Figure 6-2 at the end of this chapter.

6.3 Acoustical Performance

The primary function of highway noise barriers is to act as an obstacle to sound waves generated by vehicles on the highway, lengthening the travel path to the receivers. The characteristics of sound propagation in an outdoor environment are complex and measurement of the effectiveness of a noise barrier is not a simple task. This study did not include any field measurement of barrier insertion loss. However, it was necessary to study the literature on acoustic properties of noise barriers in order to address performance issues in light of IDOT draft policy on noise abatement, "Policies and Procedures for Noise Analysis on State Highway Projects" (April 27 1998). This policy is currently under review by the FHWA. The draft requires that materials for noise abatement walls have a sound transmission loss (TL) greater than or equal to 20 dB in all test frequency bands when tested in accordance with ASTM E90 "Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions." The draft policy statement calls for every reasonable effort to be made to obtain "substantial noise reductions" of at least 8 dB (i.e., an 8 dB insertion loss) measured at the receptor in cases where noise abatement measures are considered. Receptors are considered to be buildings abutting the highway, but the distance from the highway to the receptor is not addressed. Exterior noise levels are to be measured at a point 5 feet above ground level.

6.3.1 Insertion Loss Requirements

Depending on the dimensions and material properties of the noise barrier, portions of the sound energy generated by highway traffic will be reflected by, absorbed by, or transmitted through the barrier. Another portion of the sound wave will be diffracted over the top and around the ends of the barrier. The noise reduction related to diffraction is barrier attenuation, which is related to barrier height and length (AASHTO 1993).

A more meaningful measure from the point of view of the public is barrier insertion loss (IL), the perceived reduction in noise level at a receptor due to the addition of a barrier. Barrier insertion loss includes losses not only due to attenuation, but transmission through the barrier, reflections, and attenuation due to ground cover (FHWA 1980). For a noise barrier constructed on an existing highway, insertion loss can be measured directly as the sound energy level "L" at a receptor before barrier construction minus the sound energy level after barrier construction (Cohn 1981):

$$IL = L_{before} - L_{after}$$

For barriers constructed on new alignment, there is no traffic noise in the "before" condition. In such cases, the "before" condition can be approximated by measuring noise levels at a similar location without a barrier or using a computer noise prediction model such as STAMINA 2.0 or the Traffic Noise Model (TNM). These estimates can be compared to actual sound energy levels measured when the barrier is in place (Herman et al. 1991).

Unfortunately, barrier insertion loss is not a single value that can be assigned based on barrier dimensions or properties. Insertion loss varies depending on a number of factors, including distance of the receiver from the barrier, distance of the barrier from the highway, height of the noise source with respect to the receiver, weather conditions, and time of day (Herman et al., 1991). Although the IDOT draft policy does not specifically address distance behind the barrier for insertion loss measurements, the distance is an important aspect. Dunn (1988) studied the effectiveness of noise barriers in Florida, and measured an insertion loss of 12 dB directly behind an 18-foot concrete wall and 6 to 8 dB at 150 feet. Dunn found the barrier had little effect on noise levels at distances of more than 300 feet from the barrier. Anday (1978) reported noise measurements made at distances of 25, 50, 75, and 100 feet behind steel and concrete noise barriers in Virginia. Measured insertion loss varied from approximately 11 dBA at 25 feet to 4 dBA at 100 feet from the barrier, regardless of the barrier material.

Insertion loss also depends on the effects of sound transmission through the barrier. Transmission loss (TL), which is the drop in sound energy measured in decibels as the sound wave passes through the barrier, is related to barrier material and thickness. However, TL is also dependent on sound frequency. Klinger et al. (1996) computed the varying thicknesses of six construction materials required to produce a 30 dB TL at frequencies of 100 Hz and 500 Hz. These values lie in the dominant range of typical traffic noise frequencies which varies from about 100 Hz to 4,000 Hz (Table 6-1). The thicknesses required to achieve a 30 dB TL at 500 Hz are generally less than typical dimensions required structurally. However, at 100 Hz, the thickness required to achieve the desired acoustical performance may exceed the structurally required dimensions for steel and wood. Noise barrier designs should consider that acoustic requirements may exceed structural requirements in order to comply with IDOT draft policy calling for a minimum TL of 20 dB in all test frequency bands.

Table 6-1 Thicknesses of Construction Materials Required for 30 dB Transmission Loss at Varying Frequencies

Material	Thickness for 30 dB TL 100 Hz		Thickness for 30 dB TL 500 Hz	
	mm	inches	mm	inches
Steel	5.3	0.21	1	0.04
Concrete	16	0.63	3.3	0.13
Glass	18	0.72	3.6	0.14
Rubber	32	1.24	6.4	0.25
Plexiglass	46	1.81	9.1	0.36
Pine	93	3.66	19	0.73

Source: Klinger et al. 1996

6.3.2 Measurement of Barrier Acoustical Performance

Following the field study of the condition of noise barriers, the effect of gaps and cracks related to weathering and deterioration of noise barriers was determined to be an important question. While it would seem that visible gaps and open joints would significantly affect the acoustical performance of a noise barrier, published reports on the effects of small openings were conflicting. Cohn (1981) reported that for small openings, sound pressure will increase, resulting in amplification of the sound to the receiver. Flodine (1991) stated that the shrinkage cracks in wooden barriers allowed noise leaks through as much as 8% of the surface area, reducing the effectiveness by up to 60%. However, the ISTHA attempted to quantify the effects of vertical gaps approximately 25 mm (1 inch) wide at the posts in newly constructed precast concrete barriers on I-355, and found no significant effect at distances greater than 20 feet from the barrier (Herne 1998), and Klinger et al. (1996) minimized the effect of small gaps if they total less than 1% of the surface area of the barrier.

Although the scope of this study did not involve field noise measurements, the researchers attempted to devise a means for IDOT to quantify the degradation of barrier insertion loss over time due to cracks and gaps. Numerous published reports on the measurement of barrier insertion loss were reviewed and experts in highway noise barrier acoustics were interviewed. It was determined that the simple measurement of insertion loss of existing noise barriers would not demonstrate the effect of cracks and gaps. In fact, there are several difficulties in directly linking changes in insertion loss to barrier deterioration. The problem becomes:

$$\Delta IL = L_{deteriorated} - L_{new}$$

Obtaining a value for L_{new} requires a measurement of the noise level behind a barrier in "like-new" condition, with no gaps or cracks. Noise measurements (if any) made when the barrier was new will be a function of traffic, atmospheric, and ambient noise conditions that vary from current conditions. However, there are several possibilities for approximating a value:

- physically cover the barrier with acoustically opaque material to simulate a "like-new" condition and take field noise measurements
- measure noise levels at an adjacent section of wall in "like-new" condition
- use computer prediction models to obtain noise levels.

Each of these possible methods has limitations. Covering a deteriorated noise barrier might not accurately represent that barrier in its original condition. Noise levels at adjacent sections of the barrier might vary from those at the subject site due to differences in topography, traffic, multiple reflections, background noise, and other factors. Computer modeling has been found to be generally accurate but may not exactly represent the noise reduction of the barrier in its original condition.

Finally, the field measurement of current noise levels behind a deteriorated section of wall would have to consider the methods and assumptions used in obtaining L_{before} and L_{new}, and variable conditions would have to be matched as closely as possible. Comparison of actual field noise levels to computer-predicted levels for the "before" and "like-new" conditions could inaccurately represent any computed reduction in barrier insertion loss.

Although it appears to be difficult to conclusively prove a link between the presence of gaps and cracks in a noise barrier and a reduction in barrier insertion loss, these gaps may give the public the impression that the barrier is compromised. A relatively simple measure of the effects of small openings in a barrier might be obtained by temporarily covering a section of damaged barrier with a tarpaulin or other insulating material. Noise level measurements made in the same location before and after application of the temporary covering would nearly eliminate variation in traffic noise, atmospheric conditions, background noise, topography and ground impedance.

A reasonable criteria might be that the net change in measured noise level before and after application of the covering should be less than 3 dB, a change which is barely discernible by most observers. The practicality and accuracy of the results of this proposed methodology has not been tested in the field, and further study is required.

6.4 Structural Performance

The serviceability of most engineering materials is described by structural performance. Load-carrying elements, from highway pavements and bridges to signs and lamp posts, must be sufficiently strong to carry expected loads without excessive deflection or collapse. Noise barriers typically are designed as free-standing walls that may be subject to vehicle strikes, fire, frost heave and other soil-related movements in addition to the applied loads. Applied loads always include the dead load of the barrier and a specified wind load, and may under various circumstances include secondary loads, such as seismic load, traffic impact loads, lateral earth pressure, and snow and ice loads (AASHTO 1992).

In Illinois, review of noise barrier designs has been coordinated through the IDOT Bureau of Bridges and Structures. During the field survey of barriers throughout the state, no barriers were observed to have significant movement of the structural support elements (foundations and posts), or excessive deflection of panels related to wind or other loads. There have been no structural failures due to applied loads, although several sections have been damaged by vehicle strikes. One glue-laminated wood wall was reportedly knocked down by a vehicle impact shortly after the construction of the barrier in 1980. No photographs or exact description of the extent of damage were available. One glue-laminated wood barrier was observed to have survived a fire (Fig. 6-1). Another section of glue-laminated wood wall on I-290 was recently damaged by a vehicle strike according to reports by IDOT personnel. While a section of the wall appears to have been sheared at ground level, the barrier remains standing, apparently supported by adjacent sections. No report on the proposed method or date of repairs to this section was available.

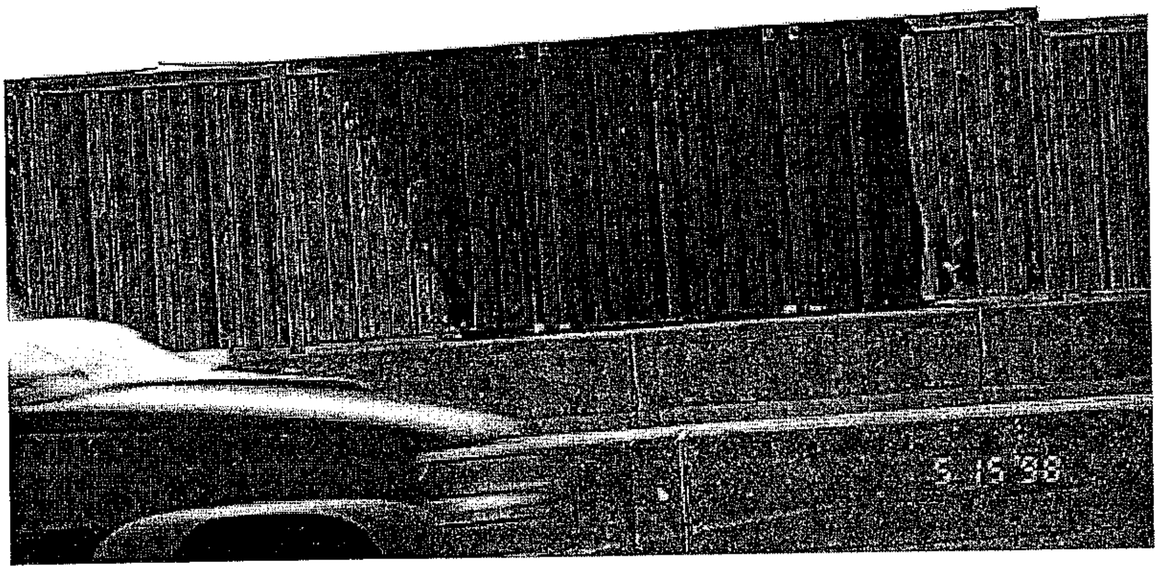


Figure 6-1 Glue-laminated wood wall damaged by fire, I-290 at St. Charles Road.

6.4.1 General Requirements

Future evaluations of the structural performance of noise barriers will rely primarily on visual inspections of the structural support elements and the wall panels by maintenance personnel. Movement or deterioration of any component of the barrier may affect the structural integrity of the barrier. Given the many types of barrier materials, products, foundation types, and structural connections, the specific types of structural distress that may be observed will vary greatly. However, some general considerations are discussed and criteria for assessment of noise barriers developed.

6.4.1.1 Connection to Foundation

Foundation types for Illinois noise barriers vary, but drilled pier foundations appear to be the most common. Dimensions of drilled piers are designed based on barrier dimensions, wind loads, and local soil conditions , but a diameter of 0.6 to 0.9 m (2 to 3 ft) is typical. Depth also varies, but typically is in the range of 2.5 to 3 m (8 to 10 ft). Significant settling or differential movement of drilled pier foundations is unlikely. However, the point of connection between above-ground posts and the drilled pier is a potential source of movement. Structural inspections should examine the post-pier connection for signs of corrosion of anchor bolts or steel posts, or rotting of wood posts. For connections sealed with grout or other material, the anchor bolts may not be visible. Inspectors should look for rust or water stains at the base of the barrier, indicating possible corrosion of the anchor bolts.

6.4.1.2 Vertical Plumbing of Panels and Posts

For "cantilever" noise barriers of precast/prestressed concrete or treated wood, the depth of imbedment required for structural stability will typically be well below frost depth in Illinois. Differential movement at the base of the barrier could be caused by nearby trench excavations, underground erosion along buried utilities, growth of trees adjacent to the barrier, or other mechanisms. Visual inspection of cantilever barriers should include a check for differential vertical movement between panels as well as leaning out of plumb. Plumbing of panels can be accomplished visually by experienced observers, or by using a 4-foot carpenter's level. Panels out of plumb more than 1% of their height should be further investigated to determine the cause of panel movement.

Post and panel systems should be examined for signs of movement of the posts. Plumbing of posts can be accomplished visually by experienced observers, or by use of a 4-foot carpenter's level. Construction tolerances for variation from plumb are typically low (less than 0.5 inch in the height of the wall), so posts significantly out of plumb (more than 0.5 inch in 4 feet) indicate structural movement, the cause of which should be investigated. Posts that are out of plumb may compromise the connection of the panels to the posts, depending on the design of the barrier, and the amount of "play" in the post/panel connection. Some barrier designs would require catastrophic movement of the posts to allow panels to fall out. Other, such as the tropical hardwood barriers, have panels held in relatively shallow notches (2 inches). Shrinkage of the boards combined with movement of the posts could allow panels to lose support and fall out.

Differential settlement of stacked panels can result from loss of support at the base of a post. This can be related to movement of the posts, warping, bowing or shrinkage of the panel, or failure of an angle, clip, or other minor support element. Monitoring of differential settlement could easily be accomplished in the field without surveying equipment if unobtrusive markings were made on the posts showing the location of the joints in the panels at the time of installation. Any future movement of the panels could be easily referenced to their original locations as shown on the posts.

6.4.1.4 Trueness of Panels

Measurement of bowing or buckling out of the plane of the wall is an indication of the trueness of the panel. Bowing or buckling is an aesthetic concern but may be an indication of poor structural performance as well. Buckling under load may indicate possible catastrophic failure of the barrier, and the cause should be investigated.

Bowing of a corroded steel wall in Centreville, Illinois was measured in order to quantify the amount of bowing that was visible to observers, making the appearance of the barrier objectionable. The maximum bowing measured was 2 inches in a 12 foot panel length (a ratio of 0.013 feet per foot). A limiting criteria for deviation from true could therefore be established as 0.01 D, where D is the distance between adjacent posts.

6.4.1.4 Panel Cracking

Finally, cracking of full-height panels can compromise the structural integrity of the panels and render the barrier unsafe. Cracking of full-height panels (both open and closed cracks) should be investigated for cause and monitored closely. Cracking may necessitate replacement of the affected panel.

6.5 Aesthetic Performance

The appearance of noise barriers is the final and most difficult characteristic to rate. The wide variety of materials, textures and colors available makes general agreement on the appearance of noise barriers difficult even in a new condition. Results of the maintenance survey (Chapter 3) indicate that aesthetic performance is one of the least important factors in determining the service life of highway noise barriers, but the survey did not give specific information regarding the respondents' opinions of the appearance of existing barriers. Given the low importance ascribed to aesthetics as a factor in service life, it appears unlikely that noise barriers would be removed solely on the basis of poor appearance.

However, often the poor appearance of a barrier is directly related to structural performance. Measurements taken on a failed stacked panel barrier near Centreville, Illinois may be useful in developing criteria for the amount of movement that can be readily detected by eye. Differential movements of 2.5 inches over 12 feet of length (a ratio of 0.017 feet per foot) were clearly visible, giving an objectionable appearance to the barrier. One possible criteria for aesthetics would therefore be to limit differential settlement of stacked panels or other systems with visible horizontal joints to less than 0.015D, where D is the horizontal distance between adjacent posts.

Figure 6-2. Sample Noise Barrier Inspection Report Form

Location:______________________________ Date:________________

Barrier Description: (material type, height)________________________________

Reason for Inspection: Inspector:______________

- ❑ Routine
- ❑ Crash Damage
- ❑ Public Complaint
- ❑ Other____

		Criteria
I.	**Structural Performance**	
	❑ Foundation______________________	
	❑ Post Connection to Foundation______________________	
	❑ Differential Movement (in./in. panel width, D)__________	(< 0.015 D)
	❑ Cracks or Gaps (size, extent)______________________	(< 1% area)
	❑ Barrier Out of Plumb(in./in. height)______________	(< 1% height)
	❑ Panels Bowing (in./in. panel width, D)______________	(< 0.01 D)
	❑ Other______________________________	

II. Aesthetic Performance

- ❑ Graffiti____
- ❑ Discoloration____
- ❑ Landscaping Needs____________________________________
- ❑ Other____

III. Acoustic Performance

- ❑ Predicted Noise Level (without barrier)____________________
- ❑ Predicted Noise Level (with barrier)______________________
- ❑ Measured Noise Level (with barrier in "like new" condition)__________
- ❑ Measured Noise Level (with barrier in current condition)____________
- ❑ Barrier insertion loss predicted__________________________
- ❑ Barrier insertion loss measured__________________________
- ❑ Change in insertion loss due to barrier aging__________________

The interest rate is used to indicate the time value of money if invested rather than used for the building of noise barriers. For this analysis, an interest rate of 5.5% was chosen based on recent trends in interest on Treasury bonds (Forbes 1999). The use of higher interest rates available in recent markets is not justified for analyses of alternatives available to a public agency (FHWA 1998). An escalation factor of 3% per year (± 0.75% per quarter) was used to account for yearly inflation of construction costs (ENR 1998, 1999). The escalation factor offsets any gains from the compounding effect of interest. The net gain in value each year is the difference between the interest rate on invested money and the escalation of costs and represents the real rate of return on investment. The net interest rate used for this analysis is, therefore, 2.5% (5.5% - 3%).

The year 2000 was assumed as the "present" for purposes of the analysis. An analysis period of 50 years was chosen based on the estimated life spans of the various materials under consideration. The service life of each material was estimated from the literature review, field observations of the researchers, and the survey responses from other state DOTs and IDOT maintenance personnel. The literature review established ranges of estimated service life based on manufacturer information, experiences of other state DOTs, and estimates used by other state DOTs. Flodine (1991) reported that Colorado DOT assumed design lives of 40 years for concrete, masonry, Durisol®, and aluminum acoustic panels, 30 years for steel acoustic panels, 25 years for plastic, and 15 years for wood. Lin, et al., reported the life spans of 22 proprietary noise barriers based on manufacturer's information. Concrete barriers had reported life spans of 20 to 100 years (average 51.8 years), wood 30 to 50 years (average 40 years), and metal 20 years. Bowlby (1992) reported that Oregon estimated that both wood and concrete barriers had service lives of 45 to 50 years in the drier climate of eastern Oregon, and that the life of wood was one-half that of concrete in the western part of the state. Minnesota estimated wood barriers had a service life of 30 years (Bowlby, 1992). The results of surveys of state DOTs and IDOT maintenance personnel gave estimates of service life generally in line with these previously published estimates. Finally research team assessed the current condition of noise barriers throughout Illinois by field observations. An estimate of the service life of each Illinois barrier type was made based on the information developed in the literature review, surveys of state DOTs and IDOT maintenance personnel, and the field observation of the current condition. The service lives (from installation to need for replacement) estimated using these methods are given in Table 7-1.

Based on these estimated service lives, an analysis period of 50 years was chosen. It was assumed that some materials (wood, steel, aluminum, and Durisol) would be replaced once during this period, while others (concrete, Carsonite, and earth berms) would be replaced only at the end of this period. The analysis period is, therefore, sufficiently long to allow differences in the service lives of barriers to affect the life cycle costs.

Table 7-1. Estimated service lives for noise barrier materials used in Illinois.

Material	Service Life (years)
Earth Berm	50 +
Precast Concrete, Full-Height Panels with Monolithic Posts	50
Precast/Prestressed Concrete "Cantilever"	50
Precast/Prestressed Conc. Stacked Panels[1]	50
Fanwall	50
Carsonite	50
Durisol	25
Noishield Steel[2]	25
Noishield Aluminum	25
Glue-Laminated Wood	25
Tropical Hardwood and Softwood Post and Panel	25

[1]precast/prestressed concrete stacked panels are included for life cycle cost comparison.
[2]the estimated service life for Noishield steel is based on redesigned panels used successfully on projects outside Illinois.

Construction costs vary geographically and are indexed by several construction reports, including R.S. Means, F.W. Dodge, Marshall & Swift, and Engineering News Record. For this analysis, the city of Springfield was chosen as the base, and all estimates of current construction costs are related to Springfield. Relative costs for constructing in other Illinois cities can be found by using averaged adjustment factors found in Table 7-2. In general, construction in most cities in northern Illinois would result in costs from 1% to 13% higher than in Springfield, while costs in downstate cities range from 1% to 4% lower.

Table 7-2. Relative cost adjustment factors for Illinois cities.

Zip Codes	Cites, Towns, Areas	Relative Adjustment Factor (to Springfield, IL)
600	Chicago, N. Suburbs	+ 1.12
601	Chicago, N. Suburbs	+ 1.12
602	Chicago, N. Suburbs	+ 1.12
603	Chicago, N. Suburbs	+ 1.12
604	Chicago, S. Suburbs	+ 1.12
605	Chicago, S. Suburbs	+ 1.12
606	Chicago, City	+ 1.13
607	Chicago, City	+ 1.13
609	Kankakee	+ 1.10
610	Rockford	+ 1.04
611	Rockford	+ 1.04
612	Rock Island	1.00
613	La Salle	+ 1.03
614	Galesburg	1.00
615	Peoria	+ 1.01
616	Peoria	+ 1.01
617	Bloomington	+ 1.03
618	Champaign	+ 1.01
619	Champaign	+ 1.01
620	East St. Louis	+ 1.06
621	East St. Louis	+ 1.06
622	East St. Louis	+ 1.06
623	Quincy	- 0.96
624	Effingham	- 0.97
625	Decatur	- 0.99
626	Springfield	1.00
627	Springfield	1.00
628	Centralia	- 0.98
629	Carbondale	- 0.97

Relative factors averaged from historical cost data for concrete and steel construction, referenced from R.S. Means, F.W. Dodge, Marshall & Swift, ENR, and Boeckh.

Initial construction costs were developed by a professional estimator for each type of barrier used in Illinois. The construction costs represent as closely as possible the actual price for constructing a barrier section as a stand-alone project. The contractor's costs for supervision, overhead, contingency and profit were included in the estimate, as well as costs for site restoration and foundations. The new estimates eliminate the uncertainties associated with cost information found in the FHWA summaries, and give better basis for comparing the actual cost of constructing alternative barriers. The costs developed for this study vary from the estimates of Lin, et al. (1997), which include only material and installation costs.

Construction cost estimates for all material types were made using an assumed barrier section 1000 feet in length and 15 feet in height, a size that would allow some economies of scale in the construction process. Drilled pier foundations were assumed for all barriers except the precast/prestressed concrete "cantilever" barrier and earth berm. The diameter of the drilled pier was assumed to be 24 inches for post spacing up to 8 feet, 30 inches for post spacing of 10 to 16 feet, 36 inches for post spacing of 18 to 26 feet, and 39 inches for post spacing of 28 to 30 feet based on a review of plans for a number of Illinois barriers and generalized design information provided by vendors.

Depth of the pier for a barrier 15 feet high was assumed to be 8 feet based on averages from actual barrier construction in variable soils reported by the ISTHA and design data provided by Carsonite International. Post spacing was based on actual designs where available and from manufacturers' information. Construction costs for the year 2000 were based on actual plans and specifications provided by IDOT and ISTHA or typical drawings from the manufacturer. The computations for each alternative are given in Appendix B.

Projections of future maintenance activities were developed using data obtained from the survey of 30 state DOTs, the survey of IDOT maintenance personnel (Chapter 3 and Chapter 5), and the experience and engineering judgment of the researchers. Costs for these activities were developed using material and labor cost data from R.S. Means *Construction Cost Indexes for 1999*. All barriers except earth berms were assumed to require periodic replacement of panels due to vehicle crashes. A length of 1% of the barrier (approximately one panel length) was assumed to be replaced every 10 years. There is insufficient data to determine the statistical rate of panel replacement over time. However, the 10-year period is in good agreement with the reports of actual panel replacement nationwide and in Illinois.

All barriers except earth berms were assumed to require periodic graffiti removal. Again there was insufficient data to determine the statistical rate of such activities. It was assumed that an area equal to 1% of the total barrier surface area of 30,000 sq. ft. would require graffiti removal every 5 years.

All other maintenance activities vary with barrier type. Painted concrete surfaces were assumed to require repainting at 20-year intervals. Unpainted concrete (cantilever barriers) would not require painting; however, a cost was included to paint the barrier once at mid-life (25 years) to improve aesthetics. Steel posts were assumed to require repainting at 10 year intervals in order to have a 50 year service life. Earth berms were the only barriers requiring annual maintenance in the form of mowing and landscape work.

Three barrier types (Durisol, Noishield, and all timber barriers) were assumed to require replacement at the end of 25 years. Because Durisol and Noishield barriers have steel posts and easily replaceable panels, it was assumed that the properly maintained posts could be reused if the barrier were not being relocated. Timber barriers were assumed to be completely replaced at the end of 25 years.

The assumptions place all barrier types at the end of their service lives at the end of the 50-year analysis period (Durisol, Noishield and all timber barriers replaced at 25 years will be at the end of their second service life). Disposal costs were calculated for all barriers except earth berms, which were assumed to remain in place without removal. If removal of berms were added to this analysis, positive salvage value of the borrow material would reduce the costs developed by the present model. The disposal costs for all barrier types assumed landfill disposal and did not consider treatment as hazardous waste (see Section 7.4.4). The assumptions made for each barrier type, including timing of maintenance and replacement activities, are displayed graphically in Figures 7-1 through 7-10.

Legend Figures 7-1 through 7-10

BP = barrier painting, 100% of barrier surface area

D = disposal
G = graffiti removal, 1% of barrier surface area
ICC = initial construction cost
JC = joint caulking, 100% of joint length
M = mowing and landscape maintenance
PP = post painting, 100% of post surface area
PR = panel replacement, 1% of barrier length
R = replacement, 100% of panels

Earth Berm

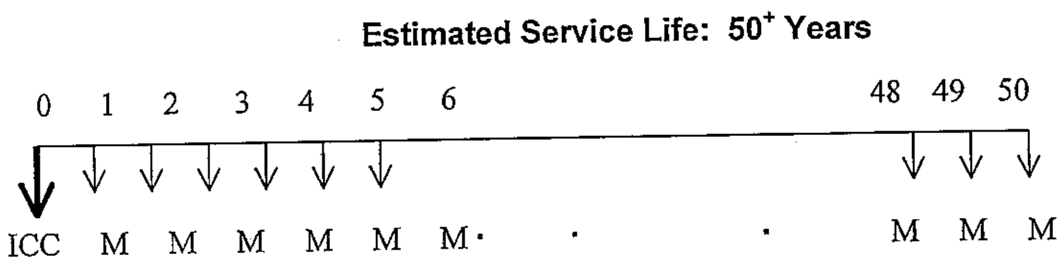


Figure 7-1. Life cycle cost model for earth berm.

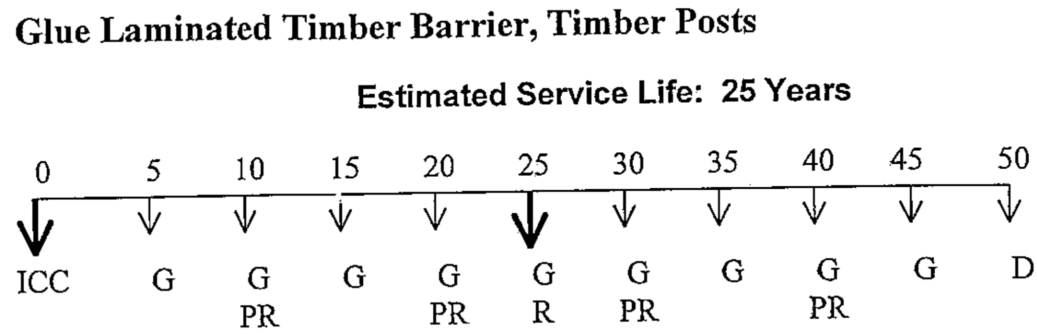


Figure 7-2. Life cycle cost model for glue-laminated timber barrier.

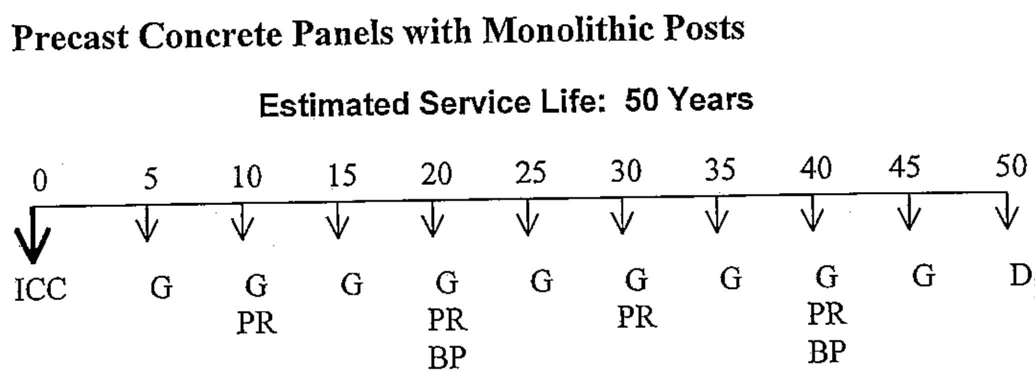


Figure 7-3. Life cycle cost model for precast concrete panels with monolithic posts.

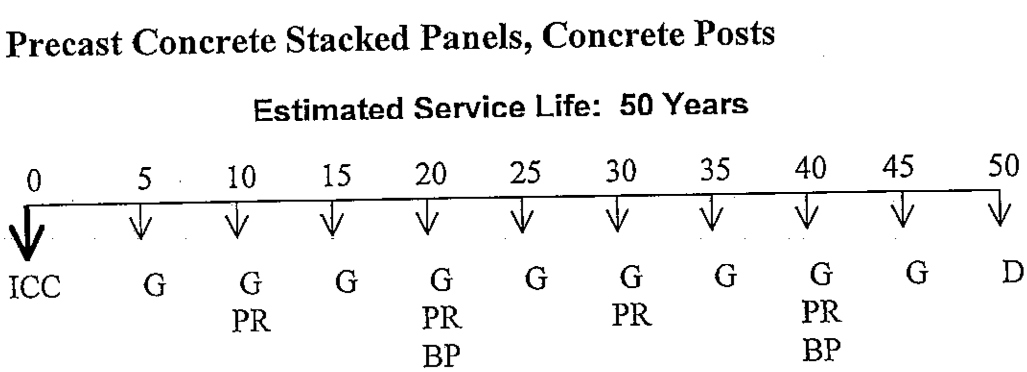


Figure 7-4. Life cycle cost model for precast/prestressed concrete stacked panels with concrete posts.

Precast Concrete Stacked Panels, Steel Posts

Estimated Service Life: 50 Years

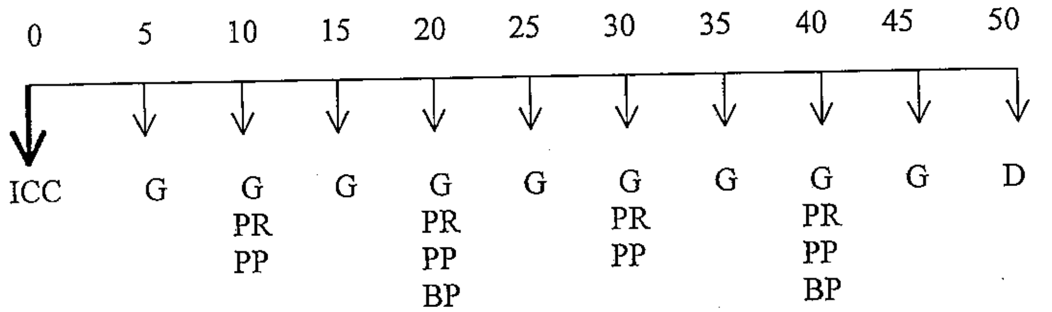


Figure 7-5. Life cycle cost model for precast concrete stacked panels,steel posts..

Structural Fiberglass Panels (Carsonite), Steel Posts

Estimated Service Life: 50 Years

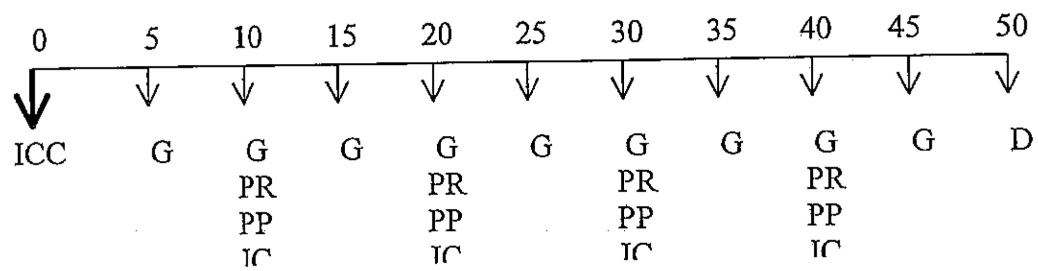


Figure 7-6. Life cycle cost model for Carsonite barrier.

Precast/Prestressed Concrete Cantilever Barrier

Estimated Service Life: 50 Years

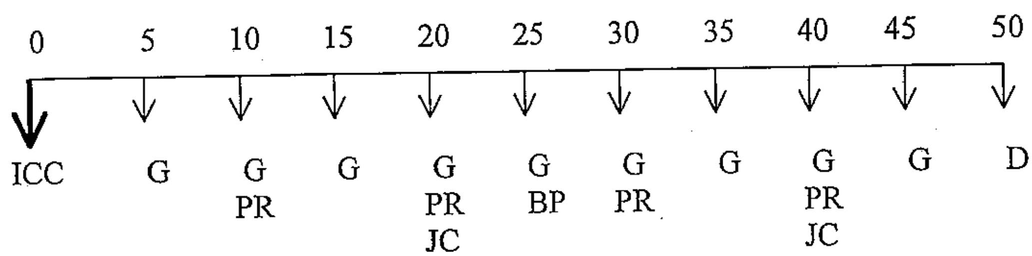


Figure 7-7. Life cycle cost model for precast/prestr. conc. cantilever barrier.

Precast Concrete Composite Panels (Durisol), Steel Posts

Estimated Service Life: 25 Years

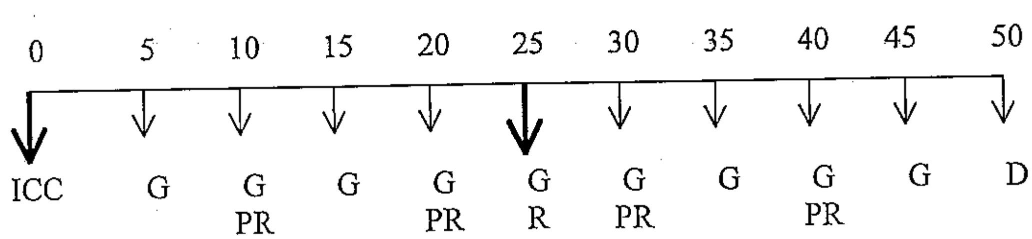


Figure 7-8. Life cycle cost model for Durisol barrier.

Steel or Aluminum Acoustical Panels (Noishield), Steel Posts

Estimated Service Life: 25 Years

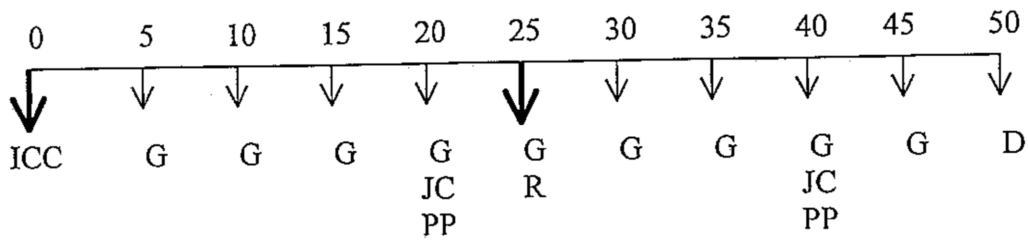


Figure 7-9. Life cycle cost model for Noishield barrier.

Timber Post and Plank, Timber Post

Estimated Service Life: 25 Years

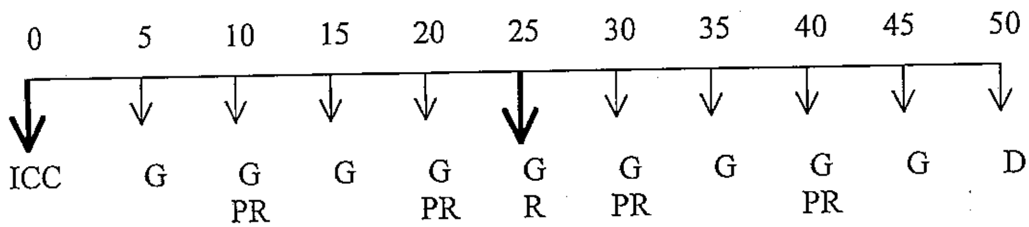


Figure 7-10. Life cycle cost model for timber post and plank barrier.

7.3 Discussion of Results

Using the LCCA models described in Figures 7-1 through 7-10, the present value (year 2000) of costs associated with each alternative material were computed. Table 7-3 ranks Illinois barriers in order of increasing estimated life cycle cost. Table 7-4 compares the ranking of those barriers by estimated initial construction cost and by estimated life cycle cost (LCC).

Table 7-3. Illinois noise barriers sorted by estimated life cycle cost.

Barrier	Estimated Initial Construction Cost ($ / sq. ft.)	Discounted Future Costs, maintenance and replacement ($ / sq. ft.)	Estimated Life Cycle Cost ($ / sq. ft.)
Earth berm	$10.33	$3.60	$13.93
Precast/prestressed concrete stacked panels, steel posts[1]	$19.67	$4.03	$23.70
Precast/prestressed concrete stacked panels, conc. posts[1]	$24.33	$2.62	$26.95
Timber Post and Panel (hardwood or softwood)	$16.70	$11.35	$28.05
Precast/Prestressed Cantilever	$27.00	$2.80	$29.80
Carsonite	$25.33	$4.65	$29.98
Precast concrete, full-ht.panels, monolithic posts	$28.33	$2.62	$30.95
Glue-laminated wood	$18.33	$13.48	$31.81
Durisol	$19.67	$14.14	$33.81
Noishield Steel	$27.67	$12.19	$39.86
Noishield Aluminum	$35.00	$15.15	$50.15

[1]Precast/prestressed concrete stacked panels (similar to the HDC-approved SoundCore barrier) are included for comparison although none have been built in Illinois to date.

The LCC ranking is significantly different than the construction cost ranking. The most striking change is in the ranking of the glue-laminated wood barrier, which ranks third in construction cost and eighth in LCC. Neither the lowest cost barrier (earth berms) nor the highest cost barrier (Noishield aluminum) changed ranking.

Table 7-4. Comparison of ranking by initial construction cost and LCC.

Barrier	Rank by Initial Construction Cost ($ / sq. ft.)	Rank by Life Cycle Cost ($ / sq. ft.)	Change in Ranking
Earth berm	1	1	--
Timber Post and Panel (hardwood or softwood)	2	4	-2
Glue-laminated wood	3	8	-5
Precast/prestressed concrete stacked panels, steel posts[1]	4/5	2	+2
Durisol	4/5	9	-4
Precast/prestressed concrete stacked panels, conc. posts[1]	6	3	-3
Carsonite	7	6	-1
Precast/Prestressed Cantilever	8	5	+3
Noishield Steel	9	10	-1
Precast concrete, full-ht. panels, monolithic posts	10	7	-3
Noishield Aluminum	11	11	--

[1]Precast/prestressed concrete stacked panels (similar to the HDC-approved SoundCore barrier) are included for comparison although none have been built in Illinois to date.

The results of the LCCA indicate that, given the stated assumptions for each alternative, earth berms represent the lowest cost alternative. Metal barriers with absorptive panels (Noishield steel or aluminum) were estimated to have the highest life cycle cost (respectively, 65% and 72% higher than earth berms). The life cycle costs of all other barrier types currently in use in Illinois fall in a range from approximately $28.00 to $32.00 per sq. ft. A variance of ±10% from the calculated life cycle cost would rank all of these alternatives approximately equivalent at $30.00/sq. ft. (Figure 7-11). Thus, the life cycle costs for 8 of 11 noise barriers currently in use in Illinois are sufficiently similar that economically justifiable choices for barrier material could be made from any of these materials.

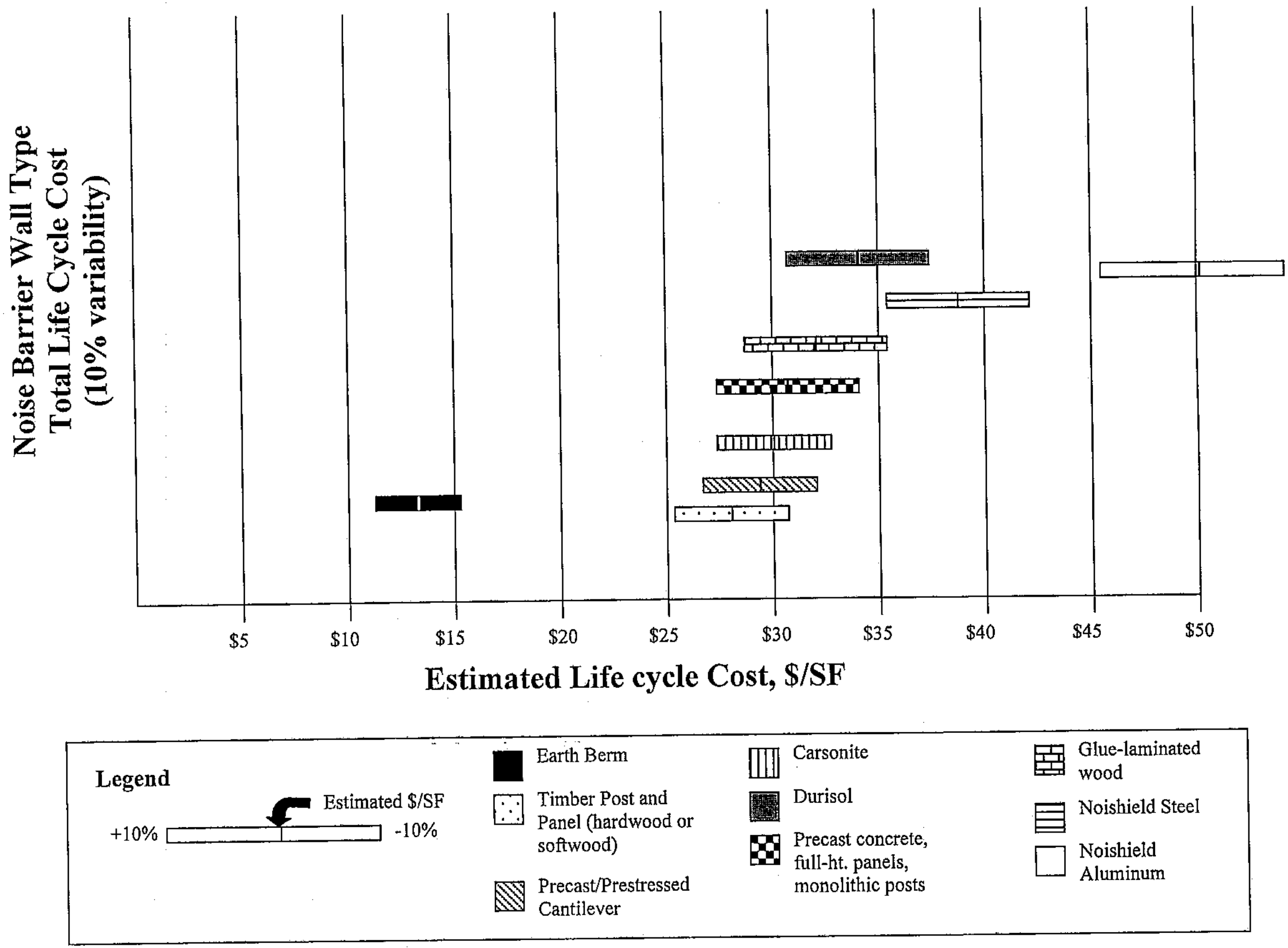


Figure 7-11. Estimated life cycle cost considering variability of ±10%.

7.4 Sensitivity Analysis

The results obtained through life cycle cost analysis are highly dependent on the selected values of variables, the assumptions made regarding maintenance activities and their costs, and the assumed service lives of alternatives. The variability of the results of LCCA when key assumptions are changed may affect the ranking of alternatives and the conclusions drawn from that ranking. The researchers studied the impact of changing the following key variables:

- interest rate
- service life (timing of replacements)
- timing of major maintenance activities.

7.4.1 Interest Rate

The interest rate chosen for this study was based on recent trends in U.S. Treasury Bond yields and construction cost escalation factors. However, if all other assumptions used for the LCCA remain the same, changes in the interest rate used for the analysis will affect the values of the estimated costs but will not affect the relative ranking of alternatives. Therefore, for purposes of comparing alternative materials, the LCCA is insensitive to changes in interest rate.

7.4.2 Timing of Replacements

The service lives chosen for this analysis were based on field observation of the current physical condition of barriers at various ages, the opinions of the researchers and IDOT maintenance personnel responding to a survey on barrier condition, and vendor claims for service life. It is not possible to state with certainty the age at which any given barrier will require replacement. In fact, two barriers rated by IDOT maintenance personnel to have failed shortly after their construction have remained in place for periods of 8 to 10 years. The replacement timing is, therefore, quite subjective and should be tested for its impact on the analysis results.

This analysis assumed that three materials (timber, Durisol, and metal) would require replacement midway during the analysis period of 50 years and that all others had service lives of 50 years or more. This assumption means that at the end of the 50-year period, all barriers except earth berms would be at the end of their service lives and would require replacement. An analysis of the impact of changing the replacement timing was performed using glue-laminated wood barriers as an example. Based on the field observations, it is not considered likely that any glue-laminated wood barriers would require replacement before 25 years. It does, however, appear that these barriers could exceed that estimated service life by 5 years or more. A recalculation of the life cycle costs based on service lives of 30 and 35 years is shown in Table 7-6. The results of this comparison show that increased service life is a significant factor in reducing the life cycle cost of glue-laminated wood barriers.

Table 7-6. Comparison of estimated life cycle cost for glue-laminated wood barrier for service life of 25, 30 and 35 years.

Estimated Service Life, years	Estimated Initial Construction Cost ($ / SF)	Discounted Future Costs, maintenance and replacement ($ / SF)	Estimated Life Cycle Cost ($ / SF)	Net Change from Original (%)
25	$18.33	$13.48	$31.81	--
30	$18.33	$10.20	$28.53	- 10
35	$18.33	$9.10	$27.43	- 13.8

It was considered that the service lives of concrete barriers and the structural fiberglass barrier (Carsonite) could be less than the assumed 50 years. While the materials themselves are known to have performed in outdoor settings for periods of 50 years or more, moisture accumulation, corrosion of reinforcement or other unanticipated problems could shorten the service life. Using precast concrete barriers with monolithic posts as an example, a recalculation of the life cycle costs based on service lives of 40 and 45 years is shown in Table 7-7. No other assumptions regarding routine graffiti removal or panel replacement or major maintenance activities were changed.

Table 7-7. Comparison of estimated life cycle cost for precast concrete barriers for service lives of 40,45 and 50 years, repainting at 20-year intervals.

Estimated Service Life, years	Estimated Initial Construction Cost ($ / SF)	Discounted Future Costs, maintenance and replacement ($ / SF)	Estimated Life Cycle Cost ($ / SF)	Net Change from Original (%)
40	$28.33	$13.30	$41.63	+34.5
45	$28.33	$11.86	$40.19	+29.9
50	$28.33	$2.62	$30.95	--

7.4.3 Timing of Maintenance Activities

Some maintenance activities were assumed to be equally likely regardless of barrier type. Others are specific to the barrier material. The impact of changing these base assumptions was studied.

Major maintenance activities for concrete barriers were limited to repainting barriers that were originally installed with a painted finish.. Information provided by the ISTHA indicates that the originally applied surface is warranted by the manufacturer for 10 years. Observation of similar barriers in Missouri that were approaching 10 years of age showed visible fading of the paint, particularly on surfaces receiving strong afternoon sun. Repainting of the barriers was originally estimated to be required at 20-year intervals. Because the benefits of repainting are purely aesthetic, it is likely that such an activity could be delayed. Recalculation of the estimated life cycle cost was made for repainting at 25 and 30 years. A final calculation tested the impact of never repainting the barrier. Table 7-8 shows the recomputed life cycle cost in comparison to the original assumption. The analysis shows that the life cycle cost for concrete barriers is insensitive to changes in the timing of repainting the barrier.

Table 7-8. Comparison of estimated life cycle costs for precast concrete barrier, 50-year service life, repainting at intervals of 20, 25, 30 and 50+ years.

Estimated Time Until Repainting, years	Estimated Initial Construction Cost ($ / SF)	Discounted Future Costs, maintenance and replacement ($ / SF)	Estimated Life Cycle Cost ($ / SF)	Net Change from Original (%)
20	$28.33	$2.62	$30.95	--
25	$28.33	$2.36	$30.69	- 0.8
30	$28.33	$2.27	$30.60	- 1.1
no repainting	$28.33	$0.97	$29.30	- 5.3

Unpainted precast/prestressed cantilever barriers were assumed to require maintenance of the joints at 20-year intervals. Caulking of the joints is needed to keep moisture from damaging the panels (freeze-thaw) and to prevent noise leakage through the joints. However, there was no indication from IDOT maintenance personnel that joint maintenance has ever occurred on the 20-year old panels in District 2. Delay or elimination of this costly activity would reduce the estimated life cycle cost for this barrier type. In addition, the unpainted barrier was assumed to receive a single paint coating midway through the analysis period. This assumption, which raises the estimated life cycle cost for this barrier, was based on the opinions of some IDOT personnel and others that the appearance of the barrier could be improved by painting. There is no indication that there are any plans by either District 2 or District 8 to paint their existing cantilever barriers. Recalculation of the estimated life cycle cost without these maintenance activities is given in Table 7-9. The results of this analysis show that the life cycle cost of precast/prestressed cantilever barriers is reduced by less than 3% if the major maintenance activities of caulking joints and painting the barrier are removed.

Table 7-9. Estimation of life cycle cost of precast/prestressed cantilever barrier without maintenance.

Estimated Service Life, years	Estimated Initial Construction Cost ($ / SF)	Discounted Future Costs, maintenance and replacement ($ / SF)	Estimated Life Cycle Cost ($ / SF)
50	$27.00	$1.94	$28.94

7.4.4 Summary of Sensitivity Analysis

The results of the sensitivity analysis show that the two most important variables are the initial construction cost and the service life, or time until replacement. The magnitude of the cost of maintenance activities is small in comparison to the cost of construction and replacement, and variations in assumptions regarding maintenance are relatively insignificant. Major maintenance activities can be delayed or even deleted without affecting the outcome of this LCCA.

Changing service life assumptions has the greatest impact on barriers that were initially assumed to have 50-year lives. Reducing the assumed service life of concrete barriers from 50 years to 45 or fewer years increases the estimated life cycle cost by at least 34%. Increasing the assumed service life of wooden barriers from 25 to 30 or more years reduces the estimated life cycle cost by 10 to 15%. Clearly, historical data on service lives will be needed to perform meaningful life cycle cost analyses.

7.4.5 Disposal

A factor in the life cycle cost of any noise barrier system is the cost of disposal of the product at the end of its service life. Accurate estimation of this cost is dependent on the required method of disposal for materials that may be regulated as hazardous.

Noise barrier walls or sections of walls that are removed require proper disposal unless they are beneficially reused immediately (for example, as fences or site screens). The disposal method depends on whether or not the barrier is considered hazardous waste. In Illinois, treated wood products that are "visibly weathered" (i.e., they do not show any mottling, discoloration, or free product) can be designated and handled as nonhazardous waste (regular demolition debris) by generator knowledge and landfilled in a municipal solid waste landfill or construction and demolition debris landfill (Smith 1998). Most landfills in Illinois are "permitted" for both municipal solid waste and demolition debris (Smith 1998). Incineration is another option. However, "treated wood should not be burned in open fires or in fireplaces, stoves, or other non-permitted units because toxic chemicals may be produced as part of the smoke or ashes" (AWPI 1996a).

A mottled surface, surface staining, and/or deposits indicate that chemicals may be leachable. Therefore, the Illinois Environmental Protection Agency (IEPA) expects a toxicity characteristic leaching procedure (TCLP) analysis of the TCLP chemicals that may be present (Smith 1998). The test is expected despite the American Wood Preservers Institute's (AWPI) assertion that "treated wood that is disposed is not a hazardous waste under federal law because it has not been listed and testing has demonstrated that is does not exhibit a hazardous characteristic" (AWPI 1996b). The only potential exception is the federal exemption for arsenical-treated wood or wood products (40 CFR 261.4(b)), which states that:

> "...the following solid wastes are not hazardous wastes...(9) Solid waste which consists of discarded arsenical-treated wood or wood products which fails the test for the Toxicity Characteristic for Hazardous Waste Codes D004 through D017 and which is not a hazardous waste for any other reason if the waste is generated by persons who utilize the arsenical-treated wood and wood product for these materials' intended end use."

Chemicals may be present from preservatives, water repellents, wood sealers, ultraviolet light inhibitors, and stains. There are several wood preservatives used during pressure treatment. Chromated copper arsenate (CCA), ammoniacal copper quat (ACQ), and ammoniacal copper zinc arsenate (ACZA) are the most common water-borne preservatives used while creosote and pentachlorophenol are the most common oil-borne preservatives (AWPI 1996a). Noise barriers are usually preserved with the water-borne (metal-bearing) chemicals, although glue-laminated barriers may be preserved with pentachlorophenol (AWPI 1996a). Table 7-9 lists chemicals typically expected to be present in treated wood due to preservatives. The TCLP extract limits are also listed. A sample fails the TCLP test if the concentration of even one chemical is exceeded. If a sample fails the TCLP analysis, then the noise wall is considered hazardous waste. To be disposed of, it will have to be sent to a secure landfill or Part B-permitted incinerator. Illinois has secure landfills near Peoria and Chicago and a hazardous waste incinerator in Sauget. The hazardous designation will result in increased disposal costs and additional paperwork. If the sample passes the TCLP test, then the wall is considered nonhazardous and can be treated as previously described.

Concrete walls that are painted or stained may also require a TCLP analysis. They will require analysis if the stain or any other treatment chemicals had TCLP components (Smith 1998). In particular, paint must pass the TCLP for lead (Table 7-10). Tires are banned from Illinois landfills, so it is likely that any walls using shredded tires would require alternate disposal.

TCLP analysis does not have to be performed on materials that are reused for a similar purpose (Smith 1998). For example, wood noise barriers may be suitable as fences or in landscaping. However, speculative accumulation of materials is not allowed (Smith 1998).

Table 7-10. Chemicals of potential concern during disposal.

Chemical	RCRA Number [1]	Concentration (mg/L) [2]
Arsenic	D004	5.0
Benzene	D018	0.5
Chromium	D007	0.60 [3]
Lead	D008	0.75 [3]
o-Cresol	D023	200.0
m-Cresol	D024	200.0
p-Cresol	D025	200.0
Total Cresol	D026	200
Pentachlorophenol	D037	100.0

[1] Resource Conservation and Recovery Act

[2] Concentration in extract from toxicity characteristic leaching procedure (TCLP).

[3] The federal EPA revised the TCLP levels of chromium and lead on May 26, 1998 from 5.0 mg/L to the values listed.

7.5 Recommendation for Use of Life Cycle Cost Analysis in Noise Barrier Selection

One objective of the present study was to make recommendations regarding the use of LCCA as a determining factor in material choice for noise barriers. Despite the potential advantages of using the analysis to aid in decision-making, the use of LCCA may not be practical for the selection of noise barriers. The survey of 30 state DOTs performed as part of this research showed that LCCA is not often used in the evaluation of alternative materials for noise barriers (Section 3.2.1.2). The reasons for this relate primarily to the lack of familiarity with LCCA and lack of data to perform the analysis. The estimation of service lives performed by the researchers in order to complete the LCCA is limited by the lack of historical perspective. No Illinois noise barriers have yet failed due to old age, making all service life estimates primarily subjective opinions. The survey of IDOT and ISTHA maintenance personnel (Section 5.3) was designed to collect data on annual maintenance costs, and to assist in better estimating the service lives of Illinois noise barriers. However, the results of the survey indicated that most noise barriers are not subject to routine inspection and maintenance, but are repaired in response to discrete events such as vehicle crashes and public complaints. The estimates of barrier service life provided by the survey respondents generally were less that those estimated by the researchers. While the results of the survey aided the researchers in developing reasonable assumptions regarding annual and periodic maintenance activities and the timing of major rehabilitation activities, there still remains a lack of data to show clear differences in the maintenance requirements or the service lives of various products currently in use.

Sensitivity analysis showed that the life cycle cost analysis responds primarily to changes in service life and initial construction cost. The nature and timing of major maintenance activities is relatively insignificant in comparison to the timing of barrier replacement. The usefulness of life cycle cost analysis as a tool for choosing between alternative materials or products will be limited until sufficient historical data on actual service lives of a variety of materials is available.

Other factors that limit the usefulness of LCCA as a means of selecting noise barrier materials are the need to respond to public input regarding aesthetic considerations, the need for design flexibility to respond to engineering considerations (weight limitations on structures being one example), and the opportunity to use innovative technologies. While LCCA may in theory provide a more rational means of selecting noise barrier materials, it should be recognized that the best choice for a given situation may involve trade-offs between several of the considerations listed. It is believed that LCCA can provide an additional piece of information in the selection process, but should not be used as the sole criterion for material selection.

CHAPTER 8

REVIEW OF SPECIFICATIONS FOR ILLINOIS NOISE BARRIERS

8.1 Introduction

A total of thirteen different materials and products have been used in the construction of more than 96 km (60 miles) of noise barriers by IDOT and ISTHA. The field conditions survey (Chapter 5) indicates that the majority of noise barriers have performed well with two exceptions. The Noishield wall in East St. Louis and the tropical hardwood bongossi walls in District 1 have undergone deterioration serious enough to warrant removal and replacement. This section examines whether the poor performance of these two barriers was related to the specifications. In addition, the specifications used by IDOT and ISTHA are reviewed to determine possible areas for improvement and to recommend changes to strengthen them. The researchers requested from the Illinois agencies drawings and specifications for each type of noise barrier used and those received are listed in Table 8-1.

Table 8-1. Drawings and Specifications Received from IDOT and ISTHA for Illinois Noise Barriers

Wall Type	Drawings	Specifications
Earth Berm	None	Standard Specifications
Berm/Retaining Wall	None	None
Combination Berm/Wood	None	None
Carsonite®	Manufacturer's Literature	Manufacturer's Literature
Durisol®	IDOT Drawings	IDOT Specifications
Fanwall® Concrete	Manufacturer's Literature	Manufacturer's Literature
Noishield®: Steel	IDOT Drawings	IDOT Specifications
Noishield®: Aluminum	IDOT Drawings	IDOT Specifications
Precast/Prestressed Wall (Cantilever)	IDOT Drawings	None
Precast Concrete (Post and Panel)	Tollway Drawings	Tollway Specifications
Softwood (Post and Panel)	None	None
Glue-laminated Softwood	Manufacturer's Literature	Manufacturer's Literature
Tropical Hardwood	IDOT Drawings	IDOT Specifications

8.2 Technical Specifications

Technical specifications describe the materials and workmanship to be used in providing a portion of a project to be constructed. The technical specifications, plans, and legal specifications (sometimes referred to as the "boilerplate") make up the contract documents that form the basis of the agreement between the owner agency and the contractor(s) who will construct the project. Highway construction involves relatively few items of work, many of which are common to all projects. Because of this, technical specifications for many aspects of highway construction have been standardized (IDOT

1996), and can be incorporated into construction contract documents by reference. The format for standard specifications includes sections covering:

- description of the work
- materials and equipment specifications
- construction requirements, including installation or construction methods, inspections, and submittals
- measurement of quantities and basis of payment

Specifications for materials and equipment may be referenced to other sections of the IDOT Standard Specifications for Road and Bridge Construction, or to other reference specifications published by recognized technical societies such as the American Society for Testing and Materials (ASTM), American Wood Preservers Institute (AWPI), American Association of State Highway and Transportation Officials (AASHTO) or others.

Items of work that are not covered in the standard specifications can be added to the contract documents in the form of special provisions. The special provisions typically are written on a project-by-project basis by the engineering consultant preparing the plans, specifications and estimates.

Preparation of effective technical specifications depends on the experience of the specification writer with item of work to be specified, the writer's familiarity with construction materials and methods, and the writer's ability to develop requirements for the materials and installation that will provide a good result. Specifications are often developed incrementally over time, and requirements are refined based on past experience, particularly failures. Such historical perspective is largely absent in the case of highway noise barriers, especially those constructed of proprietary or newly-developed materials. Specification writers may have difficulty anticipating the long-term consequences of choices in materials, or visualizing the outcome of specified construction or installation techniques. Technical literature and the results of standardized materials and acoustic tests provided by the manufacturer.

8.3 Review of Illinois Specifications for Noise Barriers

IDOT and ISTHA do not have standard specifications for the design of noise barriers. Although each IDOT district develops its own specifications tailored to a particular job based on the experience of in-house staff and/or the services of design consultants, they are coordinated through the Bureau of Design and Environment, IDOT Division of Highways, Springfield. The special provisions pertaining to the noise barriers have not been added to the IDOT's Supplemental Specifications and Recurring Special Provisions of February 1996.

The specifications used by IDOT in the procurement of noise barrier walls have worked well with the exception of the Noishield® (Steel Casing) wall in District 8 and the tropical hardwood walls in District 1. These two problem walls are discussed below:

8.3.1. Noishield® (Steel Casing)

According to IDOT District 8 personnel, the barrier began to deteriorate soon after installation in 1984. The painted coating on the face (highway side) of the panels peeled off, and the steel corroded. IDOT maintenance personnel later covered the perforated surface with solid fiberglass panels. On the back side, the solid panels also corroded and buckled, with some panels bowing out of the plane by more than 2 inches in the 12 foot length of the panel.

The specifications called for furnishing all materials, labor, and equipment to build a noise barrier system using Noishield® modular panels manufactured by Industrial Acoustics Company, Inc. The specifications further required that all "exterior panels should be protected from atmospheric corrosion, weathering, exposure to road salts..." The supplier provided the following explanation for the deterioration of the panels: "Panels were installed horizontally, and the detail of the panel allowed entrapment of water in a pocket which was intended to drain out at the end of the panel. The presence of the water which acted as an electrolyte created a corrosive environment which destroyed the integrity of the barrier. The presence of the stainless steel may or may not have been a factor in this corrosion." It is interesting to note that a second barrier located several miles north of this site and constructed in 1985 using the Noishield® system is in good shape as of this date. In the second barrier, the panels were made of aluminum (not steel) and used vertically rather than horizontally. The IDOT Highway Development Council (HDC) has disapproved further use of the Noishield® (steel casing) wall system.

8.3.2. Tropical Hardwood Barriers

As discussed in Chapter 5, the tropical hardwood barriers installed in District 1 during 1989-1993 developed significant defects. These problems included warping of the individual tongue and groove boards, gaps caused by the settlement of the panels between posts, gaps at the joints in the 2 X 2 battens on the residents' side, posts spaced too far apart allowing panels to fall out, and erosion under the wall allowing panels to slip downward. The specifications for each successive wall were modified in response to these problems: According to Prem Suri, IDOT District 1 Consultant Services Engineer, some of these changes included:

- post spacing was reduced from 12 feet to 8 feet
- a 2 X 6 cap board was added to protect the top panel and end grain of posts
- butt joints in the cap board were flashed to keep moisture out
- vertical battens on the residents' side of the barrier were fastened with screws rather than nails
- vertical 2 X 2 battens were made continuous for the entire height of the wall with no joints
- acceptable moisture content was reduced successively.

A review of the IDOT specifications for the noise walls in Cook and Dupage Counties (Elgin-O'Hare Expressway) indicates that the acceptable moisture contents specified (despite incremental reductions) for the hardwood post and panel materials were still excessive ("for the posts: not more than 35%±5% and for the panel material: not less than 14% and not more than 22%"). The posts varied in cross section from 8 inches square to 8 X 15 inches and it is most likely that the kilns had difficulty in controlling the moisture content of these massive posts. The specifications called for testing of the moisture content (per ASTM D 2016) by an independent laboratory prior to shipment and the test results submitted along with the shipments of the posts and panels to the job site. Possibly a stricter enforcement of this provision could have avoided several of the subsequent problems.

Many of the potential construction problems in wood barriers are related to moisture content of the wood at the time of fabrication. Cohn (1981) states that a moisture content in excess of 15% will cause warping in wood walls. Limiting the acceptable moisture content to within 15% and enforcement of strict quality control measures during the manufacturing and construction stages should help in mitigating durability problems in wood barriers. This is evidenced by the performance of tropical hardwood noise barrier built in Peoria in 1987; this barrier is still in good condition.

Efforts to obtain current product literature on tropical hardwood walls from the original vendor were not successful. It could not be ascertained whether these barriers are still being specified by other states. The maintenance survey (Chapter 3) conducted by the researchers indicates that only one state (11% of those reporting negative performance, or 3% of all the states participating in the survey) has rejected hardwood and reported acoustical and structural problems associated with hardwood barriers. Although tropical hardwood products have not been formally disapproved by HDC, the material is no longer recommended for use in Illinois.

8.4 Discussion of Specifications

In general, the specifications used by the Illinois agencies in the procurement of noise barriers have worked well. Many new products being introduced into the noise barrier market are not typically used in highway construction. Data on their long-term performance, (unlike traditional materials such as concrete, wood and earth) are not available. In addition, there are questions such as whether to use performance specifications to promote the use of new products, with unknown potential long-term risks, or prescriptive specifications so that less risky, traditional materials are employed, with consequent discouragement of product innovation. A broad review of the available Illinois specifications for noise barriers (Durisol, Noishield, tropical hardwood, glue-laminated softwood, precast concrete), indicates a lack of standardization and an absence of an easily-recognizable structure (e.g. general requirements, products, execution), to help the grouping of key requirements.

8.4.1 Design Criteria

Following is a checklist synthesized from various reports (HITEC Report, October 1996, and NCHRP Report 181, 1992) which the specifications might address to avoid future problems:

a. System Durability
   All proprietary products to be used should have either received the approval of the HDC or have been successfully used in other states for at least 3 years. All materials used must be able to exhibit a minimum predicted trouble-free service life of 20 years with routine maintenance.
b. Acoustical Properties
   For reflective walls, the Sound Transmission Class (STC) measured in accordance with ASTM E 413 must be 23 or greater. For absorptive walls, the Noise Reduction Coefficient (NRC) measured in accordance with ASTM C 423 must be 0.80 or greater.
c. Aesthetics

1. Should be compatible with local, project-specific conditions
2. Should offer a variety of surface textures and colors
3. Should facilitate easy removal of graffiti
4. Should minimize the removal of existing trees or plants
5. Should minimize interference with overhead electric cables and underground utilities.
6. Should avoid including areas, which might attract birds or permit the accumulation of dirt and debris.

d. Drainage

Barriers shall be designed to provide adequate drainage away from and through the barrier. All drainage must be designed so that the acoustical efficiency of the barrier is not degraded by more than 1 dBA at any sensitive receptor. Particular attention should be paid to the orientation of the panel and the cap design

e. Constructability Issues

1. Minimize use of large and heavy equipment.
2. Facilitate speedy erection.
3. Minimize time of lane closures during the wall installation process.
4. Minimize interference of equipment with overhead high voltage wires.
5. Provide a positive mechanical connection at the post and panel junction.
6. Minimize interference with existing utilities, culverts, sewer lines, ground water.
7. Facilitate close and achievable tolerances in the manufacture and the erection process so that the system's structural, acoustical and aesthetic performance is not compromised.
8. Analyze the impact of using dissimilar materials.
9. Safety Issues

   Analyze the impact of:
   - Vehicle strikes against the barrier.
   - Snowdrift caused by the barrier.
   - Shadows that can affect roadway icing.
   - Children climbing the walls from the residents' side.

f. Maintenance/ Repairability Issues

1. Facilitate mowing close to the barriers.
2. Minimize or avoid the potential for litter accumulation.
3. Design surfaces and textures that provide graffiti resistance.
4. Minimize vandalism.
5. Facilitate easy repair and/or replacement of the barriers.
6. Facilitate easy maintenance of the barriers on both sides

8.4.2 General Provisions:

a. Submittals Required:

1. Design calculations, assembly drawings, specifications, samples of materials and finishes, and data demonstrating that the product has been successfully used in other states and/or a certificate of approval from HDC.
2. Test certificates from independent testing laboratories that the product meets or exceeds various applicable ASTM specifications.

3. Manufacturer's guarantee that the product will perform trouble-free for at least 20 years with routine maintenance.

8.4.3 Product Data

Provide data on the:

a. Design Philosophy
b. Type of wall to be furnished: absorptive or reflective
c. Materials: concrete, composite, wood, etc.
d. Experience in other states (or whether approved by HDC)
e. Years the company has been in business and its products have been in use
f. Anticipated service life
g. Estimated costs (including installation)
h. Guarantees and warranties.

8.4.4 Execution

a. Installation

   A written procedure on the installation methods should be provided. This procedure should address: equipment needs, working space, method of lifting the panel, transportation of the panel to the site, method of handling horizontal/vertical alignment changes, foundation requirements, alternative techniques available in the presence of overhead utilities, and techniques for mounting the panel on or behind a Jersey barrier or a bridge guardrail.

b. Maintenance and Repairability

   Written procedures should be provided on the: repair of the product, removal of graffiti, restoration of surface textures and colors. In the case of environmentally sensitive products, (e.g. glue-laminated woods, composite materials) disposal procedures for the damaged panels should be addressed. In the case of proprietary products, estimated percentage of the spare components that need to be stockpiled for replacement parts should be indicated.

Table 8-2. Reference Specifications for Noise Barrier Construction

(Source: HITEC Report, October 1996)

1. Applicable to all Materials/Products

a. Acoustic Criteria

ASTM C 423	Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Method
ASTM C 634	Standard Terminology Relating to Environmental Acoustics
ASTM C 423	Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Method
ASTM C 634	Standard Terminology Relating to Environmental Acoustics
ASTM E 90	Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions
ASTM E 413	Classification for Rating Sound Insulation

b. Mechanical Connection of Post to Panel

ASTM A 123	Standard Specifications for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A 153	Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A 307	Standard Specification for Carbon Steel Bolts, and Studs, 60,000 PSI Tensile Strength
ASTM A 325	Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 KSI Minimum Tensile Strength

2. Painted Metal

ASTM B 117	Standard Test Method of Salt Spray (Fog) Testing
ASTM D 660	Standard Test Method for Evaluating Degree of Checking of Exterior Paints
ASTM D 661	Standard Test Method for Evaluating Degree of Cracking of Exterior Paints
ASTM D 714	Standard Test Method for Evaluating Degree of Blistering Paints

Table 8-2 (cont'd)

ASTM D 968 Standard Test Method for Abrasion Resistance of Organic Coatings by Falling Abrasive

ASTM D 2244 Standard Test Method for Calculation of Color Differences From Instrumentally Measured Color Coordinates

ASTM D 3359 Standard Test Methods for Measuring Adhesion by Tape Test

ASTM D 4214 Standard Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films

3. **Masonry**

ASTM C 90 Standard Specification for Load-Bearing Concrete Masonry Units

ASTM C 652 Standard Specification for Hollow Brick (Hollow Masonry Units Made From Clay or Shale)

4. **Concrete**

ASTM C 666 Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing

ASTM C 672 Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

ASTM E 72 Standard Methods of Conducting Strength Tests of Panels for Building Construction

ASTM E 84 Standard Test Method for Surface Burning Characteristics of Building Materials

ASTM E 695 Standard Method of Measuring Relative Resistance of Wall Floor and Roof Construction to Impact Loading

5. **Plastics**

ASTM G 21 Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi

ASTM G 23 Standard Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials

Table 8-2 (cont'd)

ASTM G 26	Standard Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials
ASTM G 53	Standard Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials

6. Wood

ANSI/AITC A190.1 (1995) American National Standards for Wood Products–Structural Glued Laminated Timber

AWPA C-28 Standard for Preservative Treatment of Structural Glued Laminate Members

U.S. Product Standard PS1-95: Construction and Industrial Plywood

Table 8-3. Other Background Information On Noise Barriers For Specification Writers

AASHTO Guide Specifications for Structural Design of Sound Barriers

AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 19^{th} Ed.

AASHTO Standard Specifications for Highway Bridges

National Cooperative Highway Research Program, Report 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features (1993)

National Cooperative Highway Research Program, Report 132, System-Wide Safety Improvements: an Approach to Safety Consistency (1987)

National Cooperative Highway Research Program, Report 181, In-Service Experience with Traffic Noise Barriers, (1992)

CHAPTER 9

SUMMARY AND CONCLUSIONS

9.1 Summary of Project

The purpose of this research was to assist the IDOT in determining the service life of the various noise barrier materials and products in service in Illinois. The scope of the project included:

- development of a means to quantify the service lives of materials used for construction of noise barrier walls in Illinois
- development of a life cycle cost model for the evaluation of alternative materials
- evaluation of the need for potential changes to the Special Provisions for noise wall construction currently used by the IDOT.

Information was obtained from interviews with IDOT and ISTHA personnel, field observations, a review of current noise barrier plans, specifications and evaluation methods, and a review of published literature about noise barrier maintenance and service lives, including technical journals, popular media, and vendor literature. In addition, a survey of 30 state DOTs and a survey of IDOT maintenance personnel were conducted to obtain information on in-field experiences and histories with various noise barrier materials and products.

9.1.1 Service Life

The estimation of service lives of noise barrier materials and products was limited by the lack of historical perspective. No Illinois noise barriers have yet failed due to old age, and it appears that the majority of noise barriers built to date nationally have performed well. Nationally, less than 1% of noise barriers by length have been repaired or replaced, or are currently being considered for repair or replacement, according to the responses of 30 state DOTs surveyed (Chapter 3).

There was no consensus among the respondents to the state DOT survey on the average service life of noise barriers, although all respondents answering the question (24 of 30) listed at least 20 years. Based on the literature, field observations, and survey responses, the service lives of materials used or approved in Illinois were estimated by the researchers (Table 9-1) and subsequently used in estimating life cycle costs.

In addition, a checklist of factors to determine the serviceability of a noise barrier was developed based on the literature, field observations, survey responses, and interviews with IDOT and ISTHA personnel. The survey of other state DOTs indicated that neither the IDOT nor 83% of respondents to the survey (25 of 30) conduct routine structural inspections of noise barrier walls. Similarly, neither IDOT nor any of the 30 respondents to the survey currently include acoustical testing as part of their maintenance programs. However, serviceability of a noise barrier should consider structural and acoustic performance as well as aesthetic performance.

Table 9-1. Estimated service lives for noise barrier materials used in Illinois.

Material	Service Life (years)
Earth Berm	50 +
Precast Concrete, Full-Height Panels with Monolithic Posts	50
Precast/Prestressed Concrete "Cantilever"	50
Precast/Prestressed Conc. Stacked Panels[1]	50
Fanwall®	50
Carsonite®	50
Durisol™	25
Noishield® Steel[2]	25
Noishield® Aluminum	25
Glue-Laminated Wood	25
Tropical Hardwood and Softwood Post and Panel	25

[1]precast/prestressed concrete stacked panels are included for life cycle cost comparison.
[2]the estimated service life for Noishield® steel is based on redesigned panels used successfully on projects outside Illinois.

9.1.2 Life Cycle Cost Analysis (LCCA)

The researchers developed a life cycle cost model using assumptions based on the information collected during the course of the research. Current materials used for noise barrier walls by IDOT, ISTHA, and products pre-approved by the Illinois Highway Development Council were analyzed using the model. The results indicate that earth berms represent the lowest cost alternative while metal barriers with absorptive panels (Noishield® steel and aluminum) are the most expensive. The life cycle costs of the other barrier materials modeled (wood, concrete, Carsonite®, and Durisol™) fall within a relatively narrow range near $30 per square foot, approximately twice the cost of earth berms. Sensitivity analysis of the model indicated that the two most important variables are initial construction cost and service life. The initial construction costs for all materials were estimated using current (year 2000) costs. Because these estimates include all costs required to construct each barrier, including such items as foundations, contractor's overhead, contingency, and profit, these estimates vary significantly from the average barrier costs reported by FHWA (1996), and should be a better indication of the actual construction cost. The service life estimations used by the researchers were based on the best available information to date, and should be periodically reviewed and revised over time to more closely model actual replacement schedules.

While it was estimated that maintenance and replacement costs account for between 8% and 42% of the life cycle cost of the materials analyzed, these costs are not readily verifiable. The difficulty of obtaining such data is the primary reason why 70% of respondents to the survey of state DOTs (21 of 30) do not use LCCA to select noise barrier materials. The research showed that noise barriers are not typically subject to routine inspection and maintenance. In fact, fewer than half the state DOT survey respondents have a barrier maintenance program. Instead, barriers are repaired in response to discrete incidents, such as vehicle crashes and public complaints. Due to the importance of the costs associated with the frequency of maintenance and replacement, and the difficulty in obtaining reliable data, LCCA may not be practical to use as the sole criterion for selecting noise barrier materials. However, it can serve as an additional tool to rank the cost effectiveness of alternative materials and designs.

9.1.3 Special Provisions

The specifications used for the construction of noise barrier walls in Illinois were reviewed to determine whether changes would yield benefits in terms of reduced construction and maintenance costs. Specifications for two barriers that failed soon after installation, tropical hardwood and Noishield® steel, were reviewed. The specifications for each of these barriers were revised by IDOT personnel in response to the observed failures, which in both cases occurred within one year of installation. The revised specifications for the Noishield® barrier resulted in a satisfactory product; however, this product, an aluminum barrier, was calculated to have the highest life cycle cost of all Illinois noise barriers. Revisions to the specifications for tropical hardwood barriers have had mixed success; some barrier sections built using the revised specifications have performed well. However, the most recently constructed section of tropical hardwood barriers, on the Elgin-O'Hare Expressway, is performing unsatisfactorily. Due to the high cost of construction, it appears that further experimentation with specification improvement for tropical hardwood barriers would be unjustified, especially for large barrier sections.

A broad review of IDOT noise barrier specifications indicated a lack of standardization and an absence of an easily recognizable structure for grouping key requirements. Therefore, it is recommended that an effort be made to standardize noise barrier specifications. Criteria developed by HITEC (1996) and NCHRP (1992) are recommended as a basis for such standardization.

REFERENCES

1. AASHTO. (1993). "Guide on Evaluation and Attenuation of Traffic Noise." Report of Task Force for Environmental Design, Highway Subcommittee on Design. Washington, D.C.
2. AASHTO. (1992). "Guide Specification for Structural Design of Sound Barriers." Highway Subcommittee on Bridges and Structures. Washington, D.C.
3. *American National Standard-Methods for Determination of Insertion Loss of Outdoor Noise Barriers.* (1987). Acoustical Society of America, ANSI S12.8-1987, New York.
4. American Wood Preservers Institute (AWPI). "Frequently Asked Questions about Treated Wood." *AWPI online* (http://www.awpi.org). 1996a.
5. American Wood Preservers Institute (AWPI). "Pressure-Treated Wood Lifecycle Management." *AWPI online* (http://www.awpi.org/lifecycle.html). 1996b.
6. Anday, A. (1979). "Sound Barrier Planning in Virginia-A Comprehensive Review and Selection Process Designed to maximize the Performance and Social Acceptance of Highway Sound Barriers." *Proceedings of Conference on Highway Traffic Noise Mitigation.* Los Angeles, California, December 11-15, 1978. Transportation Research Board.
7. Billera, D., R. Parsons, S. Hetrick. (1997). "Good Fences Make Good Neighbors." *Transportation Research Record 1601*, Transportation Research Board, National Academy of Sciences, Washington, D.C.
8. Bischoff, D. (1997). "Durisol Noise Barriers." Report WI/FEP-02-97, Wisconsin Department of Transportation, Madison.
9. Bowlby, W., J.Higgins and J.Reagan, editors. (1982). "Noise Barrier Cost Reduction Procedure STAMINA 2.0/OPTIMA: User's Manual." U.S. Department of Transportation, Federal Highway Administration. Report No. FHWA-DP-58-1,.
10. Bowlby, William. (1992). "In-Service Experience with Traffic Noise Barriers." *NCHRP Synthesis of Highway Practice 181,* Transportation Research Board, Washington, D.C.
11. Buttlar, W.G., D. Bozkurt and B.J. Dempsey. (1999). "Evaluation of Reflective Crack Control Policy." Illinois Transportation Research Center Report ITRC-F-99-1, Illinois Department of Transportation, Springfield.
12. Ceran, T., and R.B. Newman (1992). "Maintenance Consideration in Highway Design." *NCHRP Report 349.* Transportation Research Board, National Academy Press. Washington, D.C.
13. Cohn, L., and R. Harris. (1990). "Cost of Noise Barrier Construction in the United States." *Transportation Research Record 1255: Energy and Environment 1990: Transportation-Induced Noise and Air Pollution.* Transportation Research Board, National Research Council, Washington, D.C.
14. Cohn, Louis F. (1981). "Highway Noise Barriers." *NCHRP Synthesis 87.* Transportation Research Board, Washington, D.C.
15. "Construction Cost Index." (January 11, 1998). *Engineering News Record.* (Vol. 240, No. 1), p. 25.
16. "Construction Cost Index." (January 5, 1999). *Engineering News Record.* (Vol. 242, No. 2), p. 19.

17. Dhillon, B.S. (1989). *Life Cycle Costing: Techniques, Models and Applications.* Gordon and Breach Science Publishers, New York.
18. Dunn, S. (1988). "Investigation of the Effectiveness of Noise Barriers Along I-275 and I-95." Report No. FHWA/FL/BMR/88/314, Florida Department of Transportation, Tallahassee.
19. "Environmental Research Needs in Transportation." (1992). *Transportation Research Circular No. 389,* Transportation Research Board, National Research Council, Washington, D.C.
20. "Environmental Research Needs in Transportation." (1997). *Transportation Research Circular No. 469,* Transportation Research Board, National Research Council, Washington, D.C.
21. "Forbes/Bridge Economic Forecast." (February 8, 1999). *Forbes.* (Vol. 163, No. 3). p. 48.
22. *Fundamentals and Abatement of Highway Traffic Noise.* (1980) Federal Highway Administration, Washington, D.C.
23. Gabriel, L., and E. Moran. (1998). "Service Life of Drainage Pipe." *NCHRP Synthesis 254,* Transportation Research Board, National Academy Press, Washington, D.C.
24. *Guidelines for Evaluating the Performance of Highway Sound Barriers.* (1996). Highway Innovative Technology Evaluation Center (HITEC), Civil Engineering Research Foundation.
25. Hatano, M., W. Bowlby, et al. (1987). *Transportation Research Circular No. 313: Traffic Noise Research Needs of State Highway Agencies.* Transportation Research Board, National Research Council, Washington, D.C.
26. Hendriks, R.W. and Hatano, M.M., "Evaluation of Noise Barriers," Final Report FHWA/CA/TL-97/03, California Department of Transportation, Sacramento, January 1987.
27. Herman, L., M. Finney, C. Clum, and E. Pinckney. (1997). "Perception of Traffic Noise Barrier Effectiveness." *Transportation Research Record 1601*, Transportation Research Board, Washington, D.C.
28. Herman, L., W. Bowlby, T. O'Grady, C. Chen, M. Jamison, and R. Wayson. (1991). "Determination of Traffic Noise Barrier Effectiveness." Report No. TDOT-I440-1. Tennessee Department of Transportation, Nashville.
29. *Highway Traffic Noise Analysis and Abatement-Policy and Guidance.* U.S. Department of Transportation, Federal Highway Administration, Office of Environment and Planning, Noise and Air Quality Branch, Washington, D.C. June 1995.
30. *Highway Traffic Noise in the United States: Problem and Response.* (1997). Publication No. FHWA-PD-97-064. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C.
31. *Highway Traffic Noise Barrier Construction Trends.* (1996). U.S. Department of Transportation, Federal Highway Administration, Washington, D.C.
32. Kirk, S, and A. Dell'Isola. (1995). *Life Cycle Costing for Design Professionals.* McGraw-Hill, New York.

33. Klinger, Richard E., Ilene Busch-Vishniac et. al., (1996). "Effective Noise Barrier Solutions for TXDOT: A First-Year Progress Report." *Center for Transportation Research, Research Report 1471-1,* University of Texas at Austin.
34. *Life Cycle Cost Analysis for Architects.* (1977). The American Institute of Architects, Washington, D.C.
35. Lin, W., D. Martinelli, B. Reed, S. Shourky, and J. Starky. (1997). "Evaluation of Low Cost Highway Noise Barriers: Final Report." Contract No. 250056, Task 32, Pennsylvania Department of Transportation, Harrisburg.
36. Lindeman, W. (1998). "Noise Barrier Status Report." Florida Department of Transportation, Tallahassee.
37. Pedesen, S. (1996). "On the Durability of Concrete Noise Barrier Products." *The Wall Journal,* Vol. V, Issue No. 22.
38. *Procedures for Abatement of Highway Traffic Noise and Construction Noise.* (1982). 23 CFR Part 772, Federal Highway Administration, Washington, D.C.
39. Salant, P. and D. Dillman. *How To Conduct Your Own Survey.* New York: John Wiley & Sons, 1994.
40. Schmidt, R. (1998). "Living Noise Barrier." Report No. WI/FEP-01-98, Wisconsin Department of Transportation, Madison.
41. Smith, Kenneth. IEPA Bureau of Land Permits. Telephone conversation on November 23, 1998.
42. *Summary of Noise Barriers Constructed by December 31, 1995.* (1996). U.S. Department of Transportation, Federal Highway Administration, Office of Environmental Policy, Noise and Air Quality Division, Washington, D.C.
43. *Unusual Features of Noise Barriers and Other (Non-Barrier) Abatement Measures Implemented by December 31, 1988.* (1989). U.S. Department of Transportation, Federal Highway Administration, Washington, D.C.
44. Walls, J, and M. Smith. (1998). "Life Cycle Cost Analysis in Pavement Design-Interim Technical Bulletin." Federal Highway Administration, Washington, D.C.
45. Weiss, M. (1988). "Summary of Highway Noise Barrier Construction in the United States." *Transportation Research Record 1176.* Transportation Research Board, National Research Council, Washington, D.C.

APPENDIX A
SURVEY FORMS

Highway Noise Barrier Service Life

Survey of U.S. DOTs for
Illinois Transportation Research Center Project IIB-H1
"Evaluation of Service Life of Noise Barrier Walls in Illinois"

Project Director: Dianne Kay, P.E.

Co-Investigators: Susan Morgan, Ph.D., E.I.T.
Narayan Bodapati, Ph.D., P.E.

School of Engineering
Southern Illinois University at Edwardsville

INSTRUCTIONS

- Any use or publication of the data will not identify the name of the individual(s) completing the questionnaire. However, in case of the need for clarifications, we would appreciate you providing us with a contact person.

  Name: ____________________

  Title: ____________________

  Telephone: ____________________

  Fax: ____________________

  E-mail: ____________________

- Although the survey appears to be long, it is mainly composed of multiple choice questions. It also has the following sections that can be detached and completed by different individuals:

  - Part I. Policies
  - Part II. Material Selection
  - Part III. Maintenance
  - Part IV. Summary of Existing Noise Barrier Walls.

- Some questions request specific data, such as costs. If exact data are unavailable, please estimate.

- If your responses do not fit in the spaces provided, please use the space provided on the back cover or additional sheets. Please indicate the question to which the response applies.

- **If you are unable to complete the entire survey, please return it partially completed to help meet the project goals.**

- If you have any questions, do not hesitate to contact:

Dr. Susan Morgan
618-650-5014
fax: 618-650-2555
smorgan@siue.edu

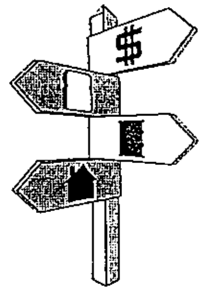
or

Professor Dianne Kay
618-650-5019
fax: 618-650-3374
dkay@siue.edu

- Please return your completed questionnaire in the enclosed envelope to:

Dr. Susan Morgan
Department of Civil Engineering
Southern Illinois University at Edwardsville
Campus Box 1800
Edwardsville, Illinois 62026-1800

PART I. Policies Concerning Noise Barrier Walls



1. What is your design life policy for noise barrier walls?

   ☐ ______________ years
   ☐ No such policy

2. Please indicate the type of design specifications you use for noise barrier walls.

   ☐ AASHTO design guidelines
   ☐ ASCE guidelines
   ☐ Naval Facilities Engineering Command (NAVFAC) requirements
   ☐ Specific for each job
   ☐ Standard specifications
   ☐ Uniform Building Code (UBC) requirements
   ☐ Vendor specifications
   ☐ Other ______________________________ Please specify.

3. Who *most often* designs the noise barrier walls?

   ☐ Outside consultants
   ☐ Contractors
   ☐ In-house staff at district (or similar) level
   ☐ In-house staff at state headquarters
   ☐ Other: ______________________________ Please specify.

4. Have you developed standard noise barrier designs for various materials?

   ☐ Yes
   ☐ No, design projects individually

5. Does your state use life cycle cost analysis (LCCA) in selecting materials for noise barriers?

   ☐ Always *Please skip the next question.*
   ☐ Sometimes
   ☐ Never
   ☐ Considering using LCCA in the future
   ☐ Formerly used LCCA but abandoned
   ☐ Use other economic evaluation ______________________ Please specify.

6. Please rank your primary reasons for not using or abandoning LCCA (1 being most important).

   ________ Insufficient data for analysis
   ________ Pressure to keep initial cost low
   ________ Unclear of the benefits of LCCA
   ________ Unfamiliar with LCCA
   ________ Other ______________________________ Please specify.

7. What inputs do you use, plan to use, or did use in computing life cycle cost?

- ❑ Annual maintenance cost
- ❑ Construction/installation cost
- ❑ Discount rate ________ % Please specify.
- ❑ Disposal cost/salvage value
- ❑ Engineering/design cost
- ❑ Inflation or escalation factor ________ % Please specify.
- ❑ Labor cost
- ❑ Material cost
- ❑ Periodic rehabilitation cost (e.g., painting, tuckpointing, panel replacement)
- ❑ Relocation costs (e.g., for utilities)
- ❑ Replacement cost
- ❑ Other ______________________________ Please specify.

8. What is the strategy(ies) for funding replacement and rehabilitation of walls?

- ❑ Consider as Type II project.
- ❑ Funds come from annual maintenance budget.
- ❑ Local jurisdictions expected to replace and rehabilitate walls.
- ❑ Replacement materials are stockpiled.
- ❑ Special fund established.
- ❑ There is no strategy.
- ❑ Other: ______________________________ Please specify.

9. Do you have a policy regarding rehabilitation and replacement of existing noise barriers?

- ❑ Yes
- ❑ No

10. What do you consider to be the average service life of a noise barrier wall? ________ years

11. Please rank these factors in determining the service life of noise barriers (1 being most important).

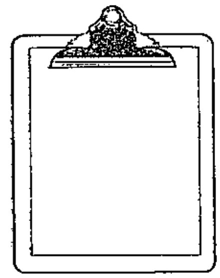
- ________ Cost, construction
- ________ Cost, maintenance
- ________ Performance, acoustical
- ________ Performance, aesthetics
- ________ Performance, structural
- ________ Other ______________________________ Please specify.
- ________ Other ______________________________ Please specify.

12. Do you have a policy promoting the use of recycled materials in noise barrier walls?

- ❑ Yes
- ❑ No

PART II. Material Selection for Noise Barrier Walls

1. What criteria influence the choice of materials for noise barrier walls? Check all that apply.



- ☐ Adjacent sites (e.g., highway or neighborhood themes)
- ☐ Appearance, initial
- ☐ Construction cost estimate
- ☐ Durability
- ☐ In-state experience
- ☐ Life cycle cost analysis
- ☐ Local availability of material
- ☐ Local availability of skilled labor
- ☐ Locally produced material
- ☐ Maintenance cost
- ☐ Multiple use or function (e.g., retaining wall)
- ☐ Noise reduction
- ☐ Other state's experiences
- ☐ Public request
- ☐ Safety issues
- ☐ Utilizes local labor force
- ☐ Other: ______________________________ Please specify.

2. How does your state evaluate new materials for noise barrier walls? Check all that apply.

- ☐ Full-scale field demonstrations
- ☐ Independent laboratory testing
- ☐ In-house laboratory testing
- ☐ Manufacturers' literature
- ☐ Experience of or data from other states
- ☐ Trial and error
- ☐ Other: ______________________________ Please specify.

3. Are your current evaluation methods adequate indicators of the long-term performance of noise barriers?

- ☐ Yes
- ☐ No

4. Please list additional evaluation methods you recommend.

____

____

____

5. Do you use absorptive noise barrier walls?

- ❑ Yes, for all new construction
- ❑ Yes, as indicated by acoustical requirements
- ❑ No *Please specify why.* ______________________________

____

6. Does your state have a pre-approved list of materials for noise barrier walls?

- ❑ Yes *Please continue with this question.*
- ❑ No *Please skip to the next question.*

a) Which products have been approved? Identify trade names if applicable.

- ❑ None
- ❑ Berm
- ❑ Block ______________________________
- ❑ Brick ______________________________
- ❑ Composite ______________________________ Please specify.
- ❑ Concrete, cast-in-place ______________________________
- ❑ Concrete, precast ______________________________
- ❑ Metal ______________________________
- ❑ Plastic ______________________________
- ❑ Recycled materials ______________________________ Please specify.
- ❑ Wood, hard ______________________________
- ❑ Wood, soft ______________________________
- ❑ Other ______________________________ Please specify.
- ❑ Other ______________________________ Please specify.

b) Do you plan to add to the list of approved materials for noisebarriers as new products become available?

- ❑ Yes
- ❑ No
- ❑ Unknown

7. a) Based on your state's experiences, check all that apply regarding the ***negative*** performance of noise barriers made of these materials. Please specify trade names where applicable.

Material	*High* Cost		*Poor* Performance			Other Negative Features (Please specify.)	Material Rejected
	Construction	Maintenance	Acoustically	Aesthetically	Structurally		
Berm							
Block							
Brick							
Composite							
Concrete, cast.[1]							
Concrete, pre.[2]							
Metal							
Plastic							
Recycled							
Wood, hard							
Wood, soft							
Other							

[1] Cast-in-place concrete
[2] Precast concrete

b) Please elaborate on why products performed poorly or had high costs. ____________________

____

8. Based on your state's experiences, check all that apply regarding the ***positive*** performance of noise barriers made of these materials. Please specify trade names where applicable.

Material	*Low* Cost		*Good* Performance			Other Positive Features (Please specify.)
	Construction	Maintenance	Acoustically	Aesthetically	Structurally	
Berm						
Block						
Brick						
Composite						
Concrete, cast.[1]						
Concrete, pre.[2]						
Metal						
Plastic						
Recycled						
Wood, hard						
Wood, soft						
Other						

[1] Cast-in-place concrete
[2] Precast concrete

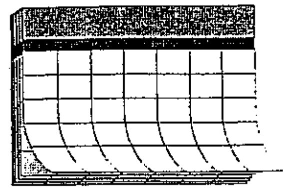
b) Please elaborate on why products performed well or had low costs. ______________________

____

Return to Dr. Susan Morgan, SIUE Department of Civil Engineering, Campus Box 1800, Edwardsville, IL 62026-1800

PART III. Maintenance of Noise Barrier Walls

1. Please indicate the portion of the walls for which the state is responsible.



- ❑ Both sides
- ❑ Highway side only
- ❑ Neither side

2. How long is the state responsible for the noise barriers?

- ❑ < 1 year
- ❑ 1 - 5 years
- ❑ 6 - 10 years
- ❑ 11 - 15 years
- ❑ 16 - 20 years
- ❑ > 20 years

3. Does your state have a maintenance program for noise barrier walls?

- ❑ Yes *Please continue with this question.*
- ❑ No *Please skip to the next question.*

a) What is the maintenance program?

- ❑ Acoustic testing
- ❑ Cleaning
- ❑ Coating, painting, or staining
- ❑ Inspections, structural
- ❑ Inspections, visual
- ❑ Interviews of homeowners
- ❑ Repair of minor cracks
- ❑ Removal of unwanted vegetation
- ❑ Replacement of wall sections
- ❑ Upkeep of landscaping (e.g., mowing and pruning)
- ❑ Other: ______________________________ Please specify.

b) What is the annual maintenance budget for noise barrier walls? ____________________

c) What portion of this funding is used for:

Routine maintenance __________ %

Major repairs __________ %

4. Has the acoustical performance (e.g., insertion loss) of existing walls ever been tested?

   ☐ Yes *Please continue with this question.*
   ☐ No *Please skip to the next question.*

   a) What prompted the testing? ______________________________

   ____

   b) How frequently is testing conducted? ______________________________

   c) What is the testing procedure? ______________________________

   ____

   d) Have any walls failed to meet your testing criteria?

   ☐ Yes
   ☐ No

5. Do you consider failure to meet insertion loss and/or noise level criteria to be reason to replace a barrier?

   ☐ Yes
   ☐ No

6. Have you had to repair or replace any walls or are you considering repairing or replacing any walls?

   ☐ Yes *Please continue answering this question.*
   ☐ No *Please skip to the next question.*

   a) What percent of the walls by length have had to be repaired or replaced? __________ %

   b) Were future *construction* specifications changed as a result of the repair(s) or replacement(s)?

   ☐ Yes
   ☐ No

   c) Were future *design* specifications changed as a result of the repair(s) or replacement(s)?

   ☐ Yes
   ☐ No

   d) Please mark why the repairs or replacements were needed.

   ☐ Natural disasters
   ☐ Normal aging
   ☐ Poor performance (e.g, aesthetically or structurally)
   ☐ Traffic accidents

e) Please complete the following table for walls that have been repaired or replaced and for walls being considered for repair or replacement.

Material	Age [1] (Years)	Reason(s) for Repair or Replacement						
		Appearance	Installation Errors	Loss of Noise Reduction	Public Complaints	Safety	Structural Failure	Other Please specify.
Berm								
Block								
Brick								
Composite								
Concrete, cast. [2]								
Concrete, pre. [3]								
Metal								
Plastic								
Recycled								
Wood, hard								
Wood, soft								
Other								

[1] Wall age when repaired or replaced.
[2] Cast-in-place concrete
[3] Precast concrete

f) Please complete the following table for entire walls and sections of walls that have been replaced or being considered for replacement.

Material	Age [1] (Years)	Replacement Cost	Replacement Barrier Wall	
			Same system	Different System (Please specify.)
Berm				
Block				
Brick				
Composite				
Concrete, cast. [2]				
Concrete, pre. [3]				
Metal				
Plastic				
Recycled				
Wood, hard				
Wood, soft				
Other				

[1] Wall age when repaired or replaced.
[2] Cast-in-place concrete
[3] Precast concrete

PART IV. Summary of Existing Noise Barrier Walls

1. Please review the attached information from the FHWA Summary of Noise Barriers Constructed by December 31, 1995 for accuracy and completeness.

2. Please update the table to include noise barriers constructed after publication of the 1995 summary. You can use the following table or send us a copy of your list.

City/County	Route	Type*	Barrier Material	Year Constructed	Length (m)	Height (m)	Total Cost

* Type I, II, S, or T

3. Did the cost of any noise barrier wall include special requirements that increased the cost (e.g., poor soil conditions necessitating deeper footings or use of the noise barrier as a retaining wall)?

☐ Yes Please specify the walls by highlighting them on the attached sheet or listing them here. __________

☐ No

THANK YOU!

Return to Dr. Susan Morgan, SIUE Department of Civil Engineering, Campus Box 1800, Edwardsville, IL 62026-1800

Your comments will be appreciated.

Thank you for your help.

Please return your completed questionnaire in the enclosed envelope to:

Dr. Susan Morgan
Department of Civil Engineering
Southern Illinois University at Edwardsville
Campus Box 1800
Edwardsville, IL 62026-1800

A Survey of Illinois
Highway Noise Barrier Maintenance

Survey for
Illinois Transportation Research Center
Project IIB-H1
"Evaluation of Service Life of Noise Barrier Walls in Illinois"

Project Director
Dianne Kay, P.E., Assistant Professor of Construction
Southern Illinois University at Edwardsville

Co-Investigators
Susan Morgan, Ph.D, E.I.T., Assistant Professor of Civil Engineering
Narayan Bodapati, Ph.D., P.E., Associate Professor of Construction
Southern Illinois University at Edwardsville

Instructions

- Individuals completing this survey will not be named in any summary of survey data. However, for telephone follow-up, please complete:

IDOT District ______________________

Maintenance Yard ______________________

Name of Respondent ______________________

Title of Respondent ______________________

Telephone ( ) ______________________

- Some questions request specific data, such as costs. If exact data are unavailable, please estimate. Your experience and input are valuable.
- If your responses do not fit in the spaces provided, please use additional sheets and indicate the question to which the response applies.
- If you are unable to complete the entire survey, please return it partially completed to help meet the project goals.

Please return the completed survey via interoffice mail to:

Mr. David B. Johnson, P.E.
Maintenance Operations Engineer
Bureau of Operations
Room 009
2300 Dirksen Parkway
Springfield, IL 62764

- If you have any questions regarding completion of this survey, contact:

Professor Dianne Kay
(618) 650-5019
e-mail: dkay@siue.edu

1. The attached information is based on the FHWA Summary of Noise Barriers Constructed by December 31, 1995, and is included to help you identify the location and type of noise barriers in your area. If there are additional noise barriers in your area which are not on the FHWA list, use the space below to add to the list.

City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (meters)	Height (meters)	Total Cost ($)

☐ Check here if no noise barriers are missing from the FHWA list.

ILLINOIS NOISE WALL BARRIERS LISTED BY LOCATION

State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost
Illinois	Addison	I-290	I	Comb/Berm/Wood	1986	2,286	6.10	1,614,027
Illinois	Addison/ DuPage	I-355/290	I	Tropical Hardwood	1990	1,332	5.50	869,949
Illinois	Cook	IL 53	I	Tropical Hardwood	1990	3,827	4.60	2,347,568
Illinois	DuPage	IL 83	I	Softwood Post/Panel	1991	1,595	2.10	737,947
Illinois	DuPage	I-290	I	Softwood Post/Panel	1992	104	2.10	39,479
Illinois	DuPage	IL 83 @ I-290	I	Softwood Post/Panel	1992	1,991	1.80	545,642
Illinois	Elmhurst	I-290 (ramp)	I	Berm Only	1985	561	2.10	257,018
Illinois	Elmhurst	I-290 (ramp)	I	Glue Laminated Softwood	1985	757	4.90	665,171
Illinois	Elmhurst	I-290	I	Comb/Berm/Wood	1986	853	4.00	532,371
Illinois	Elmhurst	I-290	I	Comb/Berm/Wood	1986	1,387	3.00	544,910
Illinois	Elmhurst	I-290	I	Comb/Berm/Wood	1986	1,741	4.00	709,088
Illinois	Elmhurst/Villa Park	SR 83	I	Glue Laminated Softwood	1986	1,770	2.10	296,460
Illinois	West Chicago, Bartlett	IL 59	I	Durisol	1993	1,489	5.50	932,729
Illinois		I-355	T	Glue Laminated Softwood	1988	21,238	2.50	8,600,000
Illinois		I-294	T	Concrete/Precast Post/Panel	1994	29,139	3.69	20,500,000
Illinois		I-294	T	Softwood Post/Panel	1994	6,597	3.00	5,700,000
Illinois		I-294	T	Carsonite	1994	1,036	5.50	3,300,000
Illinois		I-94	T	Concrete/Precast Post/Panel	1996	600	3.70	2,700,000
Illinois	Schaumburg	IL 19	I	Durisol	1993	226	5.50	510,500
Illinois	Schaumburg, Elk Grove, Roselle	Elgin-O'Hare	I	Wood/Post and Plank	1993	4,691	5.00	3,186,120
Illinois	Monroe Center	US 51	I	Fanwall Precast Concrete	1979	731	6.10	656,501
Illinois	Highland Park	US 41	I	Glue Laminated Softwood	1982	363	3.00	197,044

State	City/County	Route	Type I, II, S or T	Barrier Material	Year Constructed	Length (Meters)	Height (meters)	Total Cost
Illinois	Highland Park	US 41	S	Berm Only	1983	366	3.00	213,518
Illinois	Highland Park	US 41	I	Glue Laminated Softwood	1989	389	3.00	140,616
Illinois	Highland Park	US 41	I	Glue Laminated Softwood	1989	305	4.30	153,688
Illinois	Bartlett	IL 59	I	Durisol	1993	265	4.60	197,392
Illinois	Bolingbrook	SR 53	I	Glue Laminated Softwood	1980	305	2.10	129,518
Illinois	Rockford	US 51	I	Precast Concrete (footingless)	1980	384	4.00	203,009
Illinois	Rockford	US 51	I	Precast Concrete (footingless)	1980	1,217	4.00	774,448
Illinois	Rockford	US 51	I	Precast Concrete	1980	932	4.90	604,493
Illinois	Rockford	US 51	I	Precast Concrete	1980	956	4.00	483,178
Illinois	Peoria	I-474	I	Tropical Hardwood	1987	183	1.80	52,896
Illinois	Springfield	SR 4	I	Berm Only	1978	1,370	4.90	631,598
Illinois	Springfield	SR 4	I	Berm Only	1979	319	2.10	26,839
Illinois	Springfield	SR 4	I	Berm Only	1979	634	3.00	53,739
Illinois	Springfield	SR 4	I	Combination Berm/Retaining Wall	1979	634	3.00	508,313
Illinois	Springfield	SR 4	I	Berm Only	1986	539	3.00	68,926
Illinois	Springfield	SR 4	I	Berm Only	1989	305	3.00	39,454
Illinois	Springfield	SR 4	I	Berm Only	1989	125	3.00	16,170
Illinois	Moline	SR 5	S	Comb/Berm/Wood	1988	1,238	3.70	332,211
Illinois	Centerville	I-255	I	Noishield steel	1984	1,230	3.00	819,389
Illinois	Collinsville	I-255	I	Noishield aluminum	1985	296	2.10	259,549
Illinois	East St. Louis	I-255	I	Precast Concrete (footingless)	1981	558	3.00	393,241

2. Based on your experience, how would you rate the **current condition** of each of the noise barriers in your district?

Material	Current Condition				
	Like New (no change since installation)	Maintenance Free (no maint. required since installation)	Trouble Free (routine maintenance only)	Deteriorating (current repair needed)	Failed (needs replacement)
Earth Berm					
Carsonite ®					
Durisol ®					
Fanwall® Precast Concrete					
Precast Concrete (footingless)					
Precast Concrete (post and panel)					
Tropical Hardwood					
Glue-laminated Softwood					
Softwood Post and Panel					
Noishield® steel					
Noishield® aluminum					
Combination berm/wood wall					
Combination berm/retaining wall					
Other					
Other					

3. Based on your experience with noise barriers in your district, check all that apply with regard to the **negative** performance of these materials *(note the request for a dollar value in the first column)*:

☐ Check here if you have had no negative experiences with noise barrier materials or products.

Material	High Maintenance Cost*	High Maintenance Effort	Poor Noise Reduction	Poor Structural Performance	Poor Appearance	Installation Errors	Other Problems (Please Specify Below)
Earth Berm							
Carsonite®							
Precast concrete (Fanwall®)							
Precast concrete Post and Panel							
Precast concrete footingless							
Tropical Hardwood							
Glue-laminated Softwood							
Softwood Post and Panel							
Durisol®							
Noishield® steel							
Noishield® aluminum							
Combination berm/wood wall							
Combination berm/retaining wall							
Other							
Other							

*** Please give an estimated average annual maintenance cost associated with each material or product with which you have experience.**

Please use this space to describe "Other Problems" noted above:

4. Have any noise barriers been repaired or scheduled for repair in your district?

- ☐ No (please skip to question 6)
- ☐ Yes (please complete this page)

Material	Age at time of repair (years)	Reason(s) for Repair						
		Appearance	Loss of Noise Reduction	Public Complaints	Crash Damage	Structural Failure	Vandalism	Other (Please Describe)

5. Please describe the extent of any repairs scheduled or completed, including the estimated or actual costs of such repair. Indicate the location (city, route) of any repaired noise barrier.

Material or Product	Location (City, Route)	Description of Repairs	Repair Cost

6. Have you completely replaced, or are you currently considering replacement of any noise barriers in your district?

☐ No (please skip to question 7)
☐ Yes (please complete the table below)

Material	Location	Length of Barrier Replaced (m)	Date of Original Construction	Date of Replacement Construction	Reason for Replacement	New Material or Product	Construction Cost (total $)

7. Have you experienced maintenance issues that you feel are **negative** features of particular noise barrier materials or products?

☐ No (please skip to question 8)
☐ Yes (please complete the table below)

Material	Maintenance Issues							
	Mowing	Upkeep of Landscaping	Painting or Staining	Crack Repair	Graffiti Removal	Surface Cleaning	Vegetation Removal	Other (Please describe)

8. Have you been particularly pleased with the performance of specific materials or products?

- ☐ No (please skip to question 9)
- ☐ Yes (please complete the table)

Material	Ease of Construction /Repair	Low Maintenance Effort	Low Maintenance Cost	Good Noise Reduction	Looks Good Over Time	No Structural Problems	Other Positive Attributes

9. Estimate the service life (trouble-free life) of the noise barrier materials or products with which you are experienced.

Material or Product	Estimated Service Life (years)
Earth Berm	
Carsonite®	
Durisol®	
Fanwall® precast concrete	
Precast concrete (footingless)	
Precast concrete (post and panel)	
Tropical Hardwood	
Glue-laminated Softwood	
Softwood Post and Panel	
Noishield® steel	
Noishield® aluminum	
Combination berm/wood wall	
Combination berm/retaining wall	
Other	
Other	
Other	
Other	

END OF SURVEY

Thank you for your assistance. Please return the completed survey via interoffice mail to:

Mr. David B. Johnson, P.E.
Maintenance Operations Engineer
Bureau of Operations
Room 009
2300 South Dirksen Parkway
Springfield, IL 62764

APPENDIX B
LIFE CYCLE COST COMPUTATIONS

Highway Noise Barrier

Initial & Reoccurring Construction & Maintenance Costs

Present Value Concept

". . .the amount of money required at the present time, to accommodate future expenditures for estimated costs of maintenance, repair and replacements; assuming that money, as well as construction services has an increasing time value due to escalation of costs. . ."

The SPW (Single Present Worth) annual percentage factors used in this Life Cycle Costing (LCC) analysis, are based on a net time value of money of 2 1/2% per year (5/8ths of 1%/quarter). This net gain in value each year is based on assumed averages of 5 to 6% interest/investment gains offset by an average construction cost escalation of 2 3/4 to 3 1/4%/year increases (3/4 +/- of 1%/quarter):

Year	Time Elapsed	(SCA) Single Compound Amount	(SPW) Single Present Worth
2000	Assumed "Present"	1.0000	1.0000
2005	5	1.1314	0.8839
2010	10	1.2801	0.7812
2015	15	1.4483	0.6905
2020	20	1.6386	0.6103
2025	25	1.8539	0.5394
2030	30	2.0976	0.4767
2035	35	2.3732	0.4214
2040	40	2.6851	0.3724
2045	45	3.0379	0.3292
2050	50	3.4371	0.2909

(Based on 2 1/2% Net Compound Interest Annually)

Highway Noise Barriers

Initial & Reoccuring Construction & Maintenance Costs

If Average Spacing of Panels is	Number of Panels & Posts in 1000 LF of Wall	Assumed Pier Foundation Design & Scope (8ft. - Deep)			
		Concrete & Drilled Earth Material		Reinforcing Steel	
6'	167 ea	24"dia. 1.0CY	167CY	8 #6's, 105#	8.8 Tons
8'	125 ea	24"dia. 1.0CY	125CY	8 #6's, 105#	6.6 Tons
10'	100 ea	30"dia. 1.6CY	160CY	10 #6's, 132#	6.6 Tons
12'	83 ea	30"dia. 1.6CY	133CY	10 #6's, 132#	5.5 Tons
14'	72 ea	30"dia. 1.6CY	115CY	10 #6's, 132#	4.8 Tons
16'	63 ea	30"dia. 1.6CY	101CY	10 #6's, 132#	4.2 Tons
18'	56 ea	36"dia. 2.3CY	129CY	12 #6's, 158#	4.4 Tons
20'	50 ea	36"dia. 2.3CY	115CY	12 #6's, 158#	4.0 Tons
22'	46 ea	36"dia. 2.3CY	106CY	12 #6's, 158#	3.7 Tons
24'	42 ea	36"dia. 2.3CY	97CY	12 #6's, 158#	3.3 Tons
26'	39 ea	36"dia. 2.3CY	90CY	12 #6's, 158#	3.1 Tons
28'	36 ea	39"dia. 2.6CY	94CY	14 #7's, 259#	4.7 Tons
30'	33 ea	39"dia. 2.6CY	86CY	14 #7's, 259#	4.3 Tons

Highway Noise Barriers
Initial & Reoccurring Construction & Maintenance Costs

Type	Noise Barrier Description (& Typical Type Wall)	Initial Construct Costs (2000)	P.Y. of 50 Yrs. of Maintenance & Operations
E-1	Earth Berms (From Suitable Excess Material On Site) (On Land Available On Row)	$10.33/SF	$3.79/SF
C-1	Horizontal Pre Cast Wall Panels (Between Steel Posts) i.e. - "Hollow Core" Slabs - "Soundcore" - "Spancrete" - "Durisol"	$19.67/SF	$4.03/SF
C-2	Horizontal Pre Cast Wall Panels (Between P. Cast Concrete Posts) i.e. - "Hollow Core" Slabs - "Soundcore" - "Spancrete" - "Durisol"	$24.33/SF	$2.62/SF
C-3	Vertical One Piece Pre Cast Wall Section With Monolithic Posts i.e. - Monowall (Pickett) - The Great Divid (P.E.C.)	$28.33/SF	$2.62/SF
C-4	Vertical One Piece Pre Cast Cantilever Walls No Columns i.e. - Local P.C. Solid Walls	$27.00/SF	$2.80/SF
FG-1	Fiber Glass T&G Planks Horizontal Placed Between Steel Posts i.e. - "Carsonite"	$25.33/SF	$4.65/SF
M-1	Steel Acoustical Panels & Caps (Between Steel Posts) i.e. - "Noishield"	$27.67/SF	$12.19/SF
M-2	Aluminum Acoustical Panels & Caps (Between Steel Posts) i.e. - "Noishield"	$35.00/SF	$15.15/SF
T-1	Timber (Vertical Panels & Battens) (Between Timber Posts) i.e. - Locally Fabricated Wood - "Sentinel Structures Inc."	$18.33/SF	$13.48/SF
T-2	Timber (Horizontal Stacked Wood) With Vertical Battens Between Wood Posts i.e. - Locally Fabricated Wood - Bongossi Tropical Hardwood	$16.70/SF	$11.35/SF

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Costs

Type Wall E-1 Description Earth Berm

(page 2) - Initial Construction Cost Only (no design, plans, specs, A/E or State of IL admin. or management costs) (constructed in year 2000)

- General Conditions (on Site Overhead Supervision, etc.) $8,500

				Clarification/Comments
Site Preparation:				
• Clear & Grub Area	0.23AE	@1750 =	$ 400	
• Scarify/Compact Subgrade	0.23AE	@ 550 =	$ 125	
Earth Fills:				
• Place & Compact Earth Fills	38,000CY	@ 1.50 =	$ 57,000	Assume All Earth Materials
• Place, Topsoil, Distribute	2,250CY	@ 2.50 =	$ 5,625	Available & acceptable At Site
Grading:				
• Subgrade Top (Flar) Surf	10,000SF	@ .07 =	$ 700	
• Subgrade Inclined Surf	42,500SF	@ .11 =	$ 4,275	
• Final Grade Topsoil (Top)	10,000SF	@ .08 =	$ 800	
• Final Grade Topsoil (Slopes)	42,500SF	@ .13 =	$ 5,525	
• Erosion Control Top (Flat)	10,000SF	@ .15 =	$ 1,500	
• Erosion Control Inclined Surf	42,500SF	@ .20 =	$ 8,500	
Landscaping:				
• Ground Cover Top (Flat)	10,000SF	@ .25 =	$ 2,500	
• Ground Cover Sides (Slopes)	42,500SF	@ .30 =	$ 12,750	
• Planting, Shrubs, Trees	10,000SF	@ .50 =	$ 5,000	
• Planting, Shrubs, Trees	42,500SF	@ .60 =	$ 26,500	
Subtotal			$135,000	
Fee (G.C.)			$ 8,000	
Recommended Contingency (Allow 10%)			$ 12,000	
Anticipated Construction Cost (2000)			$155,000	

Check Impact of Land Cost @ $5,000/acre

100' x 1000' × 1 acre / 43,560SF x $5,000 / acre = $11,478

$146,478
$ 8,000
$ 15,448
$169,926

$169.93/LF
$ 11.33/SF
Adds $1 /SF for land

Total Initial Construction Cost ($/LF) of Wall $ 155.00 LF

Total Initial Construction Cost ($/SF) of Exposed Wall $ 10.33 SF

(No Owner or A/E Services: Design, Administration, Management, Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Costs

Type_______ Wall E-1 ____________________ Description ______ Earth Berm ________________

(page 3) - "LCC" - Life Cycle Costing Analysis

Cost (In Present Time Dollars) For Assumed 50-Year Life of Walls Including Maintenance, Repairs.

Reconstruction and Disposal/Salvage

- Assume 2000 Construction (Initial)
- 50-Year Life Expectancy
- 3% Escalation/Year Ave. For Const.
- 5 1/2% Interest Escalation ($)
- Net 2 1/2% + Time Value of Money
- All Life Cycle Costs in Today's $

Reoccuring Cost (LCC)

Seasonal Slope & Plant Maintenance
(1 Time/Year - Crew of 4, 2 Days = 64 MnHrs)
(Assume Materials, Equipt.=25% of Labor)
(Assume Ave Current Mmnt. Cost=25.00/hr)
(Total Hourly Rate = $31.25 Current)
(Annual Cost = 64 MnHrs x $31.25 = $2000)

Berm Maintenance

Present value of annual maintenance of $2000 over 50 year period:

$$PW = \$2000 \; \frac{(1+i)^n - 1}{i\,(1+i)^n}$$

where i = net interest rate, 2.5%
n = analysis period, 50 years

$$PW = \$2000\ [28.4001]$$
$$= \$56,800$$

Disposal/Salv.

2050________	15,000 SF @________	x 0.2909____	Assume None ____	$ 0
Total (Maintenance/Repairs For 50 Year in Current $'s)				$56,800.00
"Unit" L.C.C. (Excluding Initial Const. Cost)				$. 56.80/LF
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 3.79/SF

(No Owner or A/E Services: Design, Admin., Mgt., Etc.)

Highway Noise Barriers
Initial & Reoccurring Construction & Maintenance Costs

Type Wall C-1 Description Pre Cast Concrete Panels Stacked Horizontally 5° High - 3 Lifts Between Steel Posts 24° Apart (average spacing)

(page 2) - Initial Construction Cost Only (no design, plans, spec, A/E or State of IL admin. or management costs)
(constructed in year 2000)

• General Conditions (on site O.H.)		$17,920
• Foundations:		
• Layout, Grades Setup	42 EA @ 25.00/EA	$ 1,050
• Drill Earth (42 EA x 2.3 CY/EA = 97 CY)	42 EA @ 300.00/EA	$12,600
• Haul Away Excess	122 CY @ 15.00/CY	$ 1,830
• Concrete	97 CY @ 85.00/CY	$ 8,500
• Re Steel	3.3 Ton @ 1850.00/TS	$ 6,100
• A Bolts (4 EA x 42 FNDS)	168 EA @ 20.00/EA	$ 3,360
• Formwork, Templates	42 EA @ 100.00/EA	$ 4,200
• Walls; Materials: (Plain Standing Finish & Color)		
• Post (42 EA x 15 = 63 @ 50*/LF = 16 T)	630 LF @ 35.00/LF	$22,050
• Panels (126 EA Approx 24 x 5)	15,000 SF @ 5.75/SF	$86,250
• Freight, Delivery Walls	15,000 SF @ 0.75/SF	$11,250
Columns	630 LF @ 5.00/LF	$ 3,150
• Walls; Erection:		
• Post (42 EA x 15' LF #)	42 EA @ 125.00/EA	$ 5,250
• Panels (126 EA Approx 24 x 5)	15,000 SF @ 2.75/SF	$33,750
• Wall Painting:		
• Clean & Patch (2 x 15,000 SF =)	30,000 SF @ 0.10/SF	$ 3,000
• Paint, Seal (2 x 15,000 SF =)	30,000 SF @ 0.35/SF	$10,500
• Joint Treatment:		
• Caulk, Seal (42 x 15 x 2 x 2 =) or Gaskets/Fillers	2,520 LF @ 2.50/SF	$ 6,300
• Site Restoration:		
• Top Soil 10° Each Side	400 CY @ 20.00/CY	$ 8,000
• Seed/Sod (2 x 10 x 1000 = 20,000 SF)	2,225 SY @ 1.75/SY	$ 3,940
• Planting	"Allow"	$ 5,000
• Subtotal		$254,000
• Fee - (G.C. Main Office O.H. Profit/Risk)		$ 16,000
• Recommended Contingency		$ 25,000
• Construction Cost (2000)		$295,000

Total Initial Construction Cost ($/LF) of Wall $295.00/LF

Total Initial Construction Cost ($/SF) of Exposed Wall $19.67/SF

(No Owner or A/E: Design, Administration, Management, Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Cost

Type_____Wall C-1____________________Description_Precast Concretes Stacked Panels with Steel Posts________

(page 3) - "LCC" - Life Cycle Costing Analysis
Cost (In Present Time Dollars) For 50-Year Analysis Period for Walls Including Maintenance, Repairs, Reconstruction and Disposal/Salvage)

- Assume 2000 Construction (Initial)
- 50-Year Life Expectancy
- 3% Escalation/Year Ave. For Const.
- 5 1/2% Interest Escalation ($)
- Net 2 1/2% + Time Value of Money
- All Life Cycle Costs in Today's $

Reoccurring Costs: "LCC" Assumptions:

- Panel Replacement (1%/10 Years)
- Wall Re-Painting/Re-Sealing:
  - Posts (100%/10 Years)
  - Post Caulking (100%/10 Years)
  - Graffiti Paint-Over (1%/5 Years)
  - Re-Paint Wall (100% @ 20 Years)

	Year	Current (2000) Unit Costs	SPW Factor	
Panel Replacement:				
• Removal	2010	150 SF @ 5.00	x 0.7812	$ 586
• Removal	2020	150 SF @ 5.00	x 0.6103	$ 458
• Removal	2030	150 SF @ 5.00	x 0.4767	$ 358
• Removal	2040	150 SF @ 5.00	x 0.3724	$ 279
• Replacement	2010	150 SF @ 15.00	x 0.7812	$ 1,758
• Replacement	2020	150 SF @ 15.00	x 0.6103	
$ 1,373				
• Replacement	2030	150 SF @ 15.00	x 0.4767	$ 1,071
• Replacement	2040	150 SF @ 15.00	x 0.3724	$ 831
Post Re-Paint/Re-Caulk (Steel)				
42 EA x 15 LF	In 2010	7,500 LF @ 15.06	x 0.7812	$ 7,385
	In 2020	7,500 LF @ 15.06	x 0.6103	$ 5,765
	In 2030	7,500 LF @ 15.06	x 0.4767	$ 4,500
	In 2040	7,500 LF @ 15.06	x 0.3724	$ 3,465
Re-Painting Walls Panels				
	In 2005	300 SF@ 0.35	x 0.8839	$ 92
	In 2010	300 SF @ 0.35	x 0.7812	$ 82
	In 2015	300 SF @ 0.35	x 0.6905	$ 72
	In 2020	30,000SF @ 0.35	x 0.6103	$ 6,408
	In 2025	300 SF @ 0.35	x 0.5394	$ 56
	In 2030	300 SF @ 0.35	x 0.4767	$ 50
	In 2035	300 SF @ 0.35	x 0.4214	$ 44
	In 2040	30,000SF @ 0.35	x 0.3724	$ 3,910
	In 2045	300 SF @ 0.35	x 0.3292	$ 35
Disposal/Salv.				
	2050	15,000SF @ 5.00	x 0.2909	$21,815
Total (maintenance/Repairs For 50 Years in Current $'s)				$60,399
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 60.40/LF
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 4.03/SF (of exposed wall)

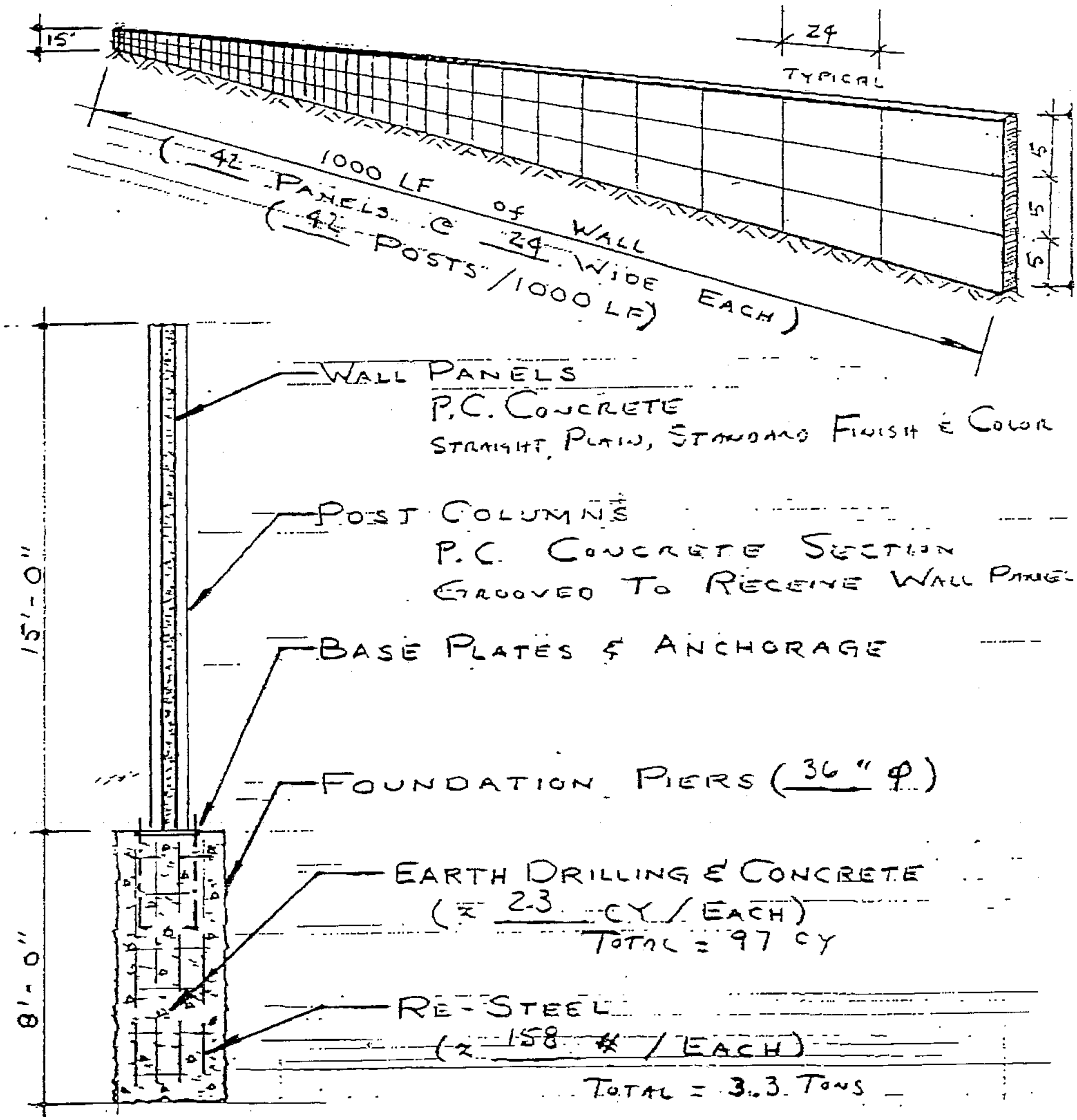
(No Owner or A/E Services: Design, Admin, Mgt., Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Costs

Type Wall C-2 Description Precast Concrete Panels Stacked Horzontally Between Concrete Posts 24' Apart (average spacing)

Assumed Wall Scope



Highway Noise Barriers
Initial & Reoccurring Construction & Maintenance Costs

Type Wall C-2 Description Precast Concrete Panles Stacked Horizontally Between Concrete Post 24' Apart (average spacing)

(page 2) - Initial Construction Cost Only (no design, plans, spec, A/E or State of IL admin. or management costs)
(constructed in year 2000)

• General Conditions (on site Overhead, Supervision Etc.)		$21,117
• Foundations:		
• Layout, Grades Setup	42 EA @ 25.00/EA	$ 1,050
• Drill Earth (42 EA x 2.3 CY/EA = 97 CY)	42 EA @ 300.00/EA	$12,600
• Haul Away Excess	122 CY @ 15.00/CY	$ 1,830
• Concrete	97 CY @ 85.00/CY	$ 8,500
• Re Steel	3.3 Ton @ 1850.00/T	$ 6,100
• A Bolts (4 EA x 42 Piers)	168 EA @ 20.00/EA	$ 3,360
• Formwork, Templates	42 EA @ 100.00/EA	$ 4,200
• Walls; Materials: (Plain Standing Finish & Color)		
• Post (Slotted P.C. LF 15' #)	630 LF @ 100.00/LF	$63,000
• Panels (126 EA Approx 24 x 5)	15,000 SF @ 5.75/SF	$86,250
• Freight, Delivery Walls	15,000 SF @ 0.75/SF	$11,250
Columns	630 LF @ 10.00/LF	$ 6,300
• Walls; Erection:		
• Post (P. Cast; Concrete LF 15' #)	630 EA @ 30.00/EA	$18,900
• Panels (126 EA Approx 24 x 5)	15,000 SF @ 2.25/SF	$33,750
• Wall Painting: Sealing		
• Clean & Patch (2 sides x 15,000 SF)	30,000 SF @ 0.10/SF	$ 3,000
• Paint, Seal (2 sides x 15,000 SF)	30,000 SF @ 0.35/SF	$10,500
• Joint Treatment:		
• Caulk, Seal, Gaskets/Fillers (42 x 15 x 4)	2,520 LF @ 2.50/SF	$ 6,300
• Site Restoration:		
• Top Soil Allow 6" - 10' wide 2 sides	400 CY @ 20.00/CY	$ 8,000
• Seed/Sod (2 x 10 x 1000 = 20,000 SF)	2,250 SY @ 1.75/SY	$ 3,940
• Planting	"Allow"	$ 5,000
• Subtotal		$315,000
• Fee - (G.C. Main Office O.H. Profit/Risk)		$ 19,000
• Recommended Contingency		$ 31,000
• Construction Cost (2000)		$365,000

Total Initial Construction Cost ($/LF) of Wall $365.00LF

Total Initial Construction Cost ($/SF) of Exposed Wall $24.33/SF

(No Owner or A/E: Design, Administration, Management, Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Cost

Type Wall C-2 Description Precast Concrete with Concrete Posts 24' Apart (average spacing)

(page 3) - "LCC" - Life Cycle Costing Analysis
Cost (In Present Time Dollars) For 50-Year Analysis Period for Walls Including Maintenance, Repairs, Reconstruction and Disposal/Salvage)

- Assume 2000 Construction (Initial)
- 50-Year Life Expectancy
- 3% Escalation/Year Ave. For Const.
- 5 1/2% Interest Escalation ($)
- Net 2 1/2% + Time Value of Money
- All Life Cycle Costs in Today's $

Reoccurring Costs: "LCC" Assumptions:

- Panel Replacement (1%/10 Years)
- Wall Re-Painting/Re-Sealing:
  - Graffiti Paint-Over (5%/5 Years)
  - Re-Paint Wall (100% @20 Years)

	Year	Current (2000) Unit Costs	SPW Factor	
Panel Replacement:				
• Removal	2010	150 SF @ 5.00	x 0.7812	$ 586
• Removal	2020	150 SF @ 5.00	x 0.6103	$ 458
• Removal	2030	150 SF @ 5.00	x 0.4767	$ 358
• Removal	2040	150 SF @ 5.00	x 0.3724	$ 279
• Replacement	2010	150 SF @ 15.00	x 0.7812	$ 1,758
• Replacement	2020	150 SF @ 15.00	x 0.6103	$ 1,373
• Replacement	2030	150 SF @ 15.00	x 0.4767	$ 1,073
• Replacement	2040	150 SF @ 15.00	x 0.3724	$ 838
Re-Painting Walls Panels				
	In 2005	300 SF@ 0.35	x 0.8839	$ 92
	In 2010	300 SF @ 0.35	x 0.7812	$ 82
	In 2015	300 SF @ 0.35	x 0.6905	$ 72
	In 2020	30000SF @ 0.35	x 0.6103	$ 6,408
	In 2025	300 SF @ 0.35	x 0.5394	$ 56
	In 2030	300 SF @ 0.35	x 0.4767	$ 50
	In 2035	300 SF @ 0.35	x 0.4214	$ 44
	In 2040	30000SF @ 0.35	x 0.3724	$ 3,910
	In 2045	300 SF @ 0.35	x 0.3292	$ 35
Disposal/Salv.	2050	15000SF @ 5.00	x 0.2909	$21,815
Total (maintenance/Repairs For 50 Years in Current $'s)				$39,284
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 3928/LF
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 2.62/SF (of exposed wall)

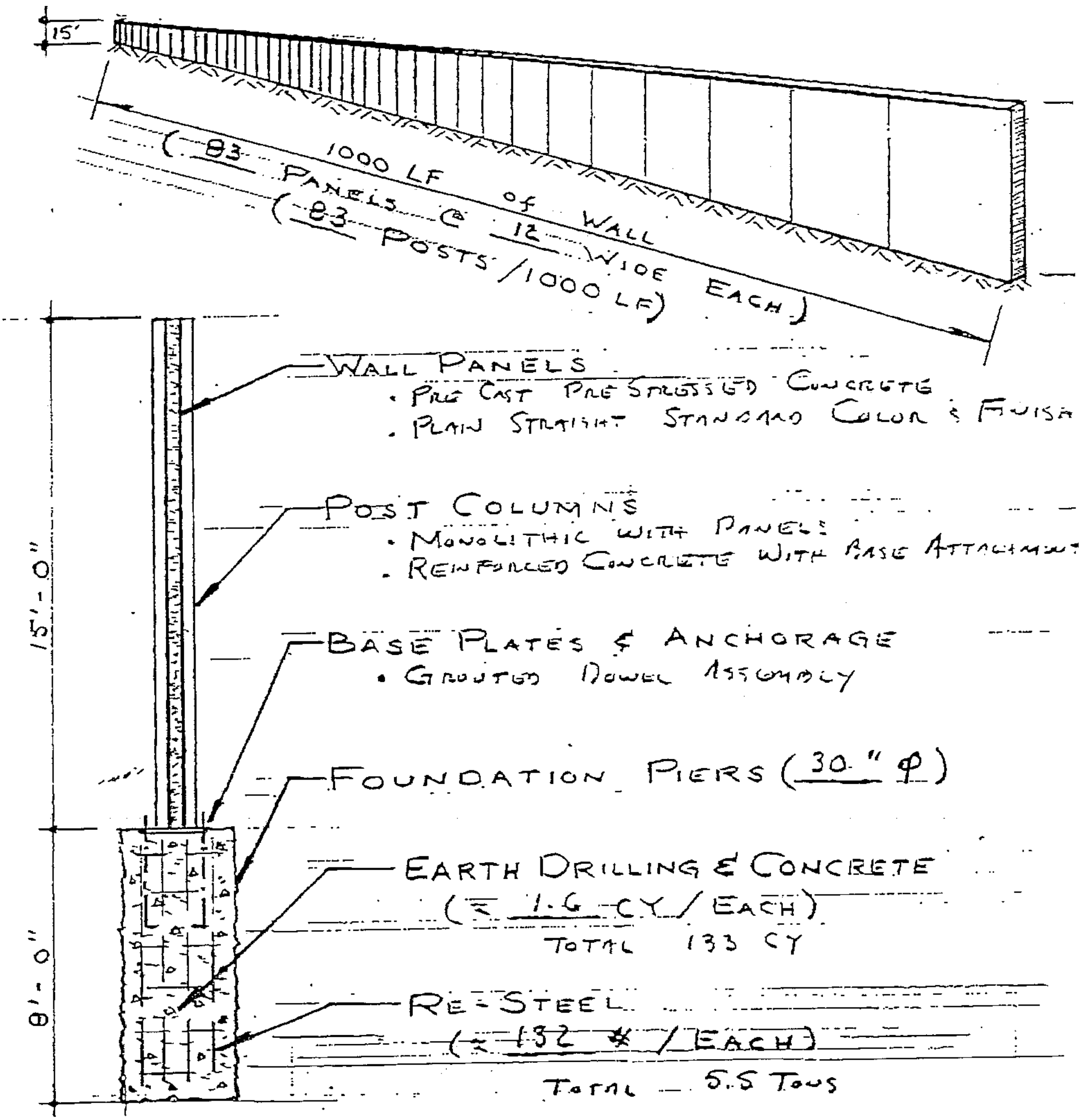
(No Owner or A/E Services: Design, Admin, Mgt., Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Costs

Type ______ Wall C-3 ______ Description Precast Concrete Wall Panels with Monolithic Columns/Posts

Assumed Wall Scope



Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Costs

Type Wall C-3 Description PreCast Concrete Wall Panels with Monolithic Columns/Posts

(page 2) - Initial Construction Cost Only (no design, plans, spec, A/E or State of IL admin. or management costs)
(constructed in year 2000)

• General Conditions (on site Overhead & Supervision)		$ 21,800
• Foundations:		
• Layout, Grades Setup	83 EA @ 25.00/EA	$ 2,075
• Drill Earth (83 EA x 1.6 CY/EA = 133 CY)	83 EA @ 225.00/EA	$ 18,675
• Haul Away Excess (133 x 1.25 Swell)	166 CY @ 15.00/CY	$ 2,496
• Concrete	133 CY @ 85.00/CY	$ 11,305
• Re Steel	5.5 Ton @ 1850.00/TS	$ 10,175
• A Bolts, Dowels & Sleeve Grouting	332 EA @ 25.00/EA	$ 8,300
• Formwork, Templates & Base Connection	83 EA @ 125.00/EA	$ 10,375
• Walls; Materials:		
• Post (Monolithic w/Panels)	0 EA @ N/A	$ 0
• Panels (83 EA Approx 12 x 15 Col)	15,000 SF @ 10.75/SF	$161,250
• Freight, Delivery	15,000 "Allow" 2.25/SF	$ 33,750
• Walls; Erection:		
• Post (Monolithic W/Panels)	0 EA @ N/A	$ 0
• Panels (83 EA Approx 12 x 15 Cols)	15,000 SF @ 3.75/SF	$ 56,250
• Wall Painting:		
• Clean & Patch (2 x 15,000 SF)	30,000 SF @ 0.10/SF	$ 3,000
• Paint, Seal (2 x 15,000 SF)	30,000 SF @ 0.35/SF	$10,500
• Joint Treatment:		
• Caulk, Seal, Gaskets, Fillers (23 x 15)	1,245 LF @ 2.50/SF	$ 3,115
• Site Restoration:		
• Top Soil 10° Each Side	400 CY @ 20.00/CY	$ 8,000
• Seed/Sod (2 x 10 x 1000 = 20,000 SF)	2,225 SY @ 1.75/SY	$ 3,940
• Planting	"Allow"	$ 5,000
• Subtotal		$370,000
• Fee - (G.C. Main Office O.H. Profit/Risk)		$ 20,000
• Recommended Contingency		$ 35,000
• Construction Cost (2000)		$425,000
Total Initial Construction Cost ($/LF) of Wall		$425.00/LF
Total Initial Construction Cost ($/SF) of Exposed Wall		$28.33/SF

(No Owner or A/E: Design, Administration, Management, Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Cost

Type Wall C-3 Description Precast Concrete Wall Panels with Monolithic Posts

(page 3) - "LCC" - Life Cycle Costing Analysis

Cost (In Present Time Dollars) For 50-Year Analysis Period for Walls Including Maintenance, Repairs, Reconstruction and Disposal/Salvage)

- Assume 2000 Construction (Initial)
- 50-Year Life Expectancy
- 3% Escalation/Year Ave. For Const.
- 5 1/2% Interest Escalation ($)
- Net 2 1/2% + Time Value of Money
- All Life Cycle Costs in Today's $

Reoccurring Costs: "LCC" Assumptions:

- Panel Replacement (1%/10 Years)
- Wall Re-Painting/Re-Sealing:
  - Graffiti Paint-Over (1%/5 Years)
  - Re-Paint Wall (100% @ 20 Years)

Panel Replacement:	Year	Current (2000) Unit Costs	SPW Factor	
• Removal	2010	150 SF @ 5.00	x 0.7812	$ 586
• Removal	2020	150 SF @ 5.00	x 0.6103	$ 458
• Removal	2030	150 SF @ 5.00	x 0.4767	$ 358
• Removal	2040	150 SF @ 5.00	x 0.3724	$ 279
• Replacement	2010	150 SF @ 15.00	x 0.7812	$ 1,758
• Replacement	2020	150 SF @ 15.00	x 0.6103	$ 1,373
• Replacement	2030	150 SF @ 15.00	x 0.4767	$ 1,073
• Replacement	2040	150 SF @ 15.00	x 0.3724	$ 838
Re-Painting Walls Panels				
	In 2005	300 SF@ 0.35	x 0.8839	$ 92
	In 2010	300 SF @ 0.35	x 0.7812	$ 82
	In 2015	300 SF @ 0.35	x 0.6905	$ 72
	In 2020	30,000SF @ 0.35	x 0.6103	$ 6,408
	In 2025	300 SF @ 0.35	x 0.5394	$ 56
	In 2030	300 SF @ 0.35	x 0.4767	$ 50
	In 2035	300 SF @ 0.35	x 0.4214	$ 44
	In 2040	30,000SF @ 0.35	x 0.3724	$ 3,910
	In 2045	300 SF @ 0.35	x 0.3292	$ 35
Disposal/Salv.	2050	15,000SF @ 5.00	x 0.2909	$21,815
Total (maintenance/Repairs For 50 Years in Current $'s)				$39,281
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 39.28/LF
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 2.62/SF (of exposed wall)

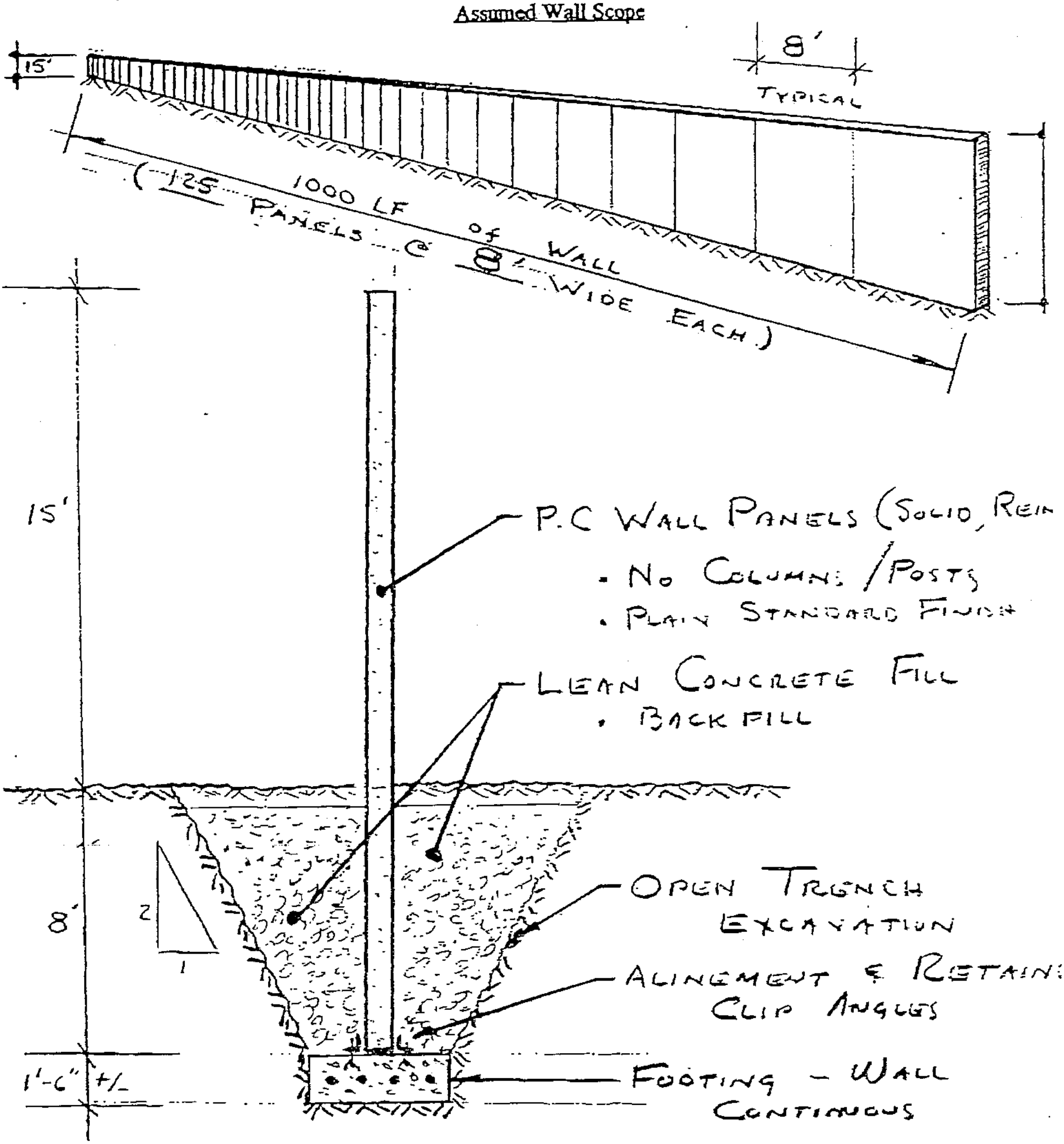
(No Owner or A/E Services: Design, Admin, Mgt., Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Costs

Type Wall C-4 Description Precast Full-Height Concrete Cantilever Walls, No Posts

Assumed Wall Scope



Highway Noise Barriers
Initial & Reoccurring Construction & Maintenance Costs

Type_Wall C-4 Description Precast Full Height Concrete Cantilever Walls with No Posts

(page 2) - Initial Construction Cost Only (no design, plans, spec, A/E or State of IL admin. or management costs)
(constructed in year 2000)

• General Conditions (on site Overhead Supervision Etc.)		$21,710
• Foundations:		
• Layout, Grades Setup	1,000 LF @ 1.25	$ 1,250
• Trench Excavation (B. Hoe)	1,800 CY @ 2.50	$ 4,500
• Footing Excavation (Hand Trim)	225 CY @ 12.50	$ 2,810
• Bank Bracing/Protection	20,000 SF @ 0.25	$ 5,000
• De Watering, Pumping	"Allow"	$ 2,500
• Footing: Concretes	225 CY @ 85.00	$ 19,125
• Footing: Re Steel	3.5 Ton @ 1850.00	$ 6,475
• Footing: Form & Finish	1,000 LF @ 3.25	$ 3,250
• Back Fill (Pug Mill or Lean Conc)	1,500 CY @ 13.75	$ 21,315
Walls; Materials:		
• Panels (125 EA Approx 8 x 23)	23,000 SF @ 5.50	$126,500
• Freight, Delivery	23,000 "Allow" 1.00	$ 23,000
• Walls; Erection:		
• Panels (125 EA Approx 8 x 23)	23,000 SF @ 1.75	$ 40,256
• Alinement & Retaining Angels	250 EA @ 25.00	$ 6,250
• Temp Wall Braces (20' +/-)	250 EA @ 50.00	$ 12,500
• Wall Brace Fnd. (Dean Man)	125 EA @ 100.00	$ 12,500
• Wall Connection Plates	125 EA @ 25.00	$ 3,120
• Wall Painting:		
• Clean & Patch	30,000 SF @ 0.10	$ 3,000
• Paint, Seal	30,000 SF @ 0.35	$ 10,500
• Joint Treatment:		
• Caulk, Seal (15 x 25 x 2	3,750 LF @ 2.00	$ 7,500
• Site Restoration:		
• Top Soil	400 CY @ 20.00	$ 8,000
• Seed/Sod (2 x 10 x 1000 = 20,000 SF)	2,250 SY @ 1.75	$ 3,940
• Planting	"Allow"	$ 5,000
• Subtotal		$350,000
• Fee - (G.C. Main Office O.H. Profit/Risk)		$ 20,000
• Recommended Contingency		$ 35,000
• Construction Cost (2000)		$405,000

Total Initial Construction Cost ($/LF) of Wall $405.00LF

Total Initial Construction Cost ($/SF) of Exposed Wall $27.00/SF

(No Owner or A/E: Design, Administration, Management, Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Cost

Type____Wall C-4__________________Description_Precast Concrete Cantilever Walls No Posts . . ._________

(page 3) - "LCC" - Life Cycle Costing Analysis
Cost (In Present Time Dollars) For 50-Year Analysis Period for Walls Including Maintenance, Repairs, Reconstruction and Disposal/Salvage)

- Assume 2000 Construction (Intial)
- 50-Year Life Expentancy
- 3% Escalation/Year Ave. For Const.
- 5 1/2% Interest Escalation ($)
- Net 2 1/2% + Time Value of Money
- All Life Cycle Costs in Today's $

Reoccurring Costs: "LCC" Assumptions:

- Panel Replacement (1%/10 Years)
- Wall Re-Painting/Re-Sealing:
  - Post Caulking (100%/20 Years)
  - Graffitti Paint-Over (1%/5 Years)
  - Re-Paint Wall (100% @ 25 Years)

	Year	Current (2000) Unit Costs	SPW Factor	
Panel Replacement:				
• Removal	2010	150 SF @ 10.00	x 0.7812	$ 1,172
• Removal	2020	150 SF @ 10.00	x 0.6103	$ 915
• Removal	2030	150 SF @ 10.00	x 0.4767	$ 715
• Removal	2040	150 SF @ 10.00	x 0.3724	$ 559
• Replacement	2010	150 SF @ 10.00	x 0.7812	$ 1,172
• Replacement	2020	150 SF @ 10.00	x 0.6103	$ 915
• Replacement	2030	150 SF @ 10.00	x 0.4767	$ 715
• Replacement	2040	150 SF @ 10.00	x 0.3724	$ 559
Joint Seal/Cover				
	In 2020	3,750 LF @ 2.00	x 0.6103	$ 4,577
	In 2040	3,750 LF @ 2.00	x 0.3724	$ 2,793
Re-Painting Walls Panels				
	In 2005	300 SF@ 0.35	x 0.8839	$ 92
	In 2010	300 SF @ 0.35	x 0.7812	$ 82
	In 2015	300 SF @ 0.35	x 0.6905	$ 72
	In 2020	300 SF @ 0.35	x 0.6103	$ 64
	In 2025	30,000SF @ 0.35	x 0.5394	$ 5,664
	In 2030	300 SF @ 0.35	x 0.4767	$ 50
	In 2035	300 SF @ 0.35	x 0.4214	$ 44
	In 2040	300 SF @ 0.35	x 0.3724	$ 39
	In 2045	300 SF@ 0.35	x 0.3292	$ 35
Disposal/Salv.				
	2050	15,000SF @ 5.00	x 0.2909	$21,815
Total (maintenance/Repairs For 50 Years in Current $'s)				$42,077
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 12.247LF
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 2.80/SF (of exposed wall)

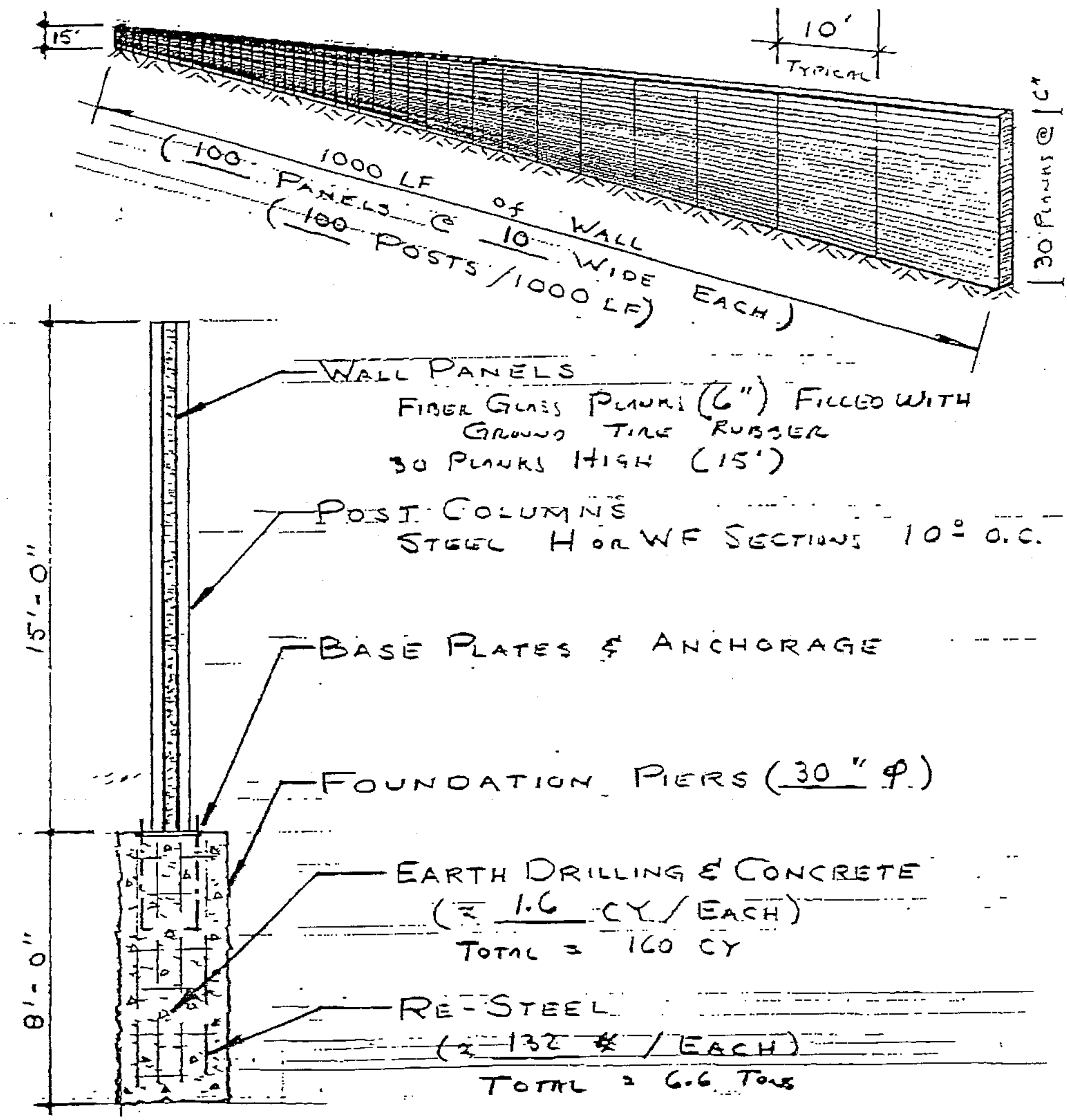
(No Owner or A/E Services: Design, Admin, Mgt., Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Costs

Type Wall FG-1 Description T&G Structural Fiberglass Panles Filled with Shredded Rubber

Assumed Wall Scope



Highway Noise Barriers
Initial & Reoccurring Construction & Maintenance Costs

Type Wall FG-1 Description T&G Structural Fiberglass Panels Filled with Shredded Rubber

(page 2) - Initial Construction Cost Only (no design, plans, spec, A/E or State of IL admin. or management costs)
(constructed in year 2000)

• General Conditions (on site Overhead Supervision, Etc.)		$18,840
• Foundations:		
• Layout, Grades Setup	100 EA @ 25.00	$ 2,500
• Drill Earth (100 EA x 1.6 CY/EA = 160 CY)	100 EA @ 225.00	$ 22,500
• Haul Away Excess (160 CY x 1.25 Swell)	200 CY @ 15.00	$ 3,000
• Concrete	160 CY @ 85.00	$ 13,600
• Re Steel (100 EA x 132#/EA = 6.6 Tons)	6.0 Ton @1,850.00	$ 12,200
• A Bolts (4 x 100)	400 EA @ 20.00	$ 8,000
• Formwork, Templates	100 EA @ 75.00	$ 7,500
• Walls; Materials:		
• Post (100 EA x 1500 LF @ 30*/LF# = 22 T)	1,500 LF @ 25.00	$ 37,500
• Panels (30 EA Approx 0' x 6' x 10) x 100 Bays	15,000 SF @ 10.00	$150,000
• Freight, Delivery Wall Panels	15,000 SF @ 0.35	$ 5,250
Columns/Posts	1,500 LF @ 5.00	$ 7,500
• Walls; Erection:		
• Post (100 EA; 15' LF 30#)	100 EA @ 125.00	$ 12,500
• Panels (EA Approx x)	15,000 SF @ 0.75	$ 11,250
• Wall Painting:		
• Clean & Patch	15,000 SF @ 0.10	$ 1,500
• Paint, Seal "Pre Finished"	N/A @ 0.00	$ 0
• Joint Treatment:		
• Caulk, Seal Filler Seal Stairs 100 x 15 x 2	3,000 LF @ 0.75	$ 2,250
• Site Restoration:		
• Top Soil	400 CY @ 20.00	$ 8,000
• Seed/Sod	2,225 SY @ 1.75	$ 3,890
• Planting	"Allow"	$ 5,000
• Subtotal		$332,780
• Fee - (G.C. Main Office O.H. Profit/Risk)		$ 16,720
• Recommended Contingency		$ 30,500
• Construction Cost (2000)		$380,000

Total Initial Construction Cost ($/LF) of Wall — $380.00/LF

Total Initial Construction Cost ($/SF) of Exposed Wall — $25.33/SF

(No Owner or A/E: Design, Administration, Management, Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Cost

Type Wall FG-1 Description T&G Fiber Glass Panels Filled with Shredded Rubber

(page 3) - "LCC" - Life Cycle Costing Analysis

Cost (In Present Time Dollars) For 50-Year Analysis Period for Walls Including Maintenance, Repairs, Reconstruction and Disposal/Salvage)

- Assume 2000 Construction (Initial)
- 50-Year Life Expectancy
- 3% Escalation/Year Ave. For Const.
- 5 1/2% Interest Escalation ($)
- Net 2 1/2% + Time Value of Money
- All Life Cycle Costs in Today's $

Reoccurring Costs: "LCC" Assumptions:

- Panel Replacement (1%/10 Years)
- Wall Re-Painting/Re-Sealing:
  - Posts (100%/10 Years)
  - Post Caulking (100%/10 Years)
  - Graffiti Cleaning (1%/5 Years)

	Year	Current (2000) Unit Costs	SPW Factor	
Panel Replacement:				
• Removal	2010	150 SF @	1.00 x 0.7812	$ 117
• Removal	2020	150 SF @	1.00 x 0.6103	$ 92
• Removal	2030	150 SF @	1.00 x 0.4767	$ 72
• Removal	2040	150 SF @	1.00 x 0.3724	$ 56
• Replacement	2010	150 SF @	12.00 x 0.7812	$ 1,406
• Replacement	2020	150 SF @	12.00 x 0.6103	$ 1,098
• Replacement	2030	150 SF @	12.00 x 0.4767	$ 858
• Replacement	2040	150 SF @	12.00 x 0.3724	$ 671
Post Re-Paint/Re-Caulk				
100 EA x 15 LF/EA	In 2010	7,500 LF @	15.06 x 0.7812	$17,580
	In 2020	7,500 LF @	15.06 x 0.6103	$13,730
	In 2030	7,500 LF @	15.06 x 0.4767	$10,725
	In 2040	7,500 LF @	15.06 x 0.3724	$ 8,381
Re-Painting Walls Panels				
(Re Finish, Clean Graffiti, Etc.)	In 2005	7,500 SF@	0.50 x 0.8839	$ 132
	In 2010	7,500 SF @	0.50 x 0.7812	$ 117
	In 2015	7,500 SF @	0.50 x 0.6905	$ 104
	In 2020	7,500 SF @	0.50 x 0.6103	$ 91
	In 2025	7,500 SF @	0.50 x 0.5394	$ 81
	In 2030	7,500 SF @	0.50 x 0.4767	$ 71
	In 2035	7,500 SF @	0.50 x 0.4214	$ 63
	In 2040	7,500 SF @	0.50 x 0.3724	$ 56
	In 2045	7,500 SF @	0.50 x 0.3292	$ 49
Disposal/Salv.				
	2050	15000SF @	3.75 x 0.2909	$14,150
Total (maintenance/Repairs For 50 Years in Current $'s)				$69,729
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 69.73/LF
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 4.65/SF (of exposed wall)

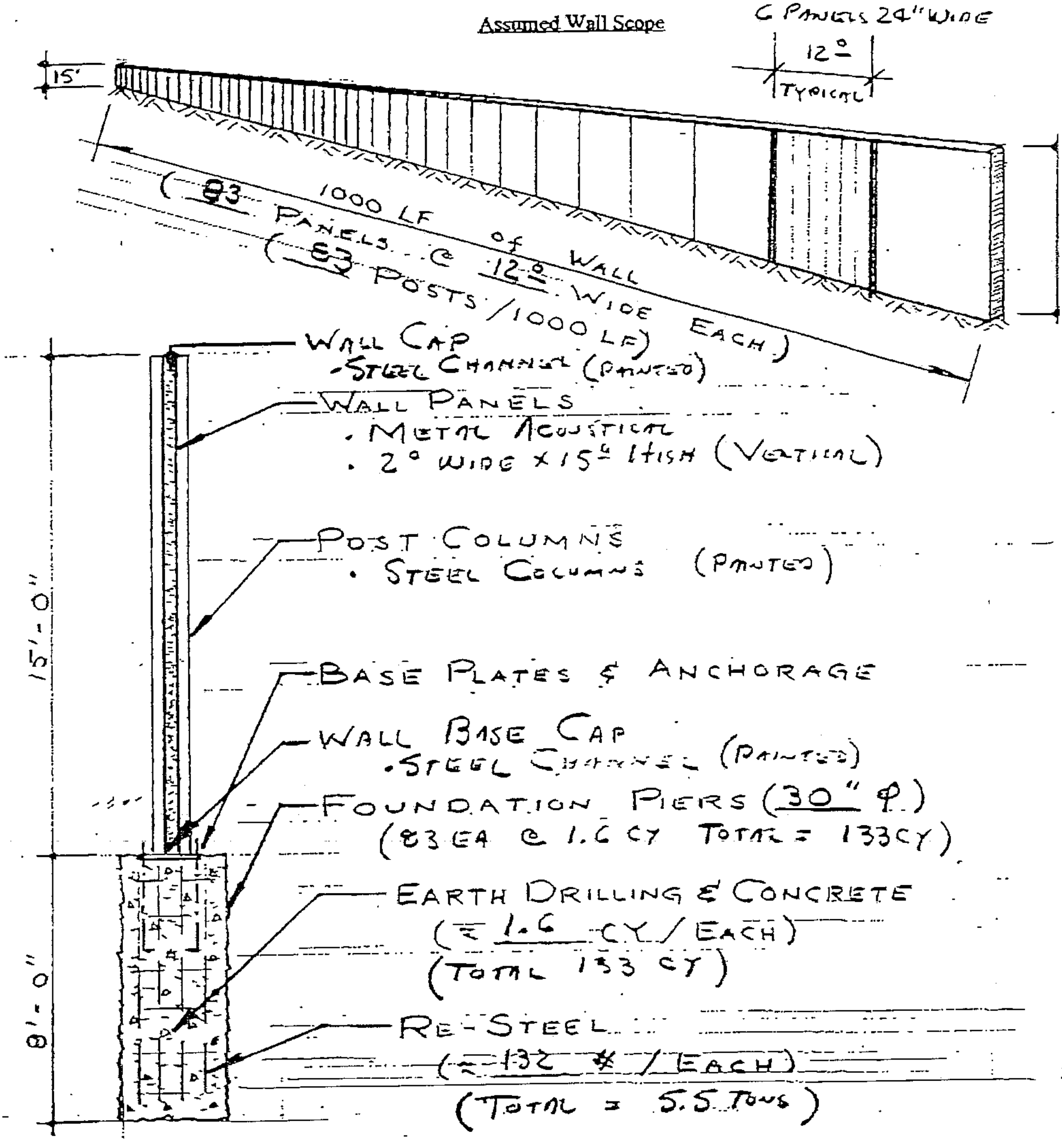
(No Owner or A/E Services: Design, Admin, Mgt., Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Costs

Type Wall M-1 Description Steel Acoustical Panels Between Steel Posts

Assumed Wall Scope



Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Costs

Type Wall M-1 Description Steel Acoustical Panels Between Steel Posts

(page 2) - Initial Construction Cost Only (no design, plans, spec, A/E or State of IL admin. or management costs)
(constructed in year 2000)

• General Conditions (on site Overhead & Supervision)		$20,540
• Foundations:		
• Layout, Grades Setup	83 EA @ 25.00	$ 2,079
• Drill Earth (83 EA x 1.6 CY/EA = 133 CY)	83 EA @ 225.00	$ 18,634
• Haul Away Excess (133 CY x 1.25 Swell)	166 CY @ 15.00	$ 2,490
• Concrete	133 CY @ 85.00	$ 11,305
• Re Steel	5.5 Ton @ 1850.00	$ 10,175
• A Bolts	332 EA @ 20.00	$ 6,640
• Formwork, Templates	83 EA @ 100.00	$ 8,300
• Walls; Materials:		
• Caps 2-T = B x 1000 LF x 10#/LF		
• Post (83 EA x 15 1245/LF x 20#/LF#)	19.5 Ton @ 1750.00	$ 34,125
• Panels (500 EA Approx 2 x 15)	15,000 SF @ 11.50	$172,500
• Freight, Delivery Walls	15,000 SF @ 0.67	$ 10,050
• Walls; Erection:		
• Caps 2 x 93 x 12	2,000 LF @ 2.50	$ 5,000
• Post (83 EA x 15' LF #)	83 EA @ 125.00	$ 12,980
• Panels (560 EA Approx 2 x15)	15,000 SF @ 0.75	$ 11,250
• Wall Painting:		
• Clean & Patch	15,000 SF @ 0.10	$ 1,500
• Paint, Seal Pre Finished	@	$ 0
• Joint Treatment:		
• Caulk, Seal @ Cols 83 x 15 x 4 = 5000 @ Caps 2 x 2 x 1000 = 4000	9,000 LF @ 1.50	$ 13,500
• Site Restoration:		
• Top Soil	400 CY @ 20.00/CY	$ 8,000
• Seed/Sod (2 x 10 x 1000 = 20,000 SF)	2,225 SY @ 1.75/SY	$ 3,940
• Planting	"Allow"	$ 5,000
• Subtotal		$358,000
• Fee - (G.C. Main Office O.H. Profit/Risk)		$ 20,000
• Recommended Contingency		$ 37,000
• Construction Cost (2000)		$415,000

Total Initial Construction Cost ($/LF) of Wall $415.00LF

Total Initial Construction Cost ($/SF) of Exposed Wall $27.67/SF

(No Owner or A/E: Design, Administration, Management, Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Cost

Type Wall M-1 Description Steel Acoustical Panels Between Steel Posts

(page 3) - "LCC" - Life Cycle Costing Analysis
Cost (In Present Time Dollars) For 50-Year Analysis Period for Walls Including Maintenance, Repairs, Reconstruction and Disposal/Salvage)

- Assume 2000 Construction (Initial)
- 25-Year Life Expectancy
- 3% Escalation/Year Ave. For Const.
- 5 1/2% Interest Escalation ($)
- Net 2 1/2% + Time Value of Money
- All Life Cycle Costs in Today's $

Reoccurring Costs: "LCC" Assumptions:

- Panel Replacement (1%/10 Years)
- Panel Replacement (100% @ 25Years), Re-use posts
- Wall Re-Painting/Re-Sealing:
  - Posts (100%/10 Years)
  - Post Caulking (100%/10 Years)
  - Graffiti Cleaning (1%/5 Years)

	Year	Current (2000) Unit Costs	SPW Factor	
Panel Replacement:				
• Removal	2010	150 SF @ 1.50	x 0.7812	$ 175
• Removal	2020	150 SF @ 1.50	x 0.6103	$ 137
• Removal	2025	15,000 SF @ 1.50	x 0.5374	$12,136
• Removal	2030	150 SF @ 1.50	x 0.4767	$ 107
• Removal	2040	150 SF @ 1.50	x 0.3724	$ 84
• Replacement	2010	150 SF @ 13.75	x 0.7812	$ 1,611
• Replacement	2020	150 SF @ 13.75	x 0.6103	$ 1,757
• Replacement	2025	15,000 SF @ 13.75	x 0.5374	$11,120
• Replacement	2030	150 SF @ 13.75	x 0.4767	$ 982
• Replacement	2040	150 SF @ 13.75	x 0.3724	$ 768
Post Re-Paint/Re-Caulk				
	In 2010	7,500 LF @ 15.00	x 0.7812	$17,580
	In 2020	7,500 LF @ 15.00	x 0.6103	$13,730
	In 2030	7,500 LF @ 15.00	x 0.4767	$10,725
	In 2040	7,500 LF @ 15.00	x 0.3724	$ 8,381
Re-Painting Walls Panels (Re Finish, Clean Graffiti, Etc.)	In 2005	300 SF@ 0.50	x 0.8839	$ 132
	In 2010	300 SF @ 0.50	x 0.7812	$ 117
	In 2015	300 SF @ 0.50	x 0.6905	$ 104
	In 2020	300 SF @ 0.50	x 0.6103	$ 91
	In 2025	300 SF @ 0.50	x 0.5394	$ 81
	In 2030	300 SF @ 0.50	x 0.4767	$ 71
	In 2040	300 SF @ 0.50	x 0.3724	$ 56
	In 2045	300 SF @ 0.50	x 0.3292	$ 49
Disposal/Salv.	2050	15,000SF @ 3.50	x 0.2909	$ 15,275
Total (maintenance/Repairs For 50 Years in Current $'s)				$182,827
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 187.83/LF
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 12.19/SF (of exposed wall)

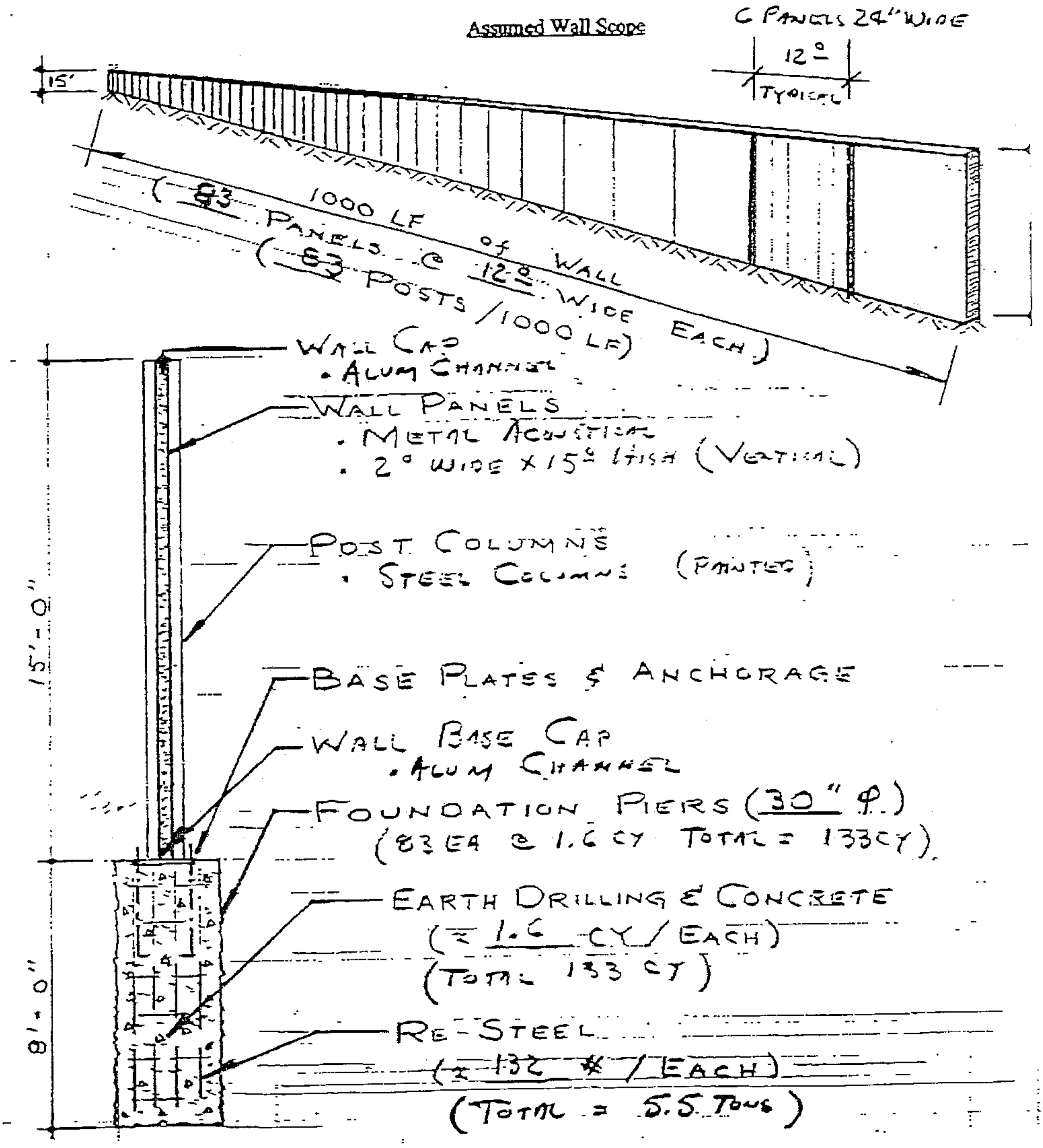
(No Owner or A/E Services: Design, Admin, Mgt., Etc.)

Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Costs

Type Wall M-2 Description Aluminum Acoustical Panels Between Steel Posts

Assumed Wall Scope



Highway Noise Barriers
Initial & Reoccurring Construction & Maintenance Costs

Type Wall M-2 Description Aluminum Acoustical Panel Between Steel Posts

(page 2) - Initial Construction Cost Only (no design, plans, spec, A/E or State of IL admin. or management costs)
(constructed in year 2000)

• General Conditions (on site Overhead & Supervision)		$25,670
• Foundations:		
• Layout, Grades Setup	83 EA @ 25.00	$ 2,075
• Drill Earth (83 EA x 1.6 CY/EA = 133 CY)	83 EA @ 225.00	$ 18,674
• Haul Away Excess (133 CY x 125 Swell)	122 CY @ 15.00	$ 2,490
• Concrete	133 CY @ 85.00	$ 11,305
• Re Steel	5.5 Ton @ 1850.00	$ 10,175
• A Bolts	332 EA @ 20.00	$ 6,600
• Formwork, Templates	83 EA @ 100.00	$ 8,800
• Walls; Materials:		
• Caps 2 - T & B x 1000 LF x 10#/LF (Alum.)	5.0 Ton @ 3200.00	$ 16,000
• Post (83 EA x 15 1245 LF x 20#/LF#) (Steel)	13.0 Ton @ 1750.00	$ 22,750
• Panels (500 EA Approx 20 x 15)	15,000 SF @ 17.25	$258,750
• Freight, Delivery	15,000 SF @ 0.67	$ 10,050
• Walls; Erection:		
• Caps 2 x 83 x 12	2,000 LF @ 2.50/LF	$ 5,000
• Post (83 EA x 15' LF #)	83 EA @ 125.00/EA	$ 12,980
• Panels (500 EA Approx 2 x 15)	15,000 SF @ 0.75/SF	$ 11,250
• Wall Painting:		
• Clean & Patch (2 x 15,000 SF =)	15,000 SF @ 0.10	$ 1,500
• Paint, Seal Pre Finished	SF @	$ 0
• Joint Treatment:		
• Caulk, Seal @ Cols 83 x 15 x 4 = 5000 @ Caps 2 x 2 x 1000 = 4000	9,000 LF @ 1.50	$ 13,500
• Site Restoration:		
• Top Soil 10° Each Side	400 CY @ 20.00/CY	$ 8,000
• Seed/Sod (2 x 10 x 1000 = 20,000 SF)	2,225 SY @ 1.75/SY	$ 3,940
• Planting	"Allow"	$ 5,000
• Subtotal		$454,000
• Fee - (G.C. Main Office O.H. Profit/Risk)		$ 25,000
• Recommended Contingency		$ 46,000
• Construction Cost (2000)		$525,000

Total Initial Construction Cost ($/LF) of Wall $525.00/LF

Total Initial Construction Cost ($/SF) of Exposed Wall $35.00/SF

(No Owner or A/E: Design, Administration, Management, Etc.)

Highway Noise Barriers
Initial & Reoccurring Construction & Maintenance Cost

Type ____ Wall M-2 ____ Description_ Aluminum Acoustical Panels Between Steel Posts ____

(page 3) - "LCC" - Life Cycle Costing Analysis
Cost (In Present Time Dollars) For 50-Year Analysis Period for Walls Including Maintenance, Repairs, Reconstruction and Disposal/Salvage)

- Assume 2000 Construction (Initial)
- 50-Year Life Expectancy
- 3% Escalation/Year Ave. For Const.
- 5 1/2% Interest Escalation ($)
- Net 2 1/2% + Time Value of Money
- All Life Cycle Costs in Today's $

Reoccurring Costs: "LCC" Assumptions:
- Panel Replacement (1%/10 Years)
- Panel Replacement (100% @ 25 Years), Re-use Panels
- Wall Re-Painting/Re-Sealing:
  - Posts (100%/10 Years)
  - Post Caulking (100%/10 Years)
  - Graffiti Paint-Over (1%/5 Years)

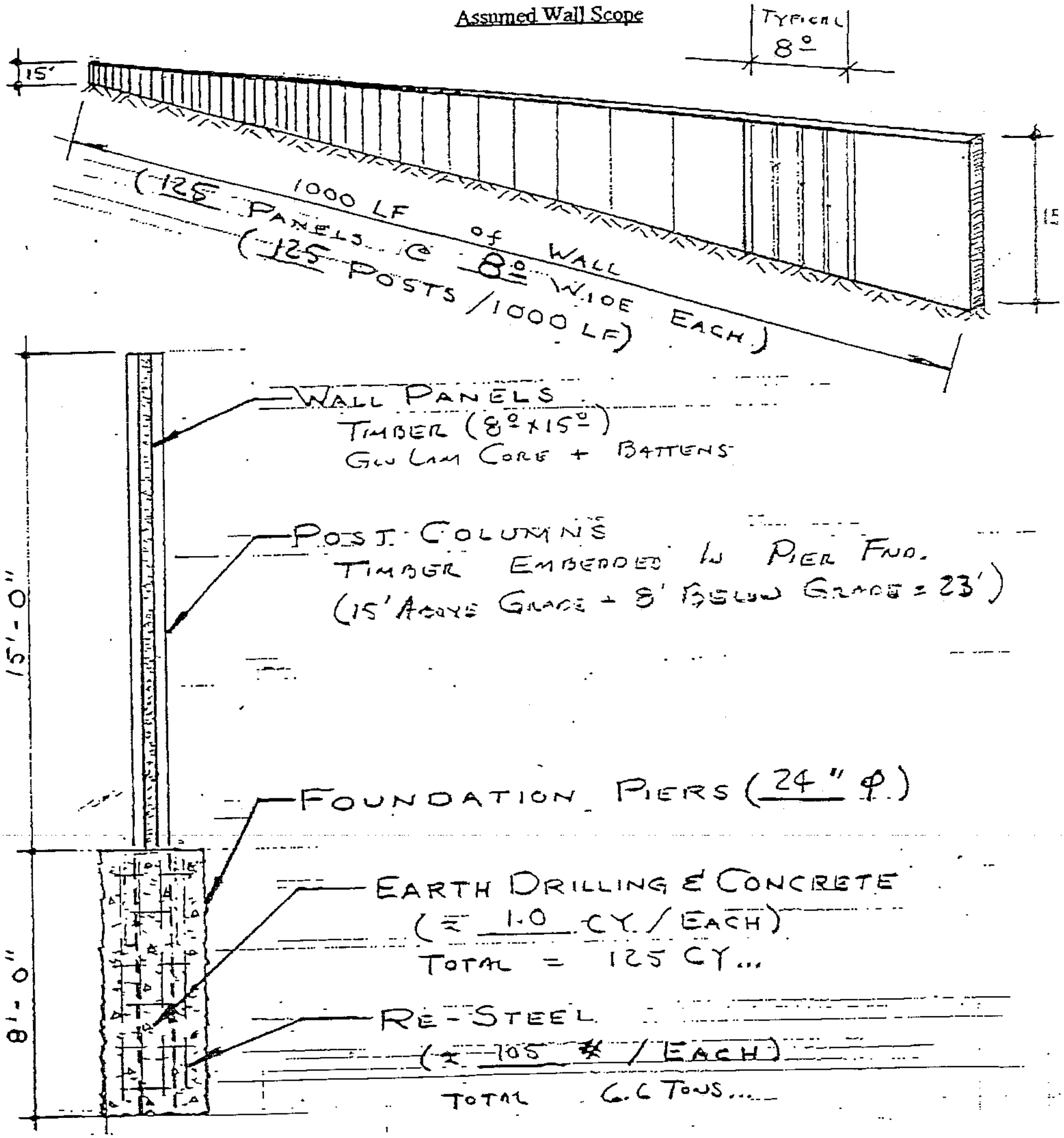
	Year	Current (2000) Unit Costs	SPW Factor	
Panel Replacement:				
• Removal	2010	150 SF @	1.50 x 0.7812	$ 175
• Removal	2020	150 SF @	1.50 x 0.6103	$ 137
• Removal	2025	15,000 SF @	1.50 x 0.5374	$ 12,136
• Removal	2030	150 SF @	1.50 x 0.4767	$ 107
• Removal	2040	150 SF @	1.50 x 0.3724	$ 84
• Replacement	2010	150 SF @	19.25 x 0.7812	$ 2,256
• Replacement	2020	150 SF @	19.25 x 0.6103	$ 1,762
• Replacement	2025	15,000 SF @	19.25 x 0.5374	$155,752
• Replacement	2030	150 SF @	19.25 x 0.4767	$ 1,376
• Replacement	2040	150 SF @	19.25 x 0.3724	$ 1,075
Post Re-Paint/Re-Caulk				
	In 2010	7,500 LF @	15.00 x 0.7812	$17,580
	In 2020	7,500 LF @	15.00 x 0.6103	$13,730
	In 2030	7,500 LF @	15.00 x 0.4767	$10,725
	In 2040	7,500 LF @	15.00 x 0.3724	$ 8,380
Re-Painting Walls Panels				
(Re Finish, Clean	In 2005	300 SF@	0.50 x 0.8839	$ 132
Graffiti, Etc.)	In 2010	300 SF @	0.50 x 0.7812	$ 117
	In 2015	300 SF @	0.50 x 0.6905	$ 104
	In 2020	300 SF @	0.50 x 0.6103	$ 91
	In 2025	300 SF @	0.50 x 0.5394	$ 81
	In 2030	300 SF @	0.50 x 0.4767	$ 71
	In 2035	300 SF @	0.50 x 0.4214	$ 63
	In 2040	300 SF @	0.50 x 0.3724	$ 56
	In 2045	300 SF @	0.50 x 0.3292	$ 49
Disposal/Salv.				
	2050	15,000SF @	3.50 x 0.2909	$ 15,275
Total (maintenance/Repairs For 50 Years in Current $'s)				$227,327
"Unit" L.C.C. (Excluding Initial Const. Cost)				$22733/LF
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 15.15/SF (of exposed wall)

(No Owner or A/E Services: Design, Admin, Mgt., Etc.)

Highway Noise Barriers
Initial & Reoccurring Construction & Maintenance Costs

Type Wall T-1 Description Glue-laminated Timber Wall Panles (Vertical Panels and Battend), Timber Posts

Assumed Wall Scope



Highway Noise Barriers

Initial & Reoccurring Construction & Maintenance Cost

Type Wall T-2 Description Timber Walls/Tropical Hardwood Between Timber Posts

(page 3) - "LCC" - Life Cycle Costing Analysis
Cost (In Present Time Dollars) For 50-Year Analysis Period Walls Including Maintenance, Repairs, Reconstruction and Disposal/Salvage)

- Assume 2000 Construction (Initial)
- 50-Year Analysis
- 3% Escalation/Year Ave. For Const.
- 5 1/2% Interest Escalation ($)
- Net 2 1/2% + Time Value of Money
- All Life Cycle Costs in Today's $

Reoccurring Costs: "LCC" Assumptions:

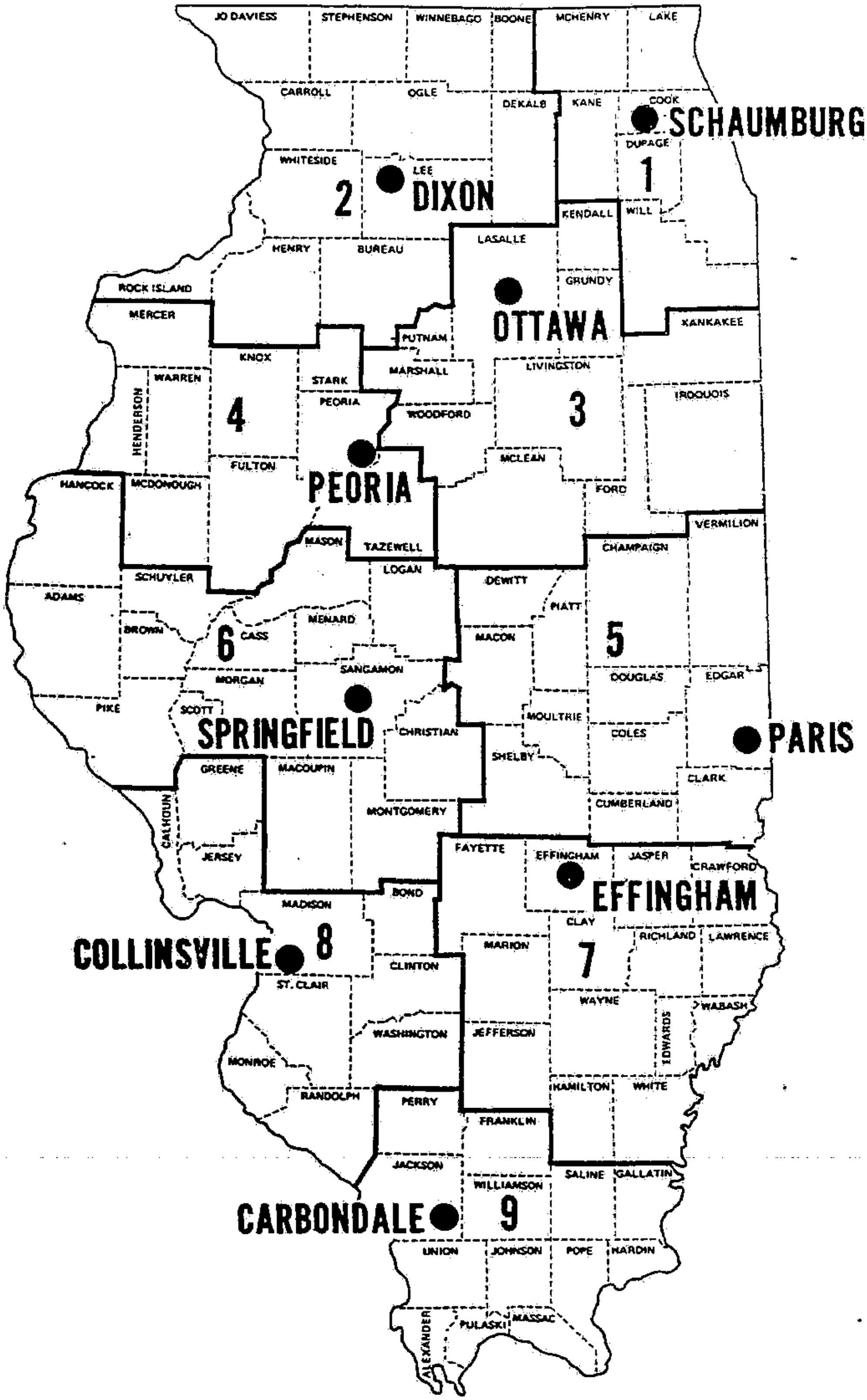
- Panel Replacement (1%/10 Years)
- Wall Re-Painting/Re-Sealing:
  - Graffiti Paint-Over (1%/5 Years)
- Wall Replacement 100 % 25 Years

	Year	Current (2000) Unit Costs	SPW Factor	
Panel Replacement:				
• Removal	2010	150 SF @	1.00 x 0.7812	$ 117
• Removal	2020	150 SF @	1.00 x 0.6103	$ 91
• Removal	2030	150 SF @	1.00 x 0.4767	$ 72
• Removal	2040	150 SF @	1.00 x 0.3724	$ 56
• Replacement	2010	150 SF @	8.50 x 0.7812	$ 996
• Replacement	2020	150 SF @	8.50 x 0.6103	$ 778
• Replacement	2030	150 SF @	8.50 x 0.4767	$ 608
• Replacement	2040	150 SF @	8.50 x 0.3724	$ 475
Graffiti Paint-Out Wall Panels				
	In 2005	300 SF@	0.50 x 0.8839	$ 132
	In 2010	300 SF @	0.50 x 0.7812	$ 117
	In 2015	300 SF @	0.50 x 0.6905	$ 104
	In 2020	300 SF @	0.50 x 0.6103	$ 91
	In 2025	300 SF @	0.50 x 0.5394	$ 81
	In 2030	300 SF @	0.50 x 0.4767	$ 71
	In 2035	300 SF @	0.50 x 0.4214	$ 63
	In 2040	300 SF @	0.50 x 0.3724	$ 56
	In 2045	300 SF @	0.50 x 0.3292	$ 49
Total Wall Replacement				
• Removal	In 2025	15,000 SF @	2.50 x 0.5394	$ 20,228
• Replacement	In 2025	15,000 SF @	16.70 x 0.5394	$135,170
Disposal/Salv.				
	2050	15,000SF @	2.50 x 0.2909	$ 10,910
Total (maintenance/Repairs For 50 Years in Current $'s)				$170,215
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 170.22/LF
"Unit" L.C.C. (Excluding Initial Const. Cost)				$ 11.35/SF (of exposed wall)

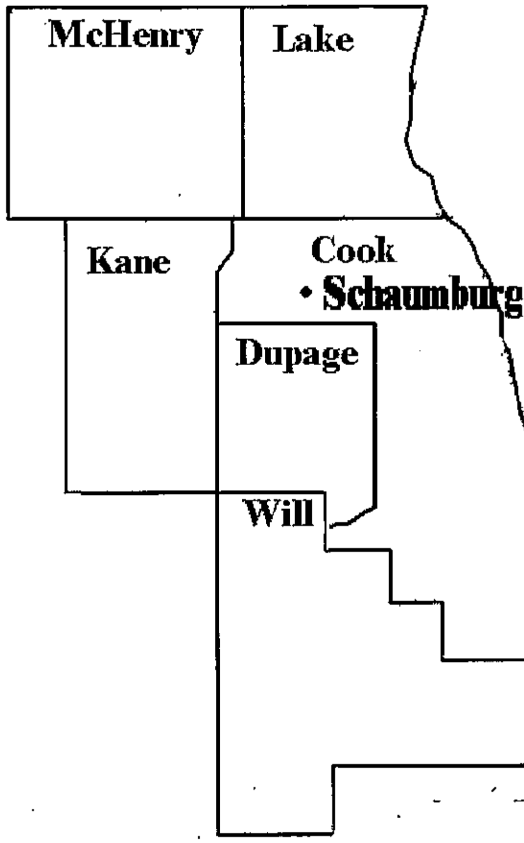
(No Owner or A/E Services: Design, Admin, Mgt., Etc.)

APPENDIX C
PHOTOGRAPHIC INDEX OF SELECTED HIGHWAY NOISE BARRIERS IN ILLINOIS AND NEIGHBORING STATES

ILLINOIS DEPARTMENT OF TRANSPORTATION
HIGHWAY DISTRICTS



District 1

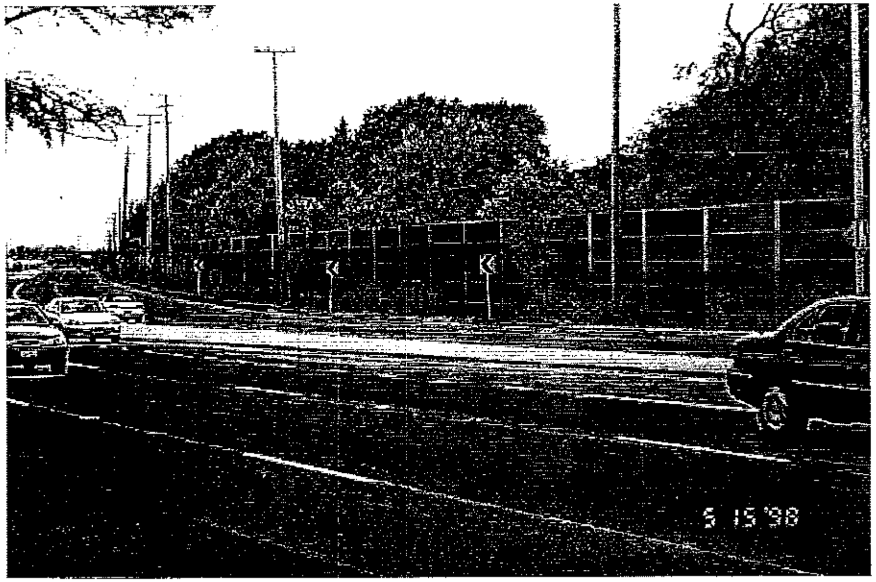


List of Photographs

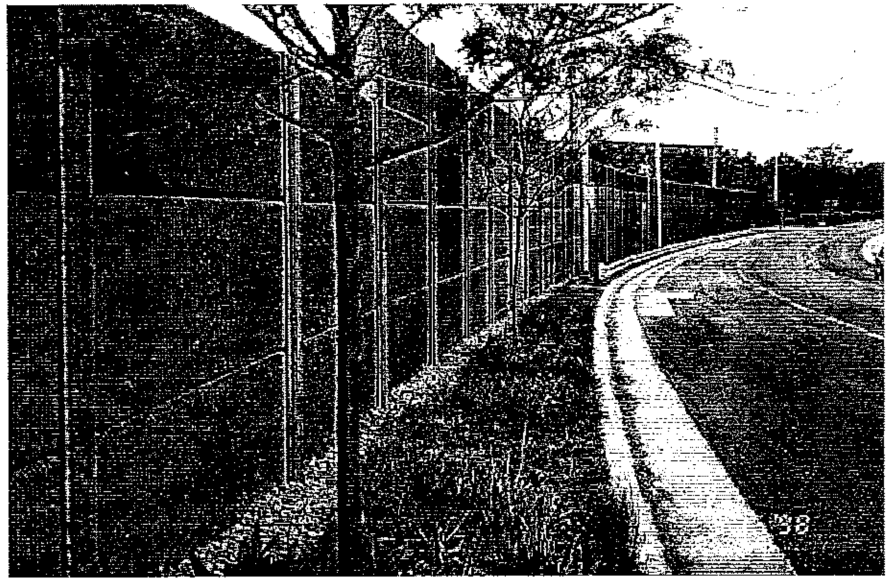
Photograph Number	Description	Page
1	Durisol, IL 19, Schaumburg	1-1
2	Durisol, IL 19, Schaumburg	1-1
3	Durisol, IL 19, Schaumburg, detail of surface texturing on highway side	1-1
4	Durisol, IL 19, Schaumburg, detail of surface texturing on residents' side	1-1
5	Durisol, detail at post, IL 19, Schaumburg	1-2
6	Durisol, fracture of covering for steel H-post, IL 19, Schaumburg	1-2
7	Durisol, IL 83 at Chicago Road	1-3
8	Durisol, IL 83 at Chicago Road, detail of surface texturing	1-3
9	Durisol facing over concrete retaining wall in underpass, IL 83 at Chicago Road	1-3
10	Durisol, IL 83 at Chicago Road	1-3
11	Durisol, IL 83 at Chicago Road	1-4

Photograph Number	Description	Page
12	Durisol, IL 83 at Chicago Road looking northwest	1-4
13	Durisol, IL 83 at Chicago Road looking northwest	1-4
14	Durisol, IL 83 at Chicago Road, residents' side of the wall (east side)	1-4
15	Durisol, fluted cast-in-place concrete on residents' side, IL 83 at Chicago Road	1-5
16	Durisol, IL 83 at Chicago Road	1-5
17	Wood glue-laminated panel scorched by fire, I-290	1-5
18	Wood glue-laminated, I-290	1-5
19	Wood glue-laminated, fire damaged, I-290	1-6
20	Tropical hardwood, I-355 north of Army Trail Road, highway side, built 1989	1-6
21	Tropical hardwood, I-355 north of Army Trail Road, highway side, built 1989	1-6
22	Tropical hardwood, I-355 north of Army Trail Road, highway side, built 1989	1-6
23	Tropical hardwood, I-355 north of Army Trail Road, highway side, built 1989	1-7
24	Tropical hardwood, I-355 north of Army Trail Road, highway side, built 1989	1-7
25	Tropical hardwood, I-355 DuPage County, vertical battens on residents' side, built 1989	1-7
26	Tropical hardwood, I-290, Thorndale Avenue, built 1989	1-7
27	Tropical hardwood, I-290 at Thorndale Avenue, built 1989	1-8
28	Tropical hardwood, I-290 at Thorndale Avenue, built 1989	1-8
29	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-8
30	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-8
31	Tropicla hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-9
32	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-9
33	Tropical hardwood, east of IL 53 at Lake Cook road, residents' side, built 1990	1-9
34	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-10
35	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-10
36	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-10
37	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-11

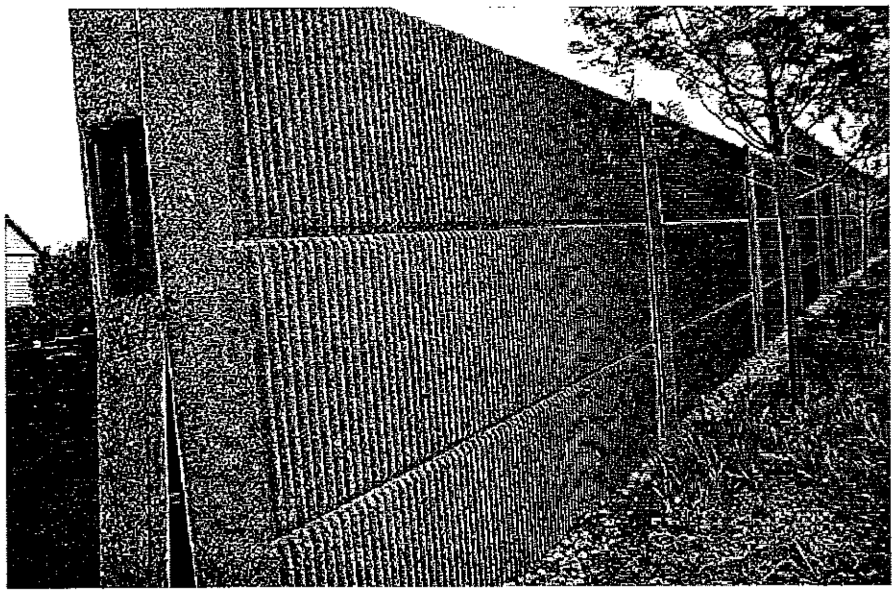
Photograph Number	Description	Page
38	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-11
39	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-11
40	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-11
41	Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side, built 1990	1-12
42	Tropical hardwood, west of IL 53 at Lake Cook Road, built 1990	1-12
43	Tropical hardwood, west of IL 53 at Lake Cook Road, built 1990	1-12
44	Tropical hardwood, west of IL 53 at Lake Cook Road, built 1990	1-12
45	Tropical hardwood, west of IL 53 at Lake Cook Road, built 1990	1-13
46	Tropical hardwood, west of IL 53 at Lake Cook Road, built 1990	1-13
47	Tropical hardwood, west of IL 53 at Lake Cook Road, built 1990	1-13
48	Tropical hardwood, west of IL 53 at Lake Cook Road, built 1990	1-13
49	Tropical hardwood, west of IL 53 at Lake Cook Road, built 1990	1-14
50	Tropical hardwood, west of IL 53 at Lake Cook Road, built 1990	1-14
51	Tropical hardwood, west of IL 53 at Lake Cook Road, built 1990	1-15
52	Glue-laminated wood barrier, IL 53, Bolingbrook, built 1980	1-15
53	Glue-laminated wood barrier, IL 53, Bolingbrook, built 1980	1-15



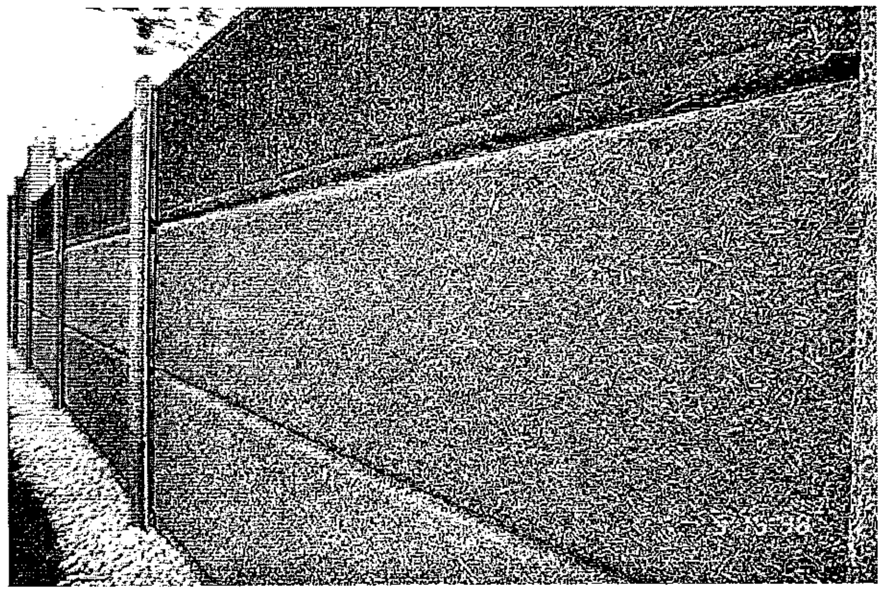
1. **Durisol, IL 19, Schaumburg**



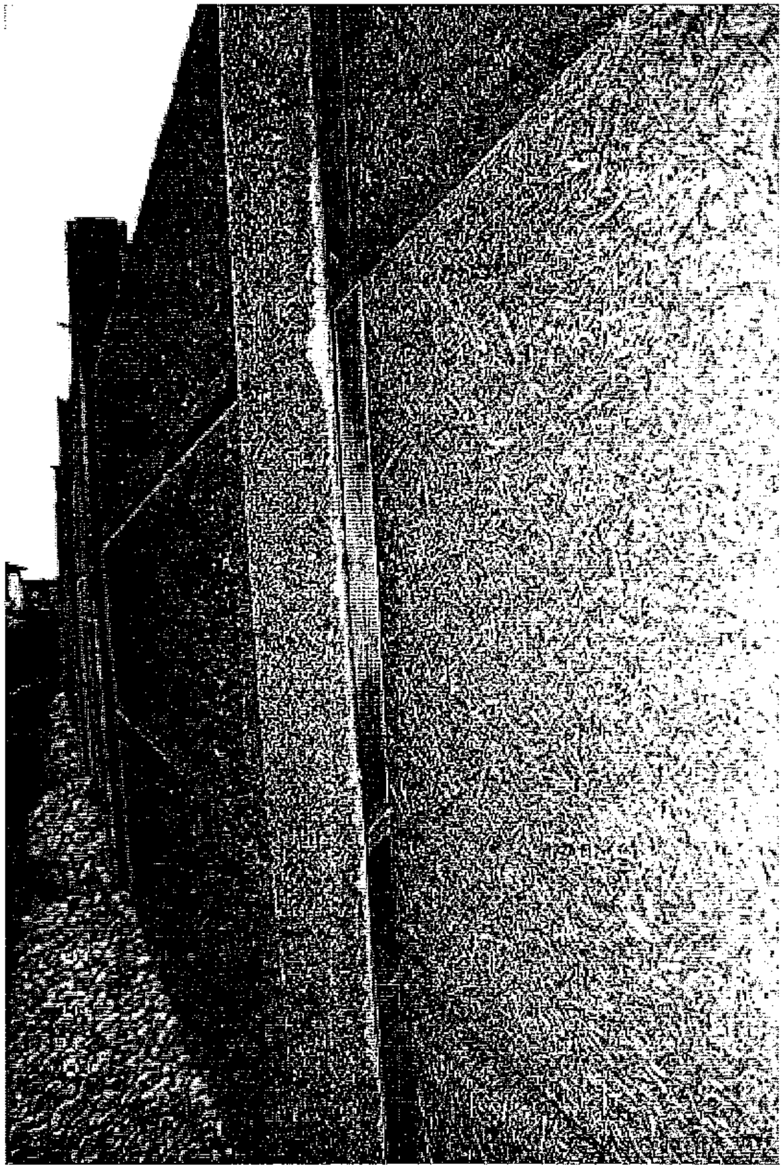
2. **Durisol, IL 19, Schaumburg**



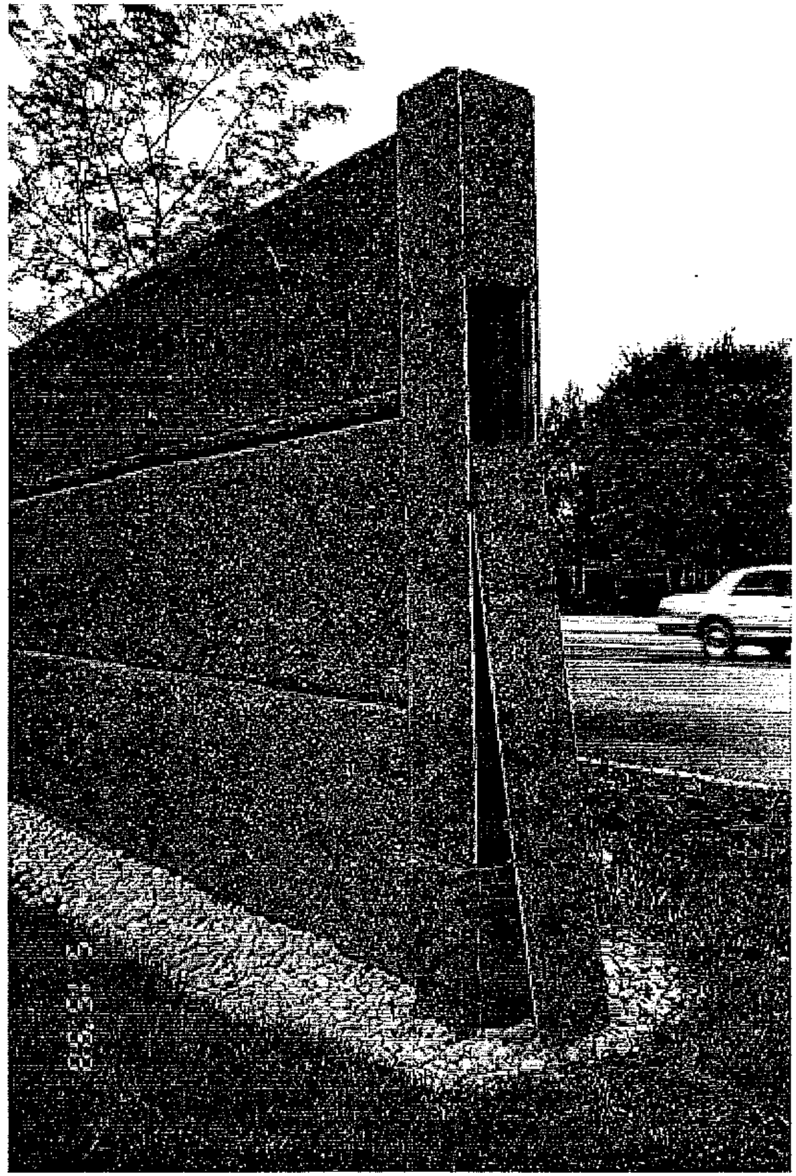
3. **Durisol, IL 19, Schaumburg, detail of surface texturing on highway side.**



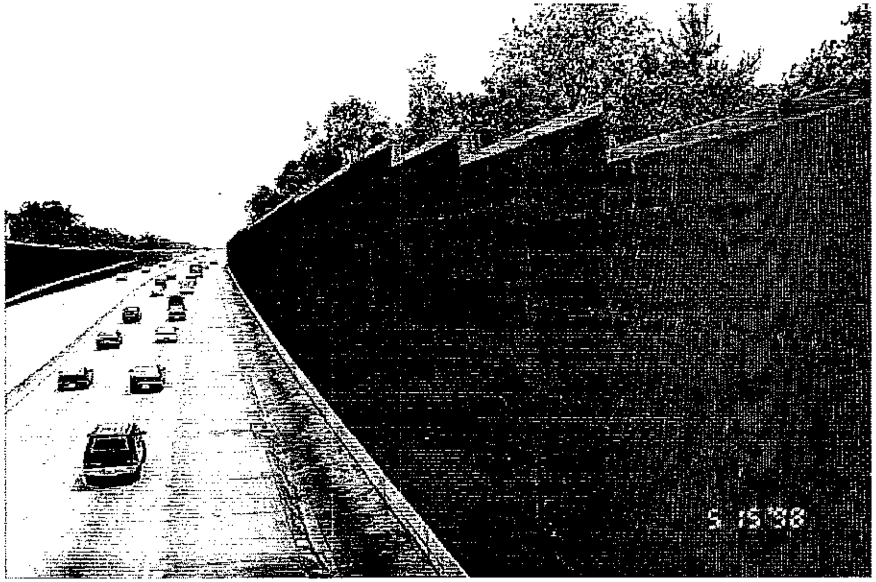
4. **Durisol, IL 19, Schaumburg, detail of surface texturing on residents' side.**



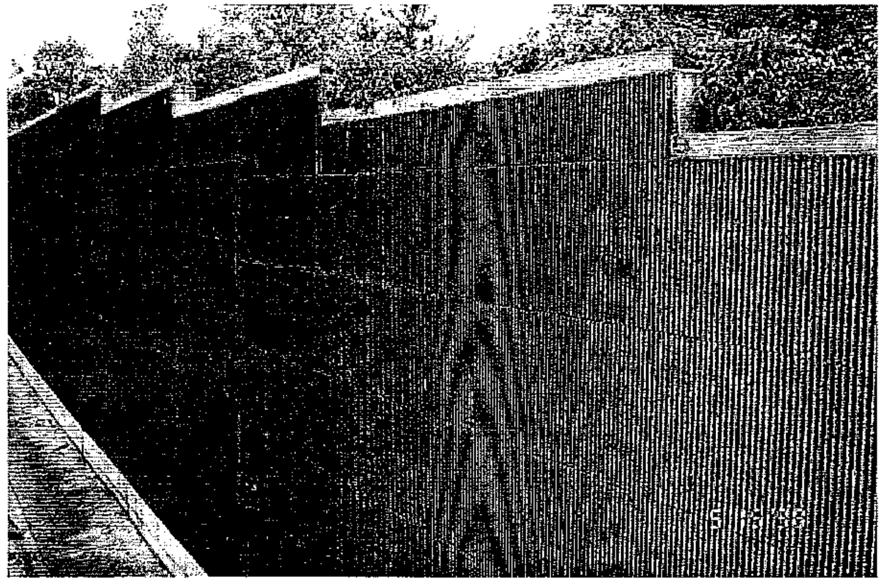
5. Durisol, detail at post, IL 19, Schaumburg



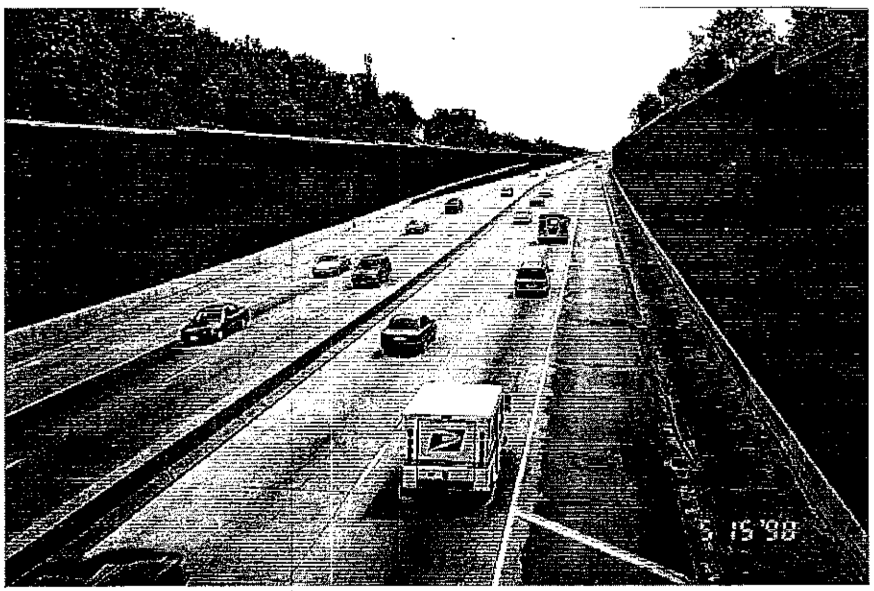
6. Durisol, fracture of covering for steel H-post, IL 19, Schaumburg



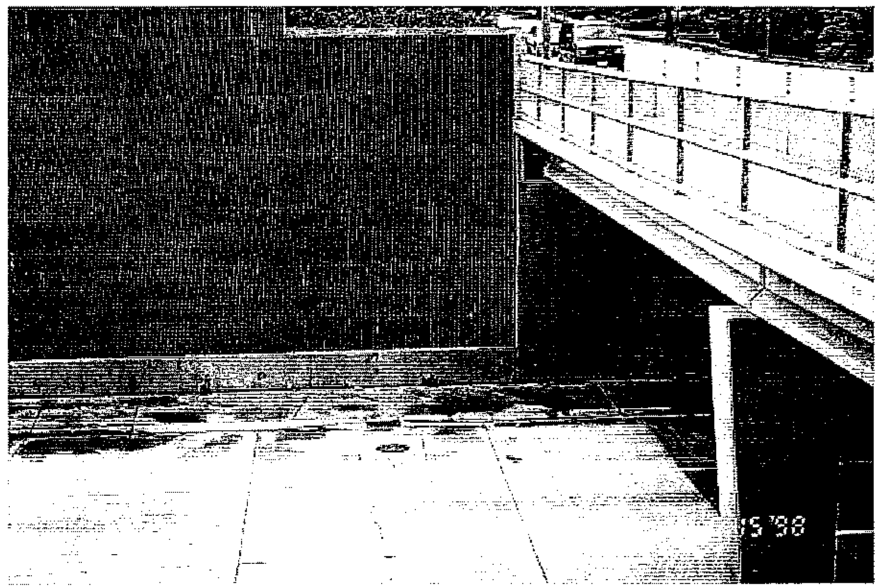
7. Durisol, IL 83 at Chicago Road



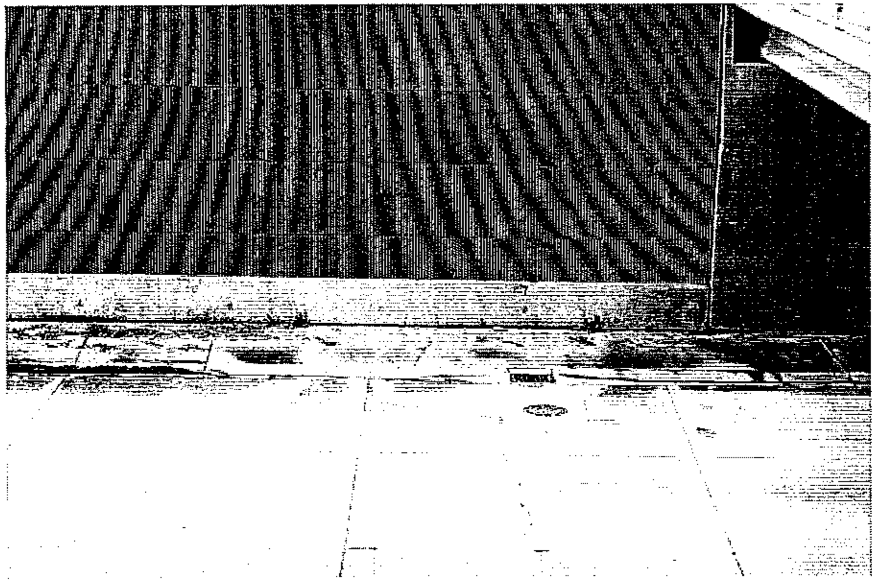
8. Durisol, IL 83 at Chicago Road, detail of surface texturing



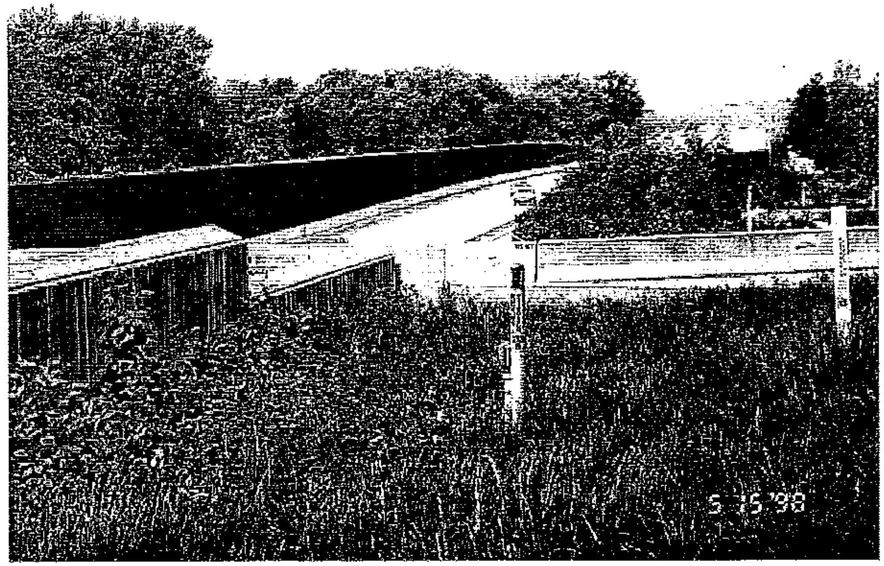
9. Durisol facing over concrete retaining wall in underpass, IL 83 at Chicago Road



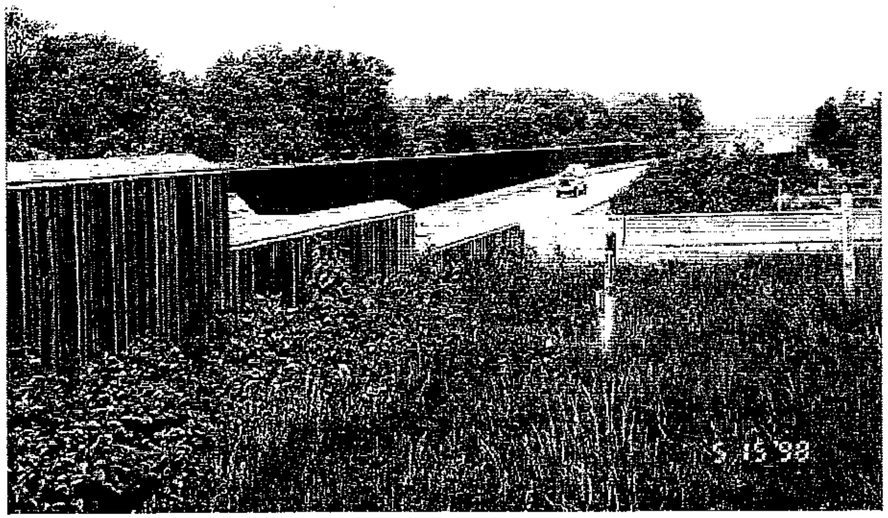
10. Durisol, IL 83 at Chicago Road



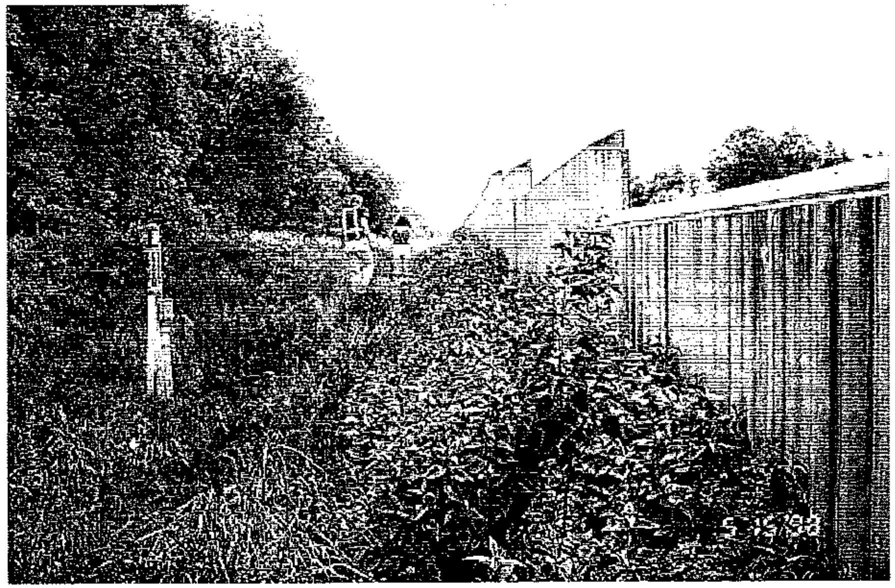
11. Durisol, IL 83 at Chicago Road



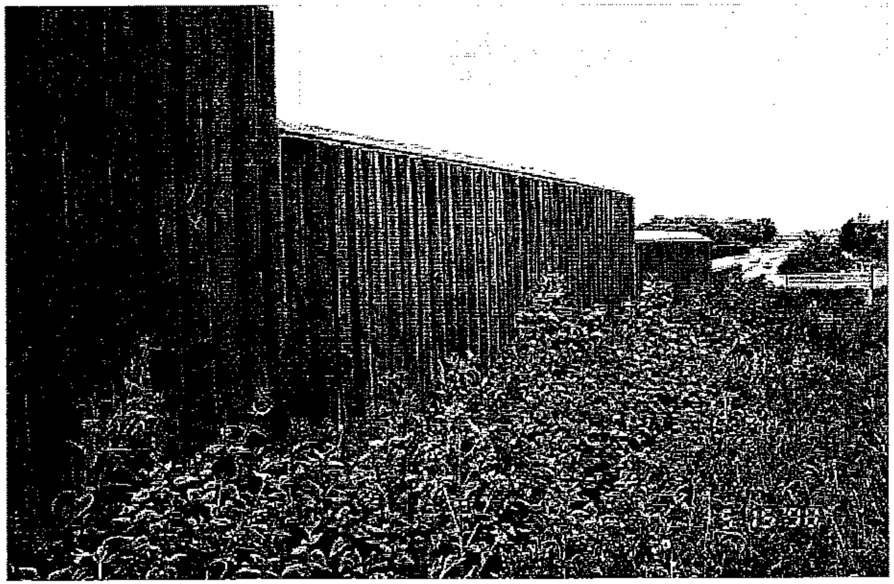
12. Durisol, IL 83 at Chicago Road looking northwest



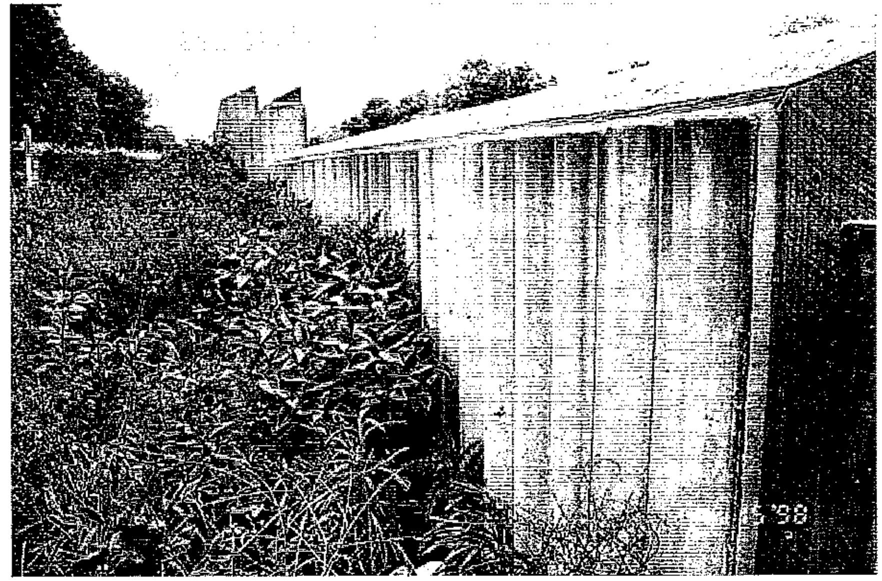
13. Durisol, IL 83 at Chicago Road looking northwest



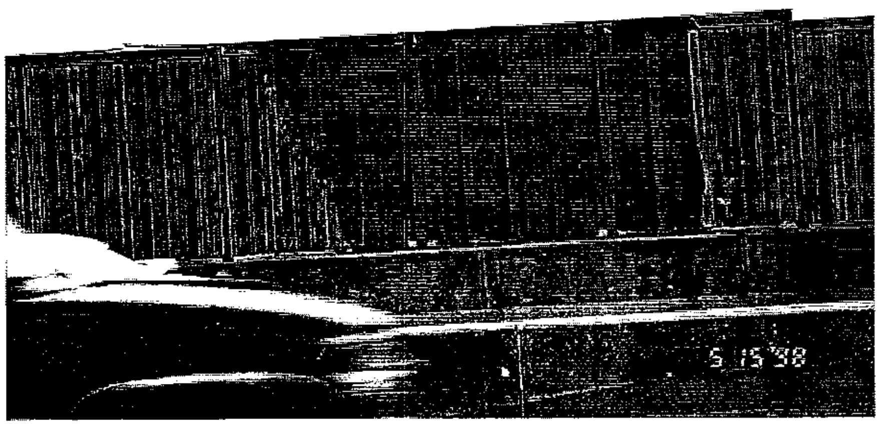
14. Durisol, IL 83 at Chicago Road, residents' side of the wall (east side)



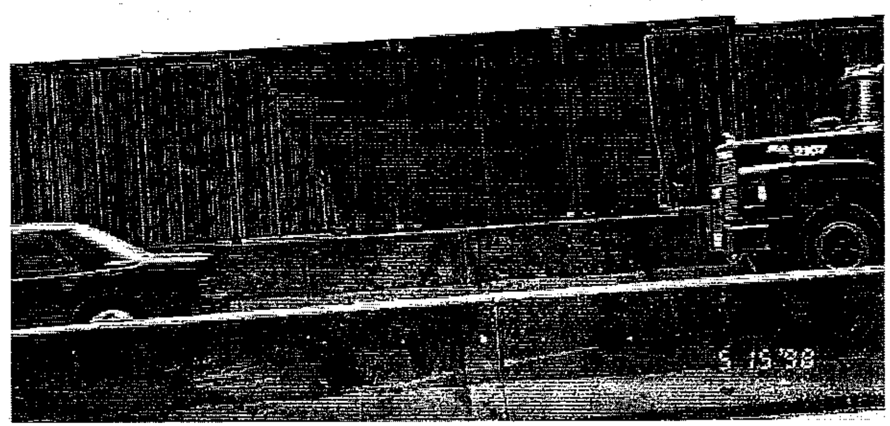
15. Durisol, fluted cast-in-place concrete on residents' side, IL 83 at Chicago Road



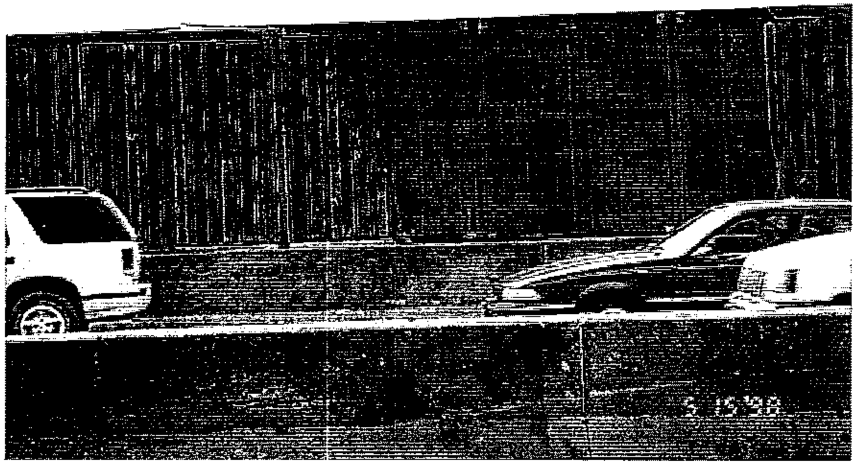
16. Durisol, IL 83 at Chicago Road

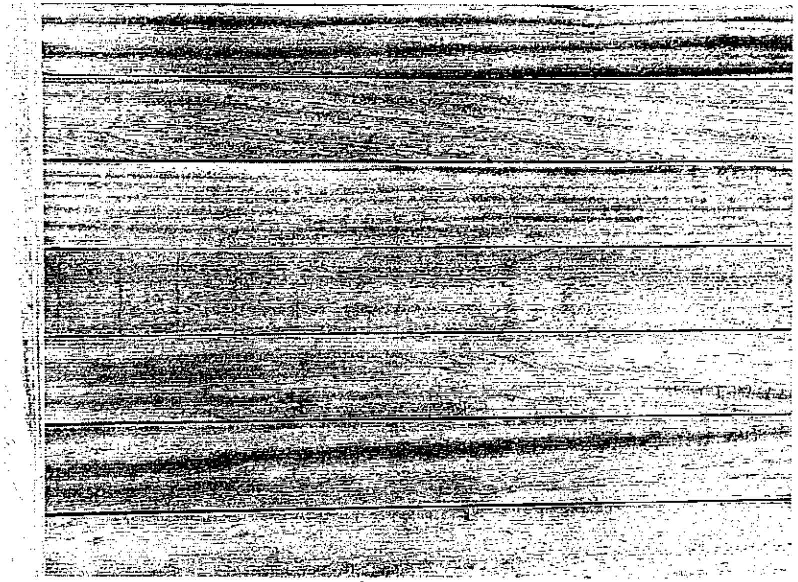


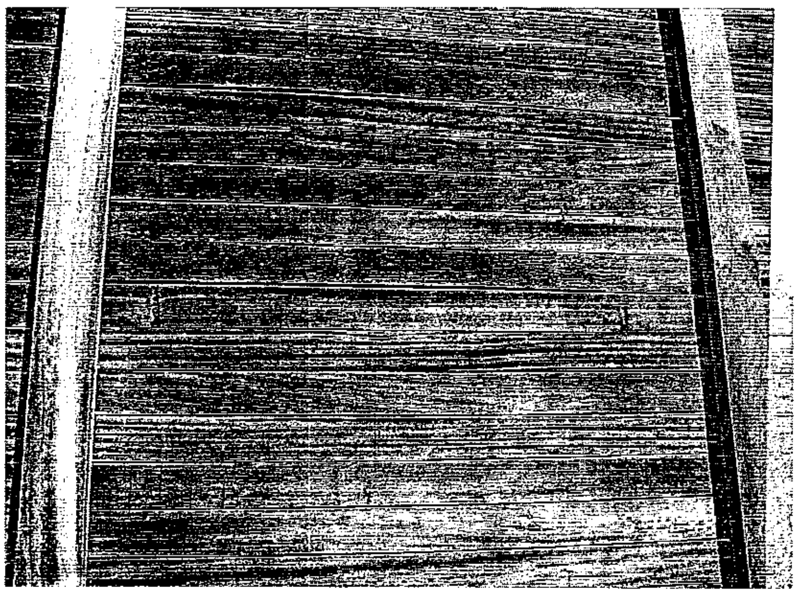
17. Wood glue-laminated panel scorched by fire, I-290

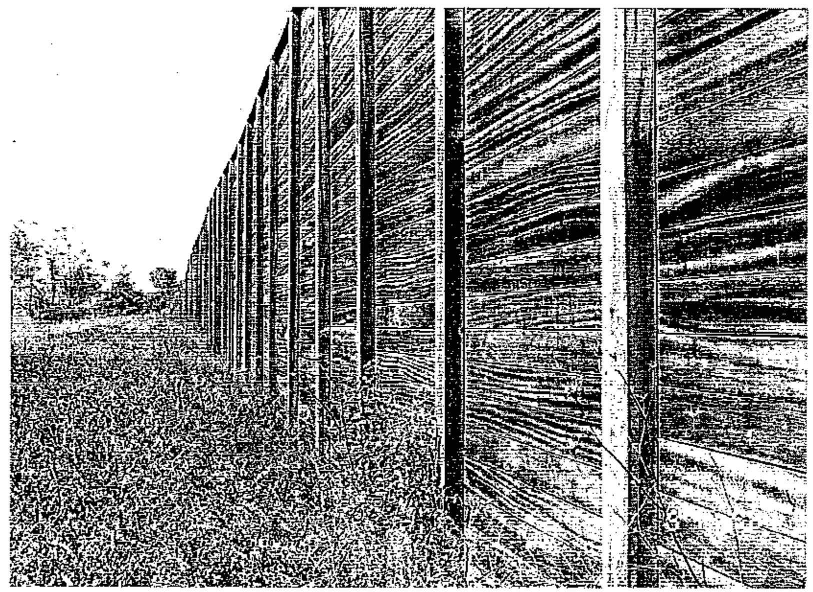


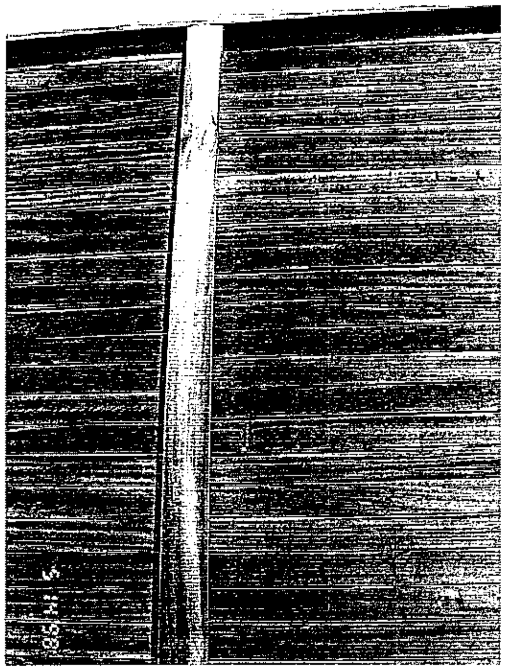
18. Wood glue-laminated, I-290


19. Wood glue-laminated, fire damaged, I-290


20. Tropical hardwood, I-355, north of Army Trail Road, highway side built 1989

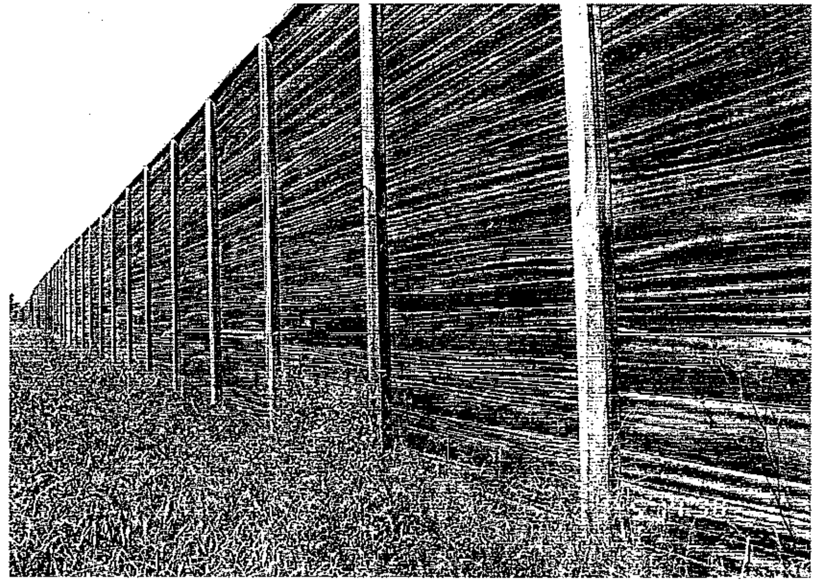

21. Tropical hardwood, I-355, north of Army Trail Road, highway side built 1989


22. Tropical hardwood, I-355, north of Army Trail Road, highway side built 1989

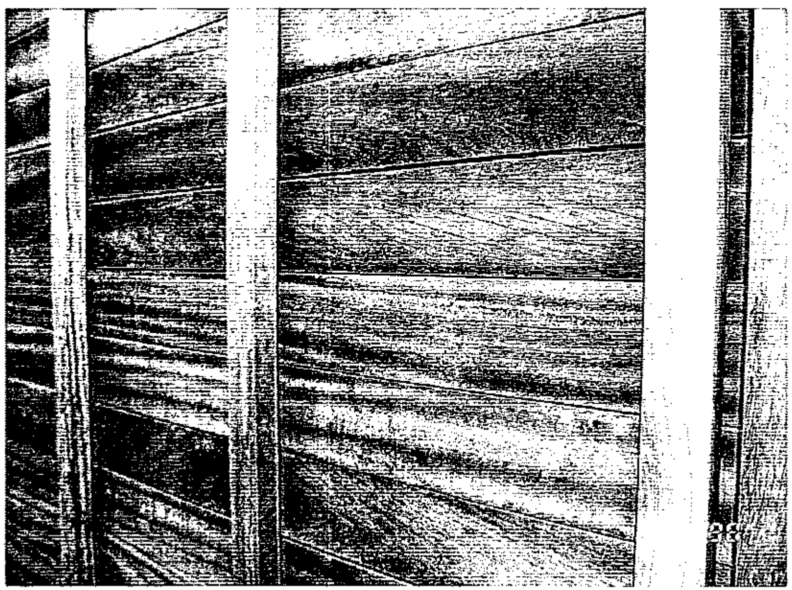


23. Tropical hardwood, I-355 north of Army Trail Road, highway side

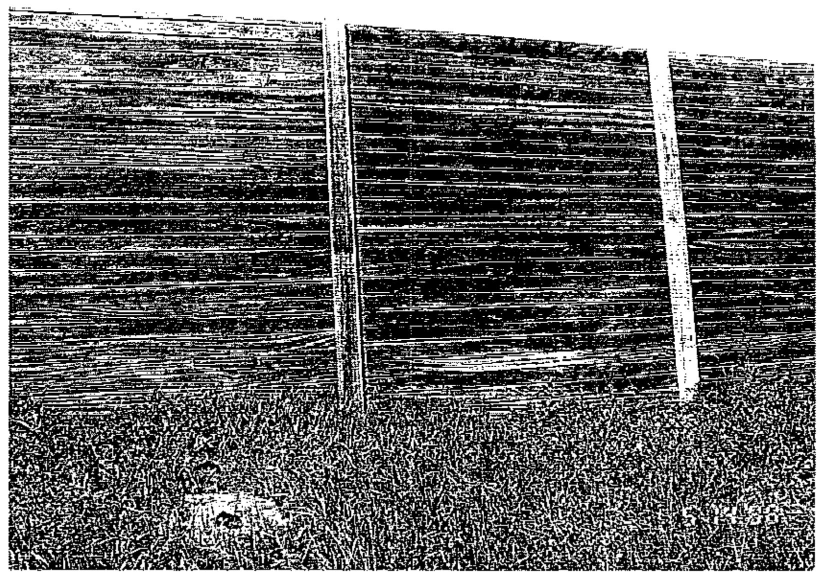
built 1989



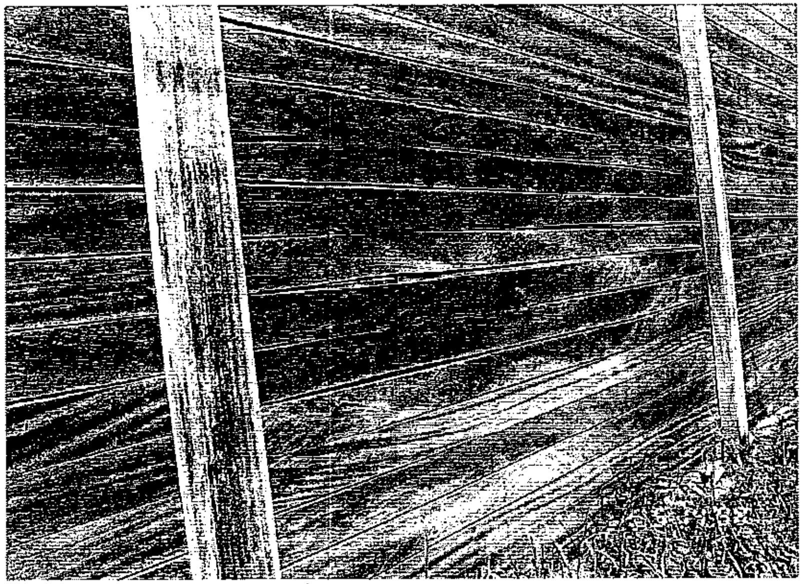
24. Tropical hardwood, I-355, north of Army Trail Road, highway side built 1989

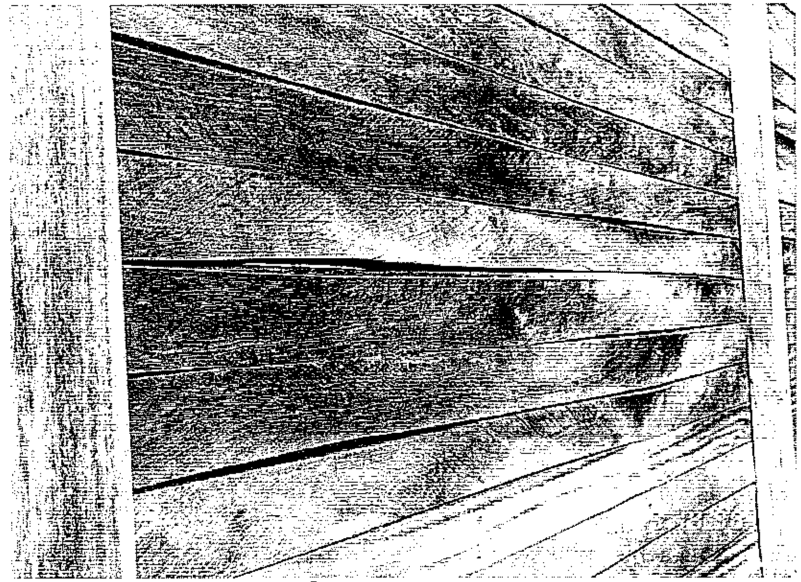


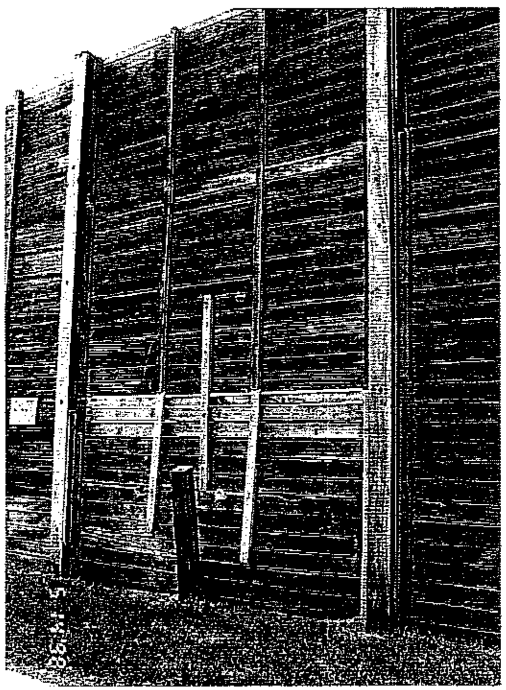
25. Tropical hardwood, I-355, DuPage County, vertical battens on residents' side built 1989



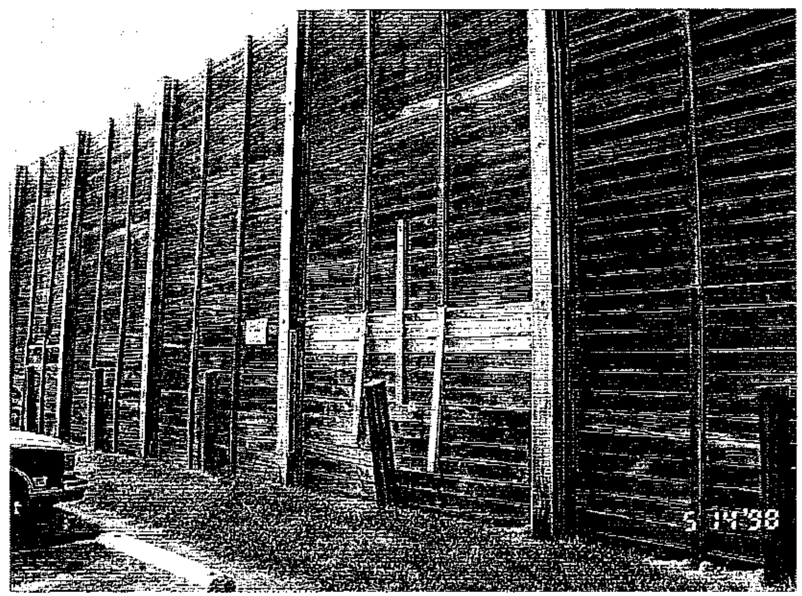
26. Tropical hardwood, I-290, Thorndale Avenue built 1989


27. Tropical hardwood, I-290 at Thorndale Avenue built 1989

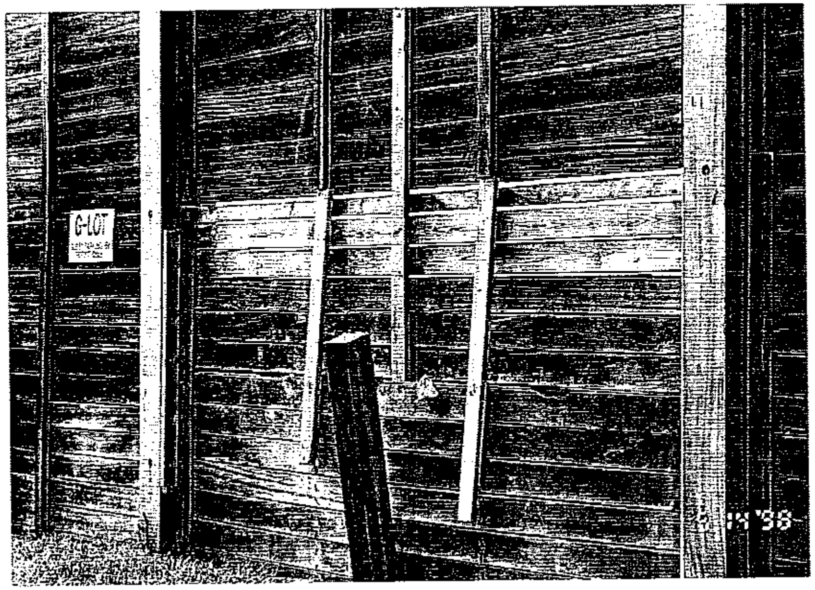

28. Tropical hardwood, I-290 at Thorndale Avenue built 1989


29. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side

built 1989

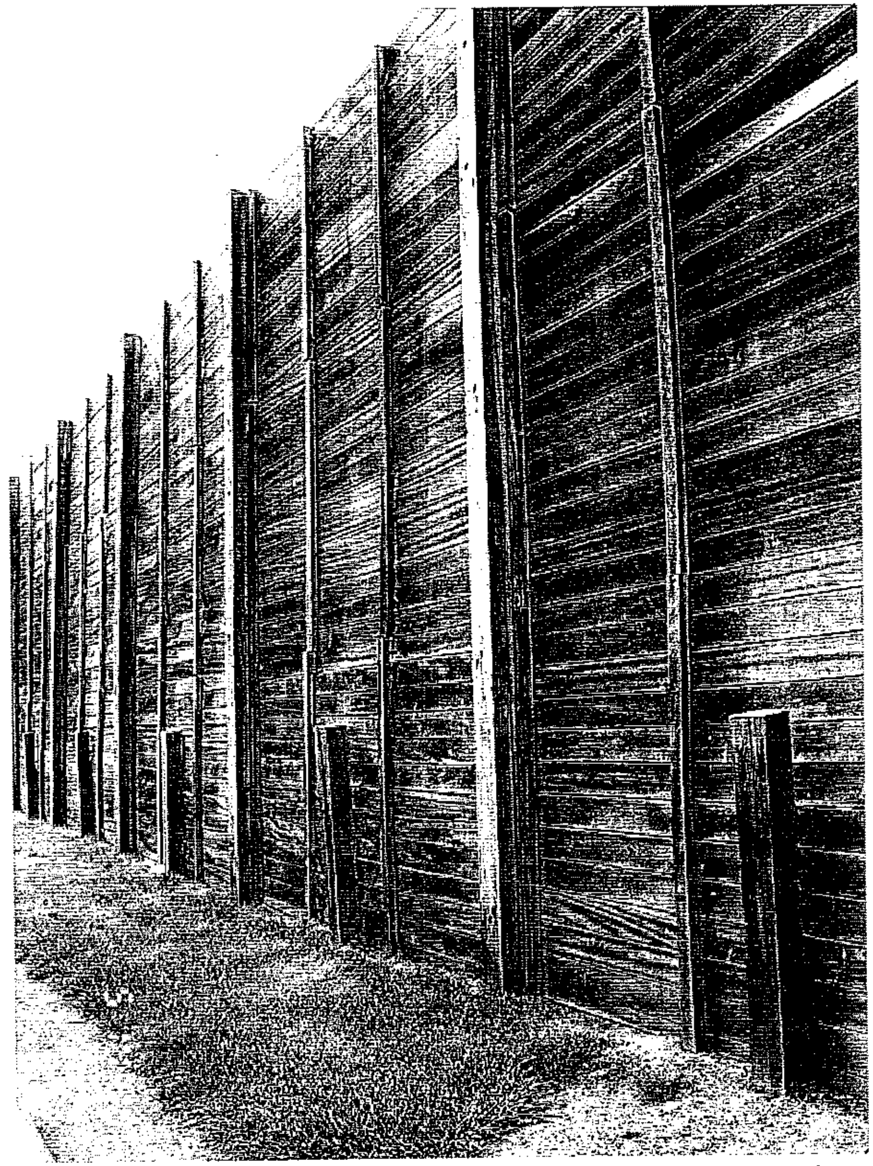


30. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990

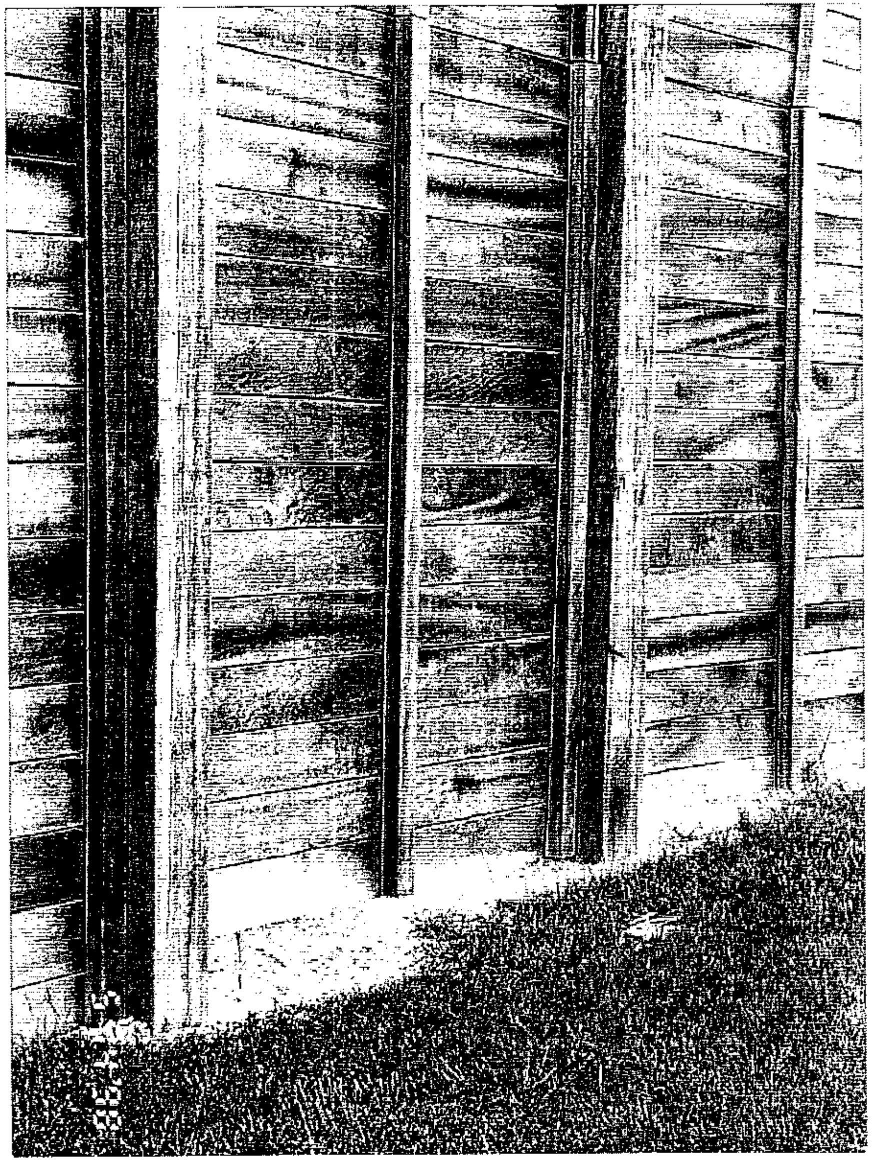


31. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990

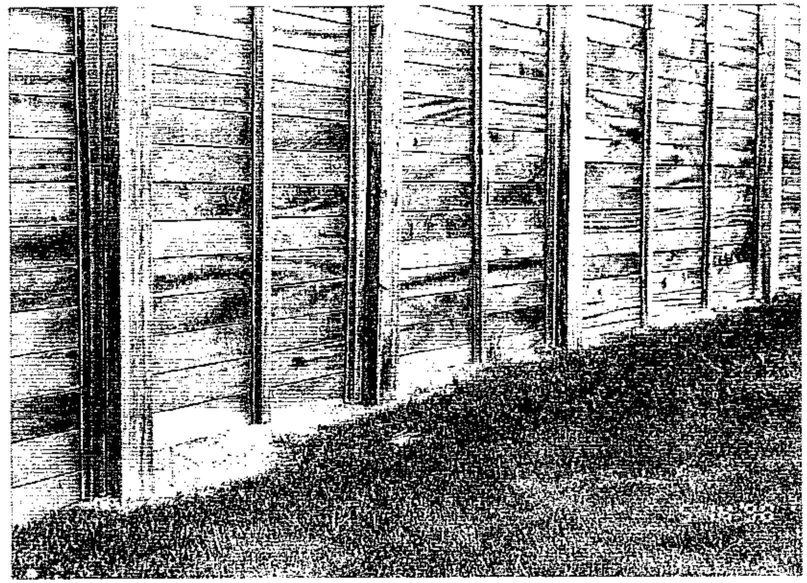
33. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990



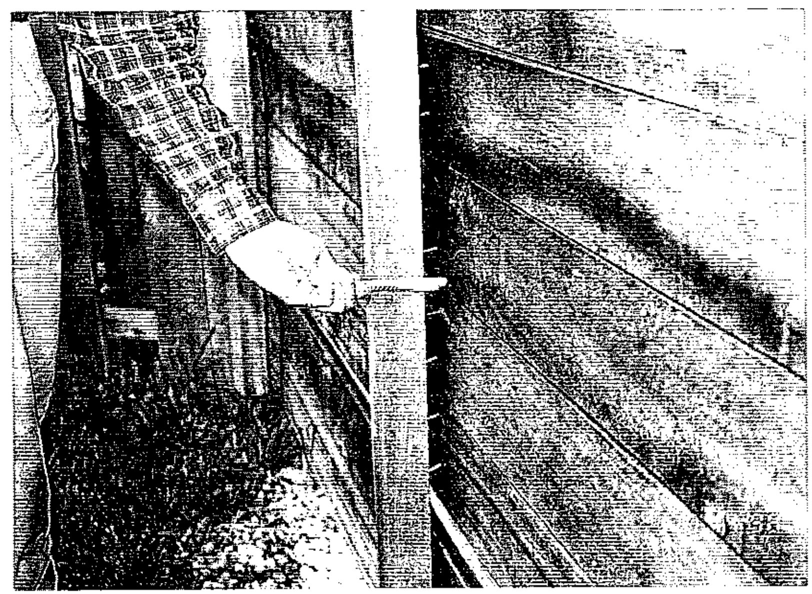
32. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990



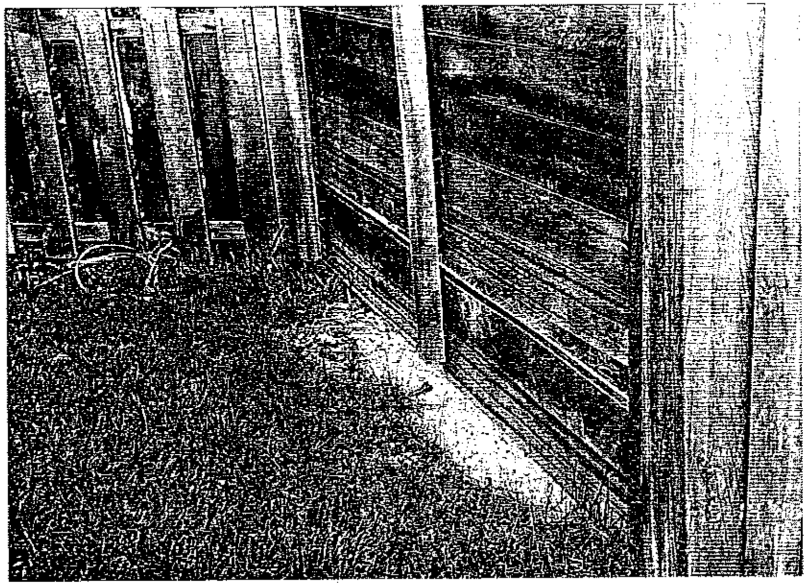
34. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990



35. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990

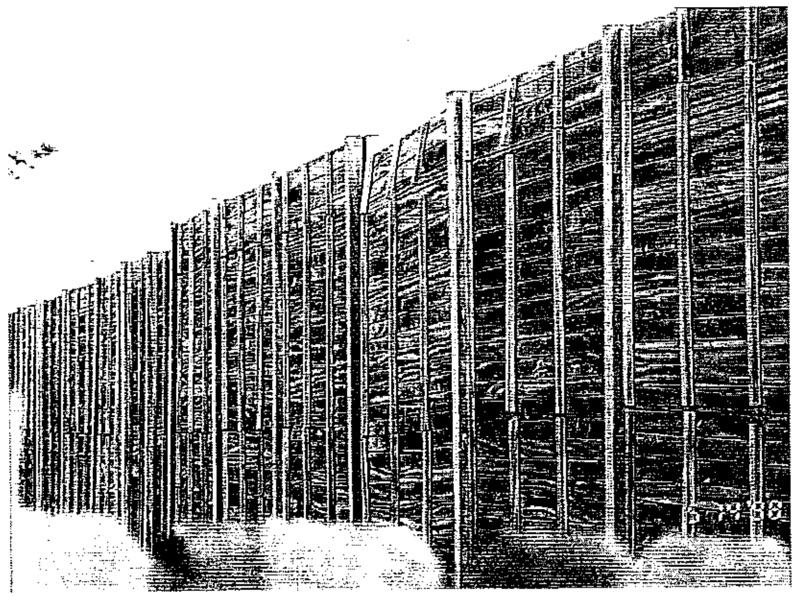


36. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990



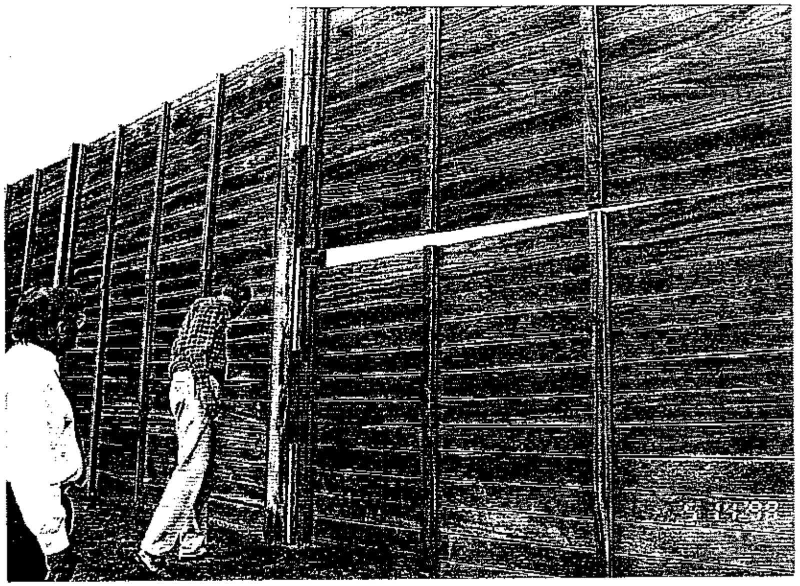
37. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990

38. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990

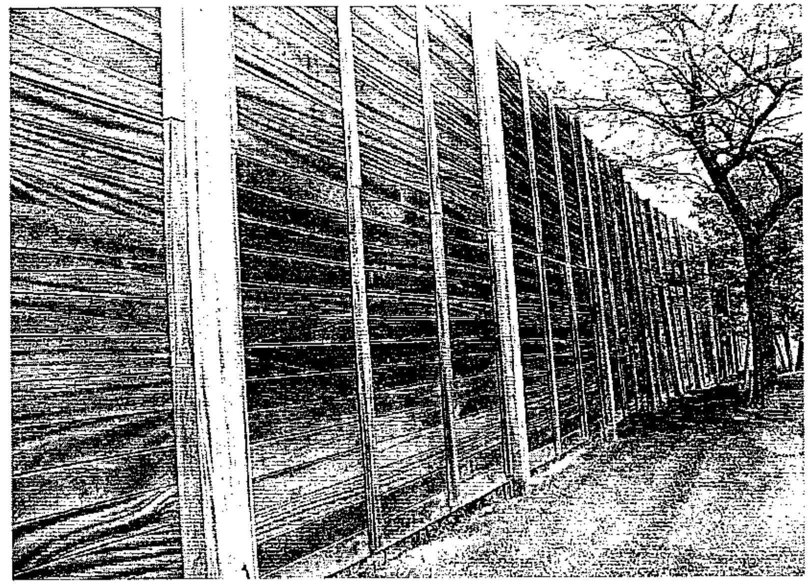


39. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990

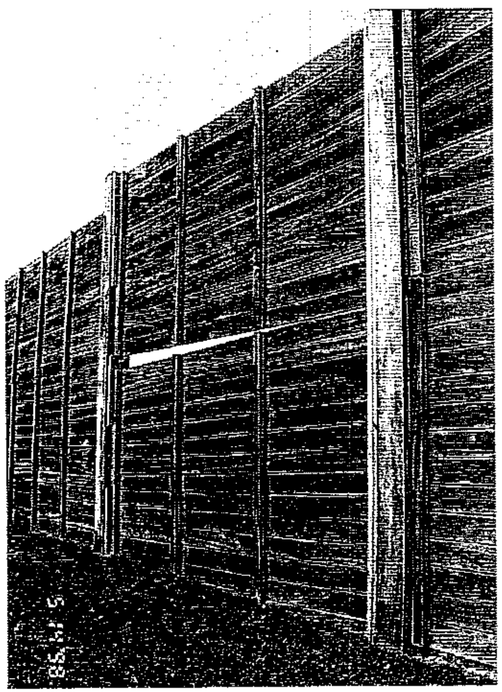
40. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990



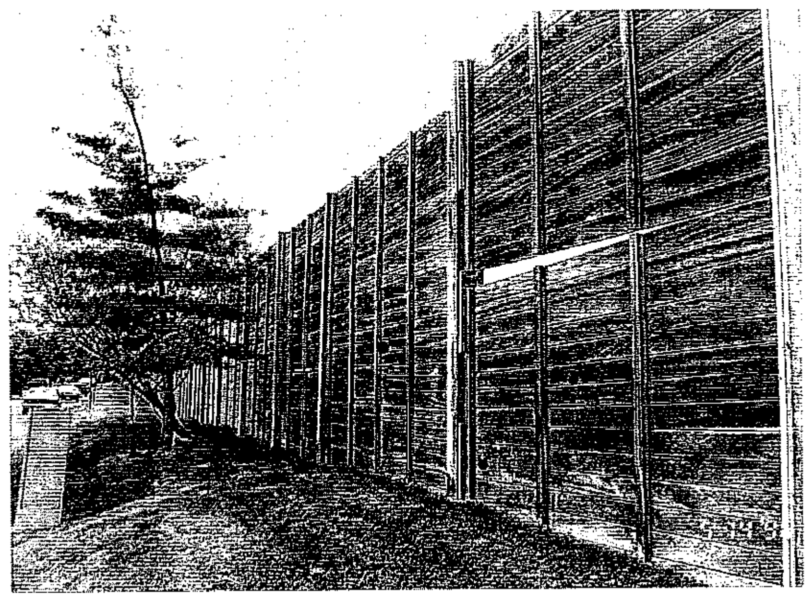
41. Tropical hardwood, east of IL 53 at Lake Cook Road, residents' side built 1990



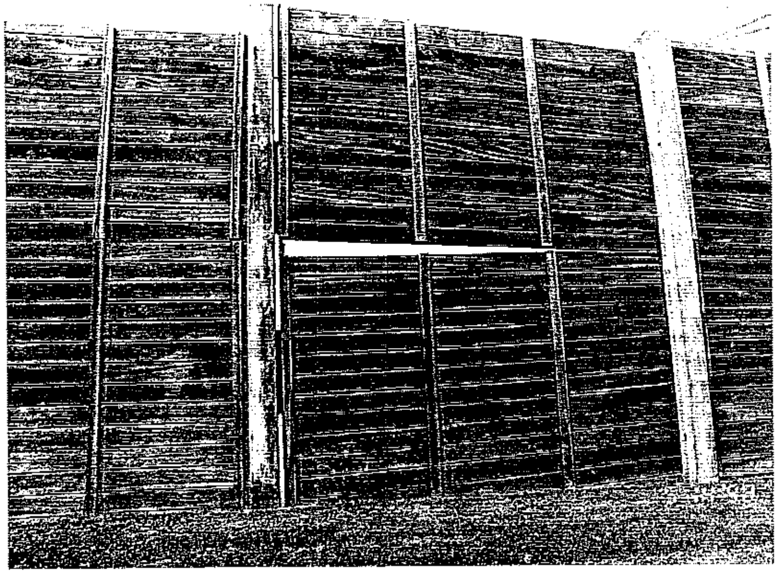
42. Tropical hardwood, west of IL 53 at Lake Cook Road built 1990



43. Tropical hardwood, west of IL 53 at Lake Cook Road built 1990

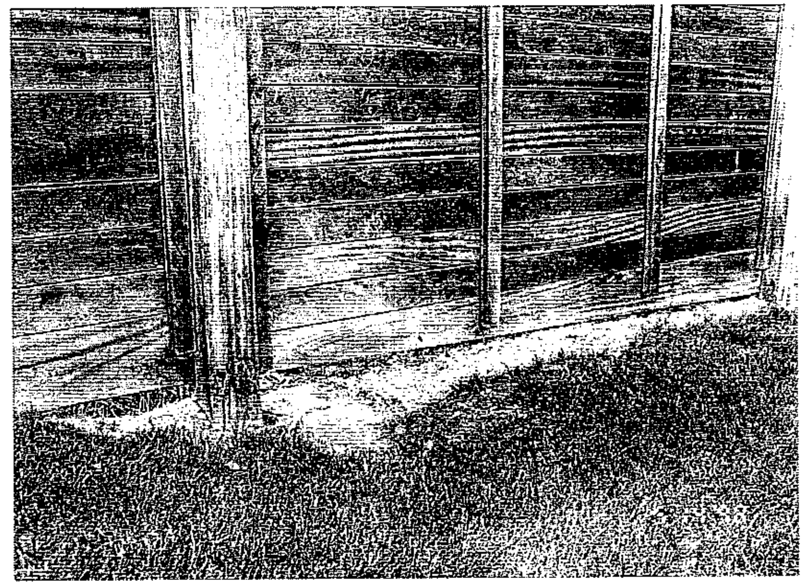


44. Tropical hardwood, west of IL 53 at Lake Cook Road built 1990



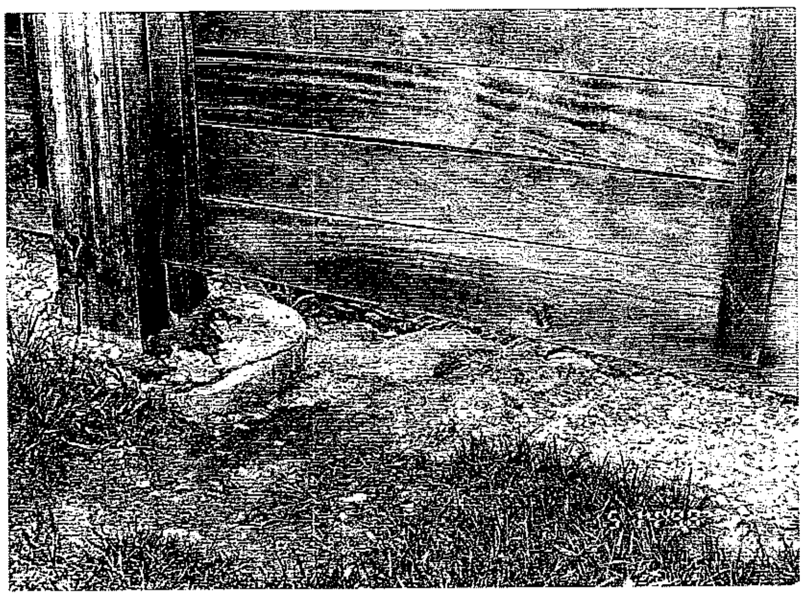
45. Tropical hardwood, west of IL 53 at Lake Cook Road

built 1990



46. Tropical hardwood, west of IL 53 at Lake Cook Road

built 1990

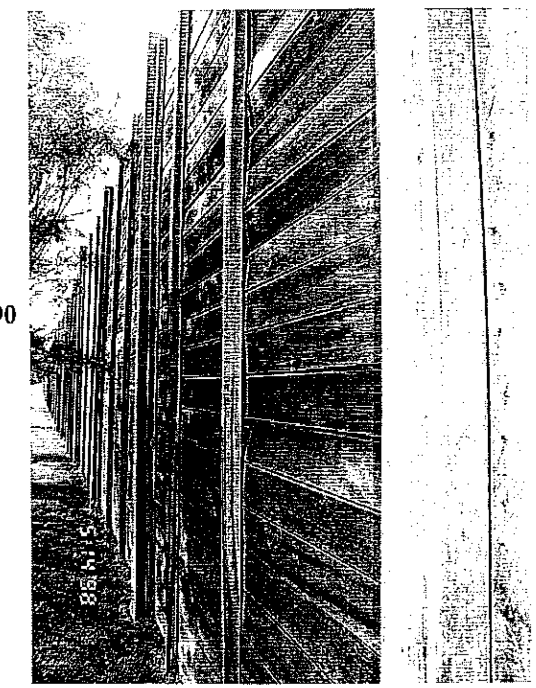


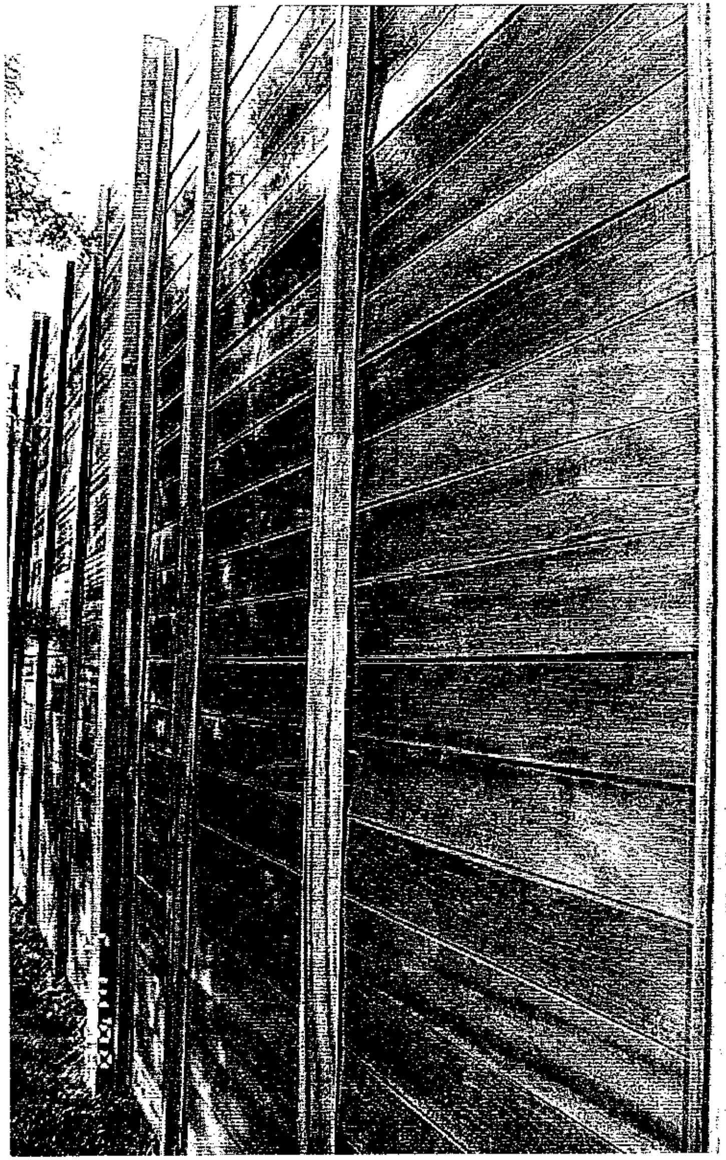
47. Tropical hardwood, west of IL 53 at Lake Cook Road

built 1990

48. Tropical hardwood, west of IL 53 at Lake Cook Road

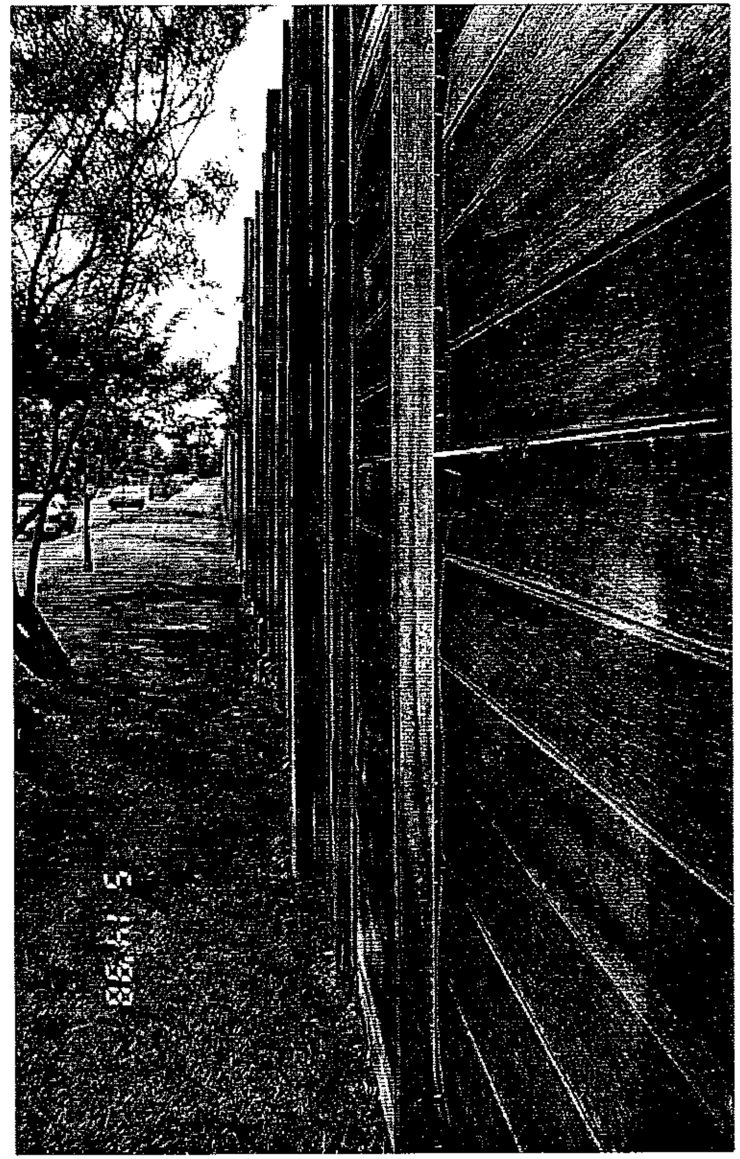
built 1990





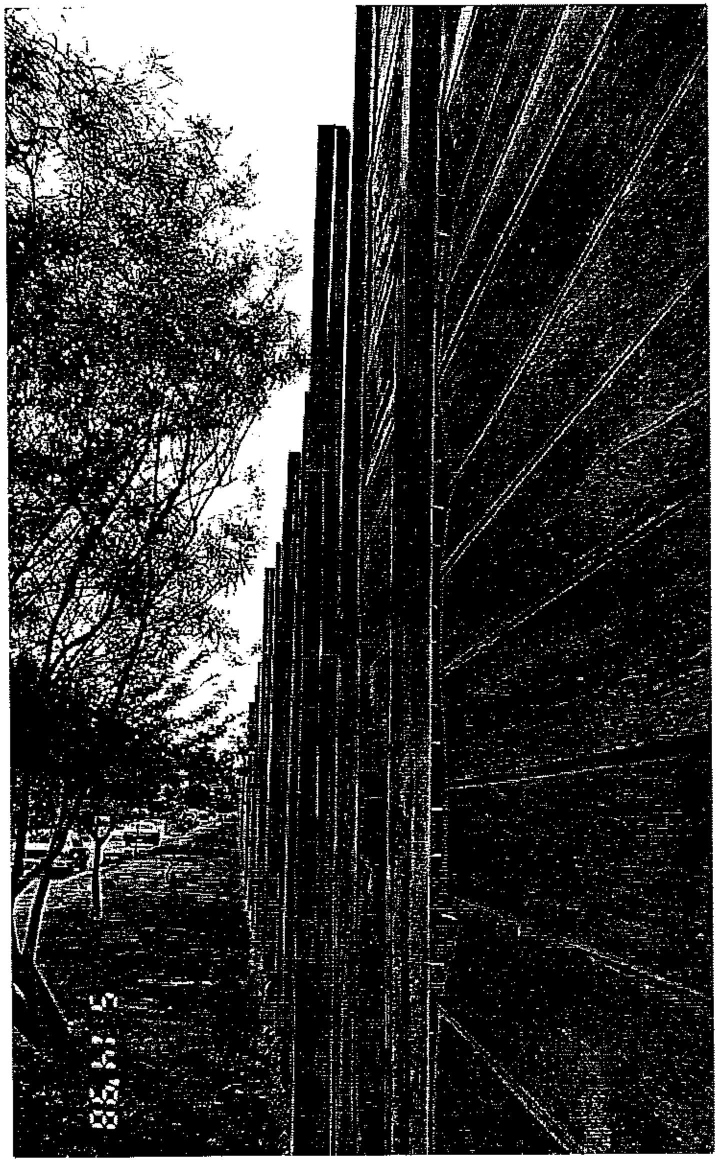
49. Tropical hardwood, west of IL 53 at Lake Cook Road

built 1990

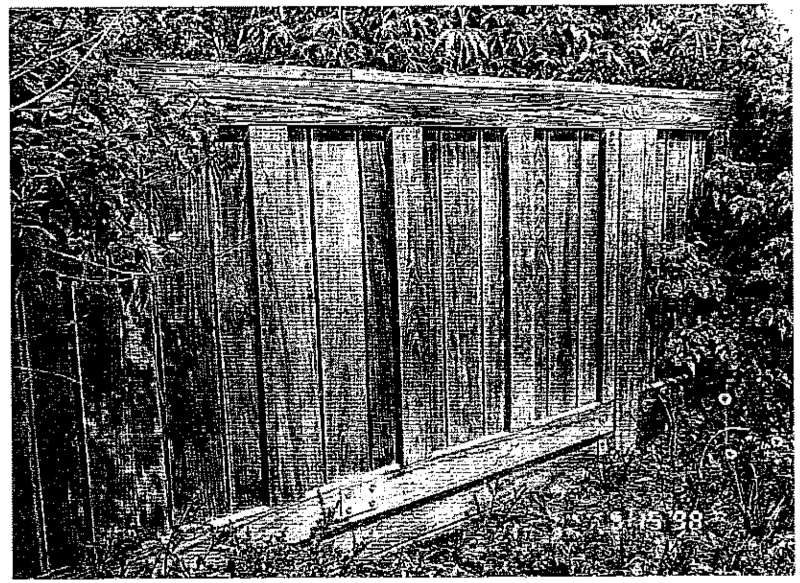


50. Tropical hardwood, west of IL 53 at Lake Cook Road

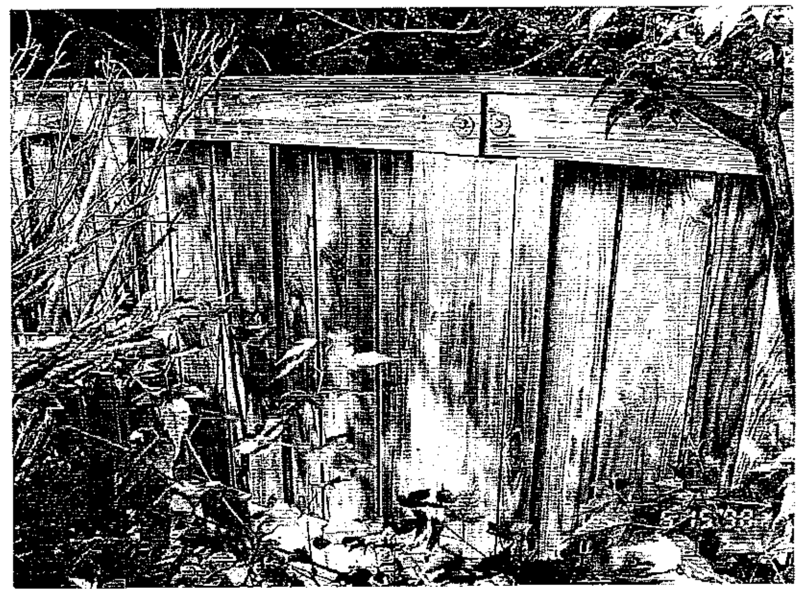
built 1990



51. Tropical hardwood, west of IL 53 at Lake Cook Road built 1990

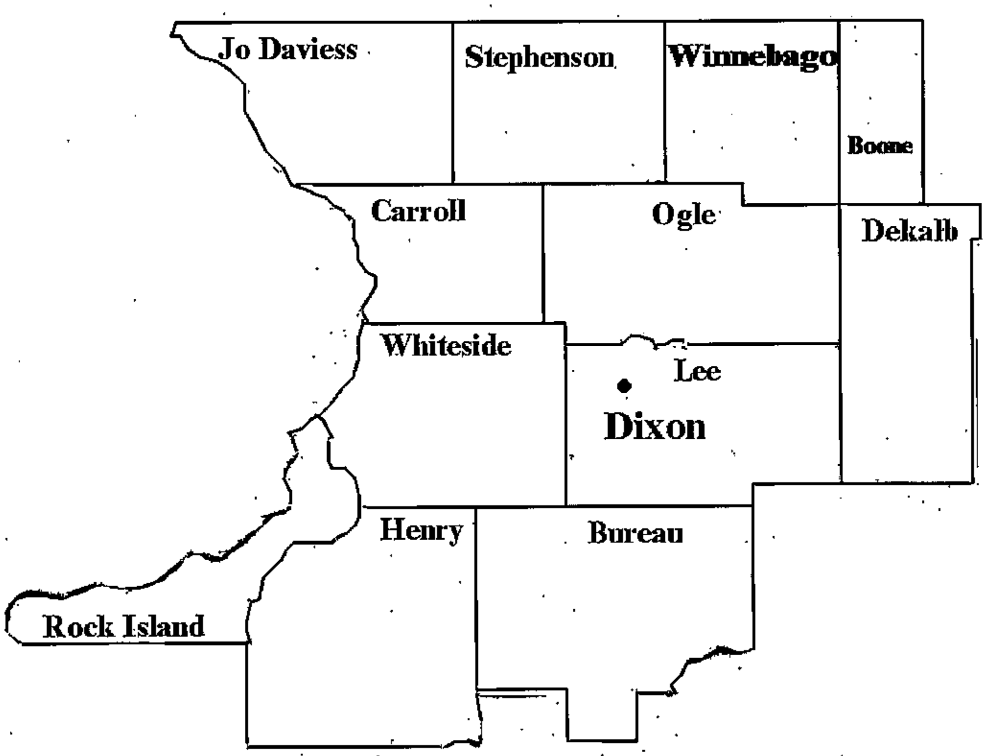


52. Glue-laminated wood barrier, IL 53 Bolingbrook built 1980

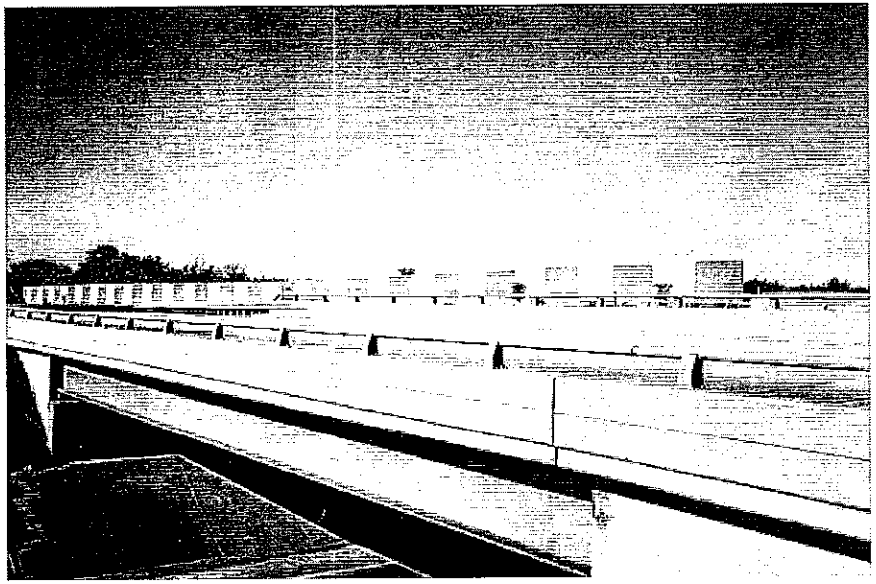


53. Glue-laminated wood barrier, IL 53, Bolingbrook built 1980

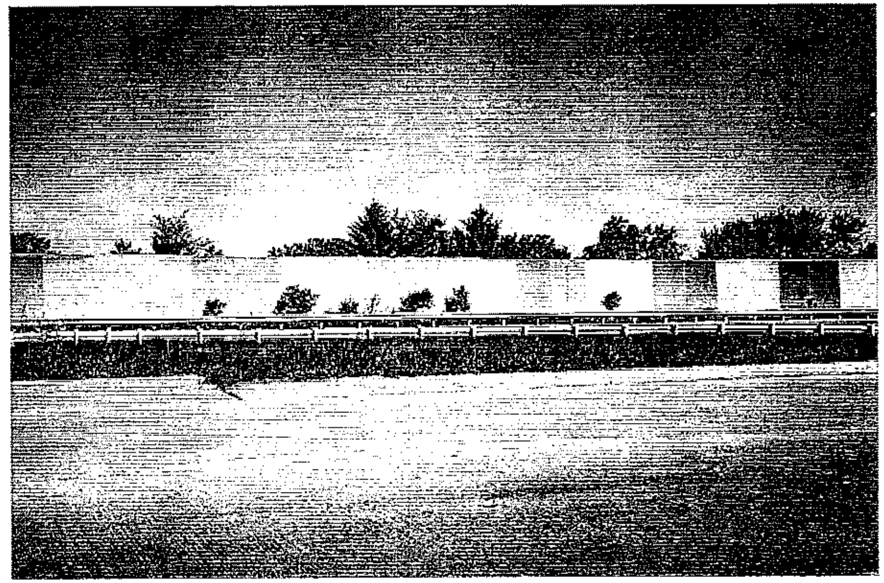
District 2



List of Photographs

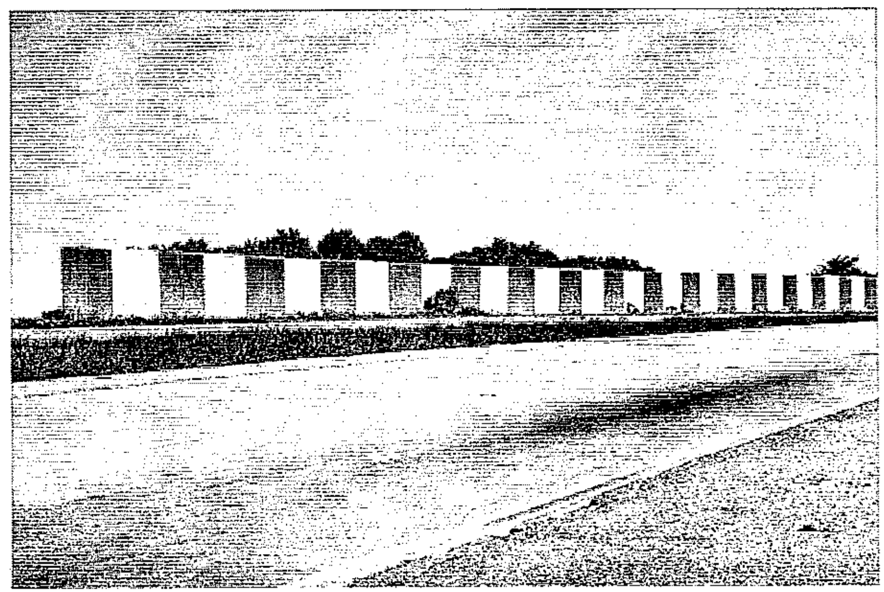


1. **Precast concrete (cantilever) with alternating surface treatments, IL 39 over Blackhawk Road, Rockford built 1980**



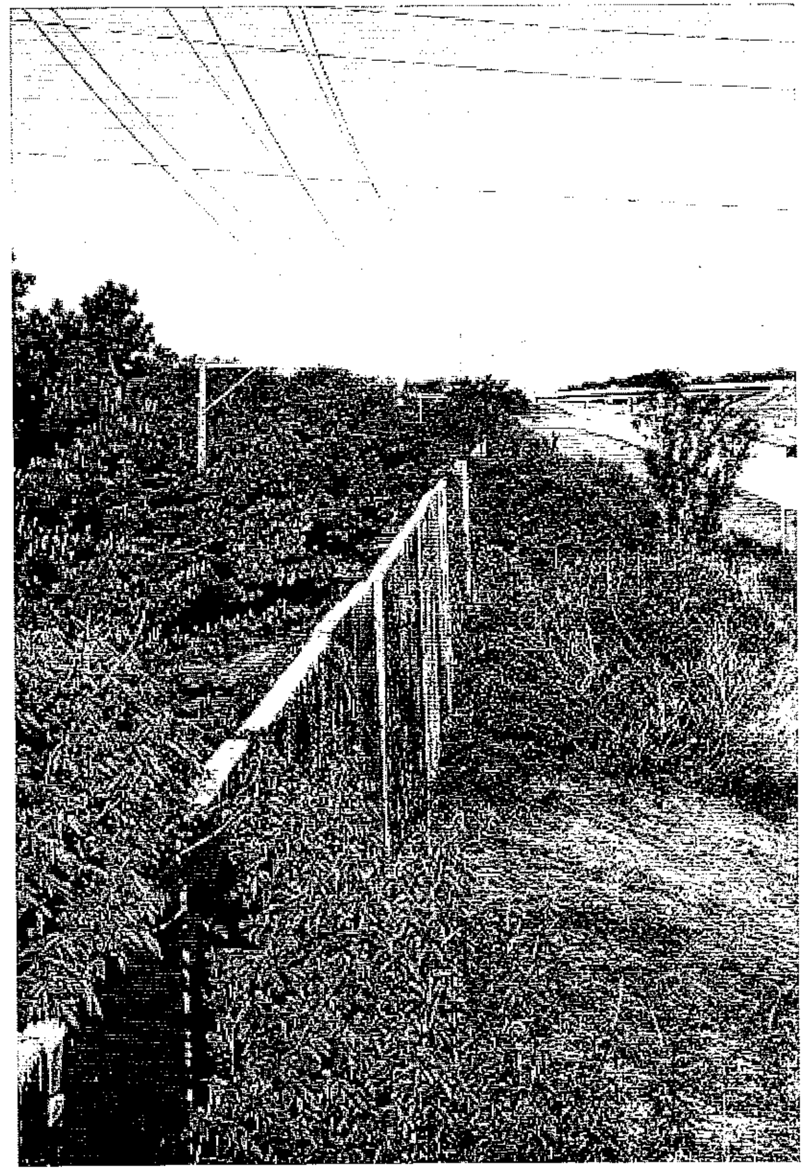
2. **Precast concrete (cantilever) with alternating surface treatments, IL 39, Rockford built 1980**

3. **Precast concrete (cantilever) with alternating surface treatments, IL 39, Rockford built 1980**



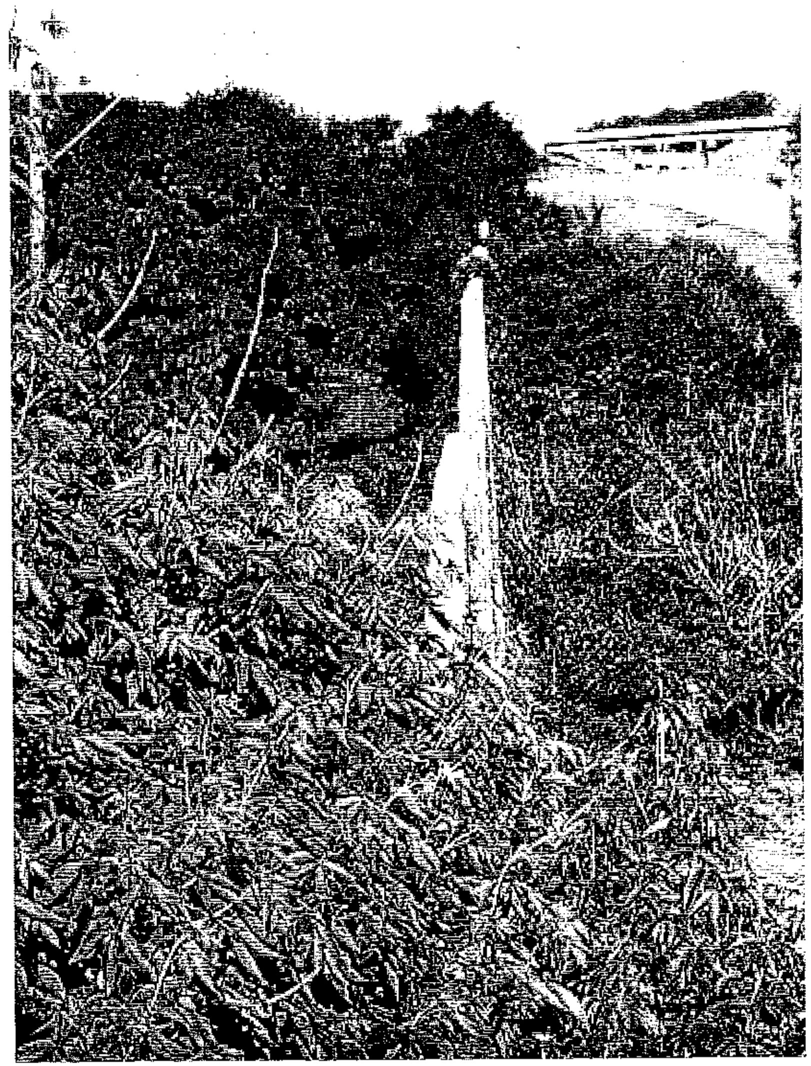
4. **Precast concrete (cantilever) with alternating surface treatments, IL 39, Rockford built 1980**

5. **Precast concrete panels, IL 39/US 51, Rockford, grafitti paint-out built 1980**

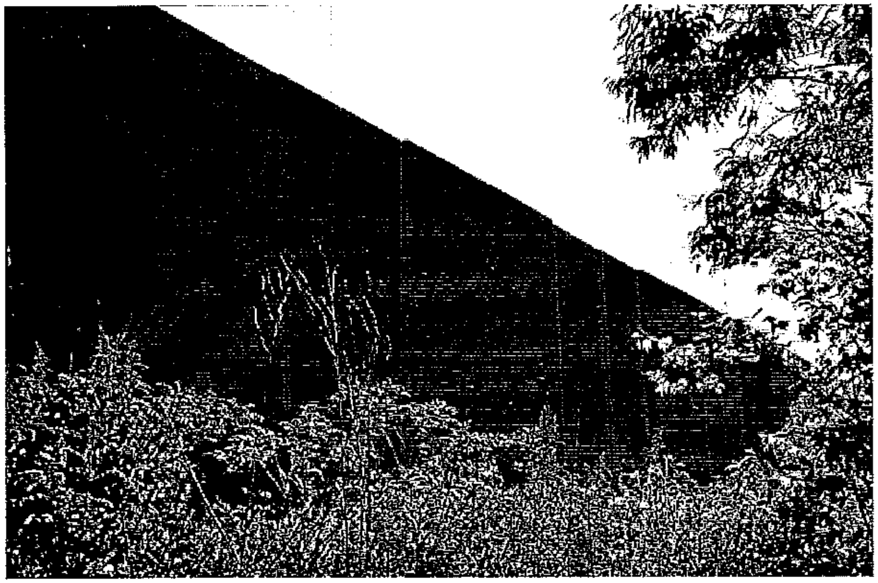


6. **Precast concrete panels, IL 39/US 51, Rockford, looking west from Milford Road built 1980**

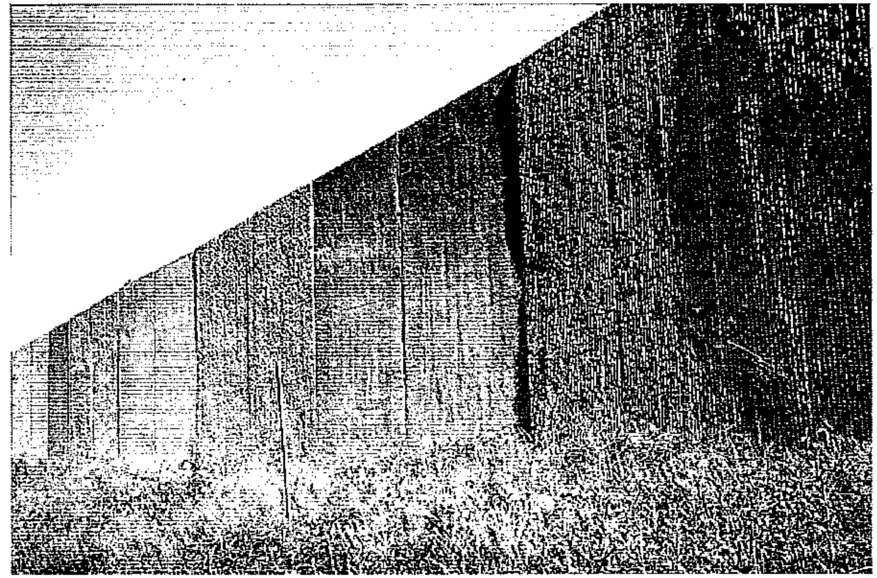
7. Detail of precast concrete post at Milford Road overpass, Rockford built 1980



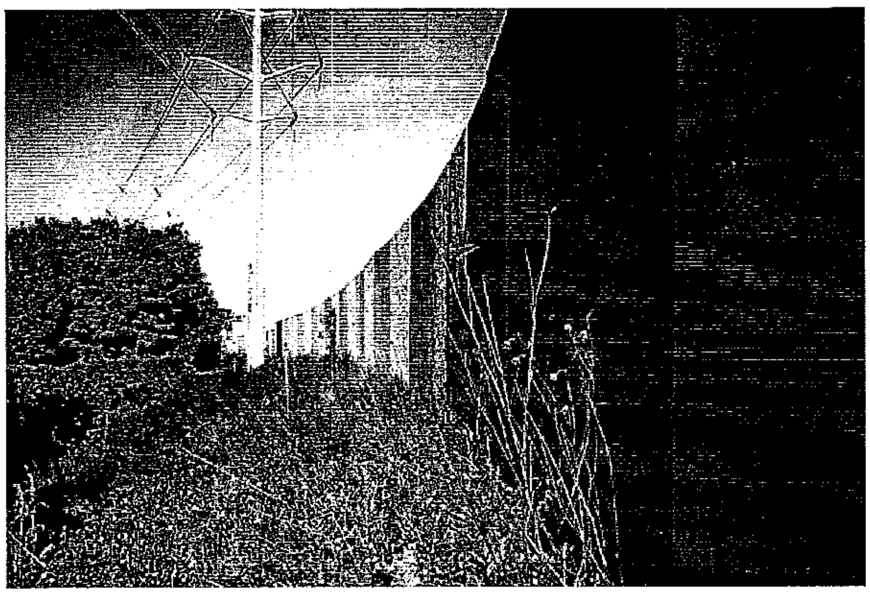
8. Precast concrete panels, Rockford, looking west on IL 39/US 51 from Milford Road overpass, showing some movement of wall panels built 1980



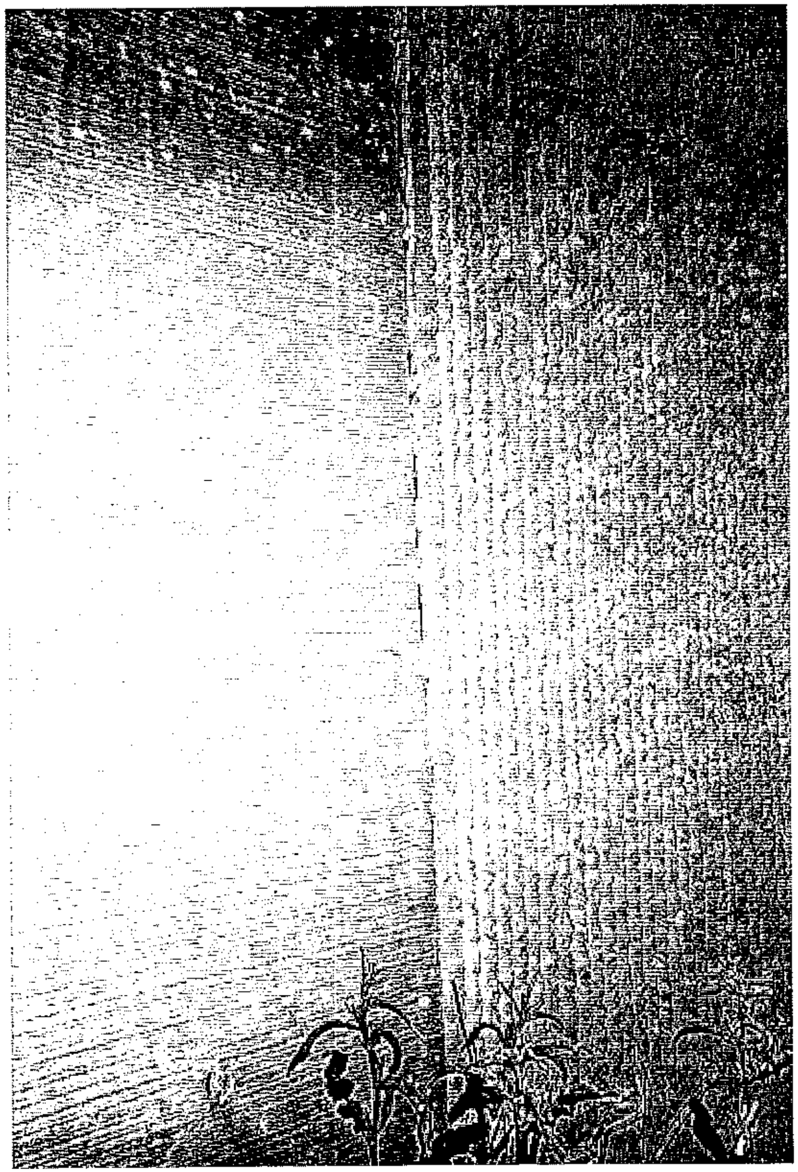
9. Precast concrete panels, Rockford, residents' side built 1980



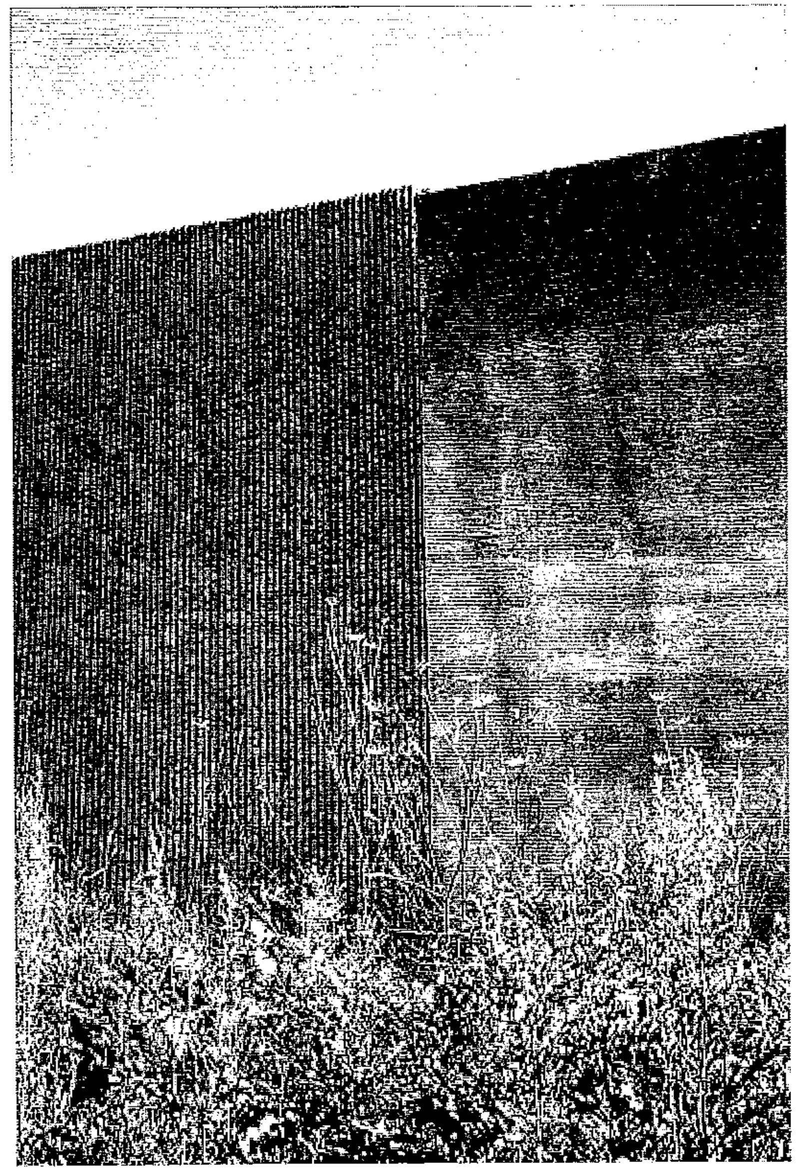
10. Precast concrete panels, IL 39/US 51, Rockford, off Millford Road, residents' side built 1980



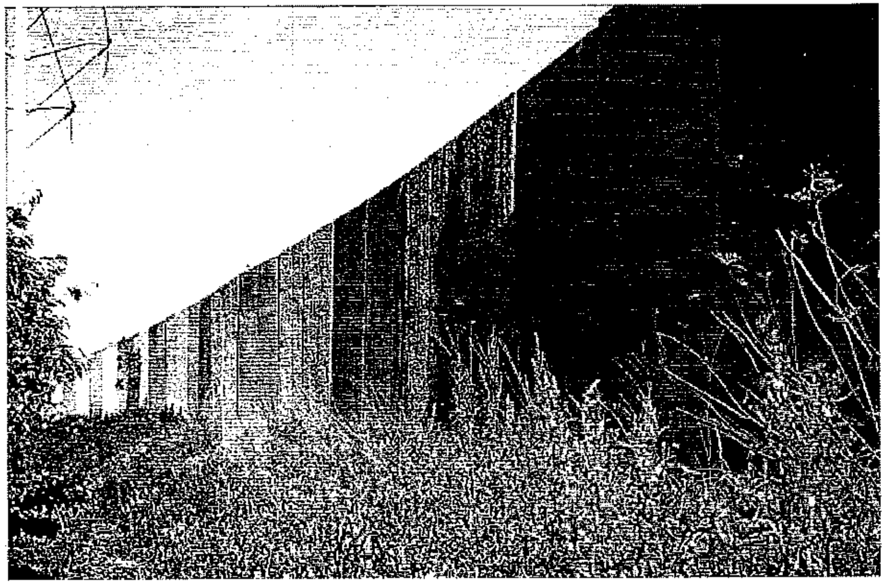
11. Precast concrete panels, IL 39/US 51, Rockford, looking west, residents' side built 1980



12. Precast concrete panels, Rockford, detail of joint caulking built 1980

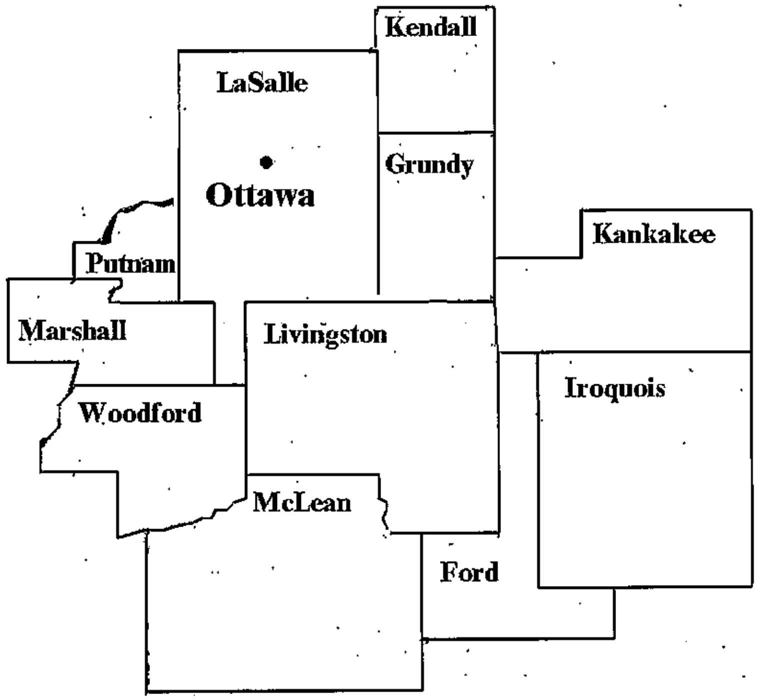


13. Precast concrete panels, IL 39/US 51, Rockford built 1980



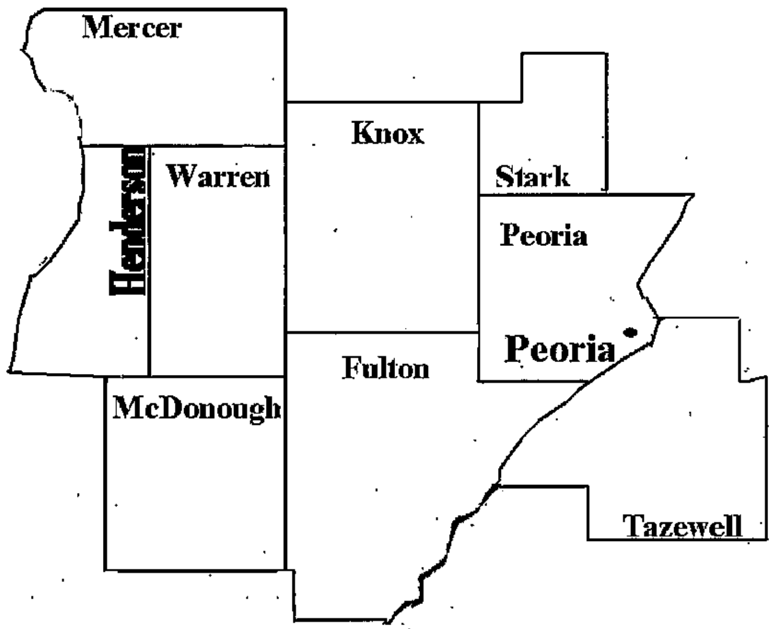
14. Precast concrete panels, IL 39, Rockford built 1980

District 3



No barriers to date

District 4



List of Photographs

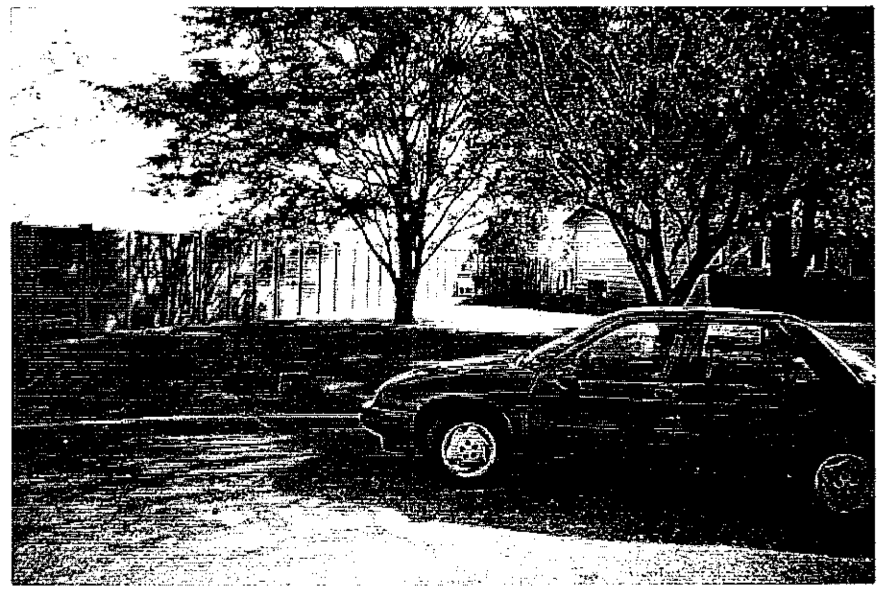
Photograph Number	Description	Page
1	Bongossi barrier, I-474, Peoria, residents' side, 1987-1998	4-1
2	Bongossi barrier, I-474, Peoria, residents' side, 1987-1998	4-1
3	Bongossi barrier, I-474, Peoria, residents' side, 1987-1998	4-1
4	Bongossi barrier, I-474, Peoria, residents' side, 1987-1998	4-1
5	Bongossi barrier, I-474, Peoria, residents' side, 1987-1998	4-2
6	Bongossi barrier, I-474, Peoria, minor unevenness along top of barrier, 1987-1998	4-2
7	Bongossi barrier, I-474, Peoria, residents' side, 1987-1998	4-2
8	Bongossi barrier, I-474, Peoria, residents' side, 1987-1998	4-2
9	Bongossi barrier, I-474, Peoria, visible joint between pre-assembled sections, 1987-1998	4-3
10	Bongossi barrier, I-474, Peoria, minor differential settlement of panels, 1987-1998	4-3
11	Bongossi barrier, I-474, Peoria, residents' side, 1987-1998	4-3
12	Bongossi barrier, I-474, Peoria, residents' side, 1987-1998	4-3
13	Bongossi barrier, I-474, Peoria, gravel drainage layer at base of barrier; gap between pre-assembled panels, 1987-1998	4-4

Photograph Number	Description	Page
14	Bongossi barrier, I-474, Peoria, vertical battens on pre-assembled barrier sections, 1987-1998	4-4
15	Bongossi barrier, I-474, Peoria, detail of attachment of 1 X 2 battens at post, 1987-1998	4-5
16	Bongossi barrier, I-474, Peoria, view of grooved post above top of panel, 1987-1998	4-5
17	End of bongossi barrier, I-474, Peoria, 1987-1998	4-5
18	Bongossi barrier, I-474, Peoria, relative location to roadway, 1987-1998	4-6
19	Bongossi barrier, I-474, Peoria, view of barrier at top of embankment, 1987-1998	4-6
20	Bongossi barrier, I-474, Peoria, view of barrier at top of embankment, 1987-1998	4-6

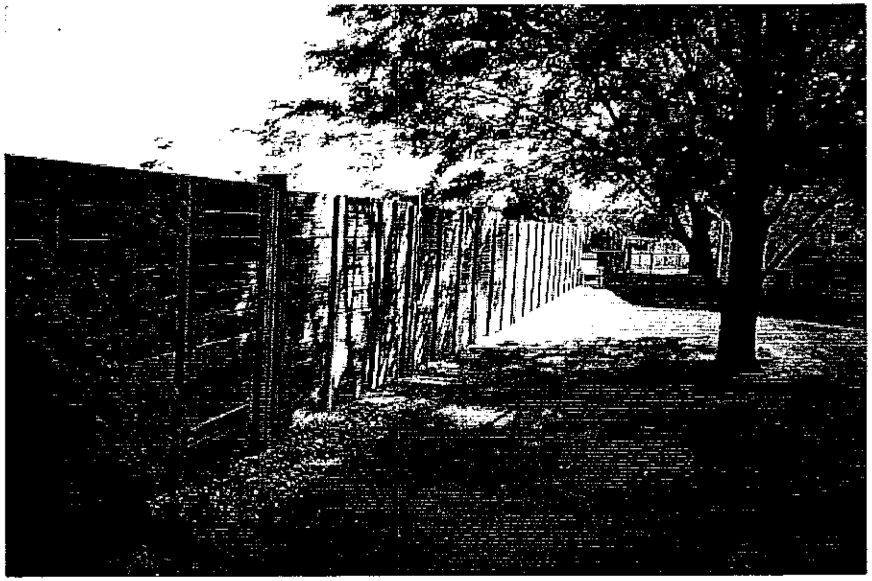
1. **Bongossi barrier, I-474, Peoria, residents' side** **1987-1998**

2. **Bongossi barrier, I-474, Peoria, residents' side** **1987-1998**

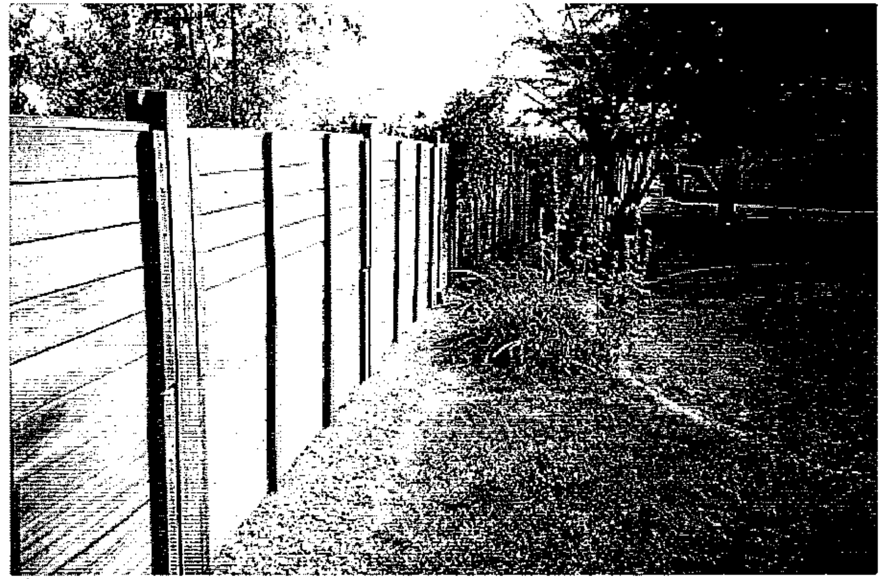
3. **Bongossi barrier, I-474, Peoria, residents' side** **1987-1998**



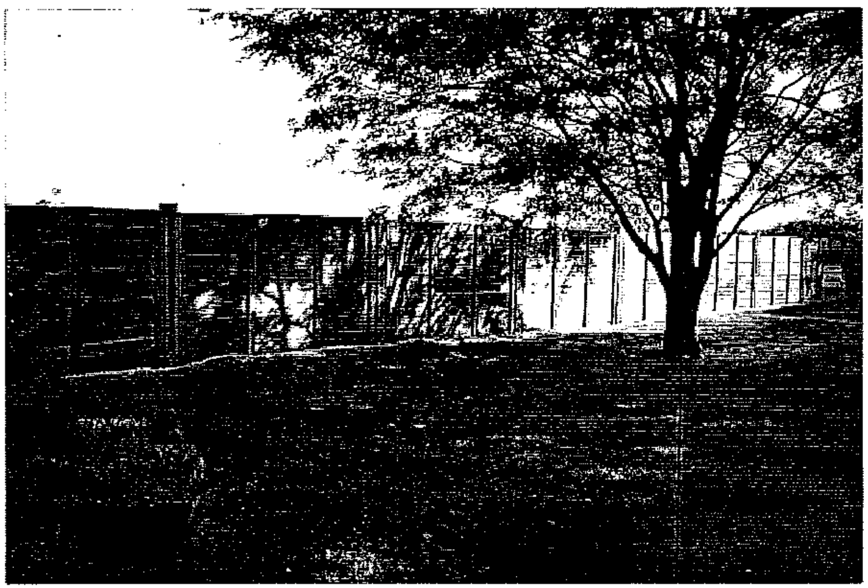
4. **Bongossi barrier, I-474, Peoria, residents' side** **1987-1998**



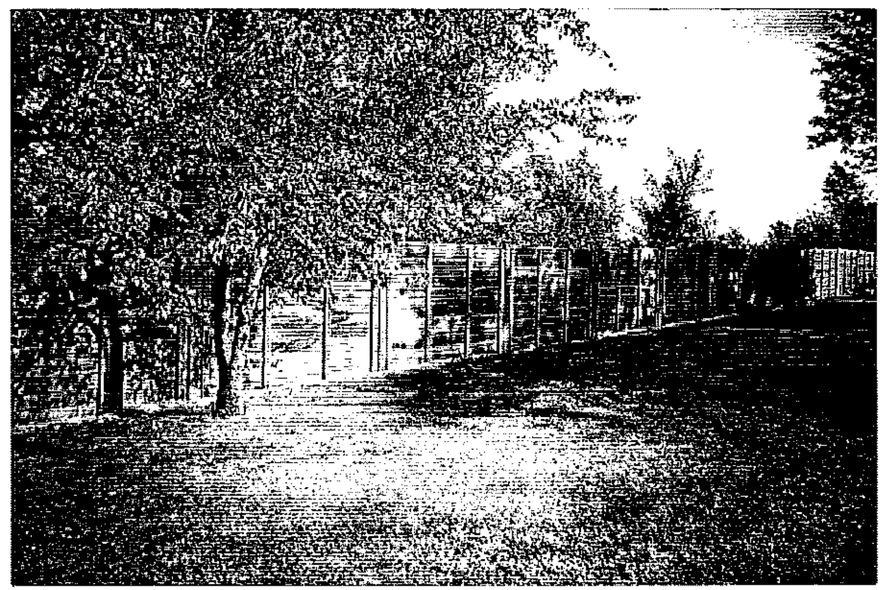
5. Bongossi barrier, I-474, Peoria, residents' side 1987-1998



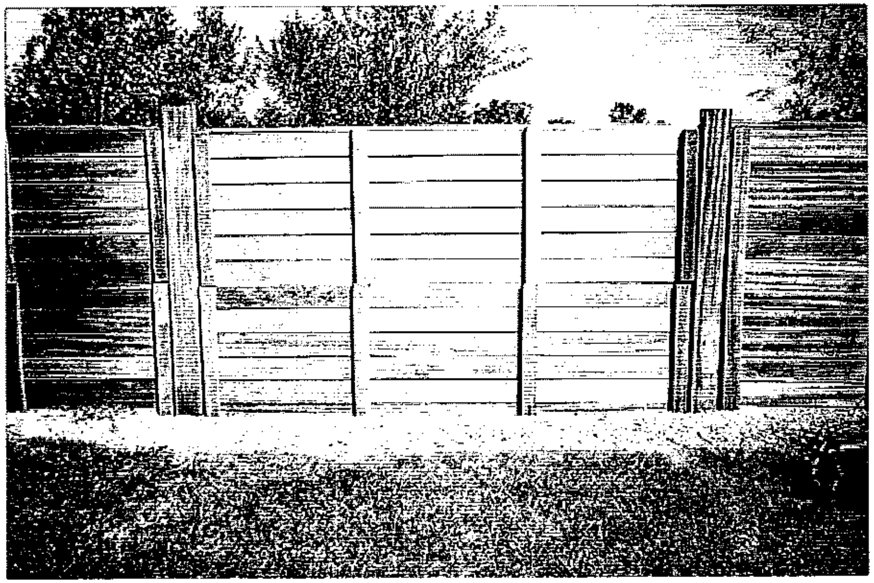
6. Bongossi barrier, I-474, Peoria, minor unevenness along top of barrier 1987-1998



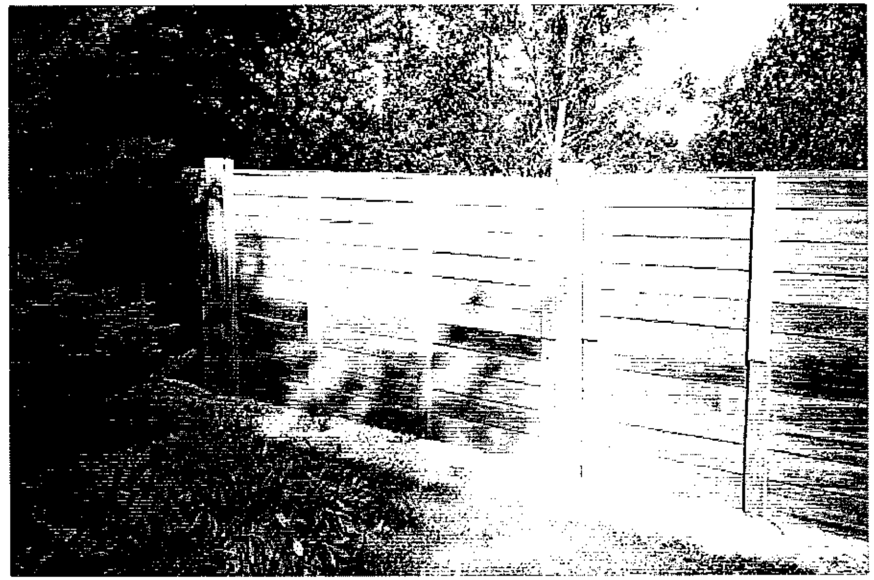
7. Bongossi barrier, I-474, Peoria, residents' side 1987-1998



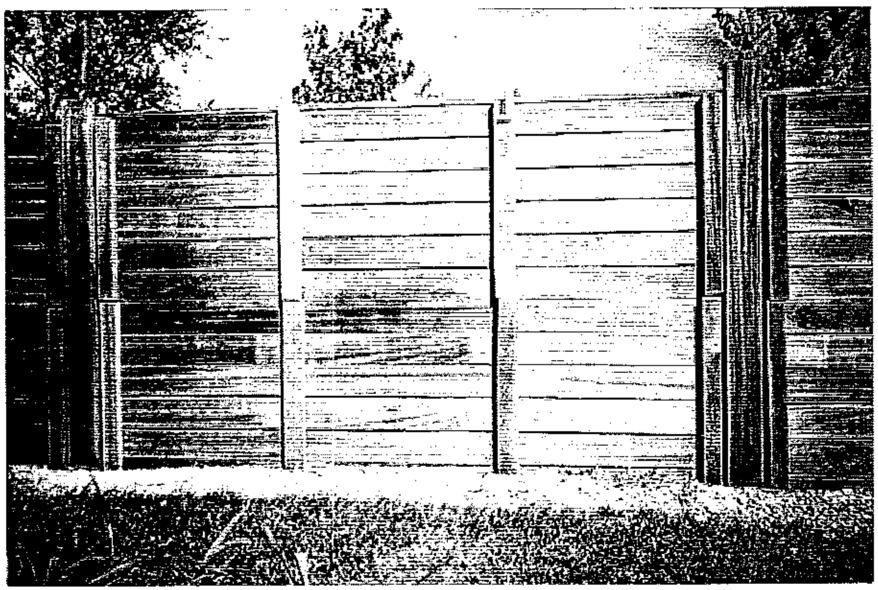
8. Bongossi barrier, I-474, Peoria, residents' side 1987-1998



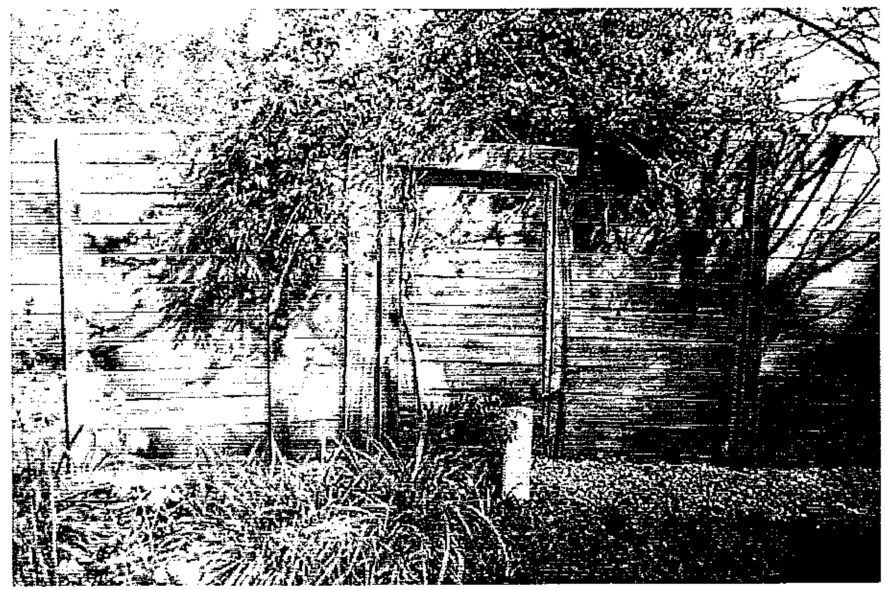
9. Bongossi barrier, I-474, Peoria, visible joint between pre-assembled sections 1987-1998



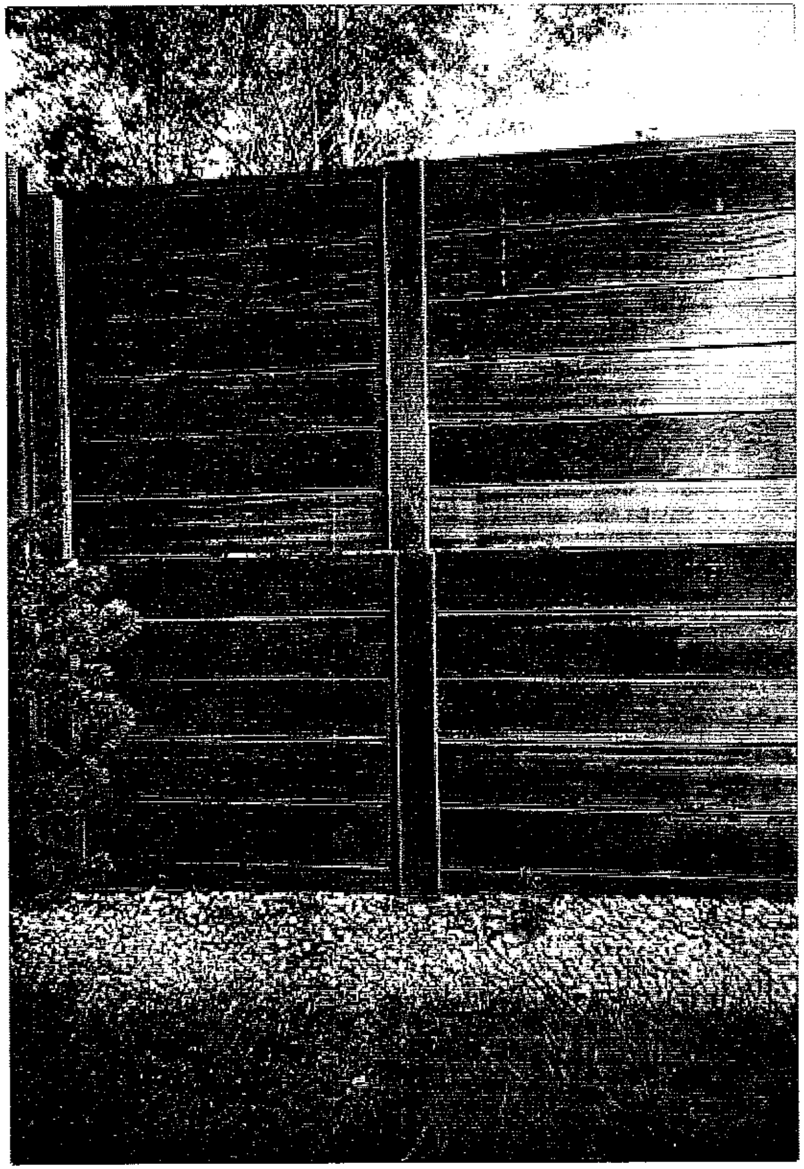
10. Bongossi barrier, I-474, Peoria, minor differential settlement of panels 1987-1998



11. Bongossi barrier, I-474, Peoria, residents' side 1987-1998



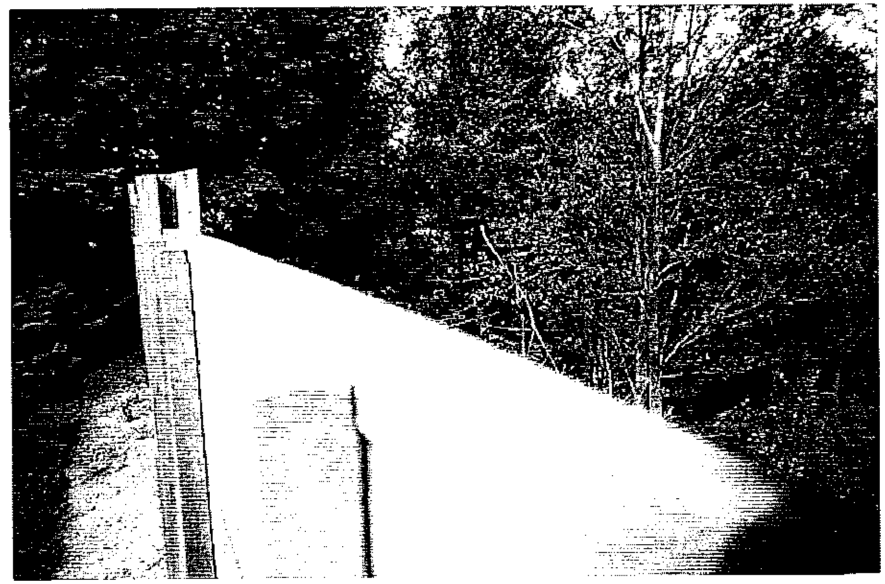
12. Bongossi barrier, I-474, Peoria, residents' side 1987-1998



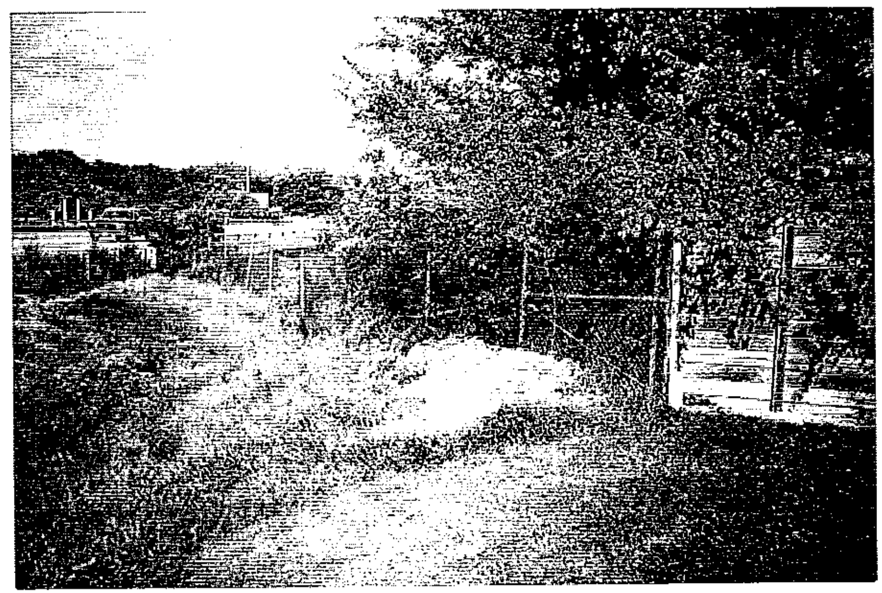
13. Bongossi barrier, I-474, Peoria, gravel drainage layer at base of barrier; gap between pre-assembled panels 1987-1998

14. Bongossi barrier, I-474, Peoria, vertical battens on pre-assembled barrier sections 1987-1998

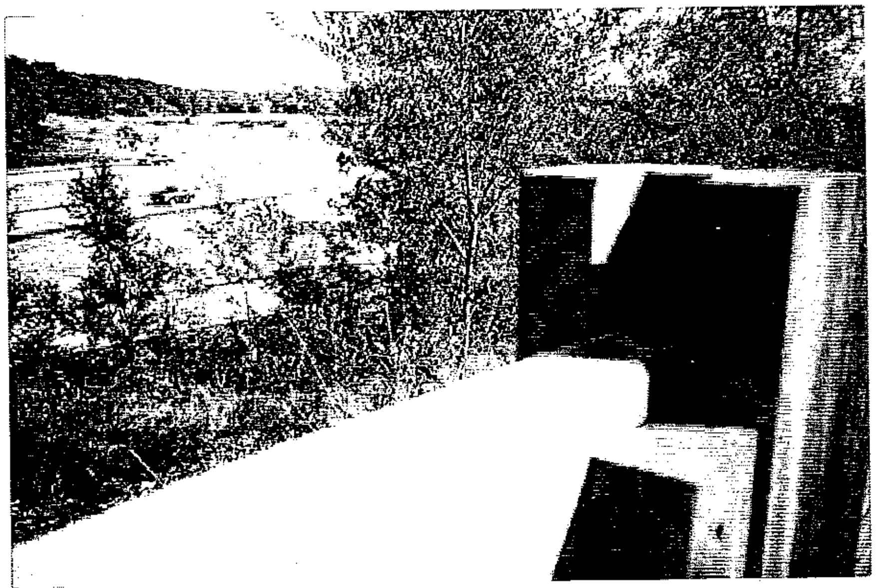
15. Bongossi barrier, I-474, Peoria, detail of attachment of 1 X 2 battens at post 1987-1998



16. Bongossi barrier, I-474, Peoria, view of grooved post above top of panel 1987-1998



17. End of bongossi barrier, I-474, Peoria 1987-1998

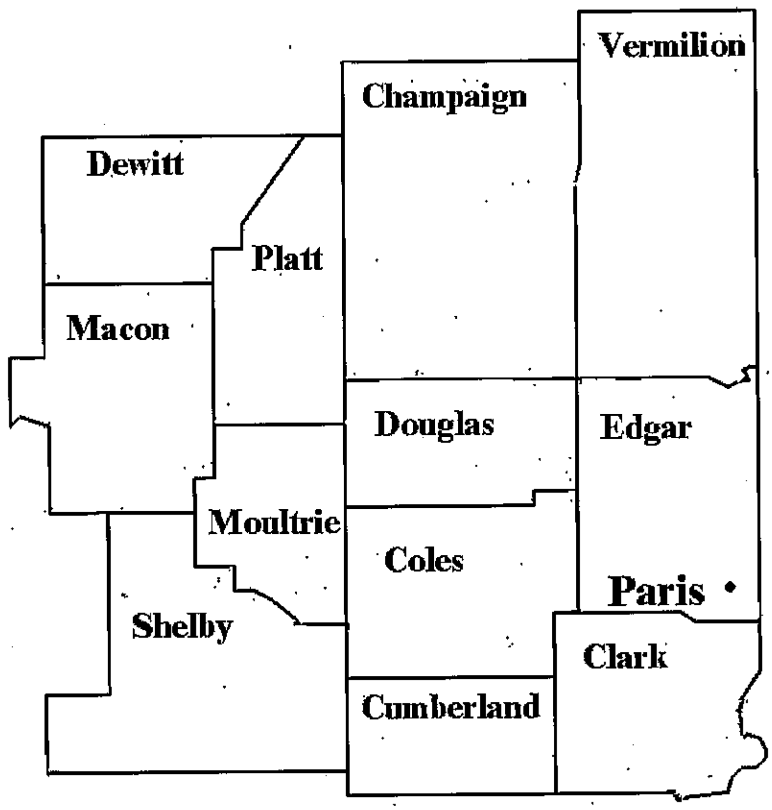


18. Bongossi barrier, I-474, Peoria, relative location to roadway
1987-1998

19. Bongossi barrier, I-474, Peoria, view of barrier at top of embankment
1987-1998

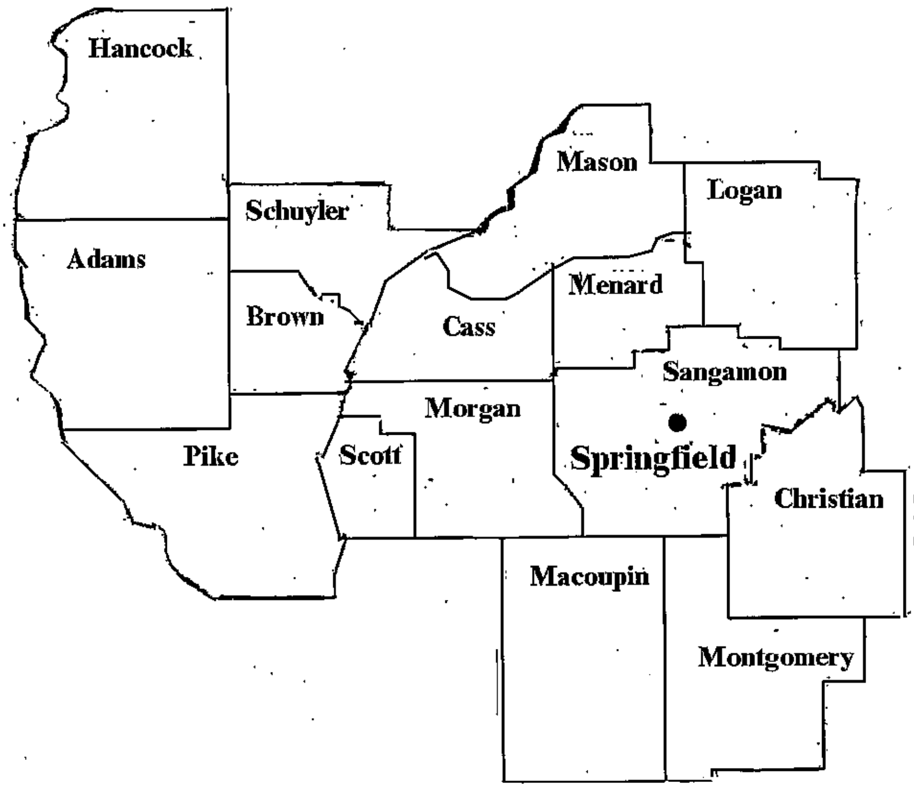
20. Bongossi barrier, I-474, Peoria, view of barrier at top of embankment
1987-1998

District 5



No barriers to date

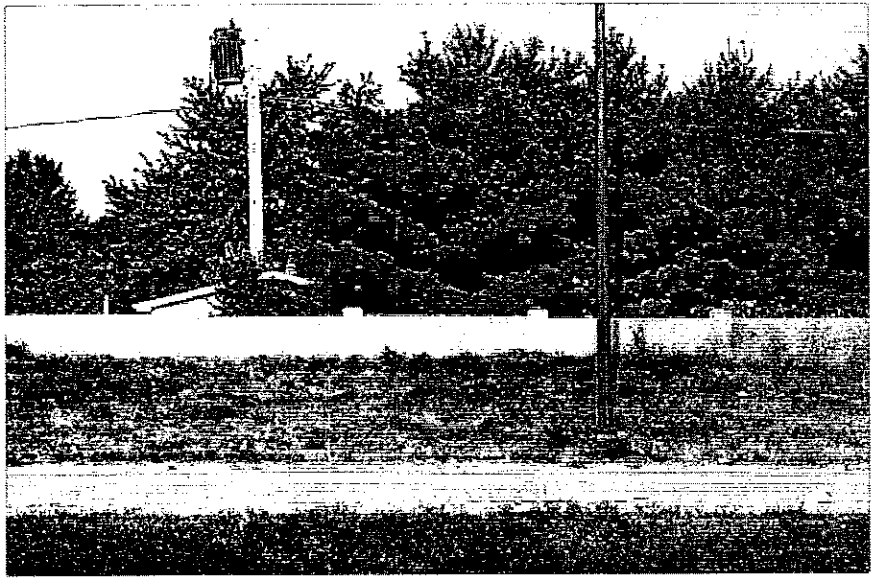
District 6



List of Photographs

Photograph Number	Description	Page
1	Combination berm/retaining wall, IL Rte. 4, Springfield, highway side, 1979-1998	6-1
2	Combination berm/retaining wall, IL Rte. 4, Springfield, highway view at cross-street, 1979-1998	6-1
3	Residents' view of retaining wall (left) and highway view of berm (right), IL Rte. 4, Springfield, 1979-1998	6-1
4	Residents' view of combination berm/retaining wall, IL Rte. 4, Springfield, 1979-1998	6-1
5	Exposed aggregate precast concrete panels, IL Rte. 4, Springfield, residents' view of retaining wall, 1979-1998	6-2
6	Exposed aggregate precast concrete panels, IL Rte. 4, Springfield, residents' view of retaining wall, 1979-1998	6-2
7	Exposed aggregate precast concrete panels, IL Rte. 4, Springfield, residents' view of retaining wall, 1979-1998	6-2

Photograph Number	Description	Page
8	Earth berms, IL Rte. 4, Springfield, mowed near base only, 1979-1998	6-2
9	Earth berms, IL Rte. 4, Springfield, mowed near base only, 1978-1998	6-3
10	Earth berms, IL Rte. 4, Springfield, mowed near base only, 1978-1998	6-3
11	Earth berms, IL Rte. 4, Springfield, mowed near base only, 1978-1998	6-3
12	Earth berms, IL Rte. 4, Springfield, mowed near base only, 1978-1998	6-3



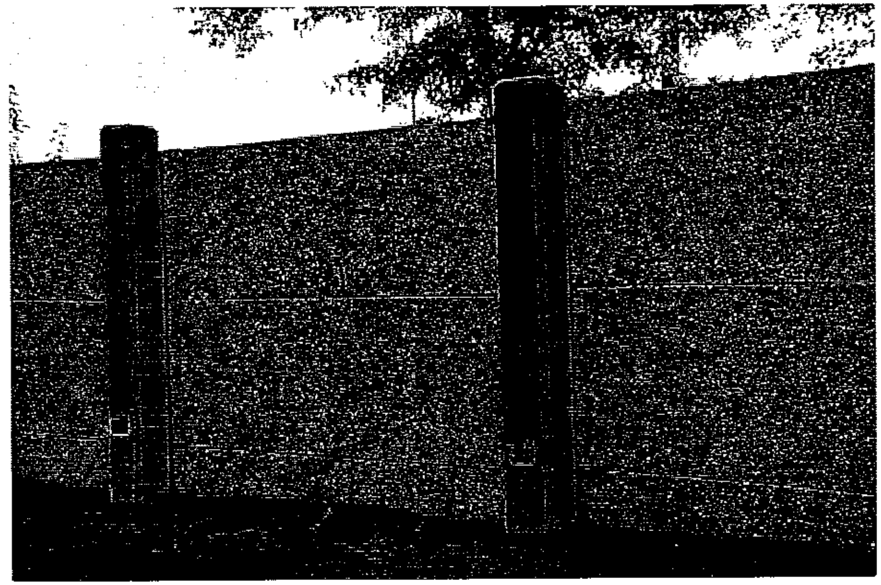
1. Combination berm/retaining wall, IL Rte. 4, Springfield, highway side 1979-1998

2. Combination berm/retaining wall, IL Rte. 4, Springfield, highway view at cross-street 1979-1998

3. Residents' view of retaining wall (left) and highway view of berm (right), IL Rte. 4, Springfield 1979-1998

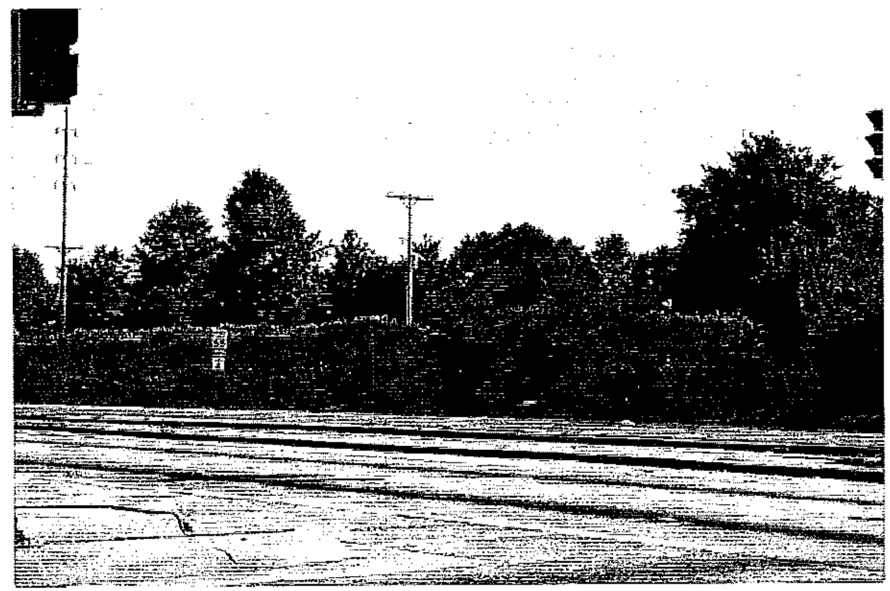
4. Residents' view of combination berm/retaining wall, IL Rte. 4, Springfield 1979-1998

5. Exposed aggregate precast concrete panels, IL Rte. 4, Springfield, residents' view of retaining wall 1979-1998



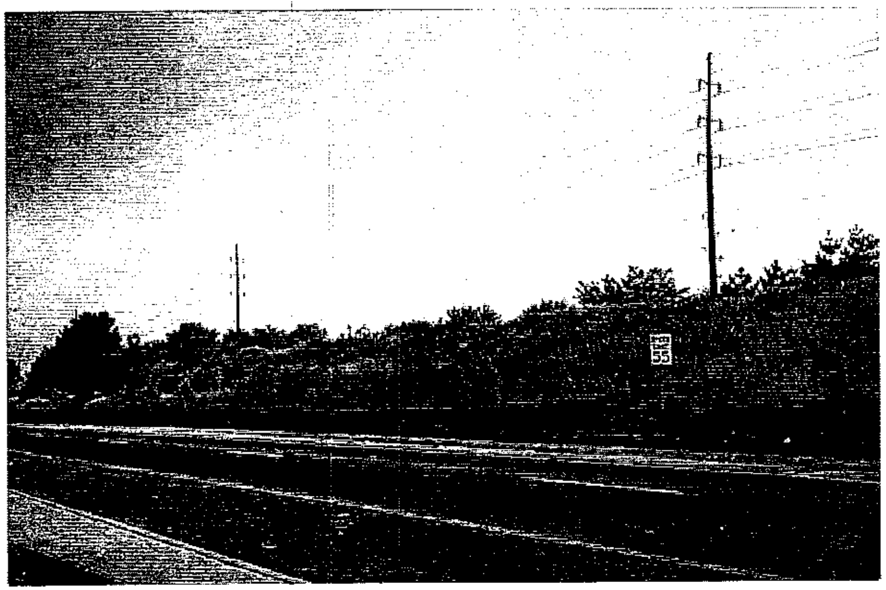
6. Exposed aggregate precast concrete panels, IL Rte. 4, Springfield, residents' view of retaining wall 1979-1998

7. Exposed aggregate precast concrete panels, IL Rte. 4, Springfield, residents' view of retaining wall 1979-1998



8. Earth berms, IL Rte. 4, Springfield, mowed near base only

1979-1998

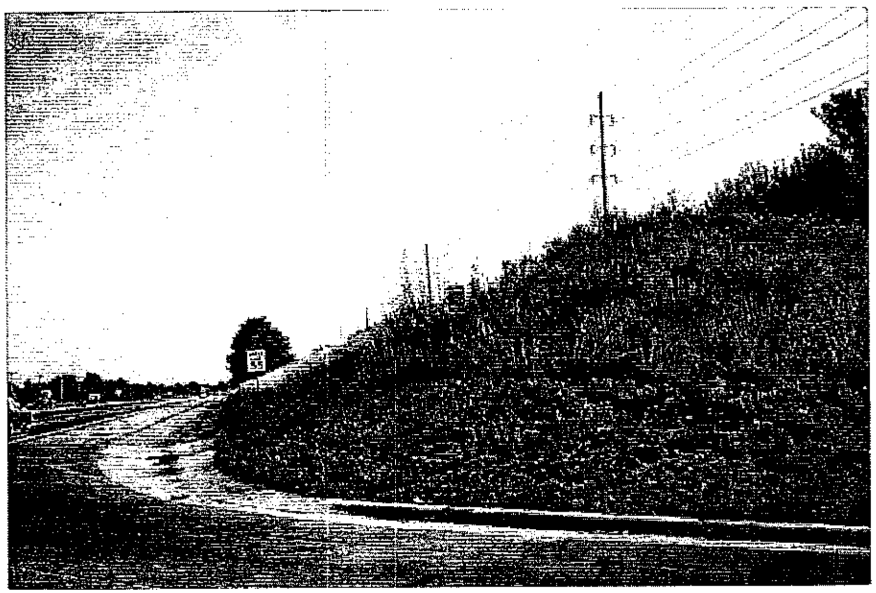


9. Earth berms, IL Rte. 4, Springfield, mowed near base only

1978-1998

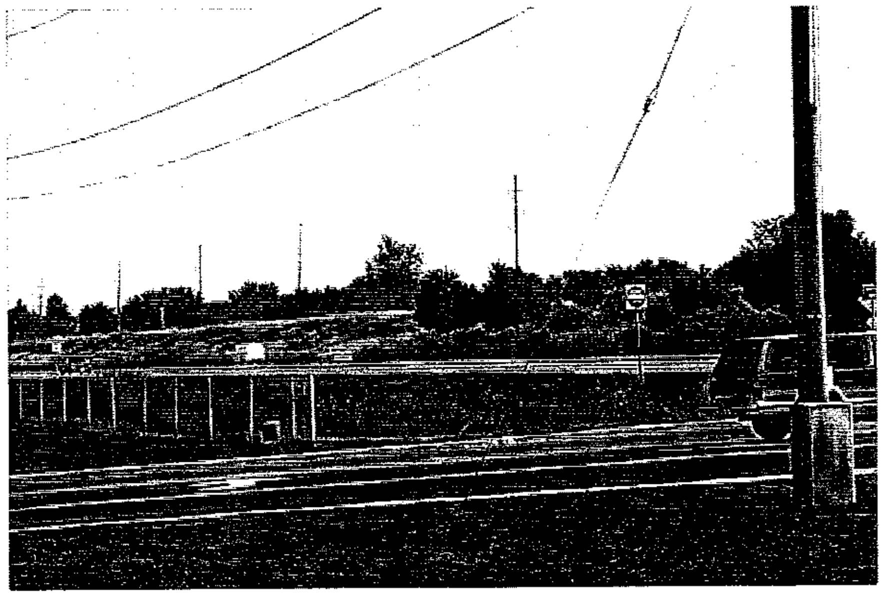
10. Earth berms, IL Rte. 4, Springfield, mowed near base only

1978-1998



11. Earth berms, IL Rte. 4, Springfield, mowed near base only

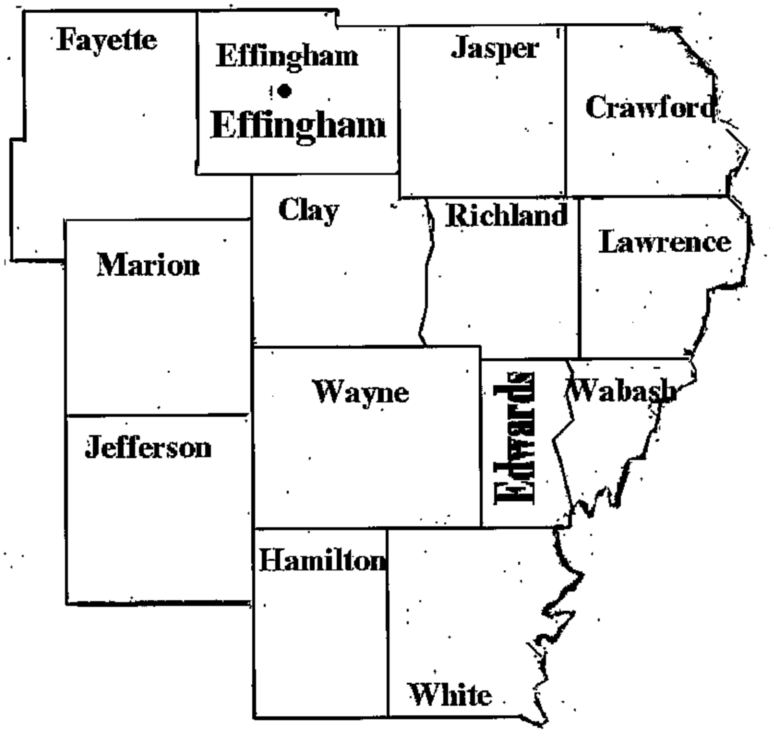
1978-1998



12. Earth berms, IL Rte. 4, Springfield, mowed near base only

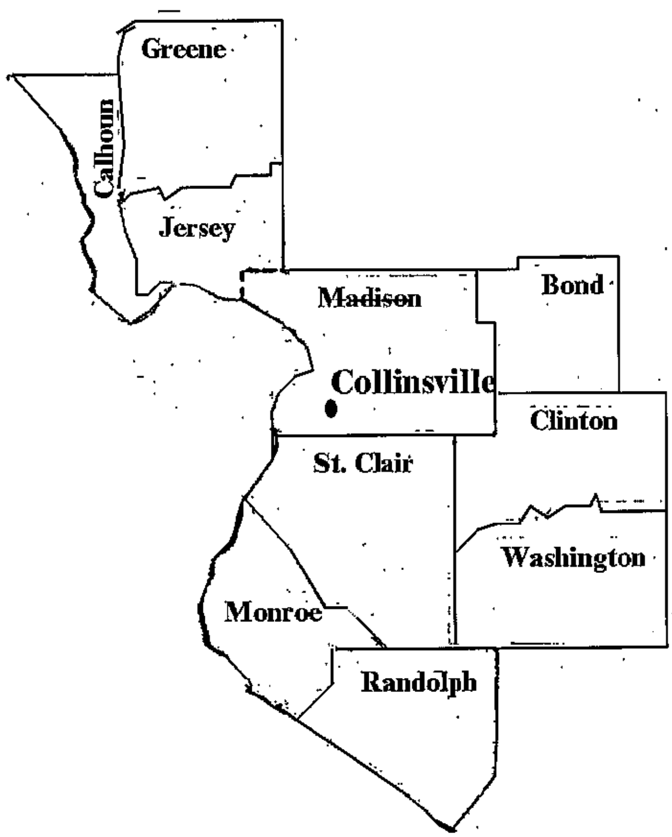
1978-1998

District 7



No barriers to date

District 8

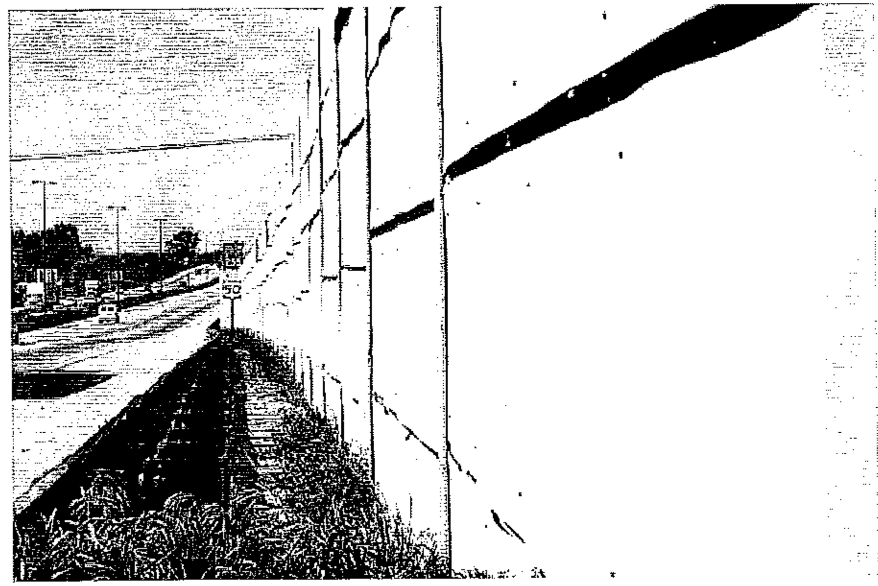


List of Photographs

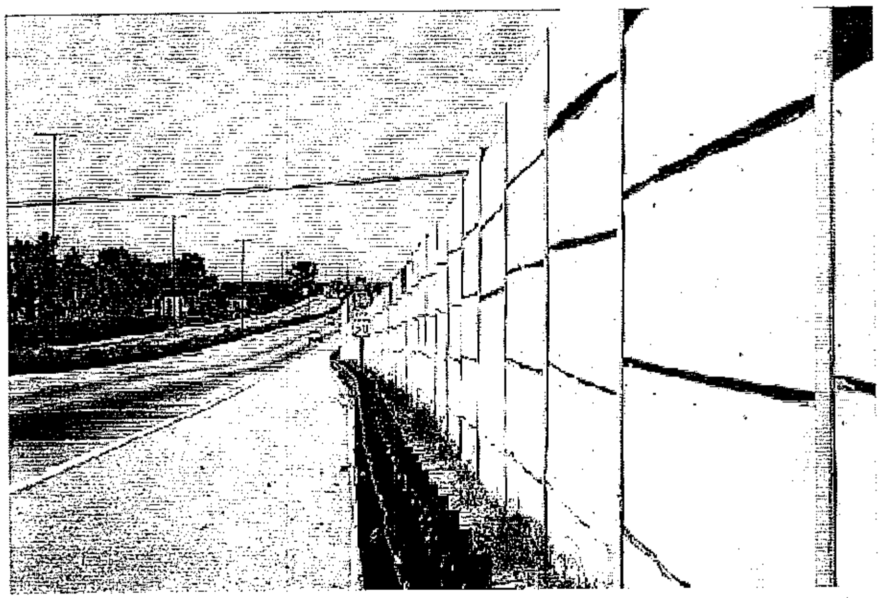
Photograph Number	Description	Page
1	Noishield steel wall with retrofit fiberglass panels added by IDOT, I-255, Centerville, built 1984	8-1
2	Fiberglass panels added over Noishield wall, I-255, built 1984	8-1
3	Fiberglass panels added over Noishield wall, I-255, built 1984	8-1
4	Fiberglass panels added over Noishield wall, I-255, built 1984	8-1
5	Fiberglass panels added over Noishield wall, I-255, built 1984	8-2
6	Fiberglass panels added over Noishield wall, I-255, built 1984	8-2

Photograph Number	Description	Page
29	Noishield aluminum, I-255, Collinsville, residents' side, built 1985	8-9
30	Noishield aluminum, I-255 at US 40, Collinsville, perforated surface on traffic side, built 1985	8-9
31	Noishield aluminum, I-255, Collinsville, perforated surface on traffic side, built 1985	8-9
32	Noishield aluminum, I-255, Collinsville, end post, built 1985	8-9
33	Noishield aluminum, I-255, Collinsville, backside detail of bottom channel, built 1985	8-10
34	Precast/prestressed (cantilever) barrier, I-255, East St. Louis, built 1981	8-10
35	Precast/prestressed (cantilever) barrier, I-255, East St. Louis, built 1981	8-10
36	Precast/prestressed (cantilever) barrier, I-255, East St. Louis, built 1981	8-10
37	Precast/prestressed (cantilever) barrier, I-255, East St. Louis, built 1981	8-11
38	Precast/prestressed (cantilever) barrier, I-255, East St. Louis, built 1981	8-11

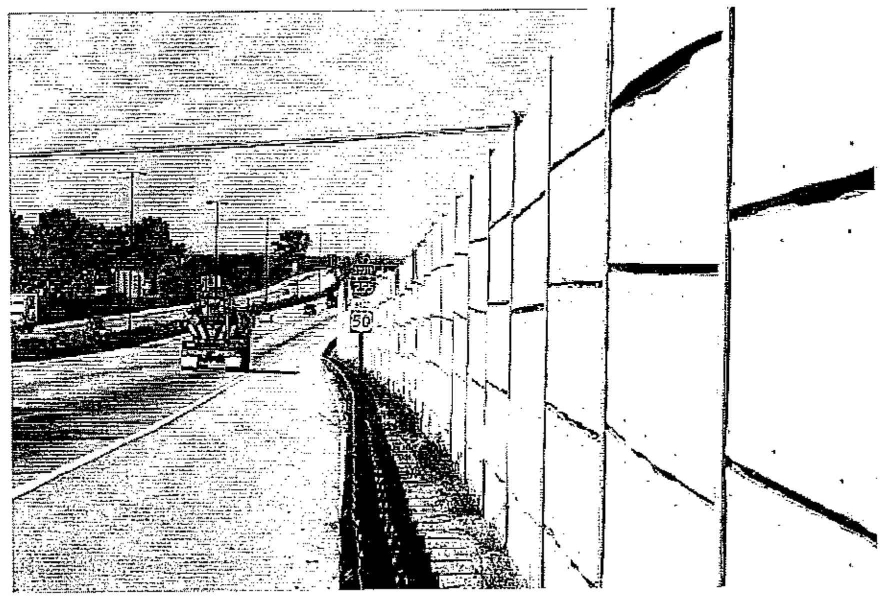
1. Noishield steel wall with retrofit fiberglass panels added by IDOT, I-255 Centerville built 1984



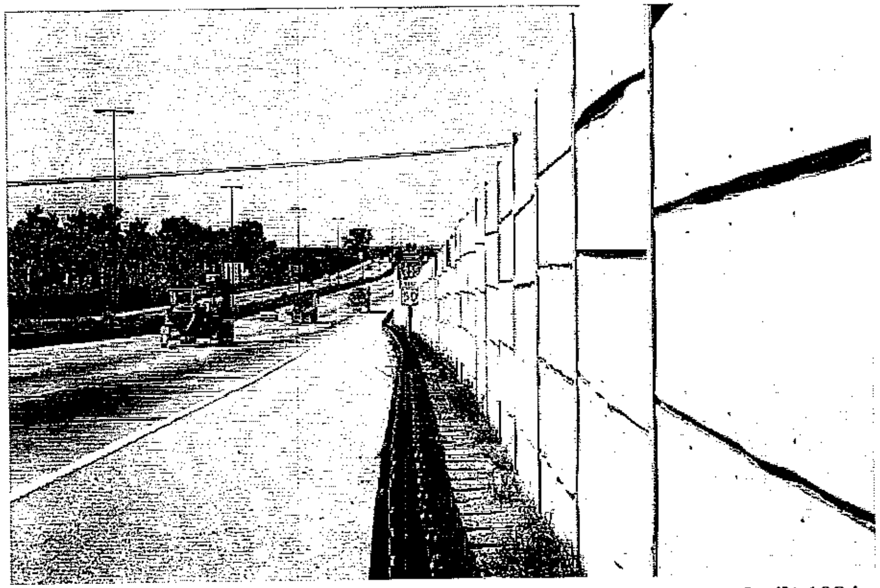
2. Fiberglass panels added over Noishield wall, I-255 built 1984



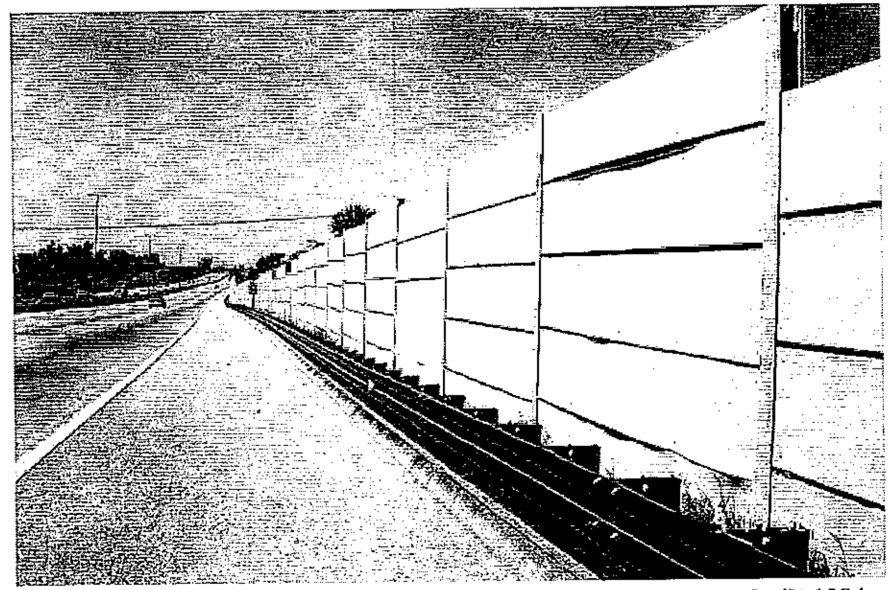
3. Fiberglass panels added over Noishield wall, I-255 built 1984



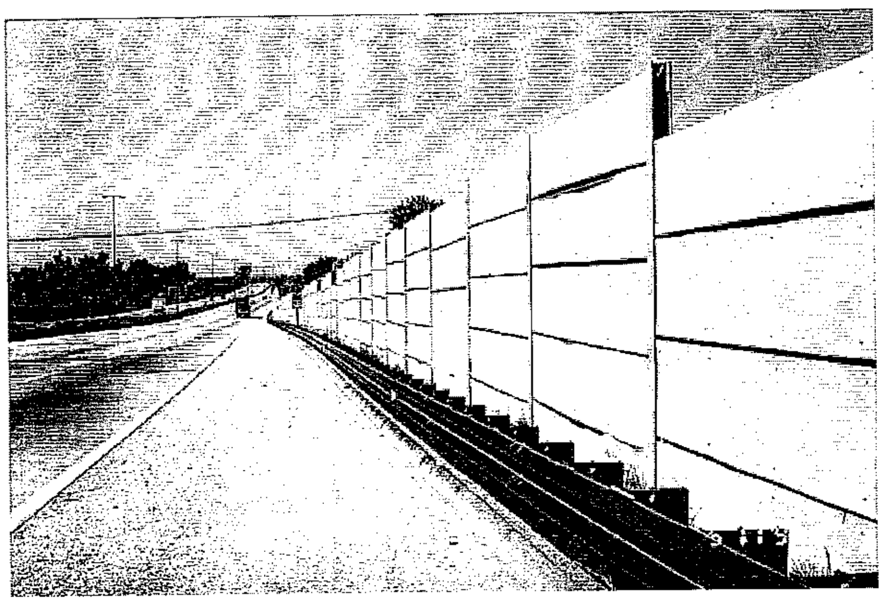
4. I-255 Fiberglass panels added over Noishield wall built 1984



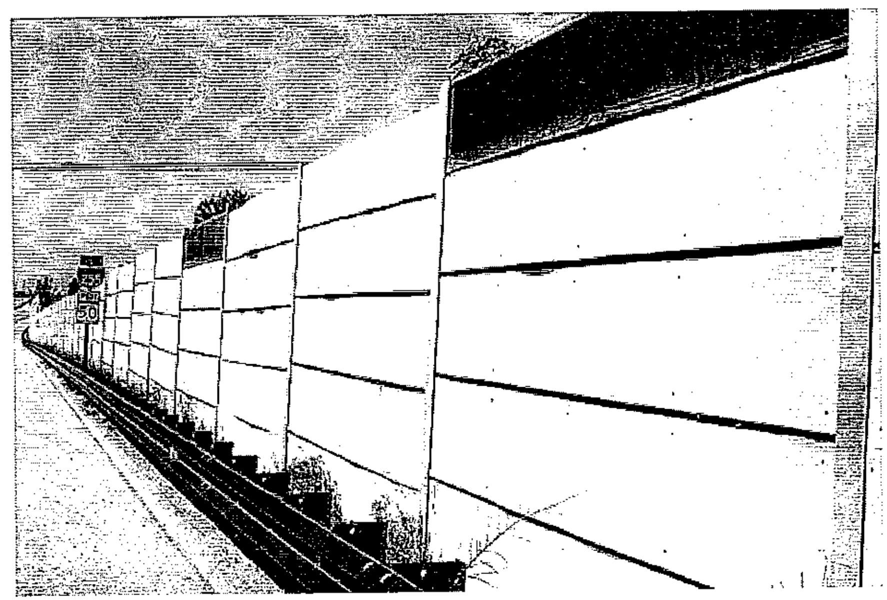
5. Fiberglass panels added over Noishield wall , I-255 built 1984



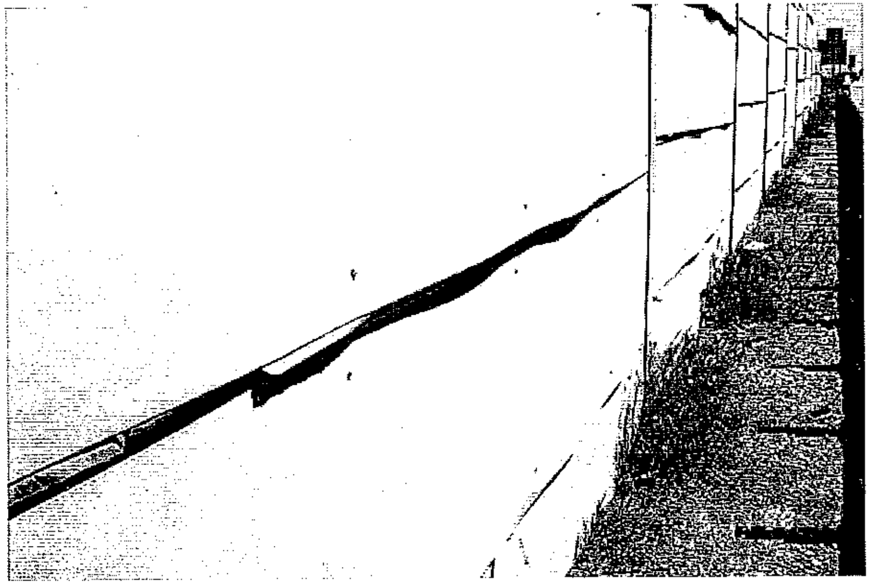
6. Fiberglass panels added over Noishield wall, I-255 built 1984



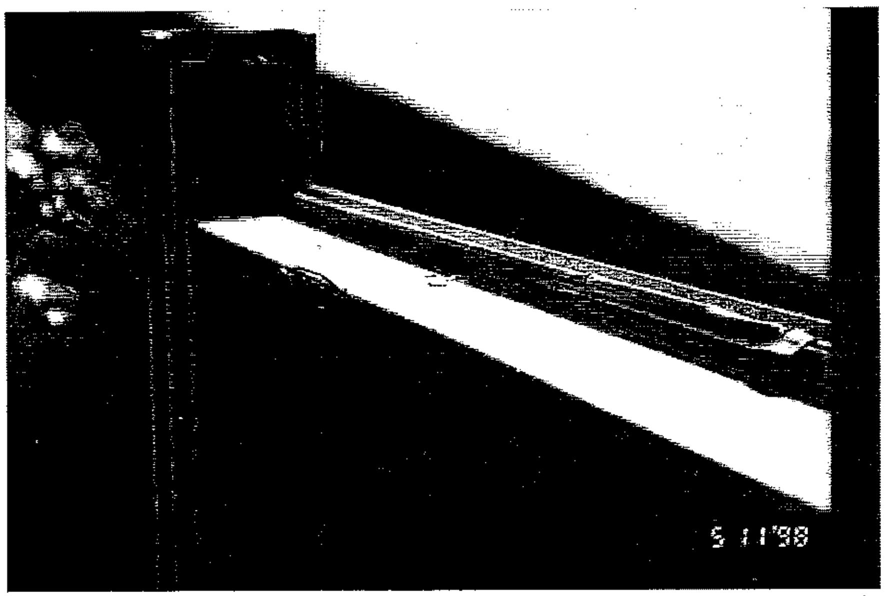
7. Fiberglass panels added over Noishield wall, I-255 built 1984



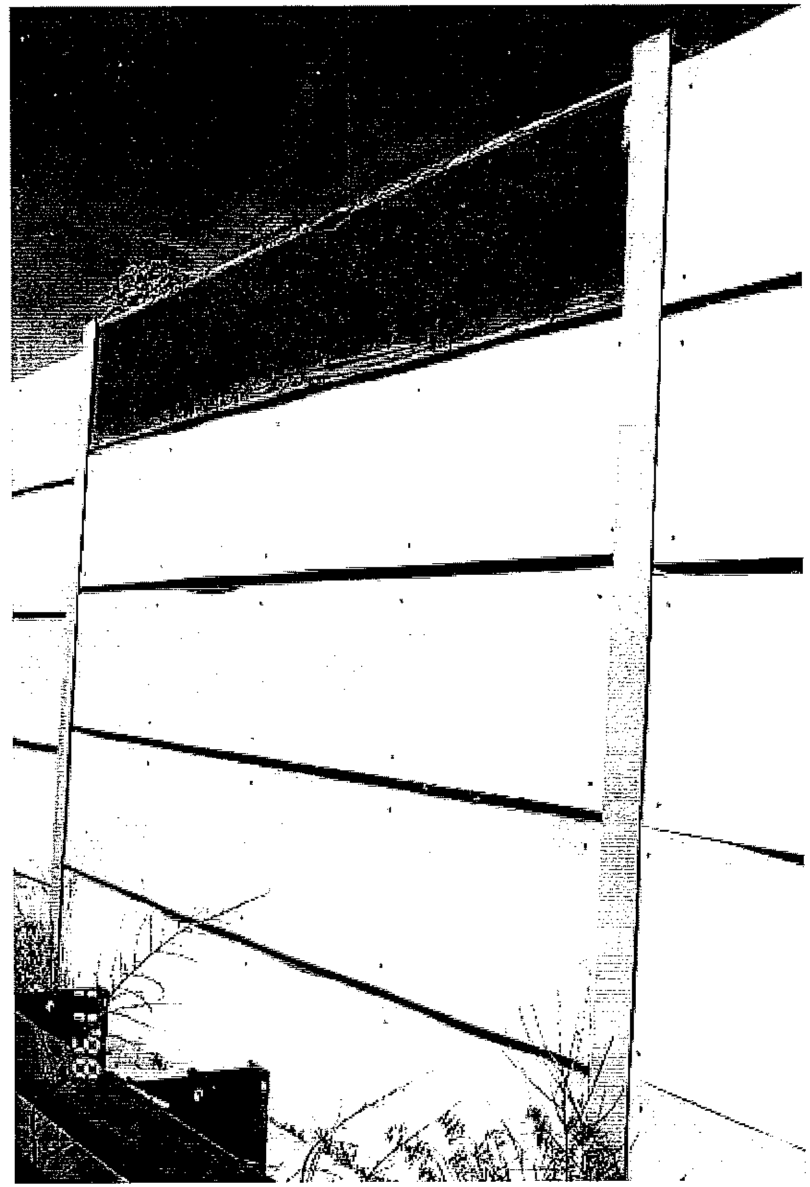
8. Corroded steel wall panels (visible at top right) covered with fiberglass panels for remediation, I-255 Centerville built 1984



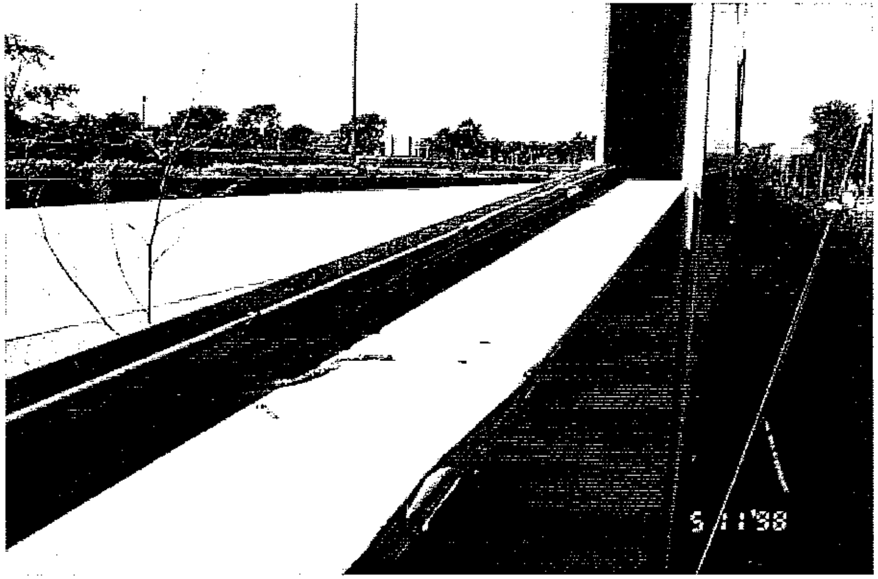
9. Corroded steel panel's original paint protruding from fiberglass covering I-255, Centerville built 1984



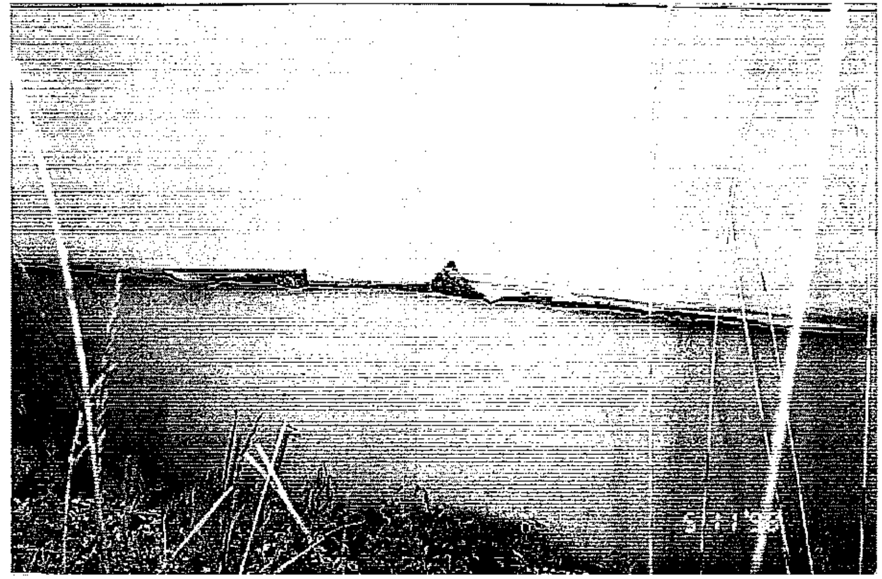
11. Noishield metal wall; view of top panel showing detail of finishing I-255, Centerville built 1984



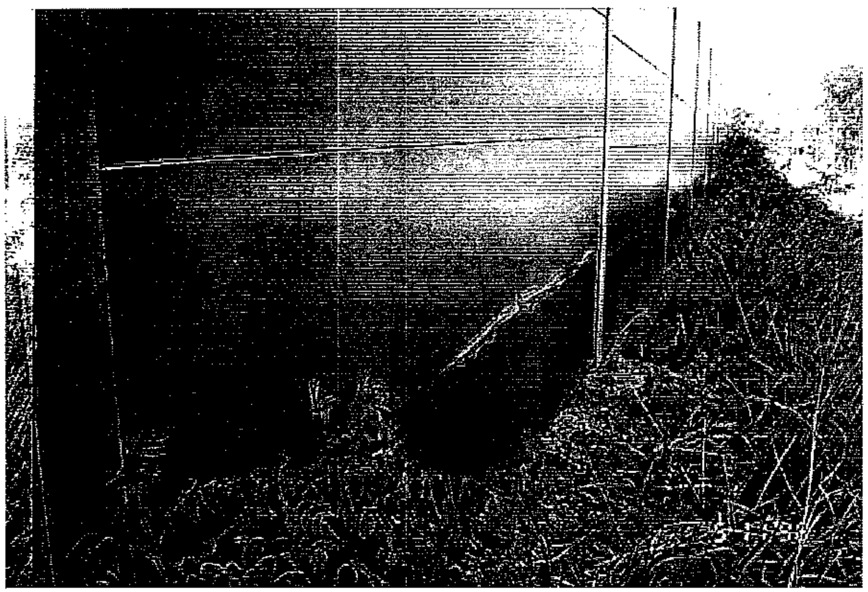
10. Exposed steel panel with fiberglass covering absent I-255, Centerville built 1984



12. I-255, Centerville, Detail of top of wall built 1984

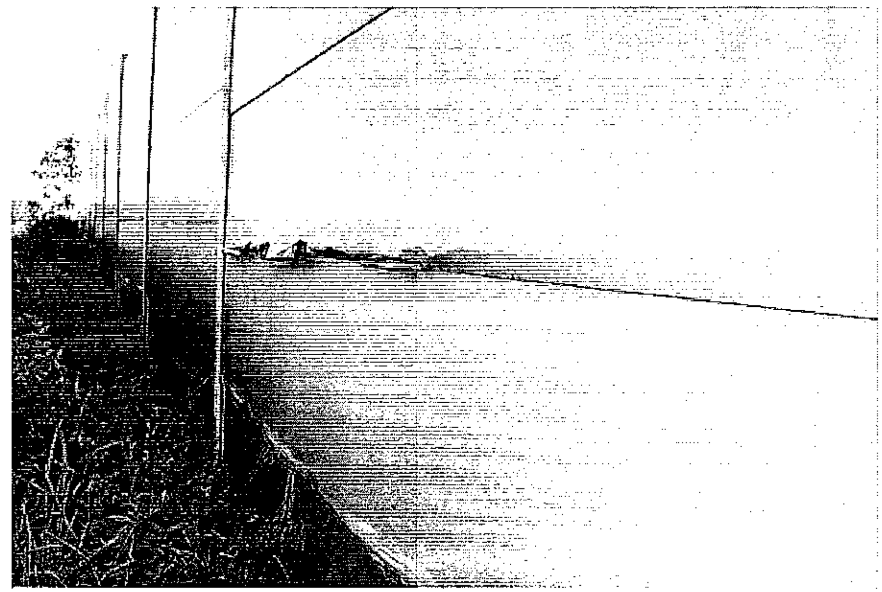


13. I-255, Centerville, corrosion damage on backside of wall built 1984



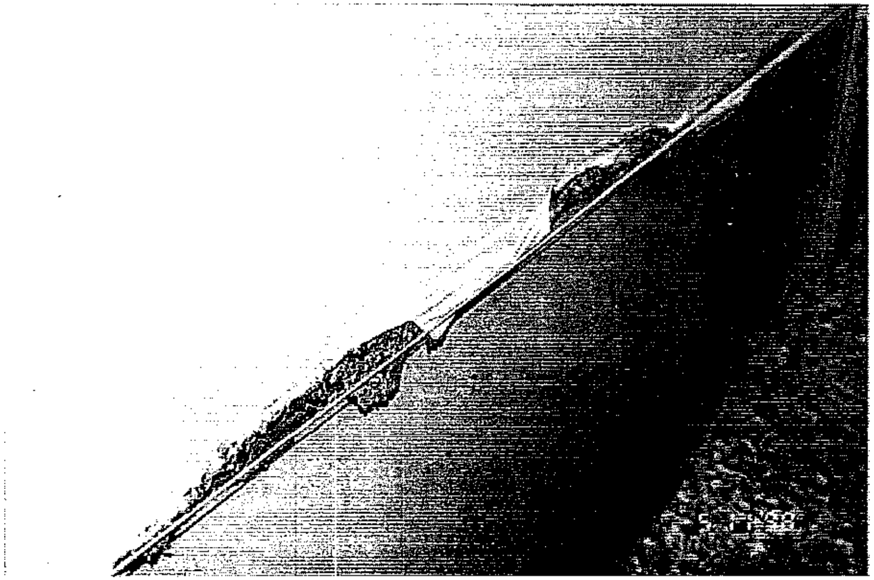
14. I-255, Centerville, corrosion damage on backside of wall

built 1984

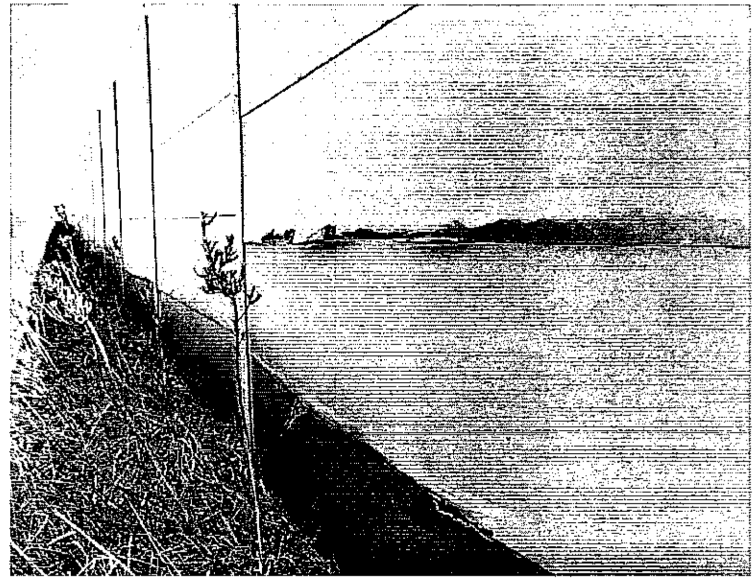


15. I-255, Centerville, corrosion damage on backside of wall

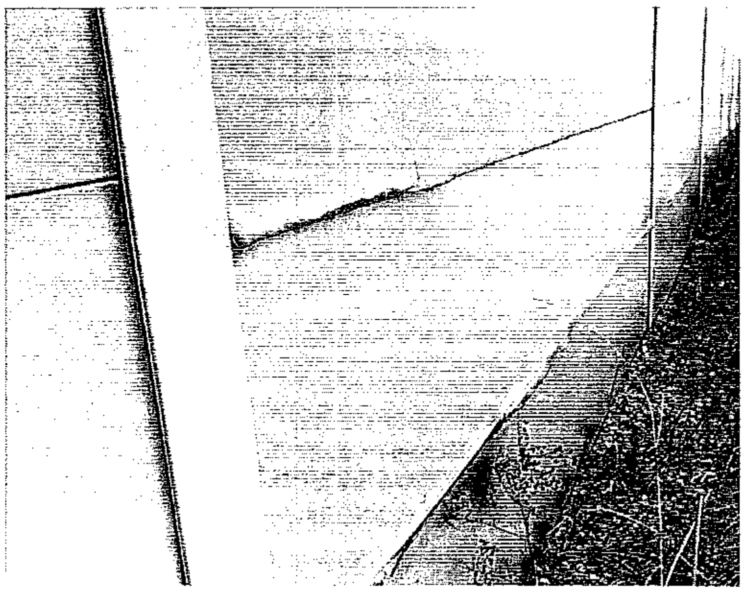
built 1984



16. I-255, Centerville, corrosion damage on backside of wall built 1984

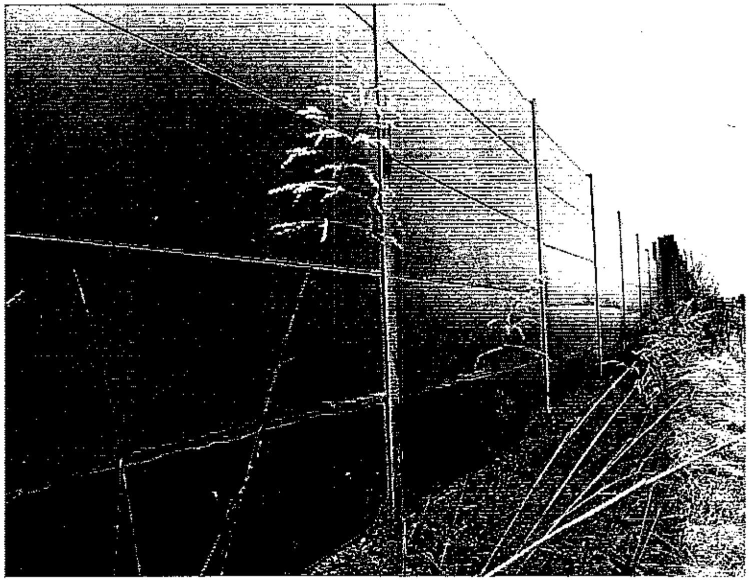


17. I-255, Centerville, corrosion damage on backside of wall built 1984



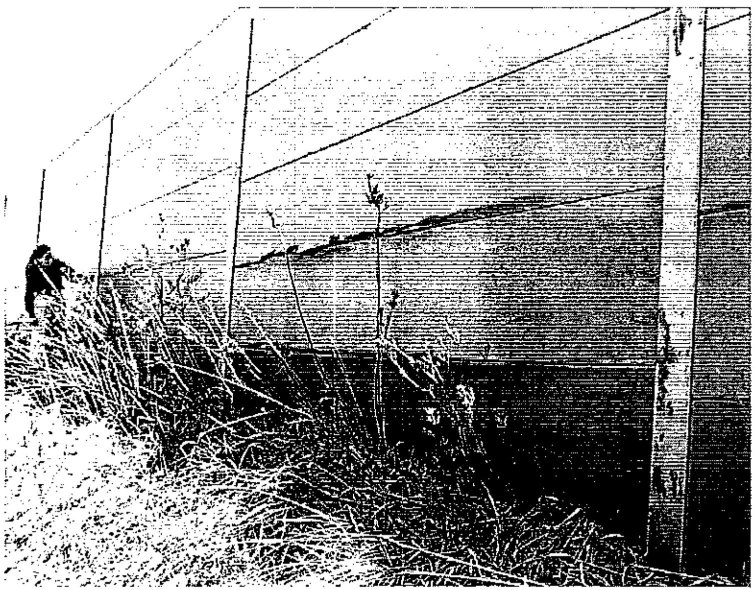
18. I-255, Centerville, corrosion damage on backside of wall built 1984

19. I-255, Centerville, corrosion damage on backside of wall built 1984



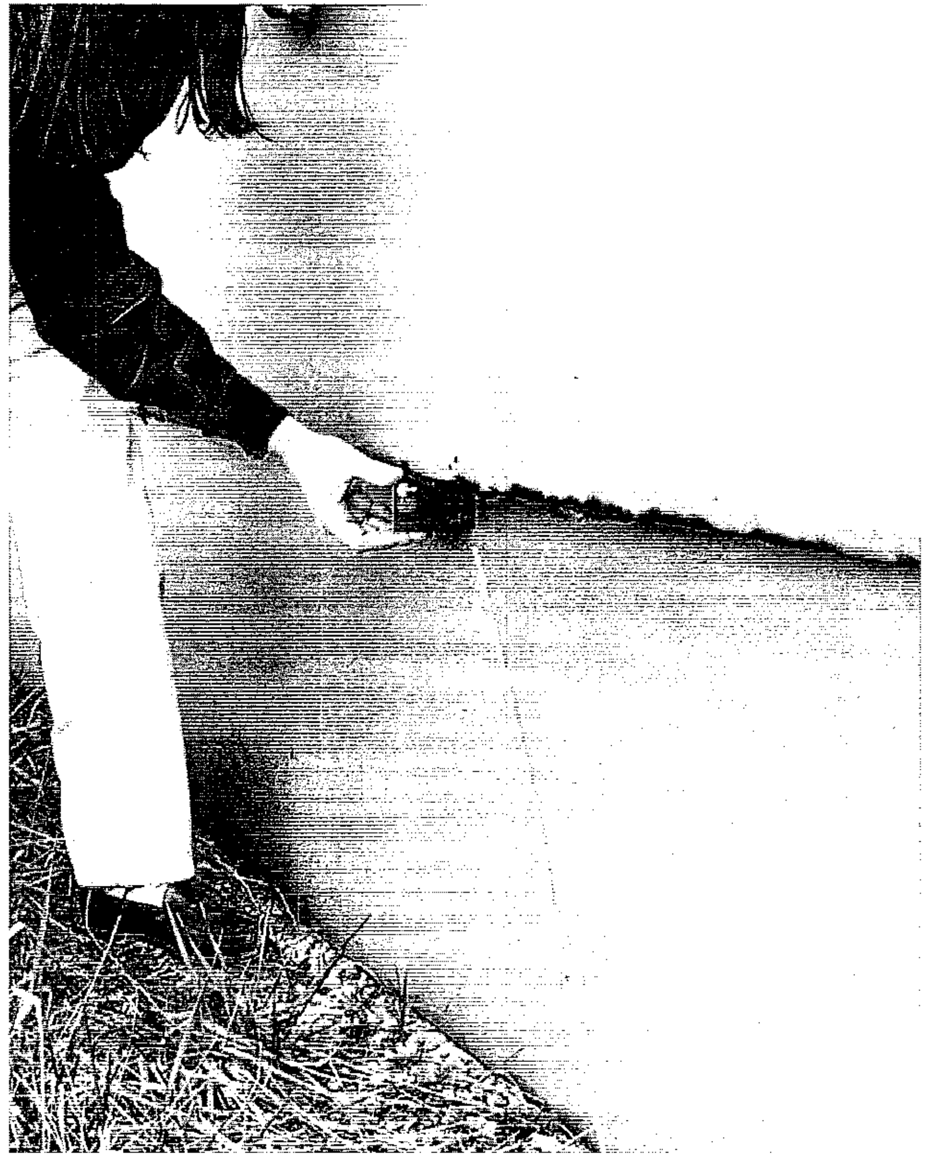
20. I-255, Centerville, corrosion damage on backside of wall

built 1984

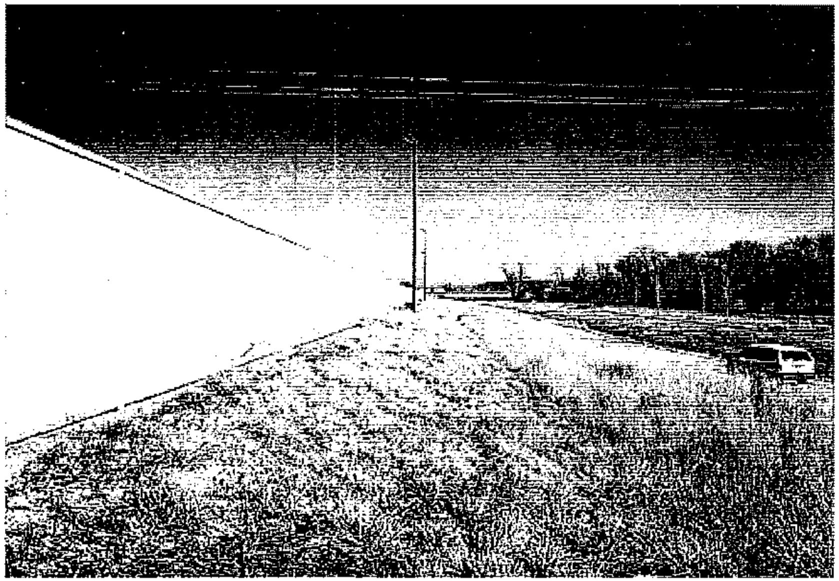


22. I-255, Centerville, corrosion damage on backside of wall

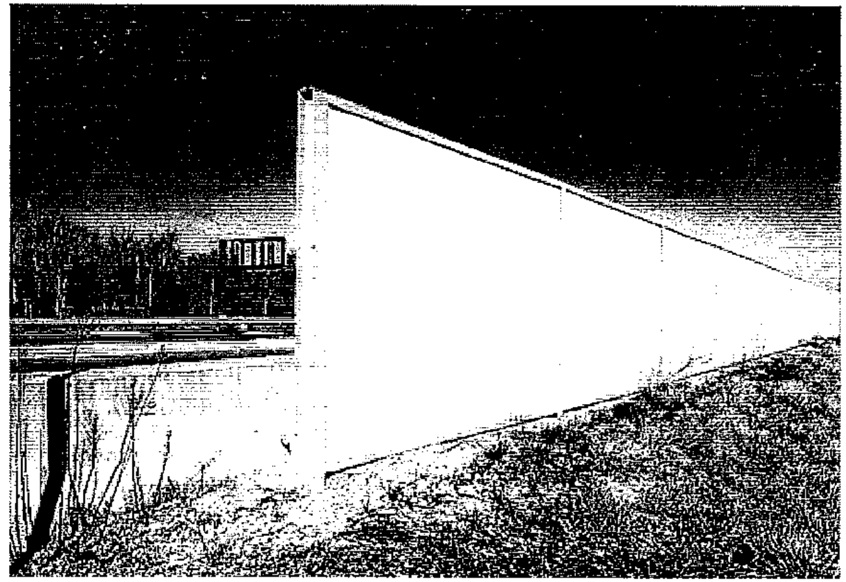
built 1984



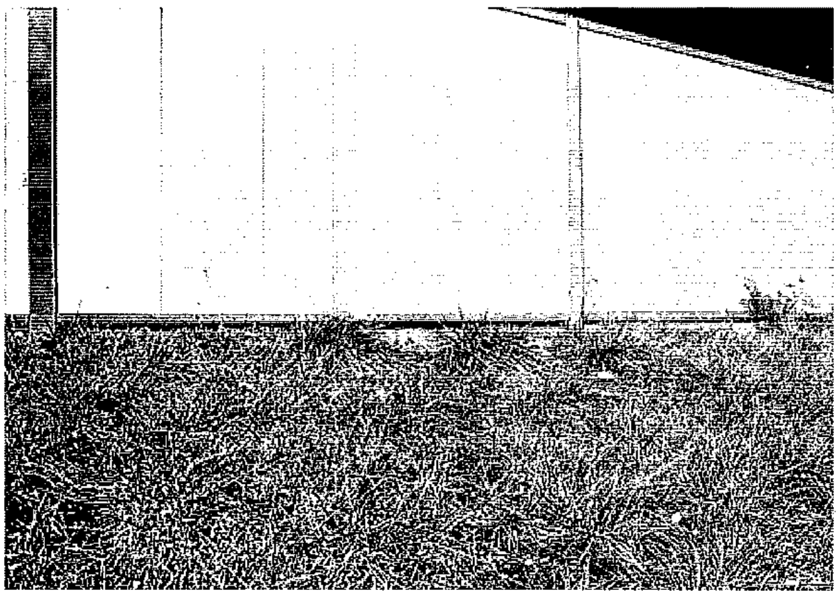
21. I-255, Centerville, bulging of backside of panels **built 1984**



23. Noishield aluminum, I-255 at US 40, Collinsville, vertically oriented panels, excellent condition built 1985

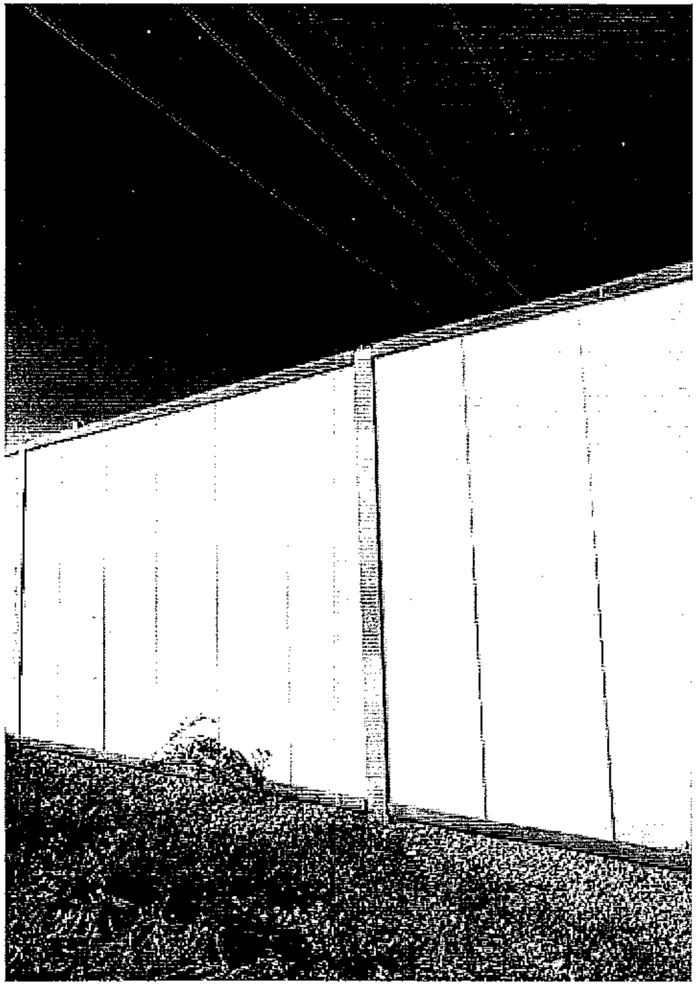


24. Noishield aluminum, I-255, Collinsville, vertically oriented panels, top and bottom channels built 1985

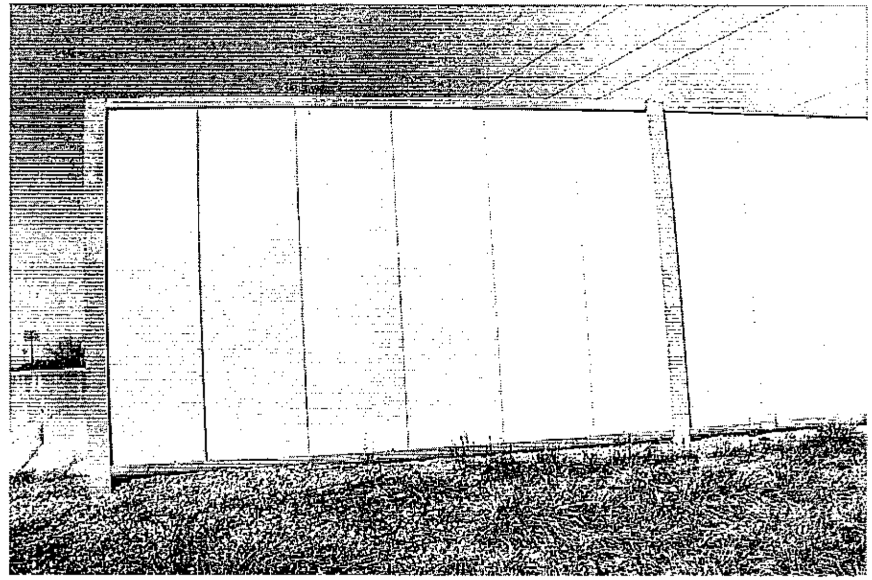


25. Noishield aluminum, I-255, Collinsville, residents' side

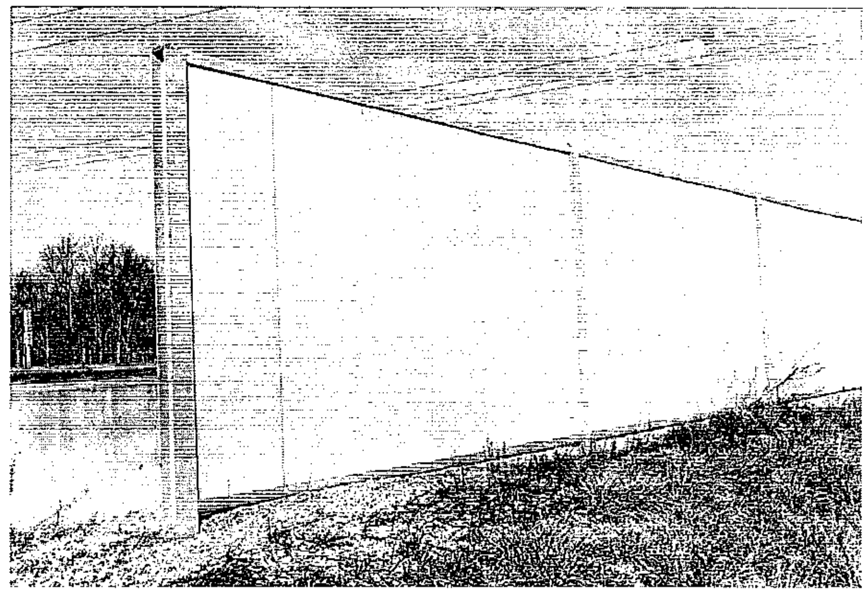
built 1985



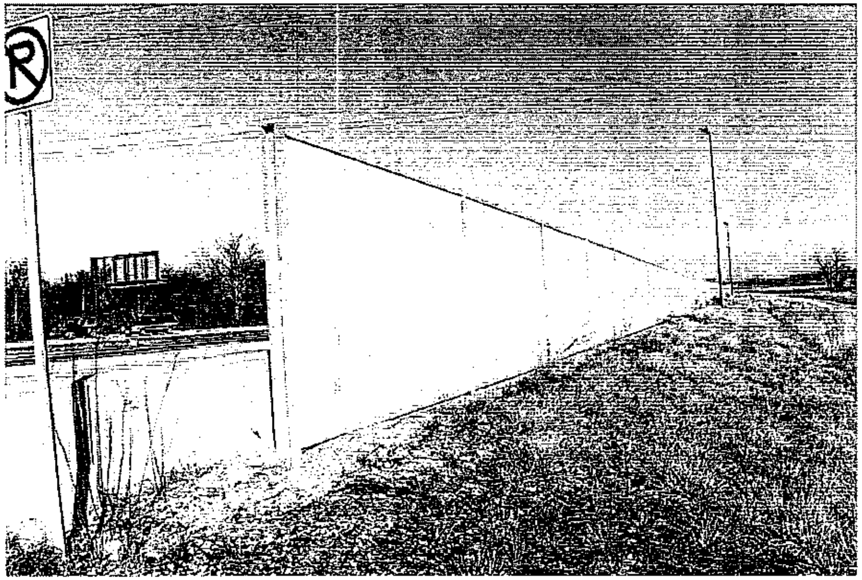
26. Noishield aluminum, I-255, Collinsville, residents' side built 1985



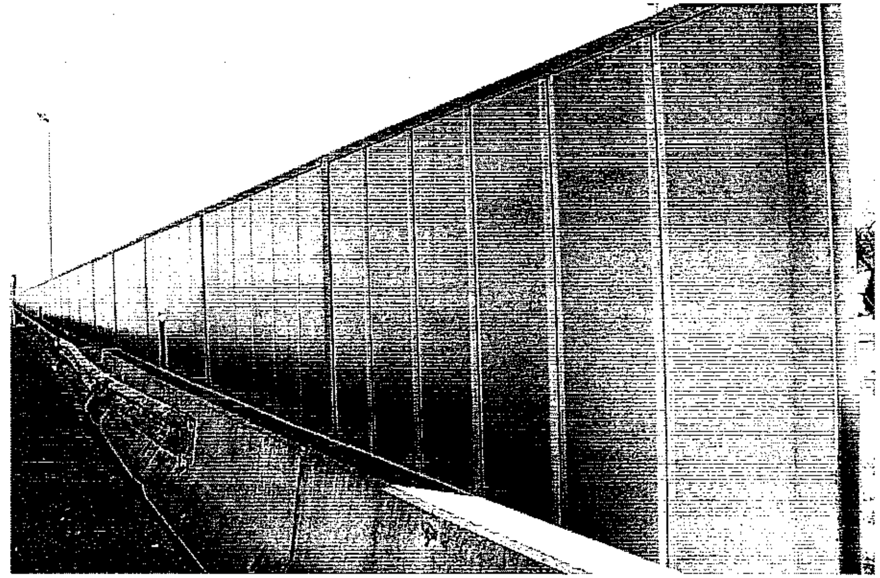
27. Noishield aluminum, I-255, Collinsville, residents' side built 1985



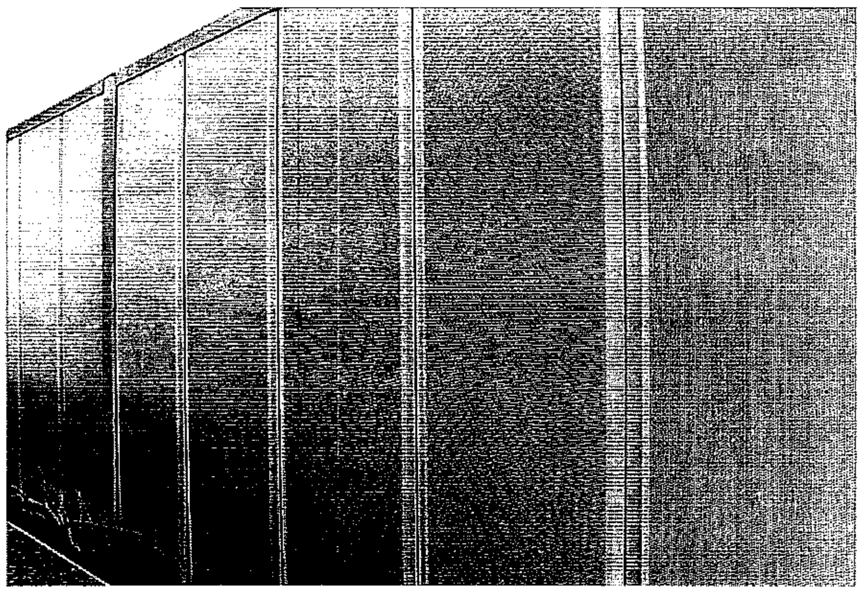
28. Noishield aluminum, I-255, Collinsville, residents' side built 1985



29. Noishield aluminum, I-255, Collinsville, residents' side built 1985

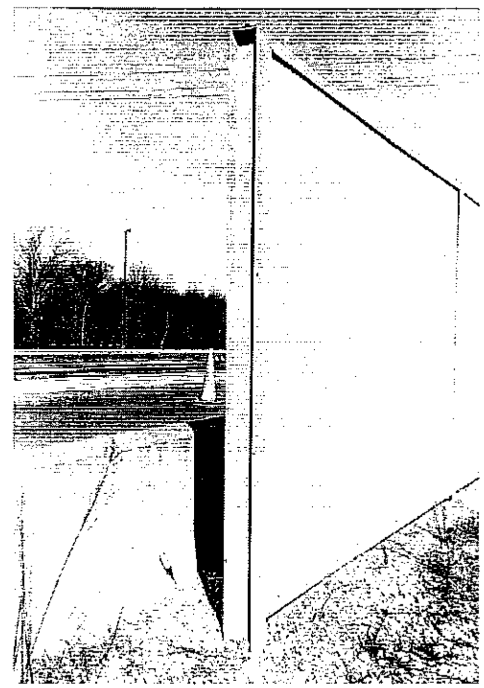


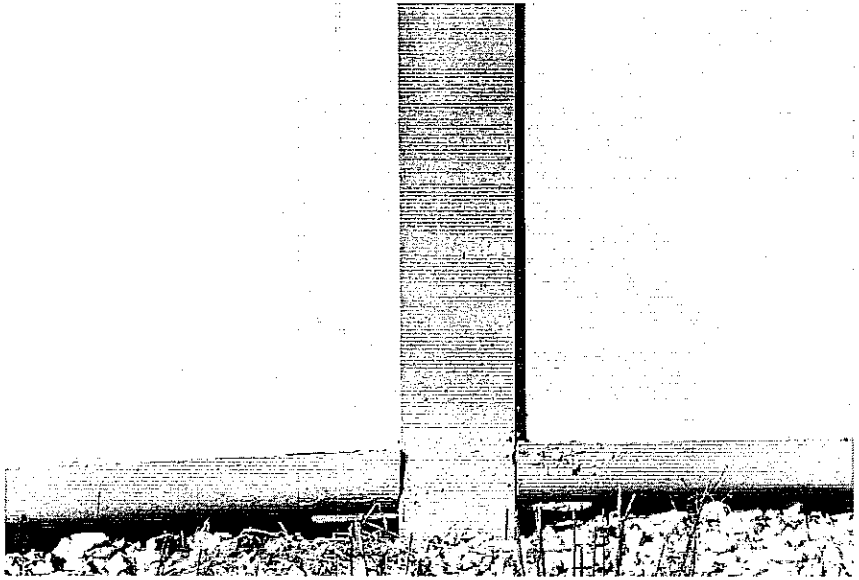
30. Noishield aluminum, I-255 at US 40, Collinsville, perforated surface on traffic side built 1985



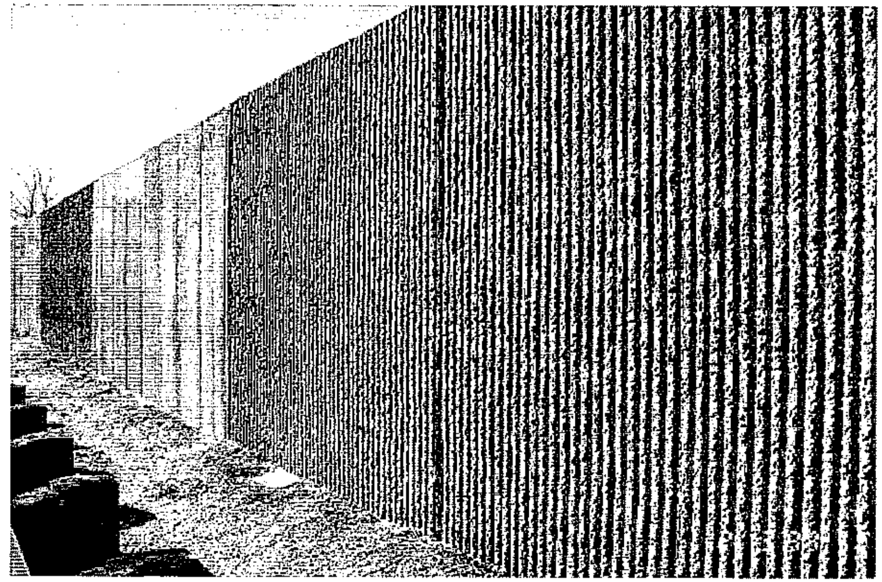
31. Noishield aluminum, I-255, Collinsville, perforated surface on traffic side built 1985

32. Noishield aluminum, I-255, Collinsville, end post built 1985

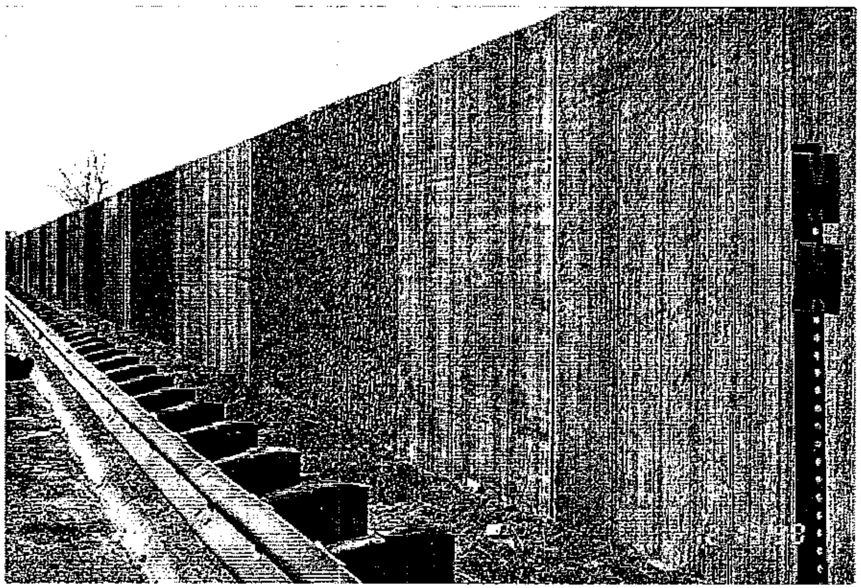




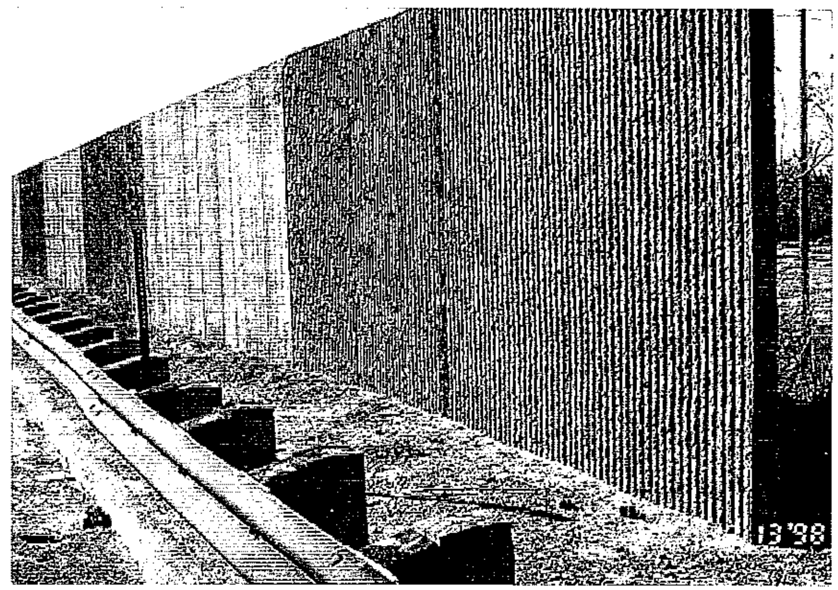
33. Noishield aluminum, I-255, Collinsville, backside detail of bottom channel **built 1985**



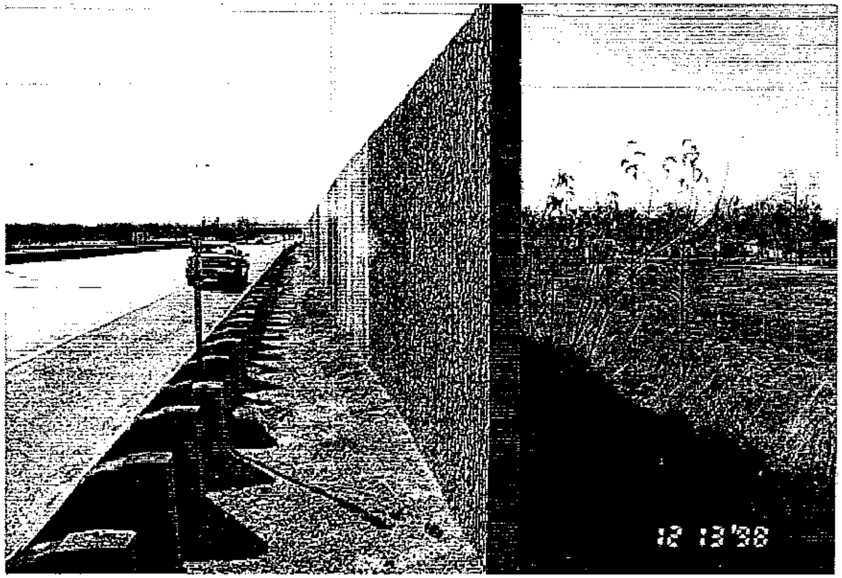
34. Precast/prestressed (cantilever) barrier, I-255, East St. Louis **built 1981**



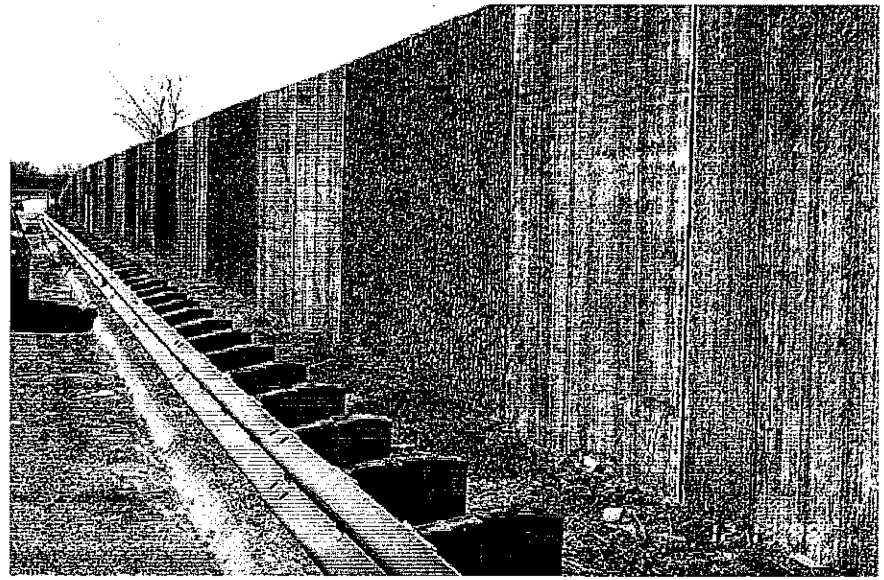
35. Precast/prestressed (cantilever) barrier, I-255, East St. Louis **built 1981**



36. Precast/prestressed (cantilever) barrier, I-255, East St. Louis **built 1981**

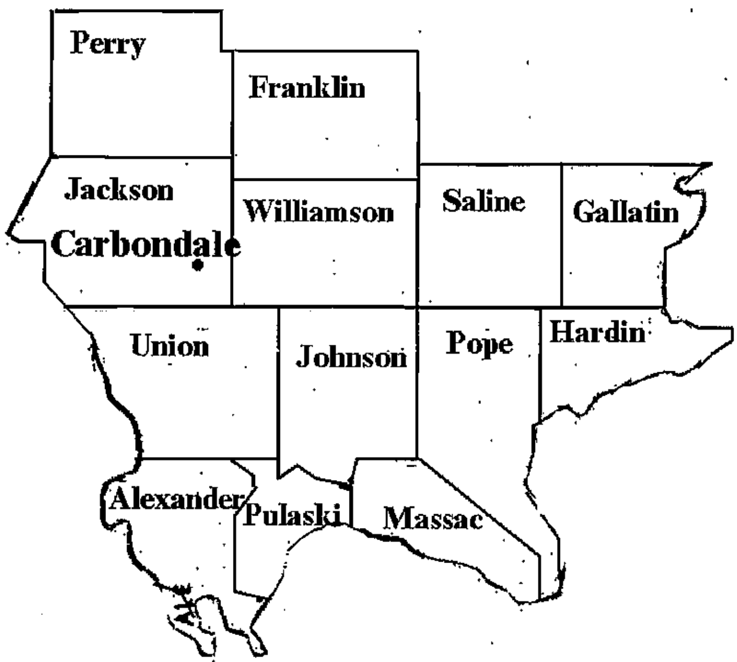


37. Precast/prestressed (cantilever) barrier, I-255, East St. Louis
built 1981



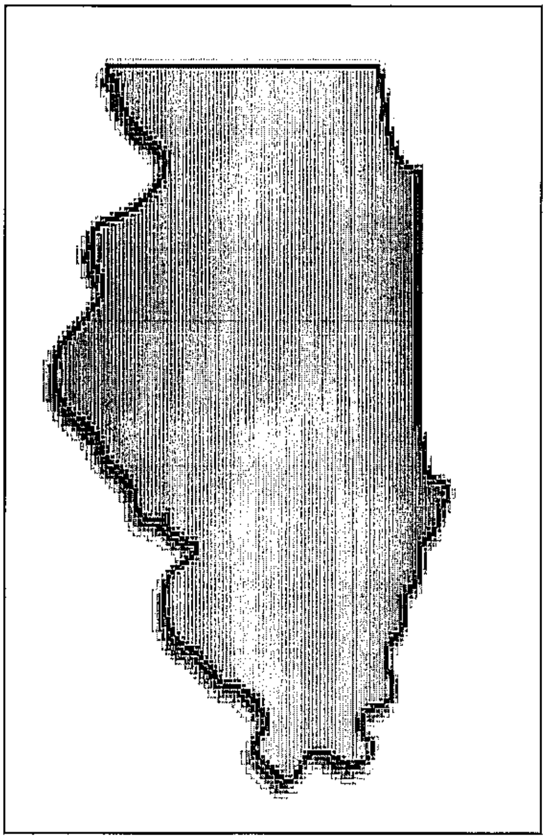
38. Precast/prestressed (cantilever) barrier, I-255, East St. Louis
built 1981

District 9



No barriers to date

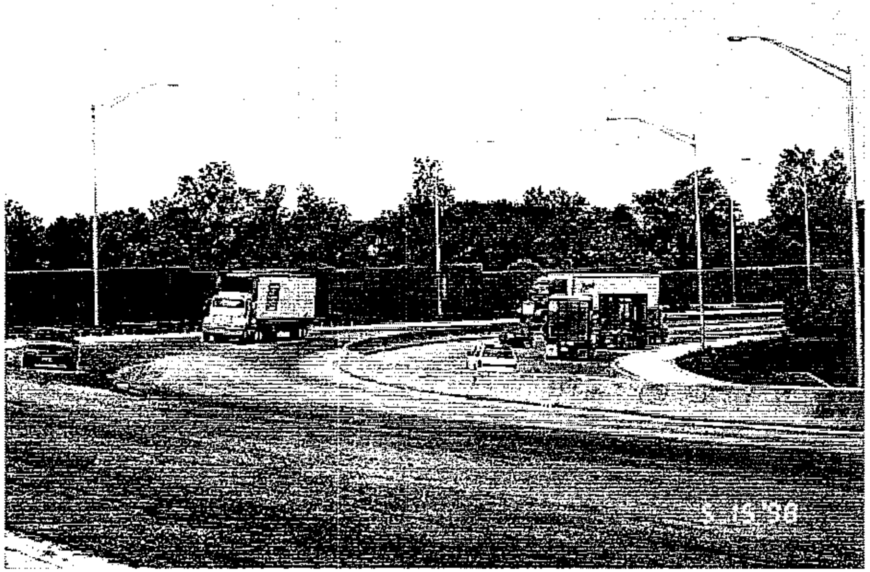
Illinois State Toll Highway Authority



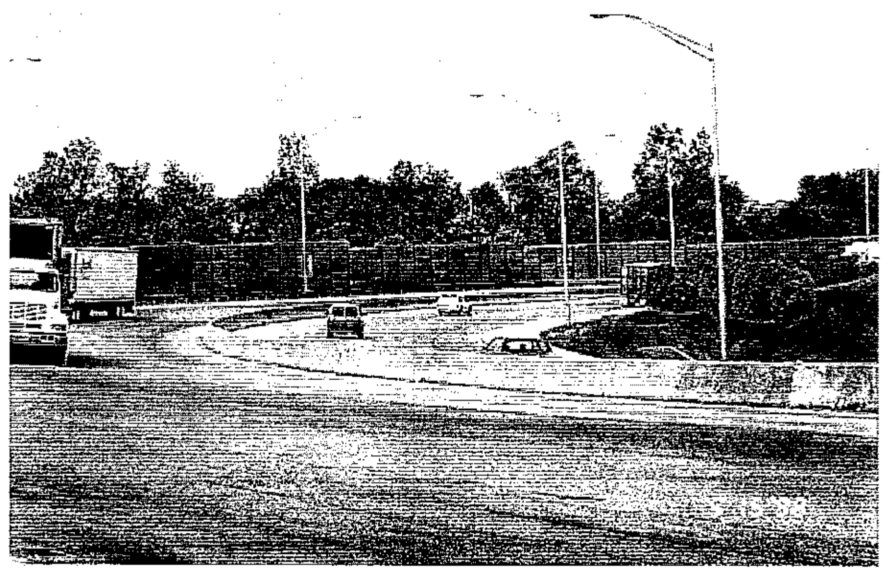
List of Photographs

Photograph Number	Description	Page
9	Carsonite, I-294, 1994-1998	10-3
10	Carsonite, I-294 at I-55 ramp toll plaza, 1994-1998	10-3
11	Carsonite, I-294, view of end post, 1994-1998	10-3
12	Carsonite, I-294, aerial view showing random color variation of boards, 1994-1998	10-4
13	Carsonite, I-294, overlap in barriers at access point (left), 1994-1998	10-4
14	Precast concrete integral post and panel, I-294, residents' side, showing gaps at joints, 1994-1998	10-4
15	Precast concrete integral post and panel, at change in alignment, 1994-1998	10-4
16	Precast concrete noise wall (foreground) transitioning to glue-laminated wood wall beyond, I-294, 1994-1998	10-5
17	Precast concrete noise wall (foreground) transitioning to glue-laminated wood wall, I-294; note access gap in wall, 1994-1998	10-5
18	Caisson foundations and anchor bolts in place for precast concrete post and panel installation, I-294 at IL 20, 1994	10-6
19	Afer erection of wall panels; note method of transport to site from precasting plant in Blackstone, IL, I-294 at IL 20, 1994	10-6
20	Erection of precast concrete panels with integral posts, I-294 at IL 20, 1994	10-6
21	Installation of precast concrete panels, I-294, 1994	10-6
22	Section of precast concrete integral post and panel nearing completion, I-294, 1994	10-7
23	View of installation of precast concrete panel, I-294, 1994	10-7
24	Maintenance of traffic during wall installation, I-294, 1994	10-8
25	Equipment required for installation, I-294, 1994	10-8
26	Wall panel mounted on two anchor bolts; design was later revised to require four, I-294, 1994	10-8
27	Precast concrete integral post and panel, I-294, panels shimmed to plumb, 1994	10-8
28	Precast concrete panels in place with temporary shims, I-294, 1994	10-9
29	Precast concrete panels stored at plant for transport to I-294 project, 1994	10-9
30	Precast concrete integral post and panel sections, end view showing cross section, 1994	10-9
31	Precast concrete integral post and panel, I-355, new construction of combination retaining wall/barrier at Boughton Road, 1998	10-10
32	Precast concrete integral post and panel, I-355 and Boughton Road, combination retaining wall/barrier, 1998	10-10

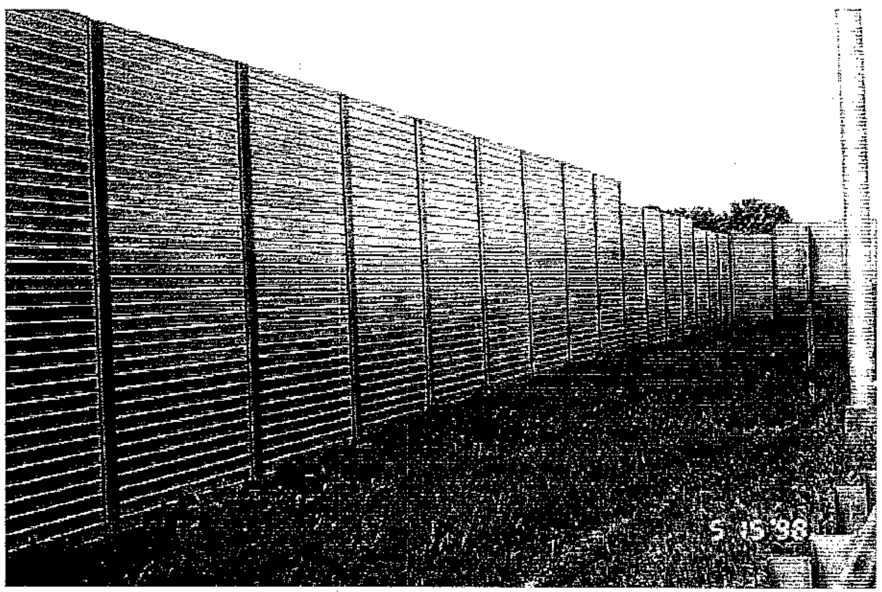
Photograph Number	Description	Page
33	Glue-laminated wood barrier Boughton Road overpass at I-355, 1988-1998	10-10
34	Glue-laminated wood barrier, Boughton Road overpass at I-355, end view showing cross section, 1988-1998	10-10



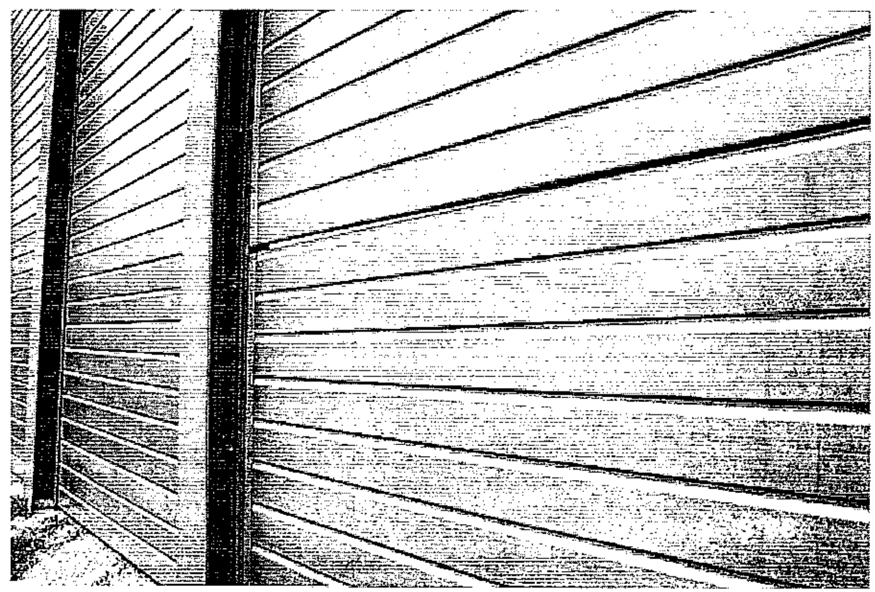
1. **Carsonite, I-294, showing uneven coloration of panel components when viewed from a distance 1994-1998**



2. **Carsonite, I-294 at toll plaza, showing uneven discoloration of panels 1994-1998**

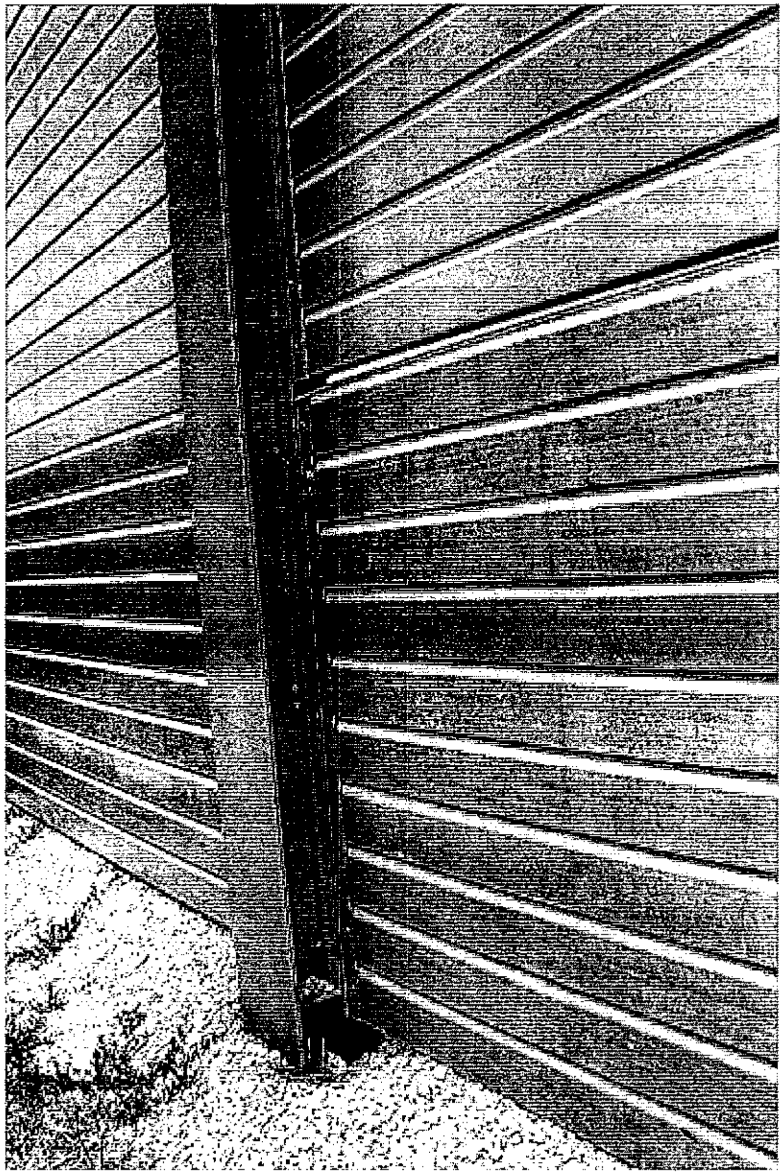


3. **Carsonite, I-294 at toll plaza, showing excellent appearance at close range 1994-1998**

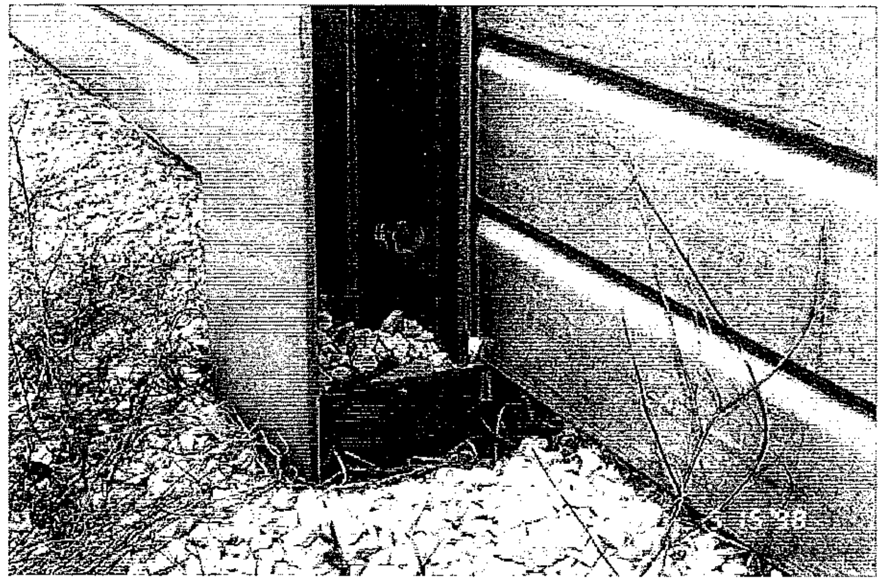


4. **Carsonite, I-294, small gap between panel sections**

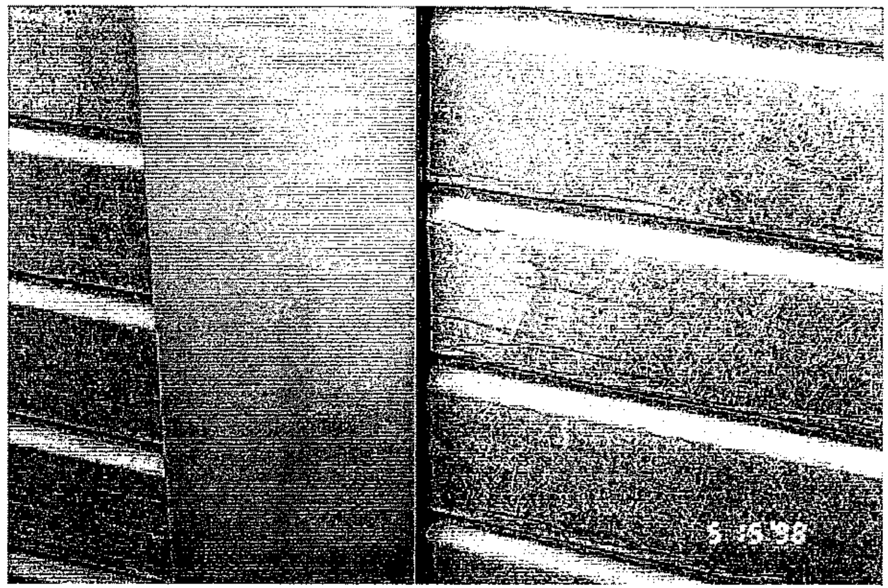
1994-1998



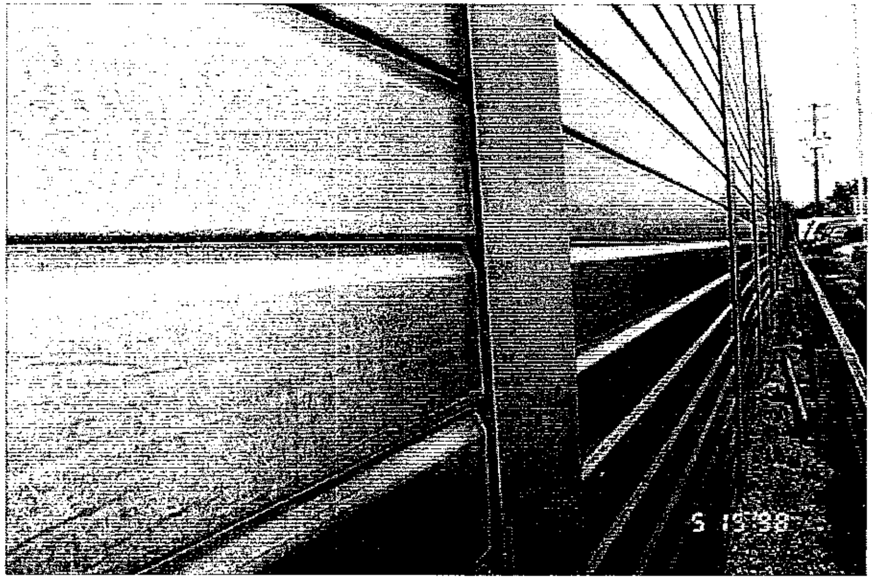
5. Carsonite, I-294 at toll plaza, showing 1.5 inch drop of bottom panel section, gap created in wall 1994-1998



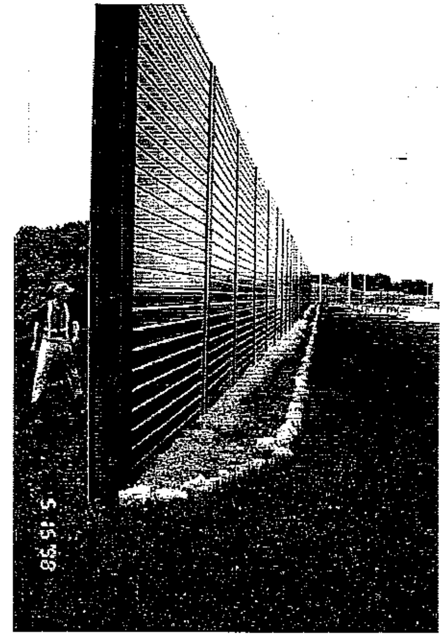
6. Carsonite, I-294, detail of support of panels on steel posts 1994-1998



7. Carsonite, I-294, detail of steel post 1994-1998

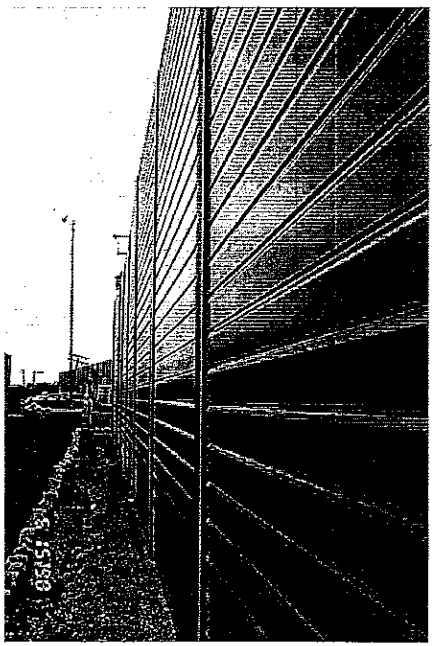


8. Carsonite, I-294, detail of steel post 1994-1998



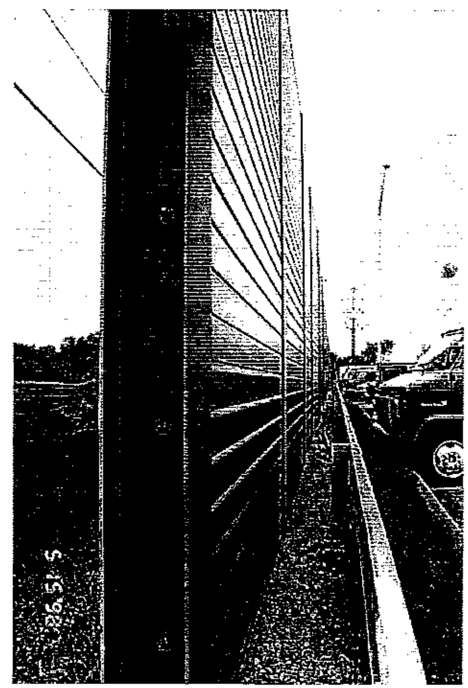
9. Carsonite, I-294

1994-1998

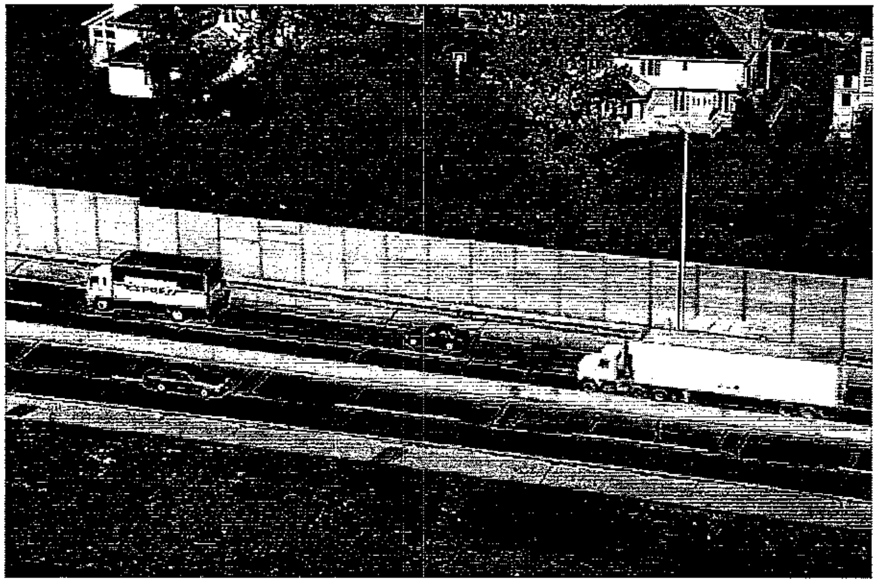


10. Carsonite, I-294 at I-55 ramp toll plaza

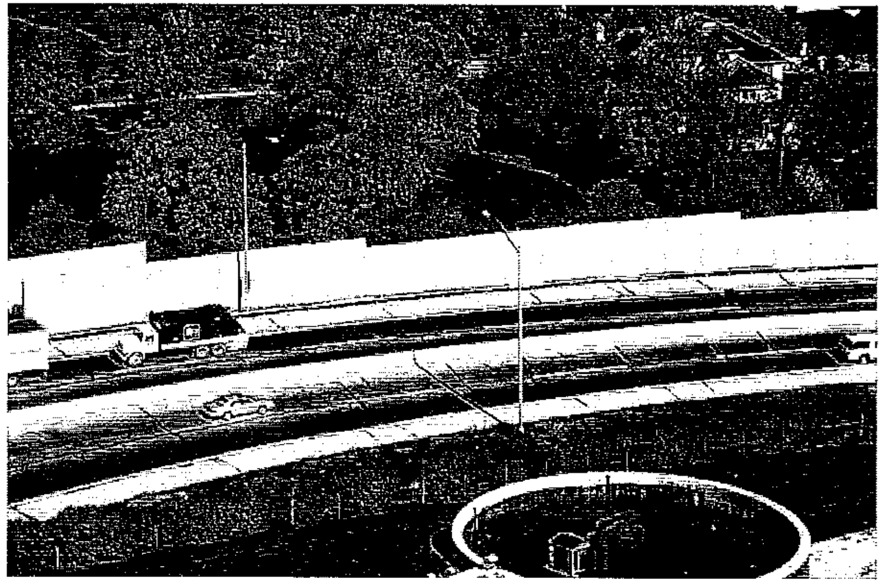
1994-1998



11. Carsonite, I-294, view of end post 1994-1998

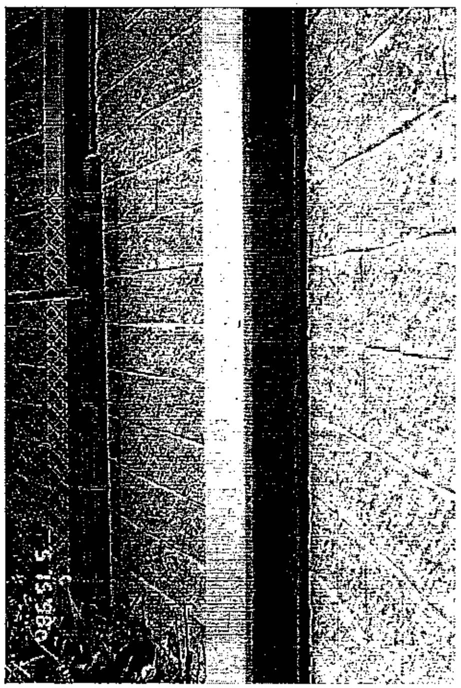


12. Carsonite, I-294, aerial view showing random color variation of boards 1994-1998



13. Carsonite, I-294, overlap in barriers at access point (left)

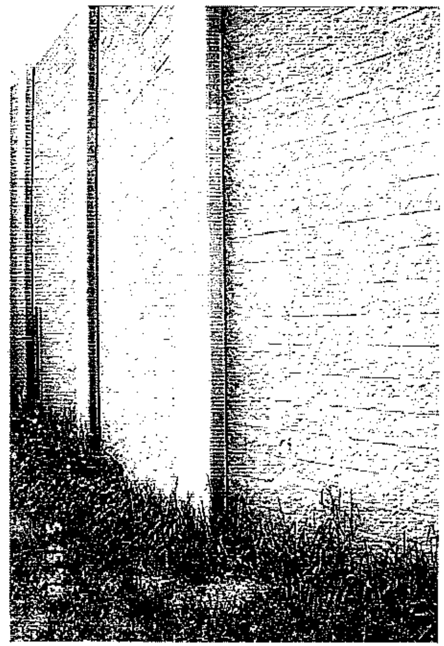
1994-1998

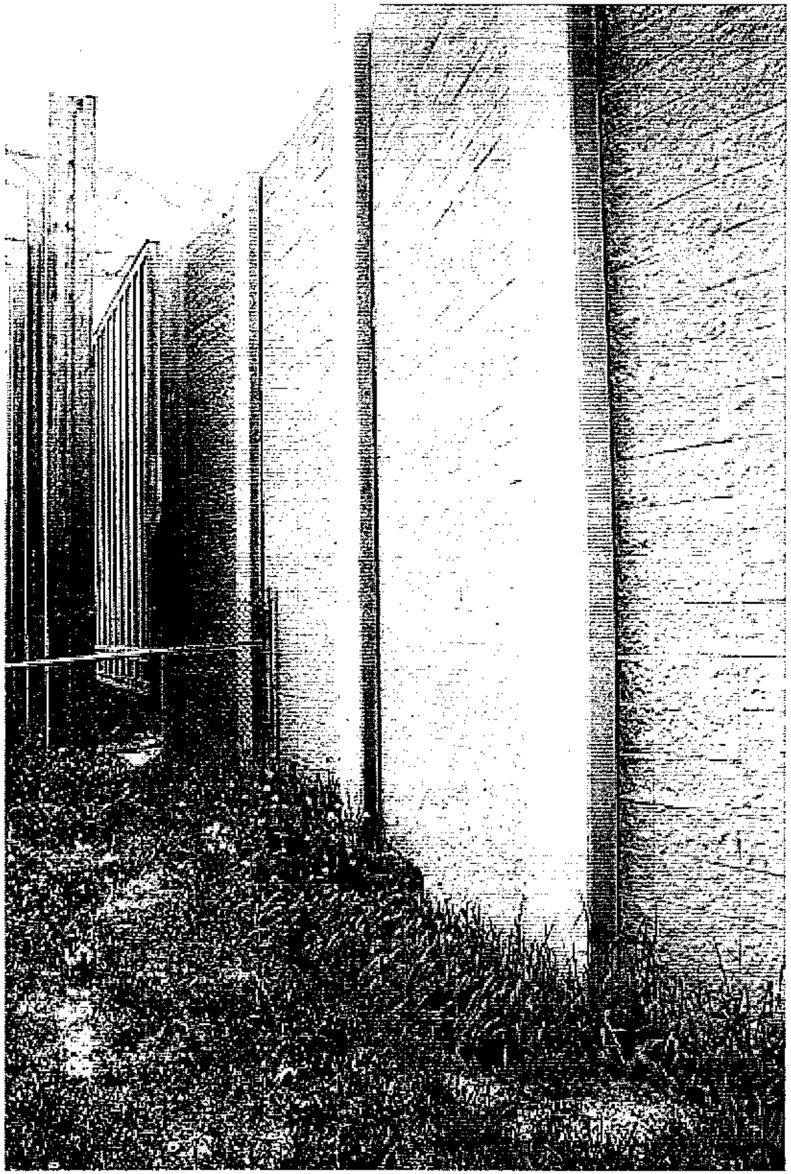


14. Precast concrete integral post and panel, I-294, residents' side, showing gaps at joints

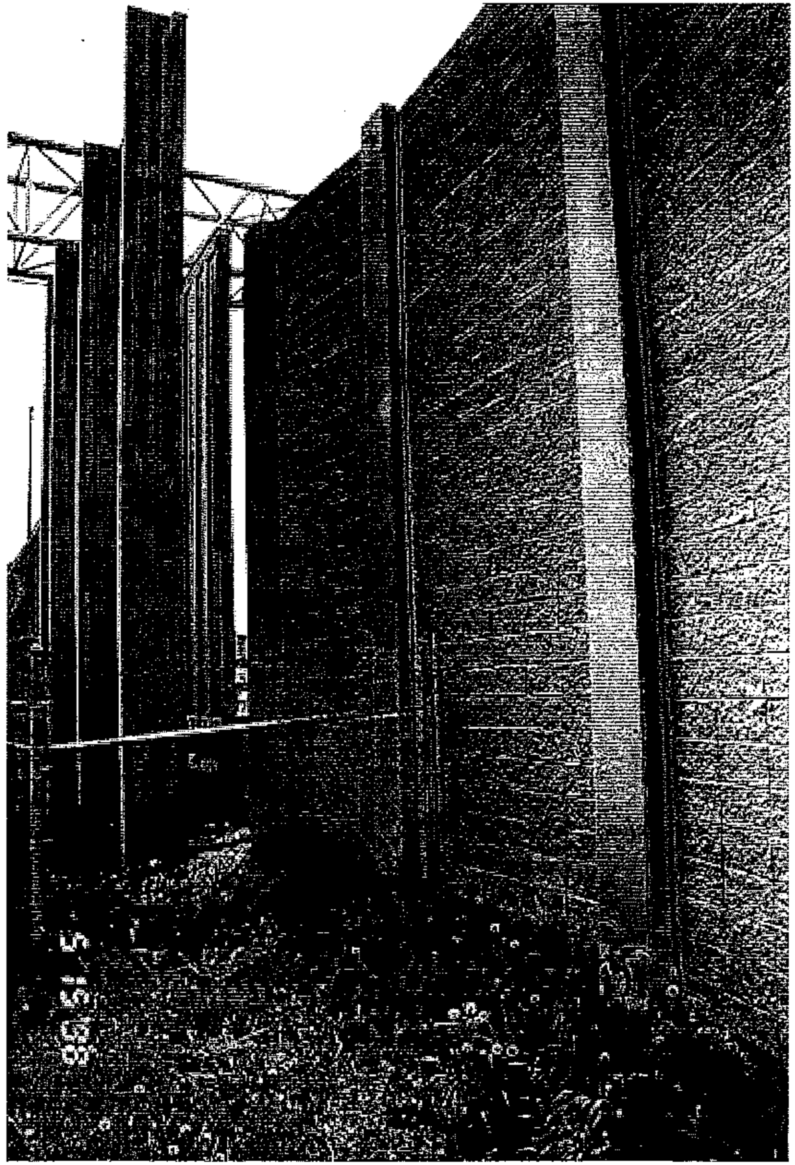
1994-1998

15. Precast concrete integral post and panel, at change in alignment 1994-1998





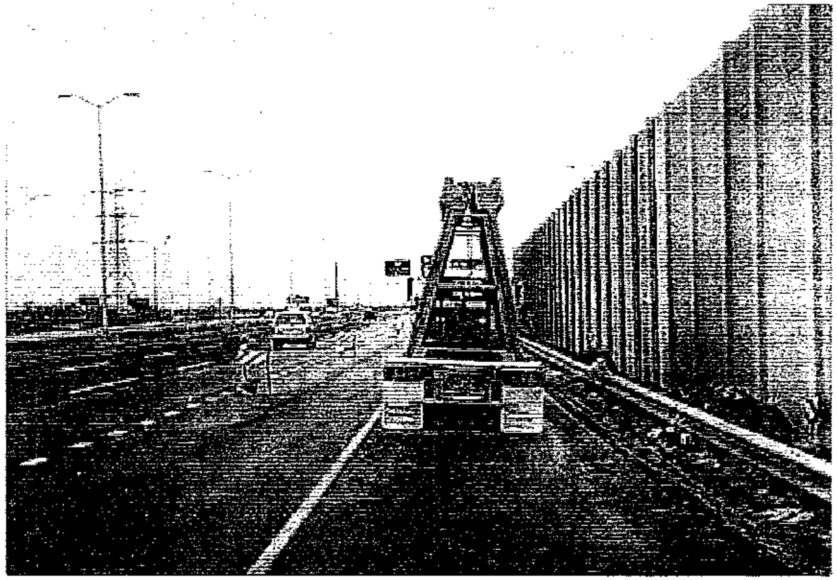
16. Precast concrete noise wall (foreground) transitioning to glue-laminated wood wall beyond, I-294 1994-1998



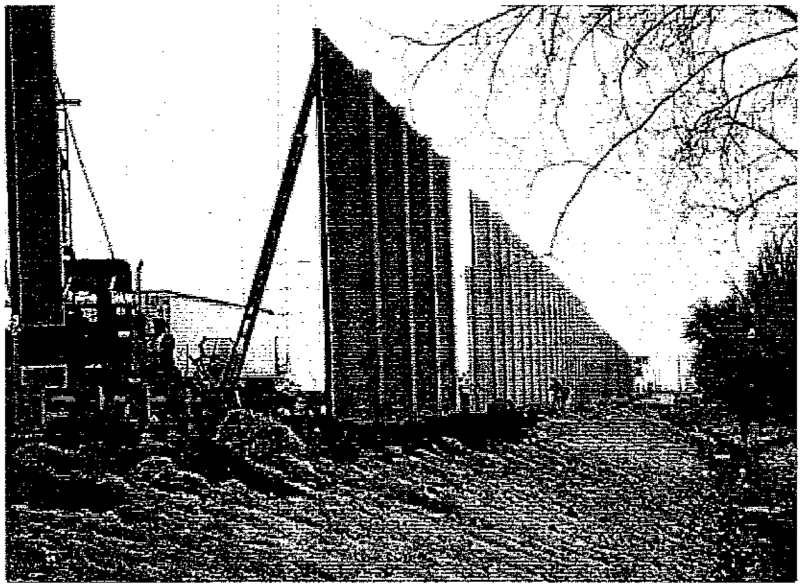
17. Precast concrete noise wall (foreground) transitioning to glue-laminated wood wall, I-294; note access gap in wall

1994-1998

18. Caisson foundations and anchor bolts in place for precast concrete post and panel installation, I-294 at IL 20 1994

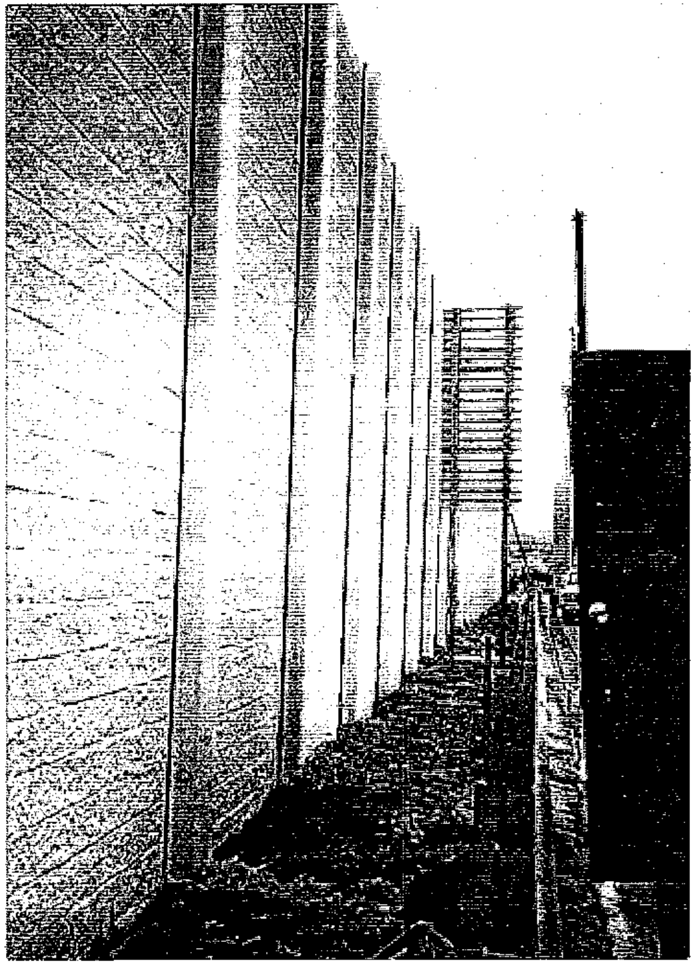


19. After erection of wall panels; note method of transport to site from precasting plant in Blackstone, IL, I-294 at IL 20 1994

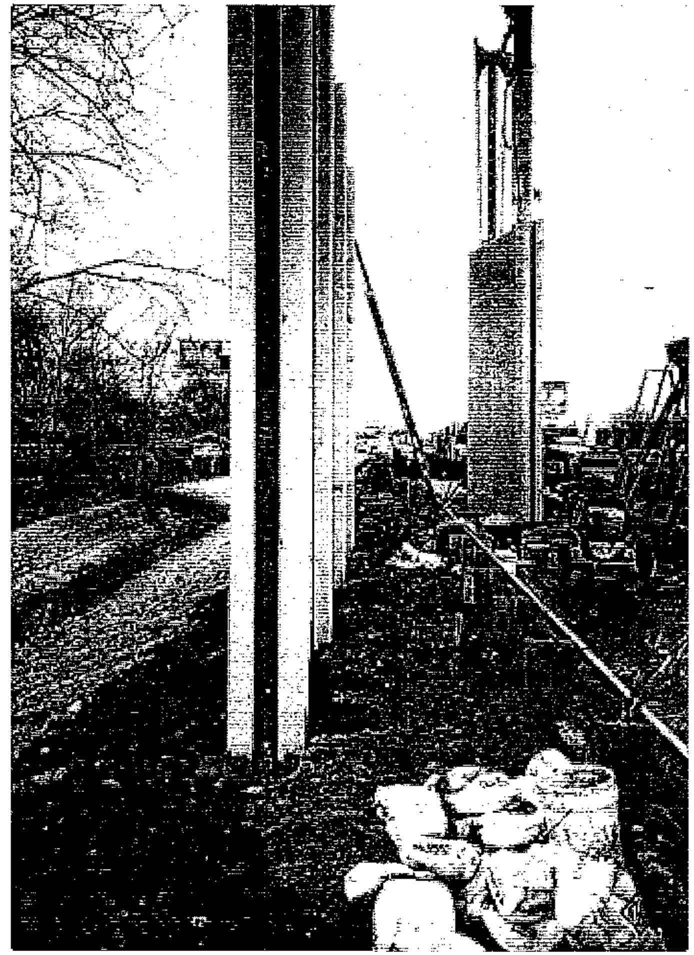


20. Erection of precast concrete panels with integral posts, I-294 at IL 20 1994

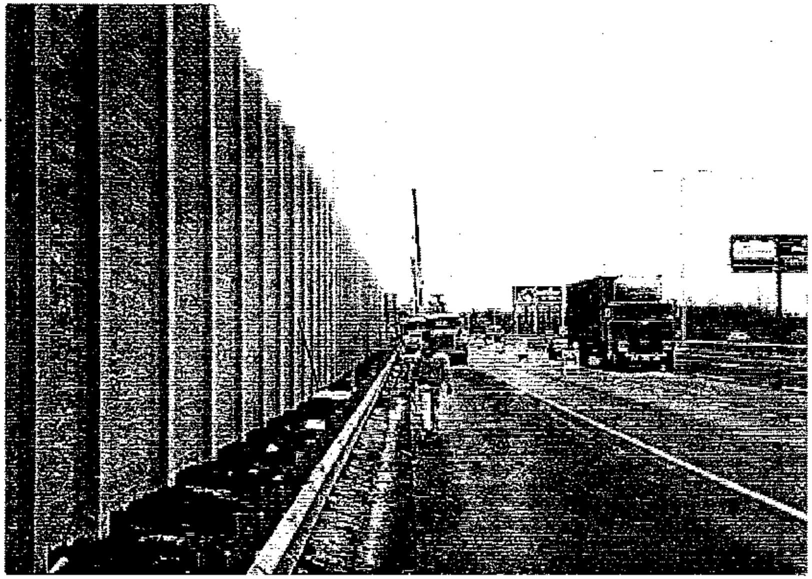
21. Installation of precast concrete panels, I-294 1994



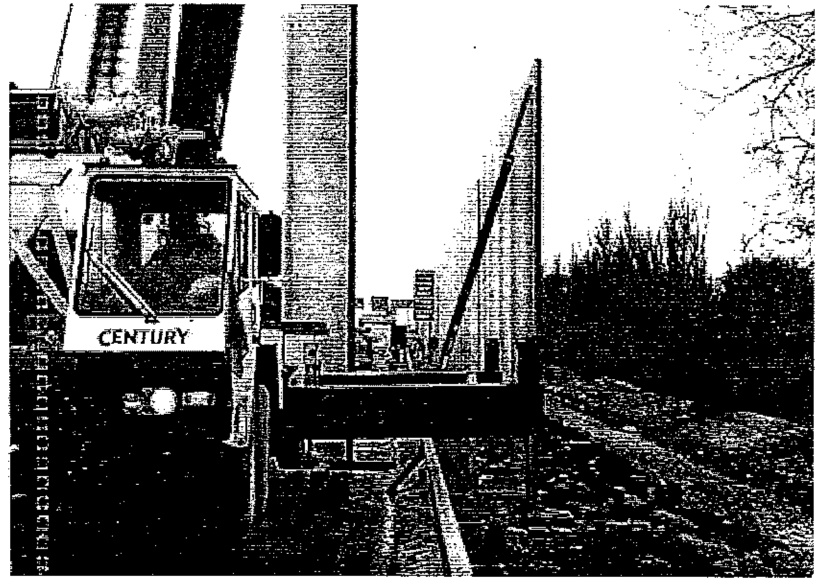
22. Section of precast concrete integral post and panel nearing completion, I-294 1994



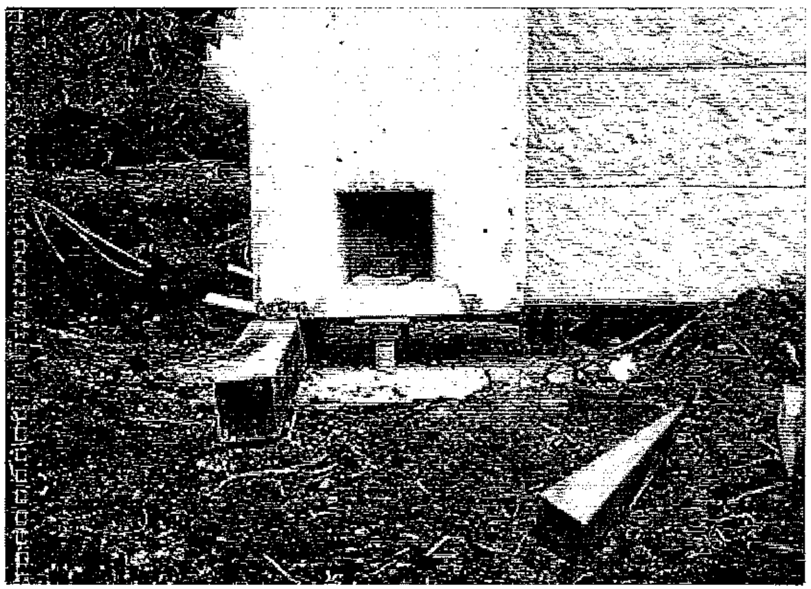
23. View of installation of precast concrete panel, I-294 1994



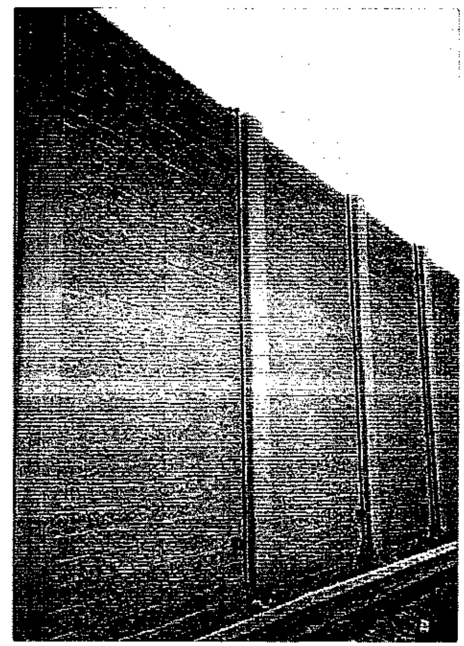
24. Maintenance of traffic during wall installation, I-294 1994



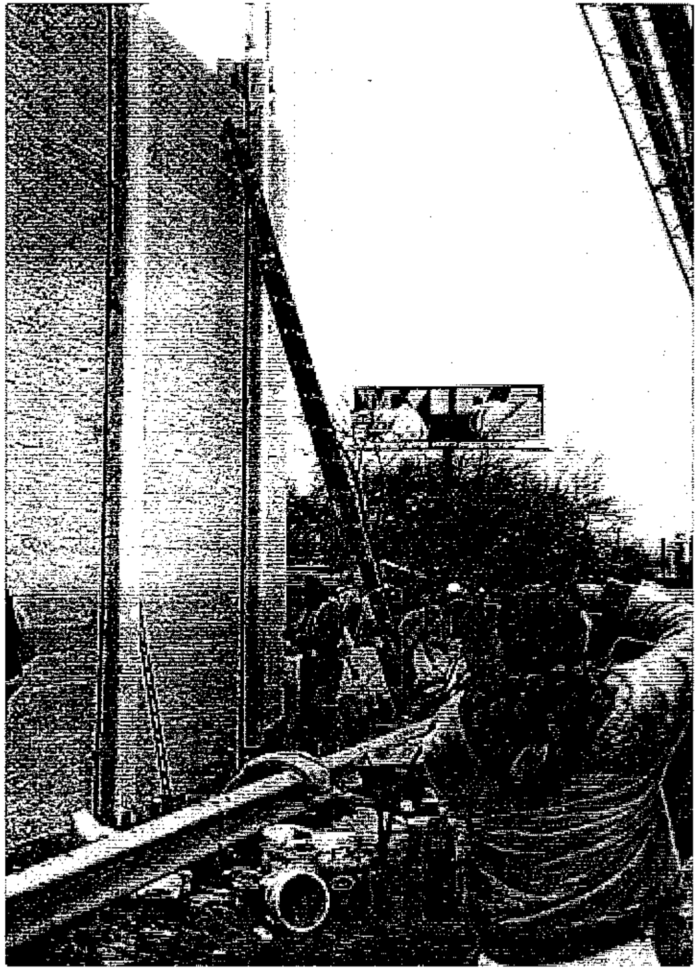
25. Equipment required for installation, I-294 1994



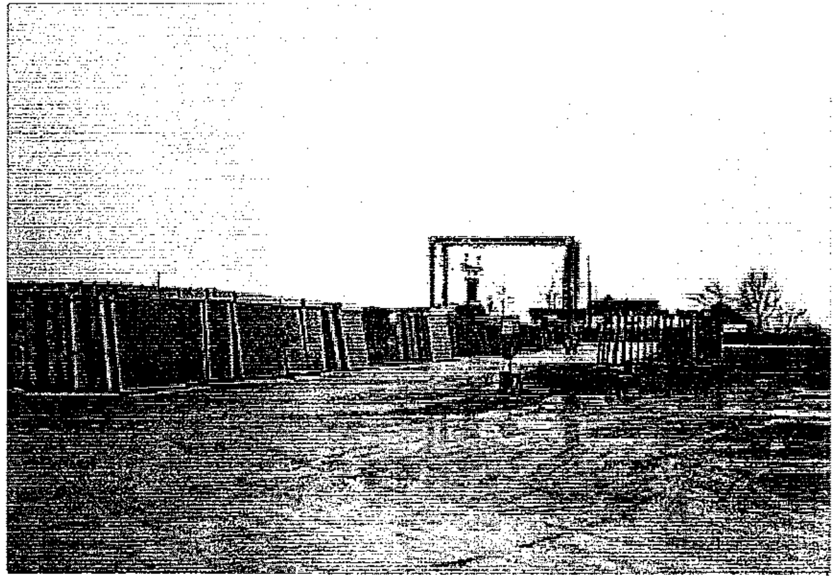
26. Wall panel mounted on two anchor bolts; design was later revised to require four, I-294 1994



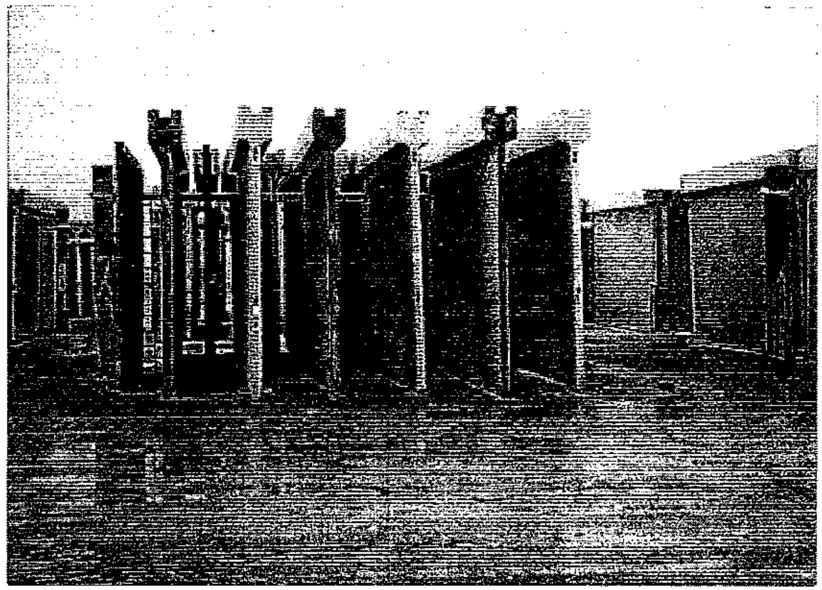
27. Precast concrete integral post and panel, I-294, panels shimmed to plumb 1994



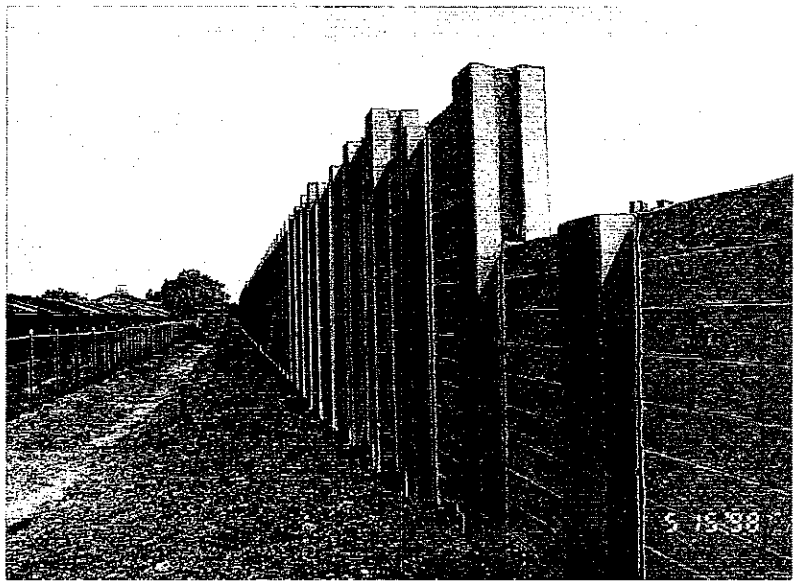
28. Precast concrete panels in place with temporary shims, I-294 1994



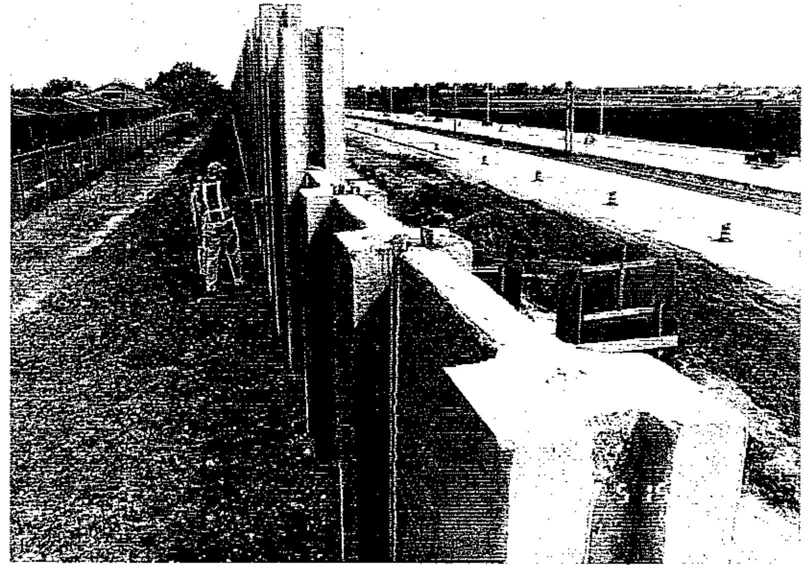
29. Precast concrete panels stored at plant for transport to I-294 project 1994



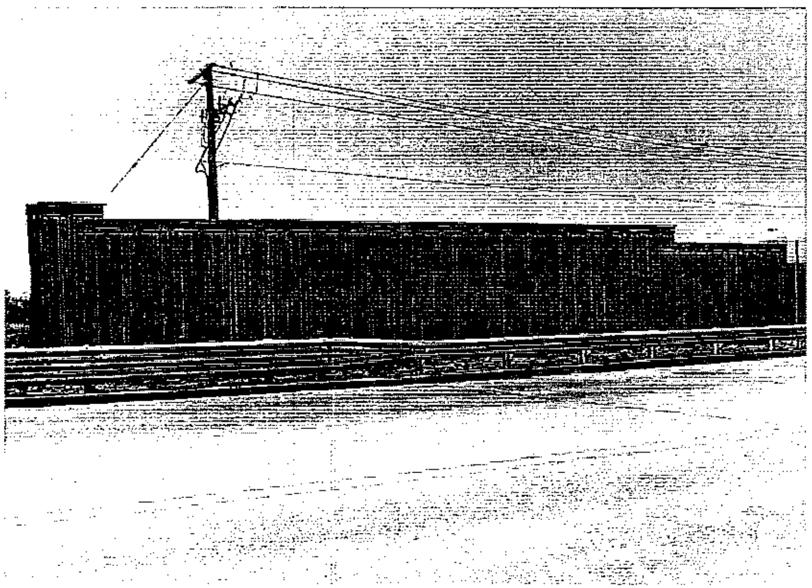
30. Precast concrete integral post and panel sections, end view showing cross section 1994



31. Precast concrete integral post and panel, I-355, new construction of combination retaining wall/barrier at Boughton Road 1998



32. Precast concrete integral post and panel, I-355 and Boughton Road, combination retaining wall/barrier 1998

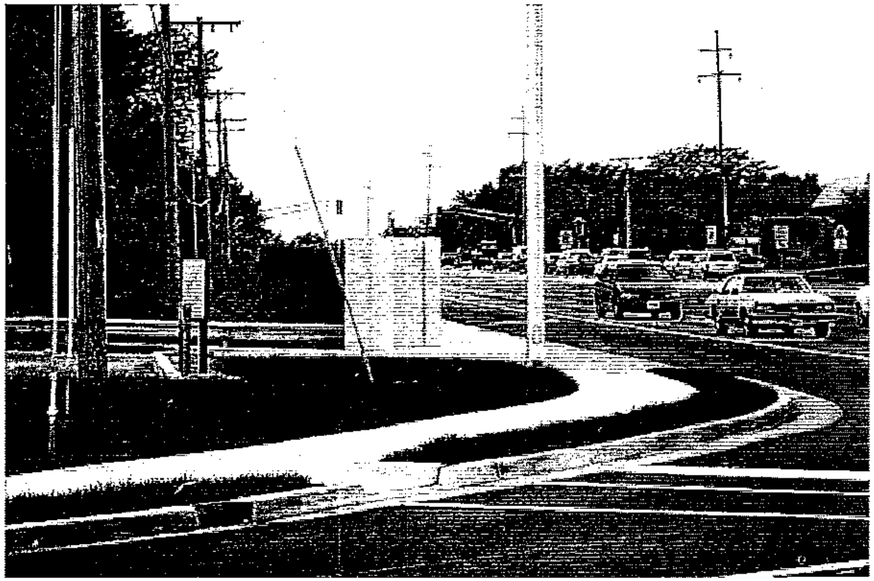


33. Glue-laminated wood barrier Boughton Road overpass at I-355 1988-1998

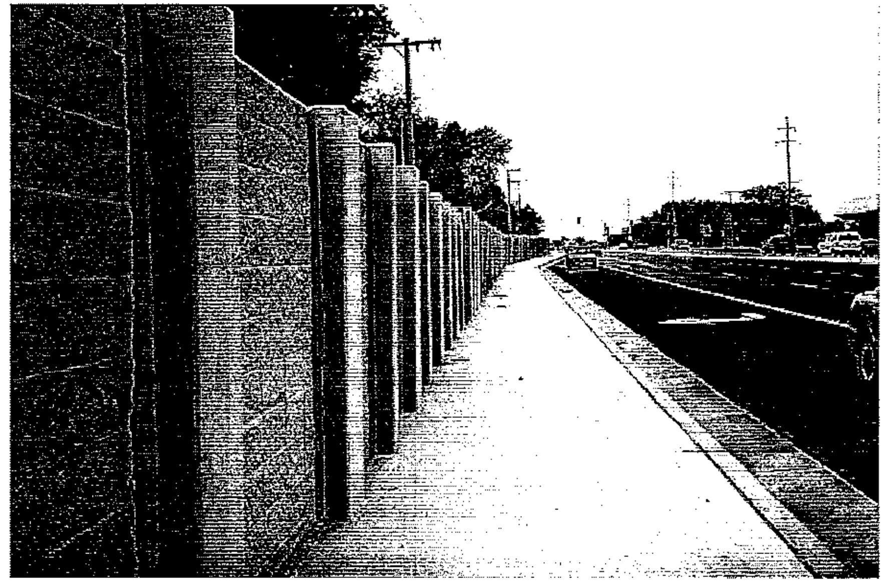
34. Glue-laminated wood barrier, Boughton Road overpass at I-355, end view showing cross section 1988-1998

City of Springfield Project

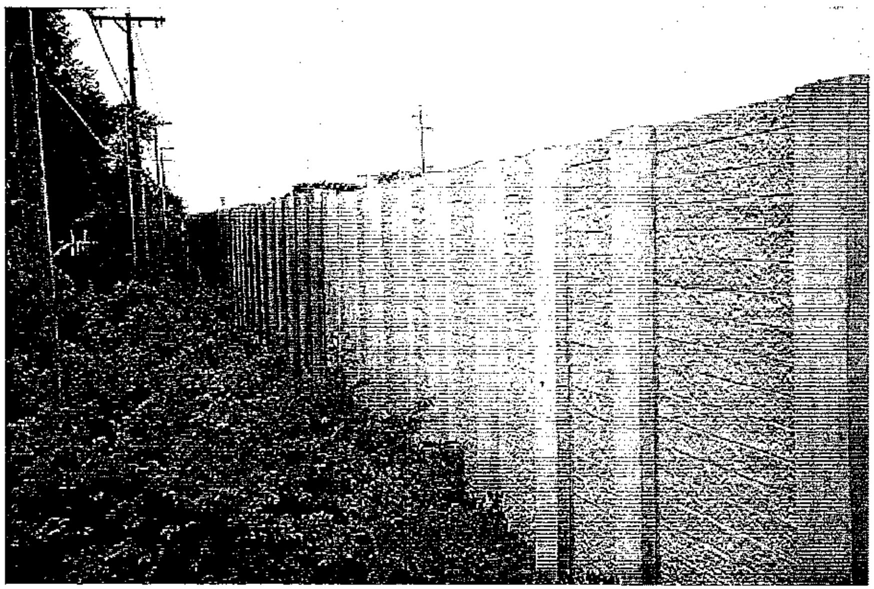
List of Photographs



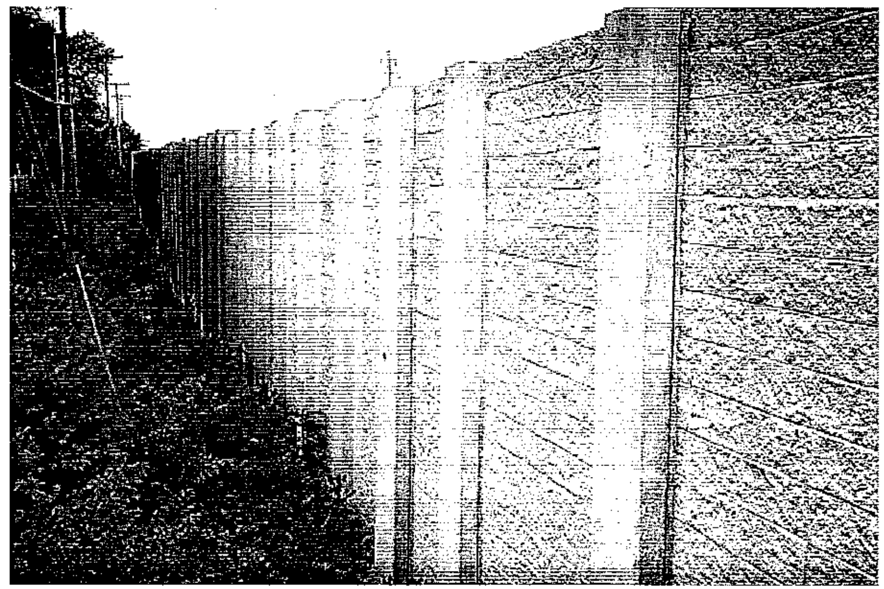
1. Springfield, Wabash Avenue at Chatham Road



2. Springfield, Wabash Avenue at Chatham Road, looking west

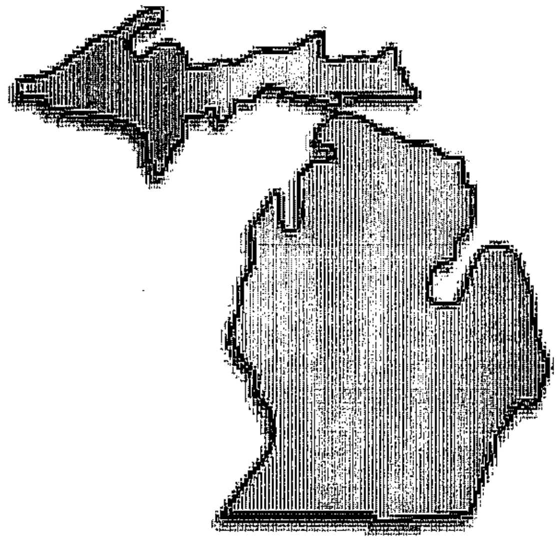


3. Springfield, Wabash Avenue at Chatham Road. City of Springfield project, combination retaining wall, noise barrier wall using precast concrete integral post and panel construction (residents' side)



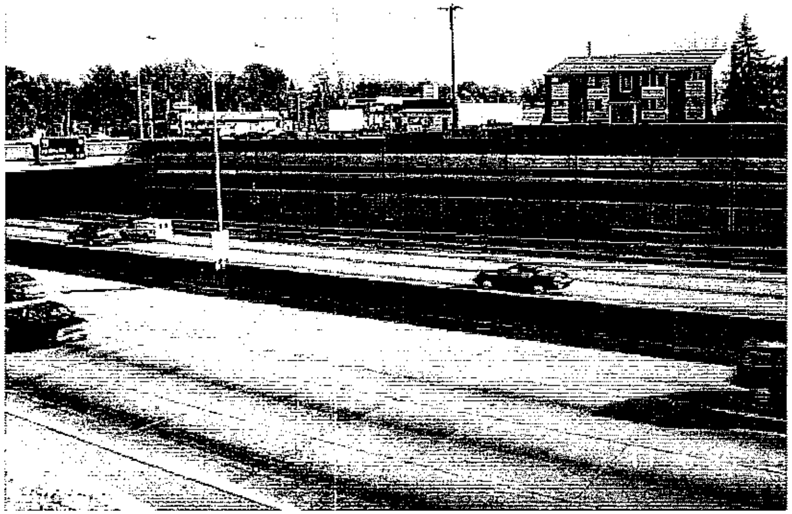
4. Springfield, Wabash Avenue

Michigan Noise Barrier Walls



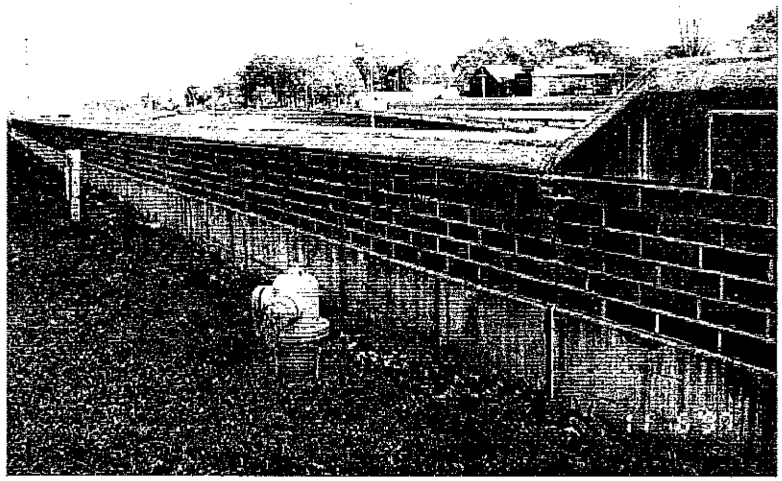
List of Photographs

11	Brick noise barrier, I-696, Detroit suburbs, with temporary 2 X 4 braces at failed wall panel, 1986-1997	12-3
12	Brick noise barrier, I-696, Detroit suburbs, with temporary 2 X 4 braces at failed wall panel, 1986-1997	12-3
13	Brick noise barrier, I-696, Detroit suburbs, with temporary 2 X 4 braces at failed wall panel, 1986-1997	12-4
14	Earth berm, I-696, Detroit suburbs	12-4
15	Earth berm, I-696, Detroit suburbs	12-4
16	Brick noise barrier, I-696, Detroit, residents' side	12-4
17	Brick noise barrier, I-696, Detroit, residents' side	12-5
18	Concrete post and stacked panels, private property, Detroit, new construction, 1997	12-5
19	Concrete post and stacked panels, private property, Detroit, new construction, 1997	12-5
20	Concrete post and stacked panels, private property, Detroit, new construction, 1997	12-5
21	Cast-in-place concrete barrier, private property, Detroit	12-6
22	Cast-in-place concrete barrier, private property, Detroit	12-6



1. **Depressed freeway section, I-696, Detroit suburbs**

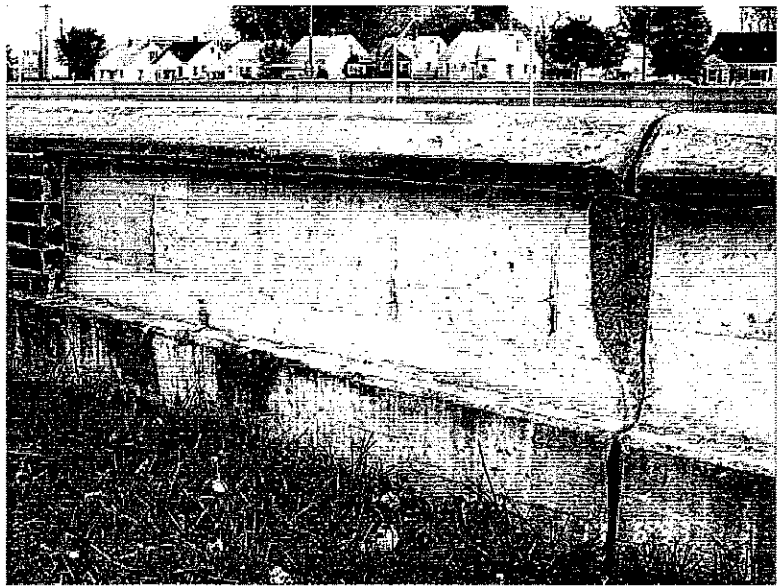
1986-1997



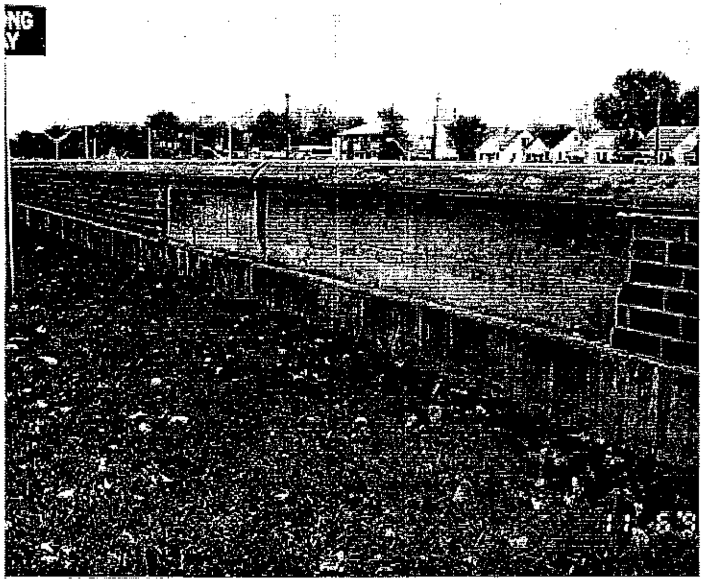
2. **Parapet wall along depressed freeway section, cast-in-place concrete with brick facing, I-696, Detroit suburbs**

1986-1997

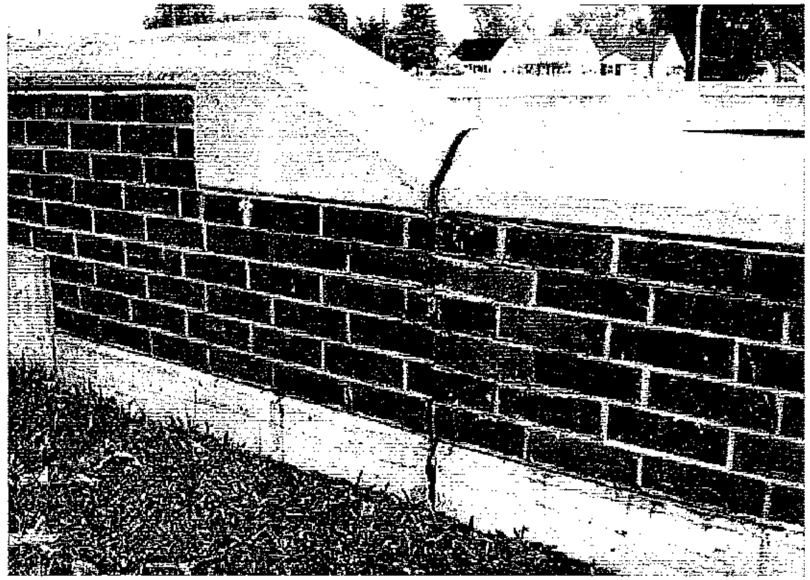
3. **Parapet wall along depressed freeway section, I-696, Detroit suburbs, with brick spalling** **1986-1997**



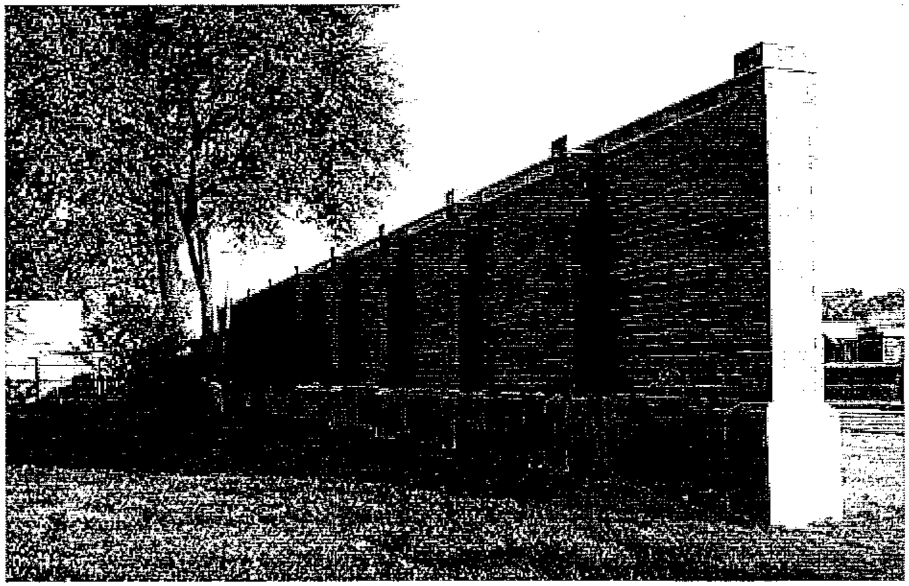
4. **Parapet wall along depressed freeway section, I-696, Detroit suburbs, with brick and concrete spalling, movement at expansion joint** **1986-1997**



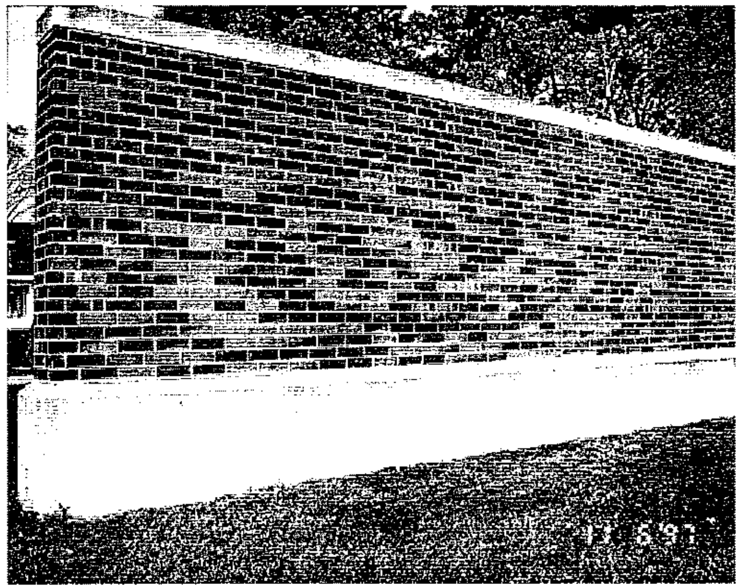
5. Parapet wall along depressed freeway section, I-696, Detroit suburbs, with brick and concrete spalling, movement at expansion joint 1986-1997



6. Parapet wall along depressed freeway section, I-696, Detroit suburbs, with movement at expansion joint 1986-1997

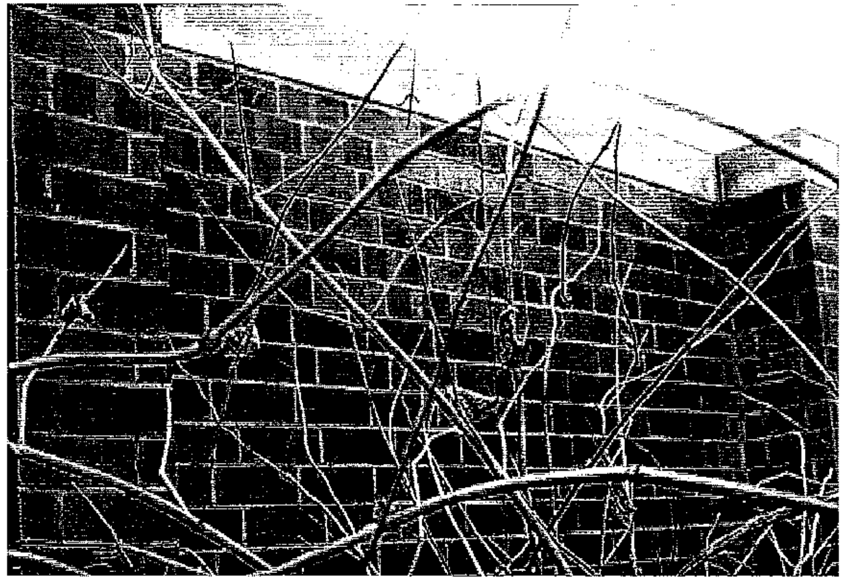


7. Brick noise barrier, I-696, Detroit suburbs, residents' side 1986-1997

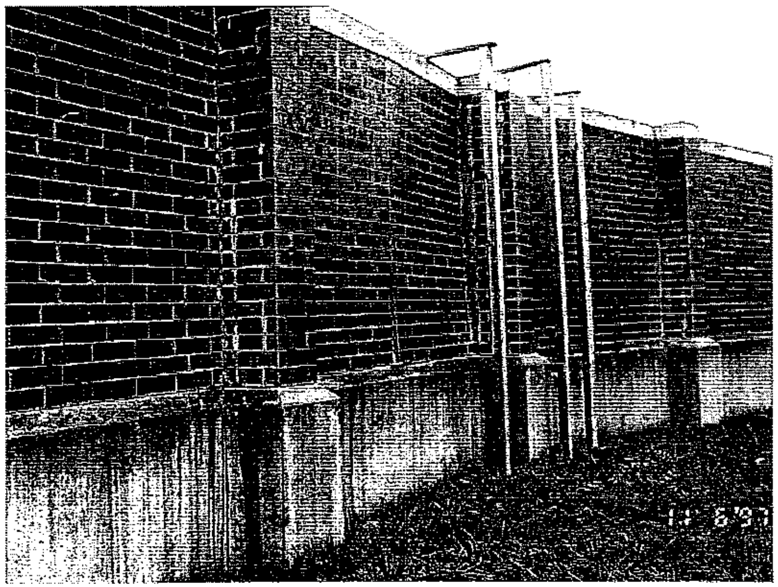


8. Brick noise barrier, I-696, Detroit suburbs, highway side 1986-1997

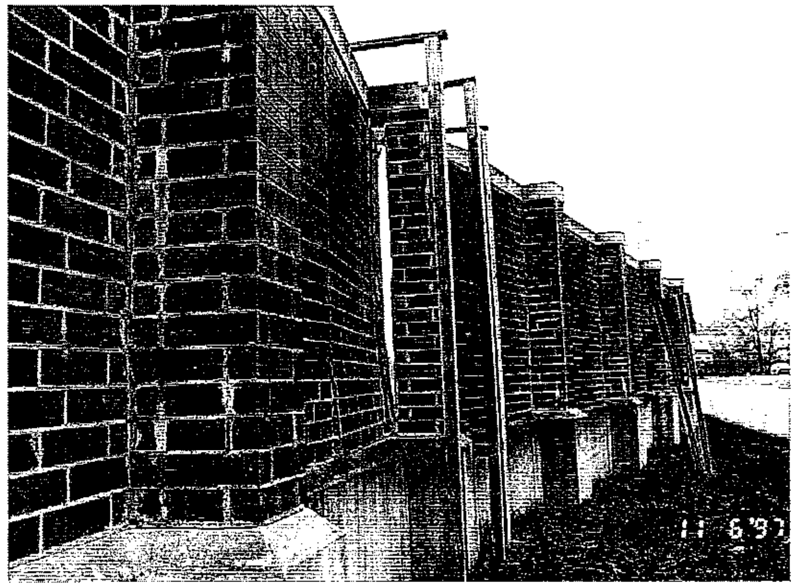
9. Brick noise barrier, I-696, Detroit suburbs, residents' side 1986-1997



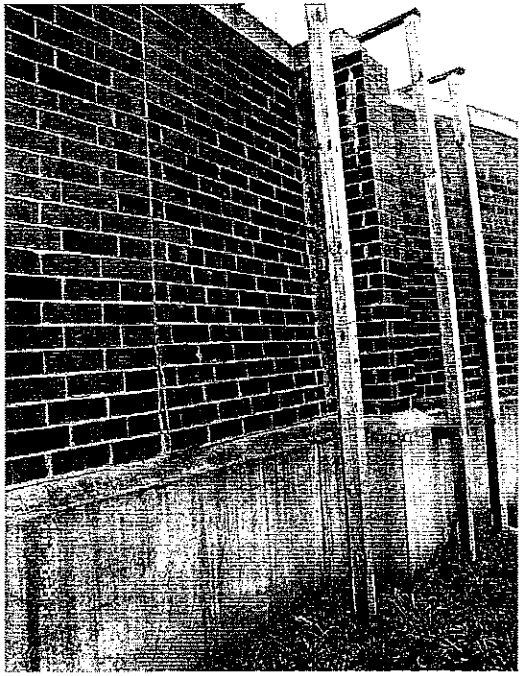
10. Brick noise barrier, I-696, Detroit suburbs, residents' side, cracking along joints near top of wall 1986-1997



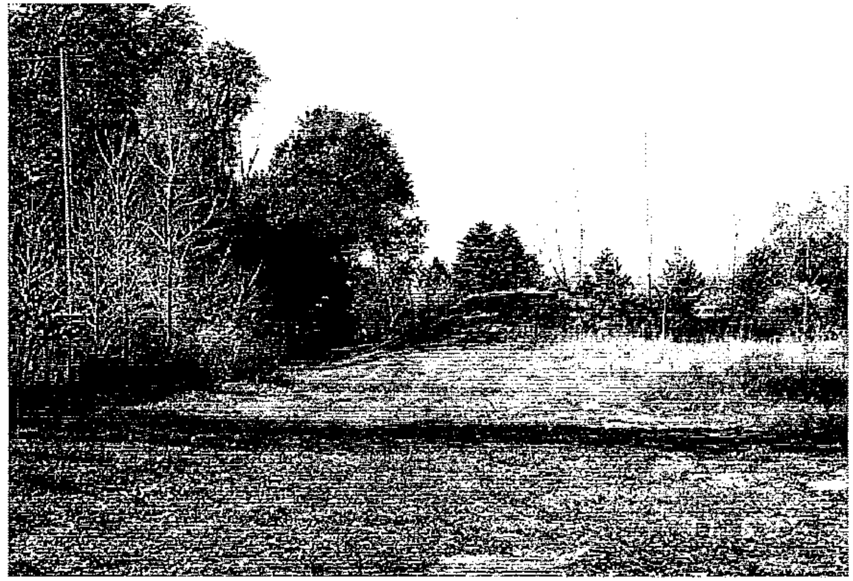
11. Brick noise barrier, I-696, Detroit suburbs, with temporary 2 X 4 braces at failed wall panel 1986-1997



12. Brick noise barrier, I-696, Detroit suburbs, with temporary 2 X 4 braces at failed wall panel 1986-1997

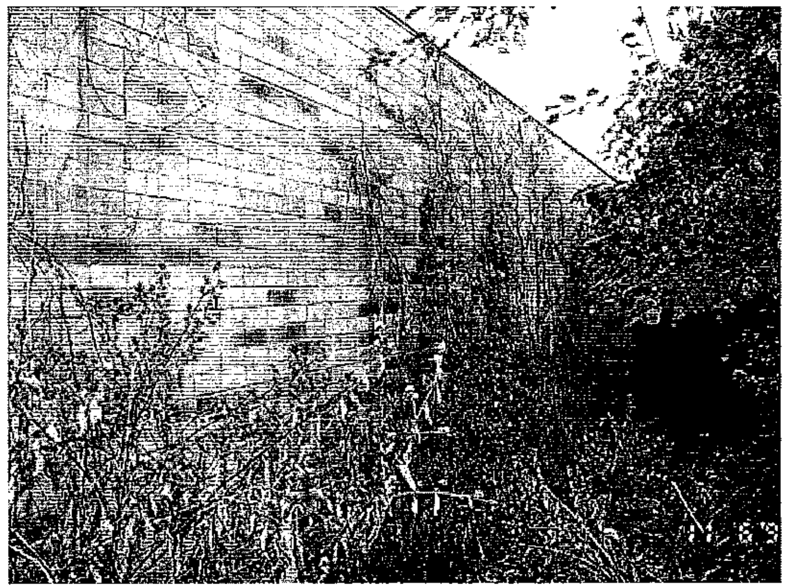


13. Brick noise barrier, I-696, Detroit suburbs, with temporary 2 X 4 braces at failed wall panel 1986-1997

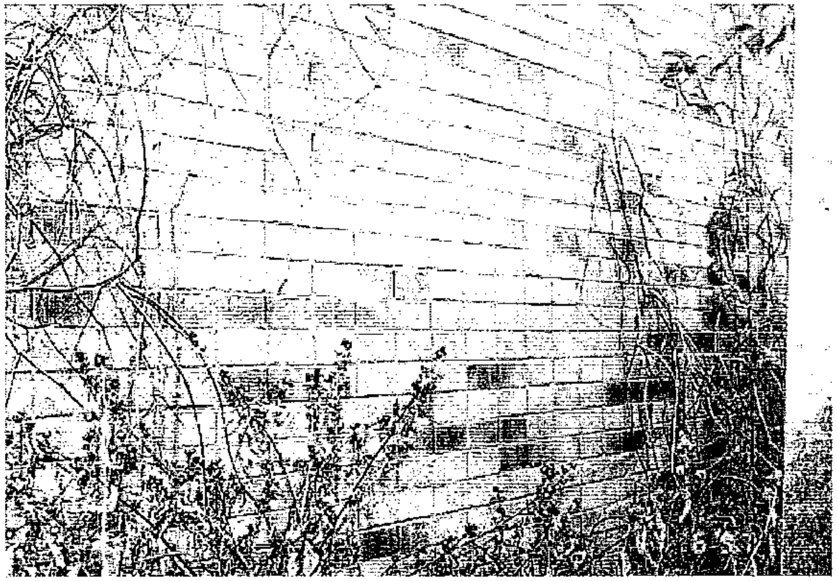


14. Earth berm, I-696, Detroit suburbs

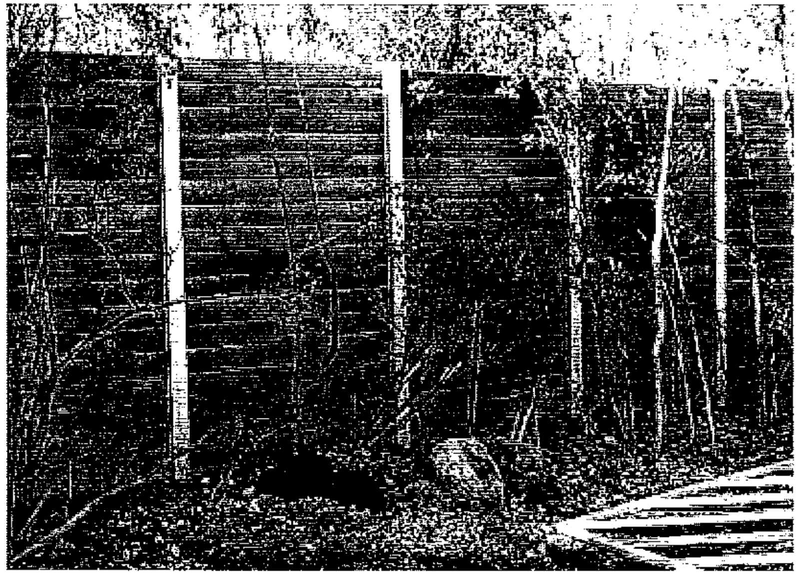
15. Earth berm, I-696, Detroit suburbs



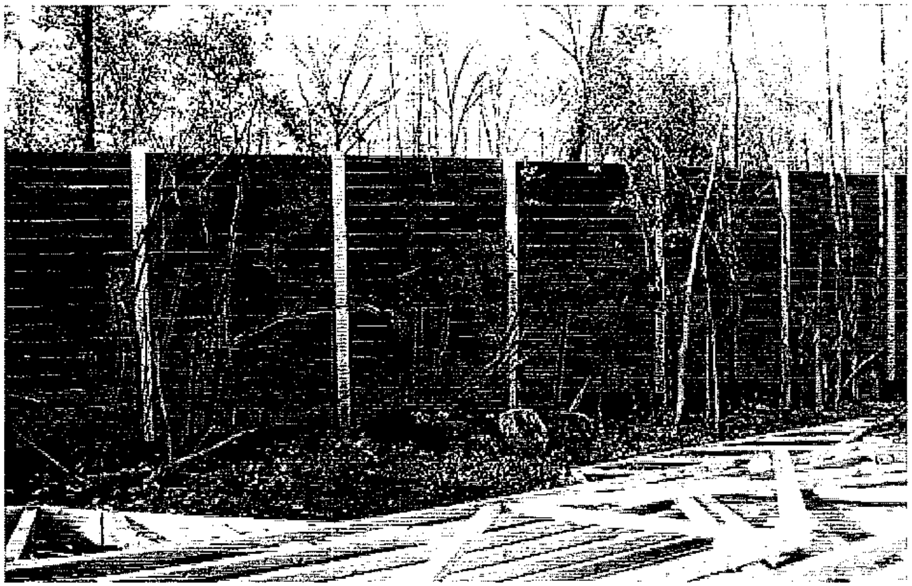
16. Brick noise barrier, I-696, Detroit, residents' side



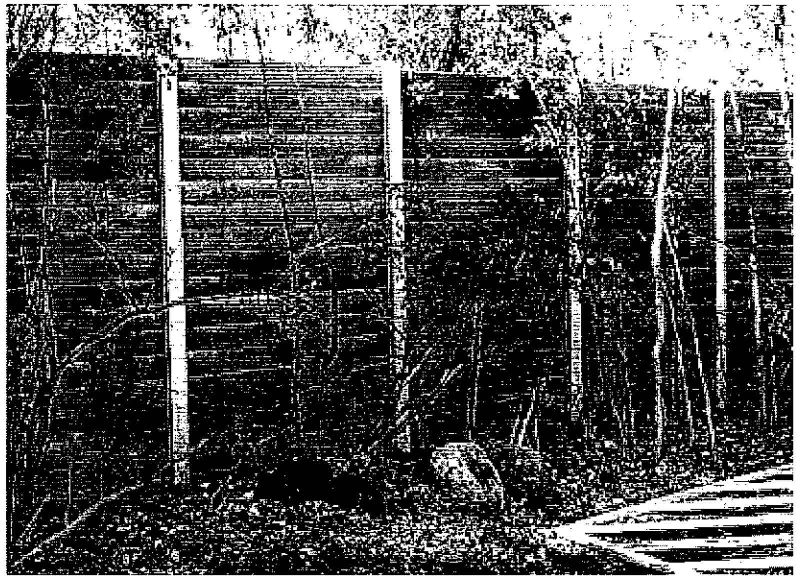
17. Brick noise barrier, I-696, Detroit, residents' side



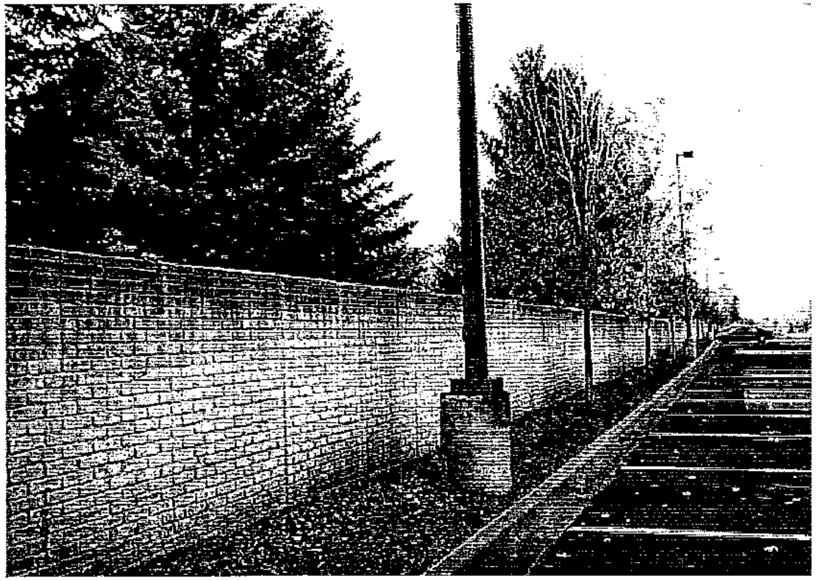
18. Concrete post and stacked panels, private property, Detroit, new construction 1997

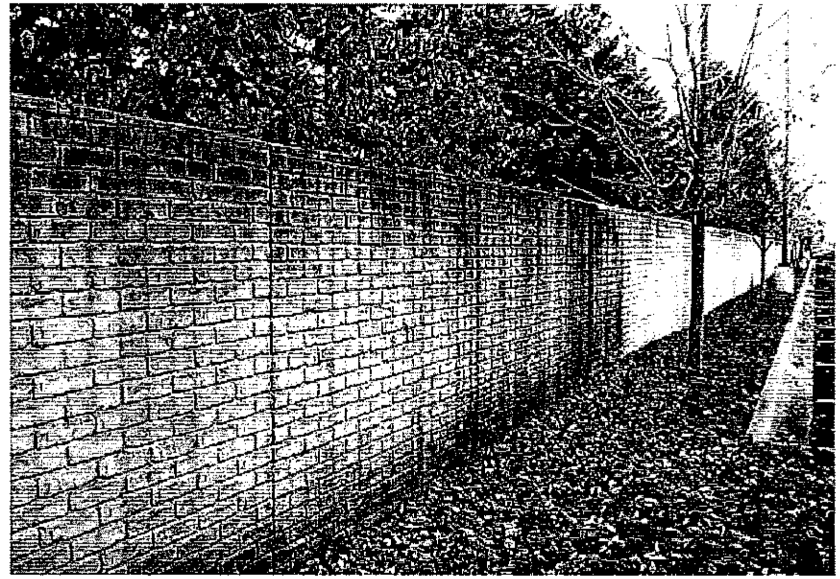


19. Concrete post and stacked panels, private property, Detroit, new construction 1997

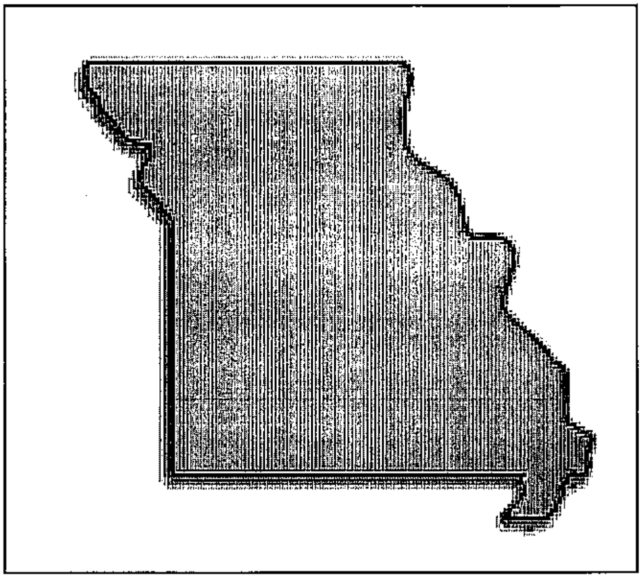


20. Concrete post and stacked panels, private property, Detroit, new construction 1997


21. Cast-in-place concrete barrier, private property, Detroit

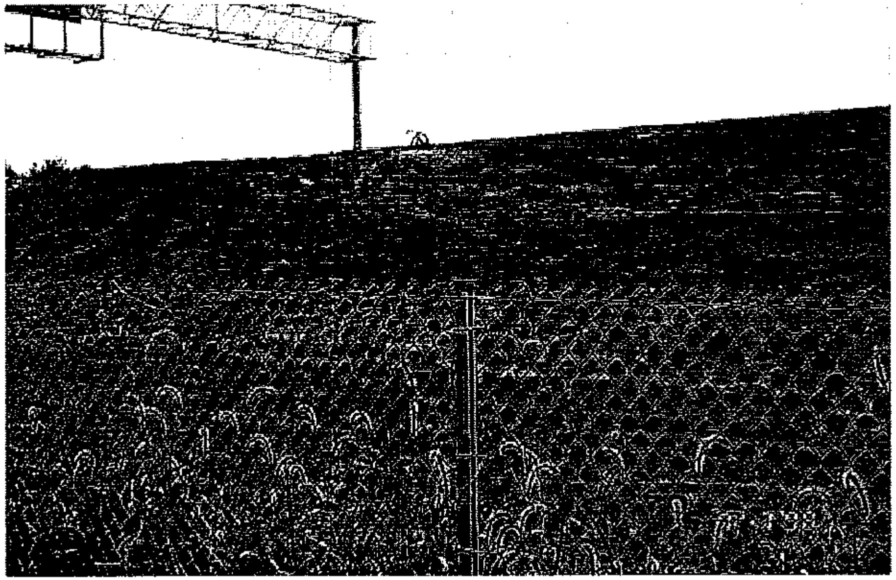

22. Cast-in-place concrete barrier, private property, Detroit

Missouri Noise Barrier Walls

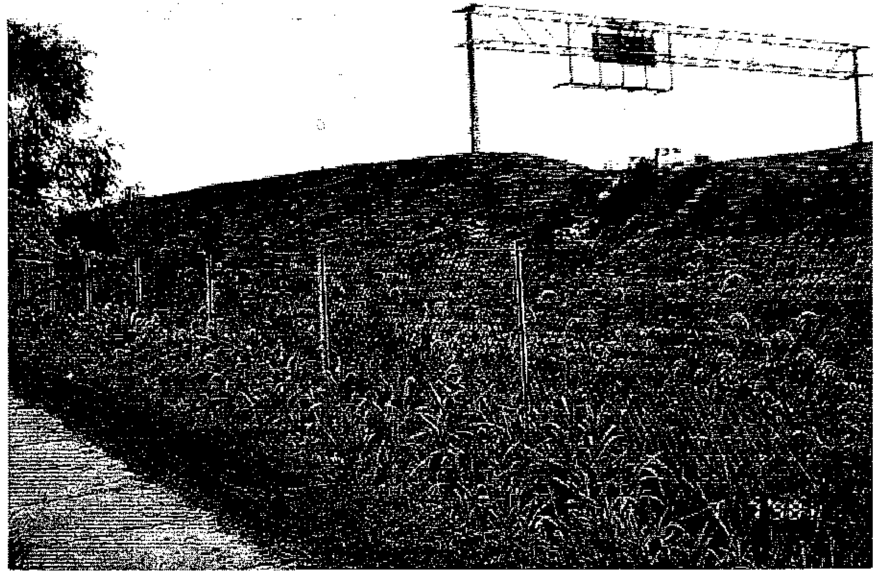


List of Photographs

Photograph Number	Description	Page
16	Precast concrete posts and stacked panels, Manchester Road, St. Louis, integrally pigmented concrete, slight color variations in panels (2' high), 1998	13-5
17	Precast concrete posts, Manchester Road, St. Louis, under construction, 1998	13-5
18	Precast concrete posts and stacked panels, Manchester Road, St. Louis, undulating wall section, 1998	13-5
19	Precast concrete posts and stacked panels, Manchester Road, St. Louis, undulating wall section, 1998	13-5
20	Precast concrete post, Manchester Road, St. Louis, base plate connection to continuous wall footing, new construction, 1998	13-6

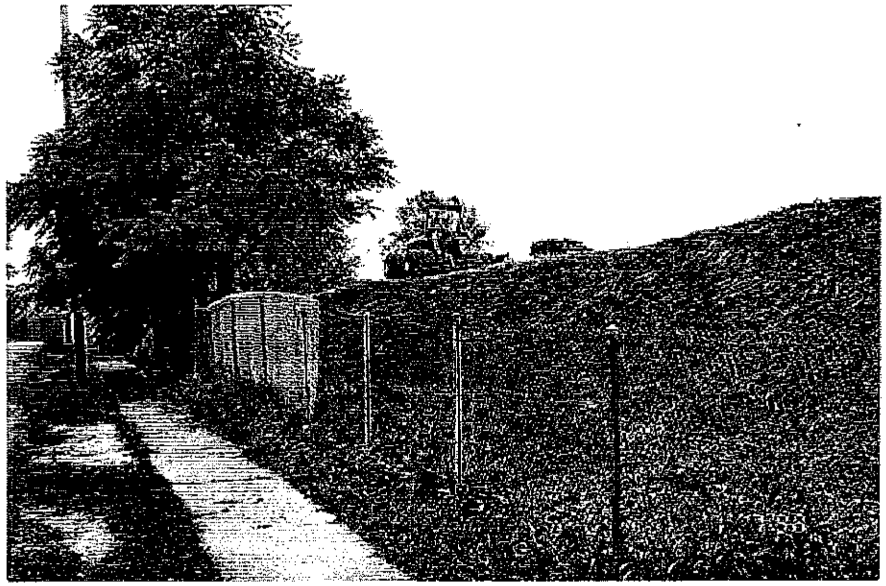


1. Earth berm, I-170, St. Louis

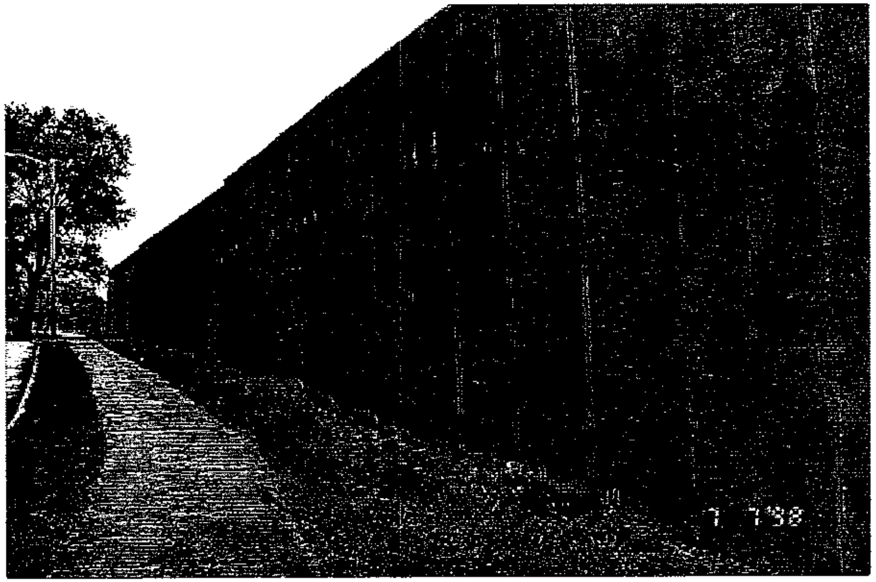


2. Earth berm, I-170, St. Louis, at transition to embankment

3. Earth berm, I-170, St. Louis, recently mowed

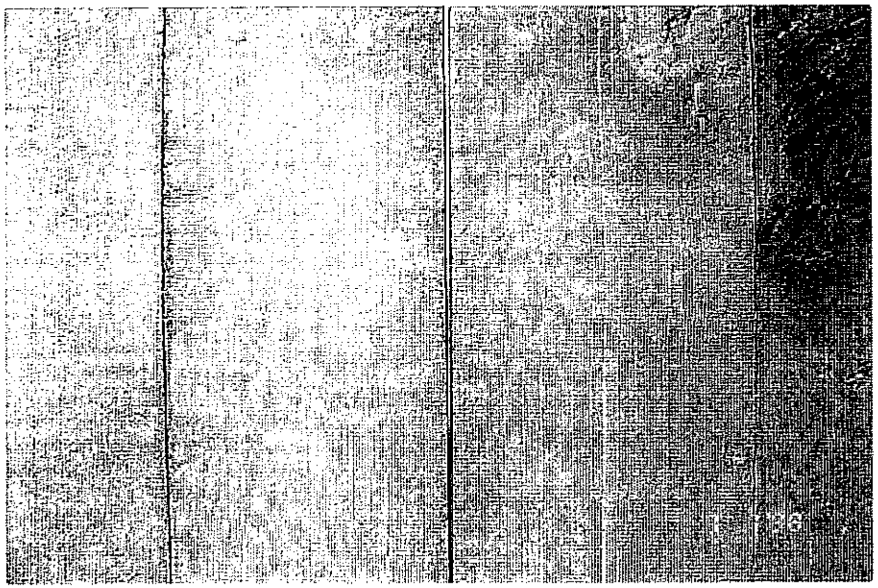


4. Earth berm transitioning to precast/prestressed barrier (at left), I-170, St. Louis

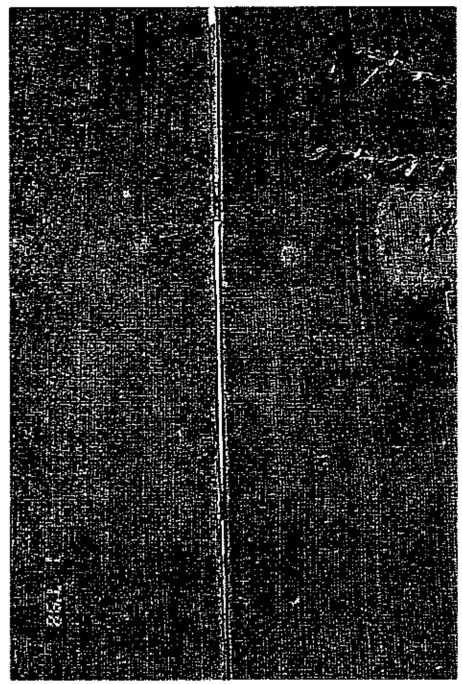


5. Precast/prestressed concrete barrier, I-170, St. Louis

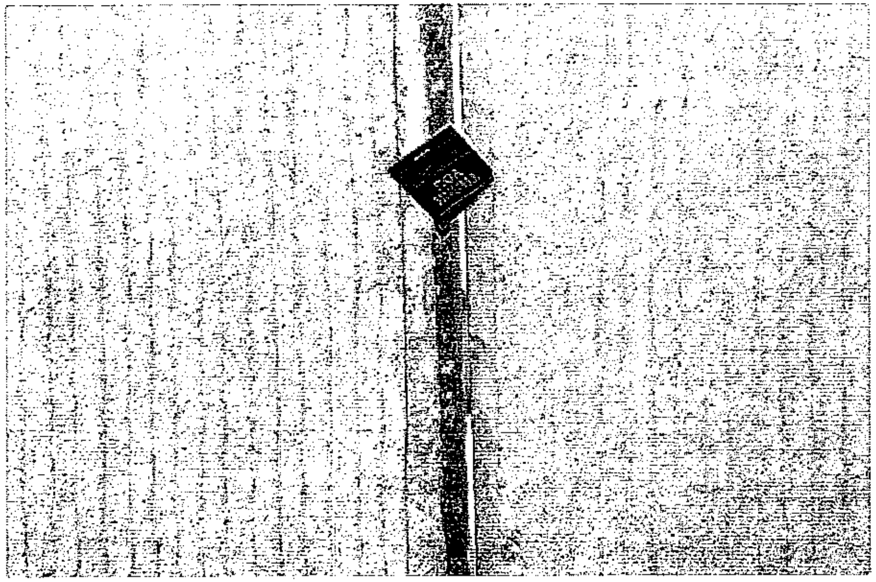
6. Precast/prestressed concrete barrier, I-170, St. Louis, with tree at base; wall leans toward roadway (left)



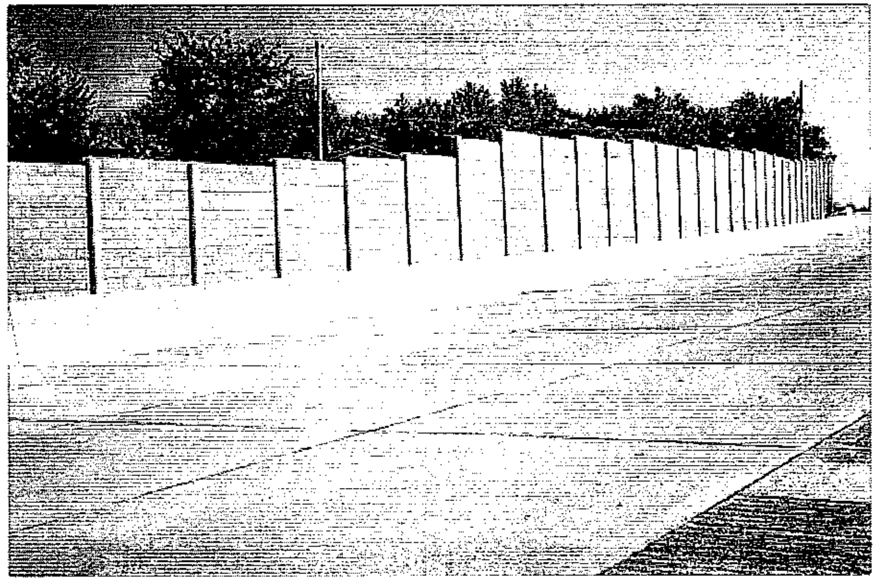
7. Precast/prestressed concrete barrier, I-170, St. Louis, with daylight visible through joint (center)



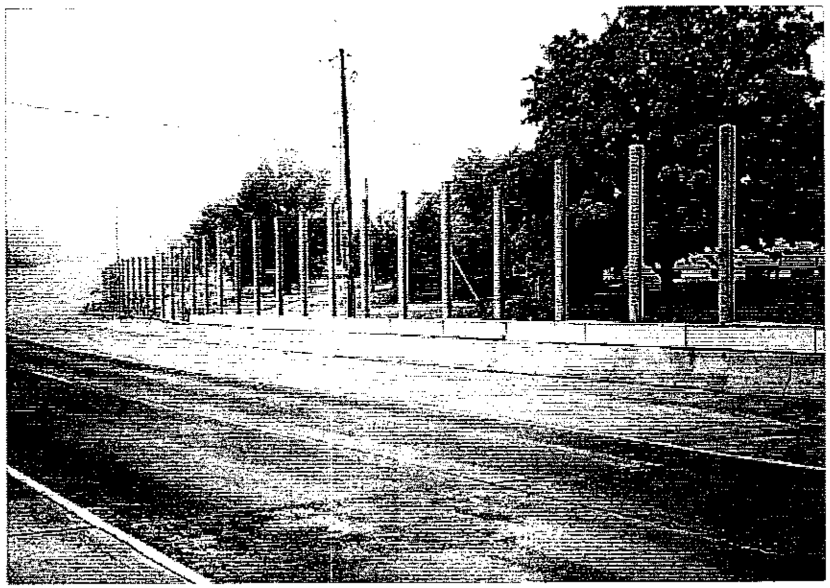
8. Precast/prestressed concrete barrier, I-170, St. Louis, with daylight visible through joint (center)



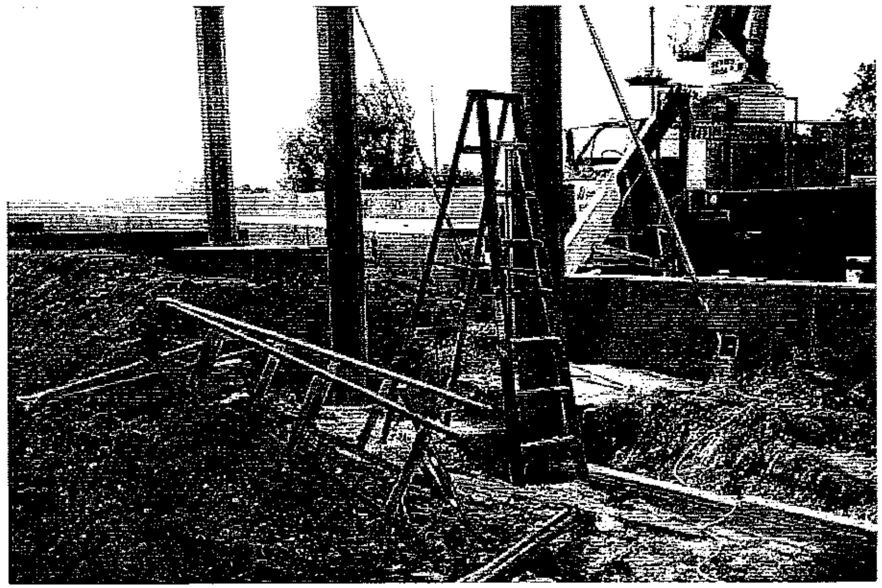
9. Precast/prestressed concrete barrier, I-170, St. Louis, with daylight visible through joint (center)



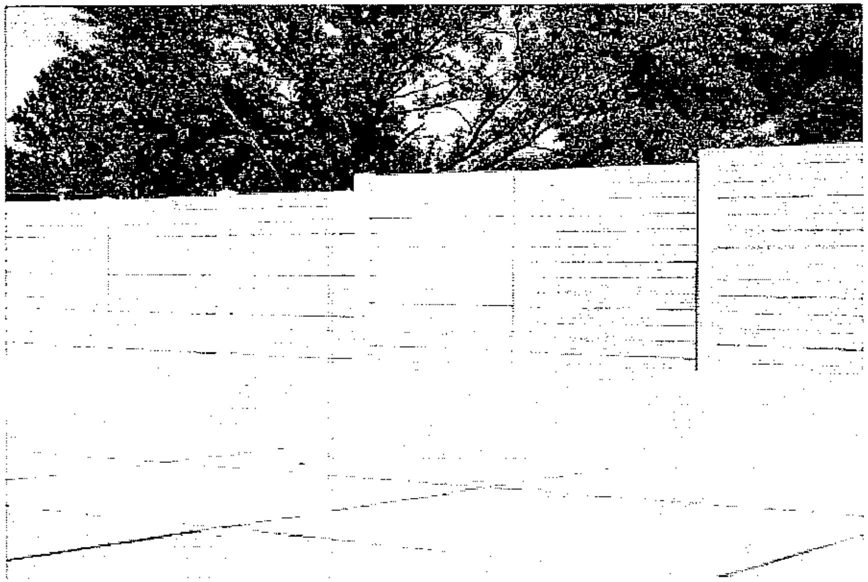
10. Precast concrete post and stacked panels, Manchester Road, St. Louis, new construction 1998



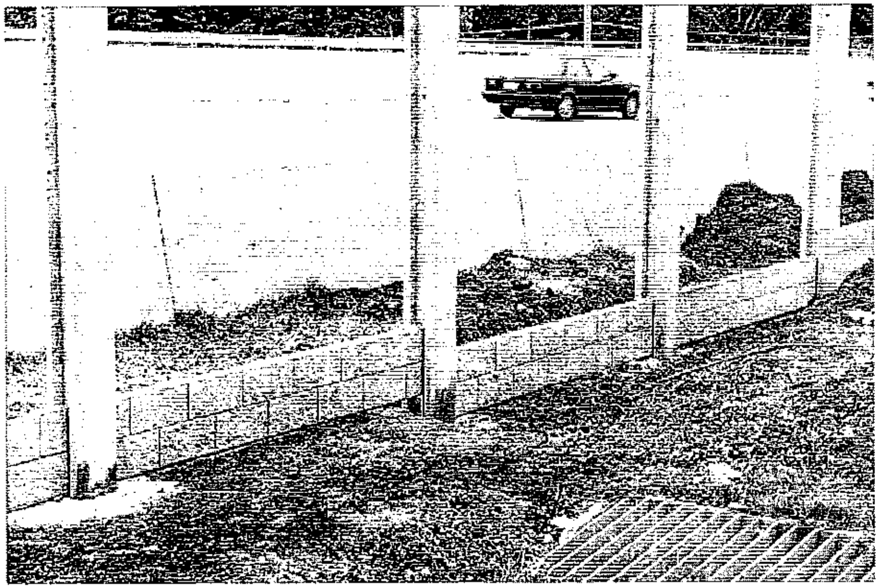
11. Precast concrete posts, Manchester Road, St. Louis, new construction 1998



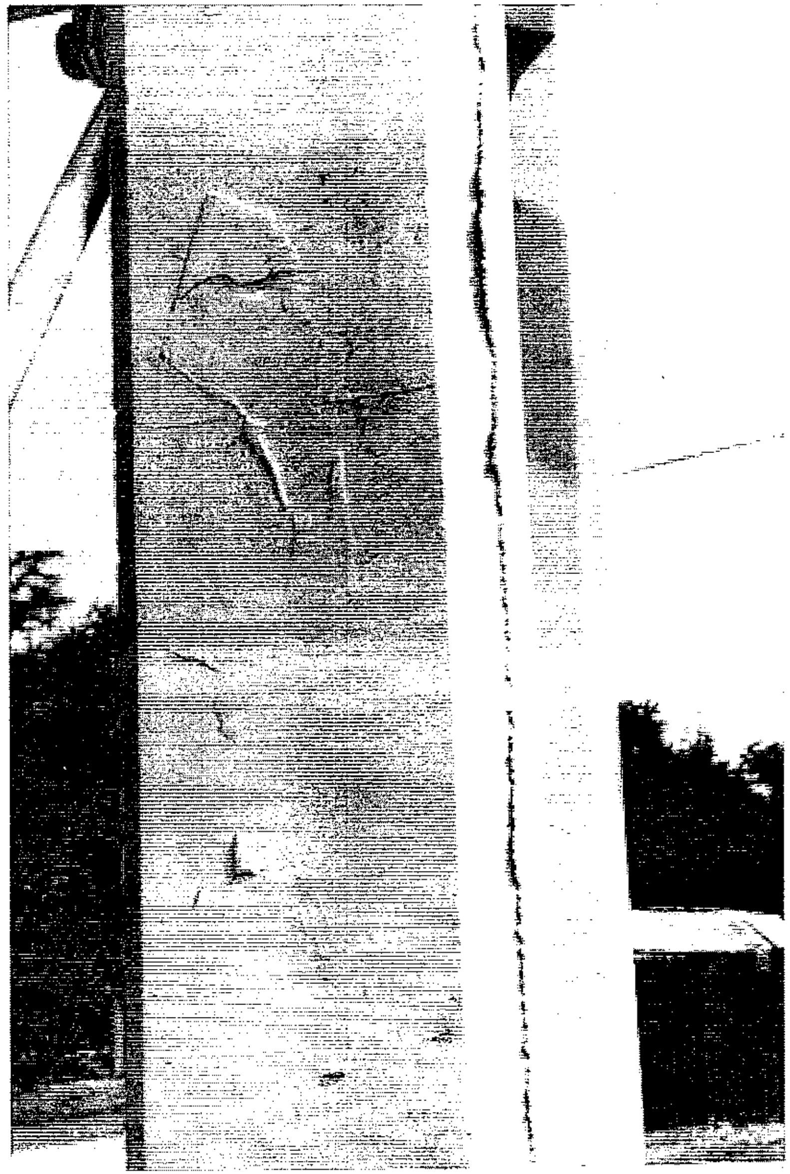
12. Precast concrete posts, Manchester Road, St. Louis, under construction 1998



13. Precast concrete posts and stacked panels, Manchester Road, St. Louis, integrally pigmented concrete, slight color variation 1998

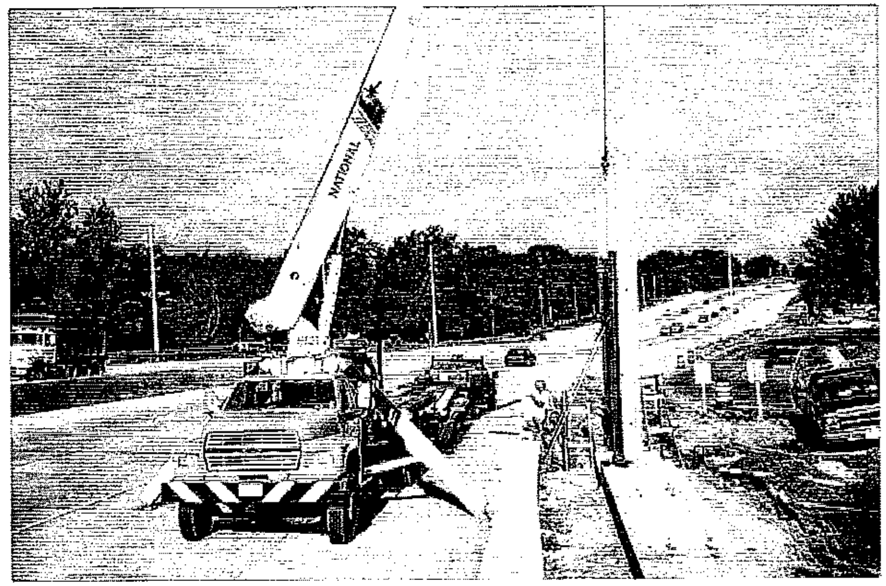


15. Precast concrete posts and stacked panels, Manchester Road, St. Louis, initial course under construction 1998

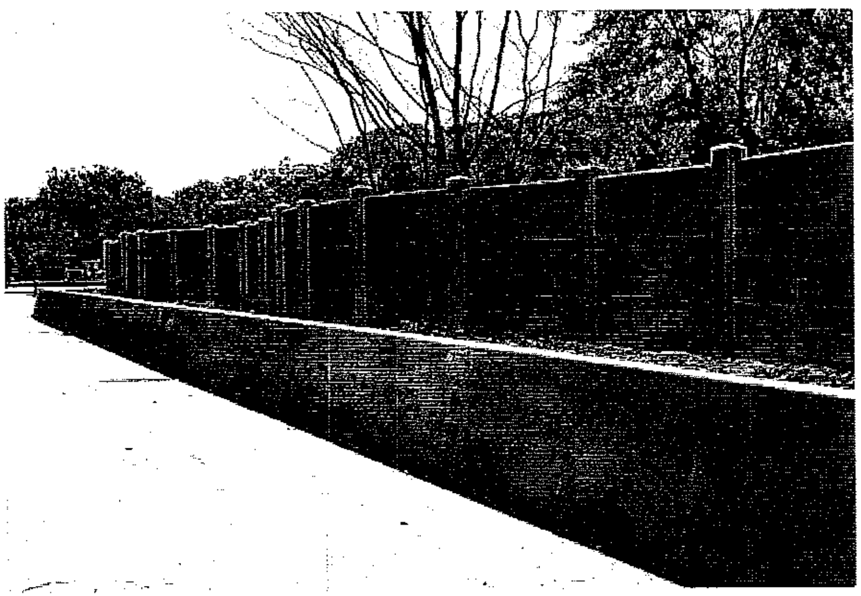


14. Precast concrete post, Manchester Road, St. Louis, isolated surface irregularities, new construction 1998

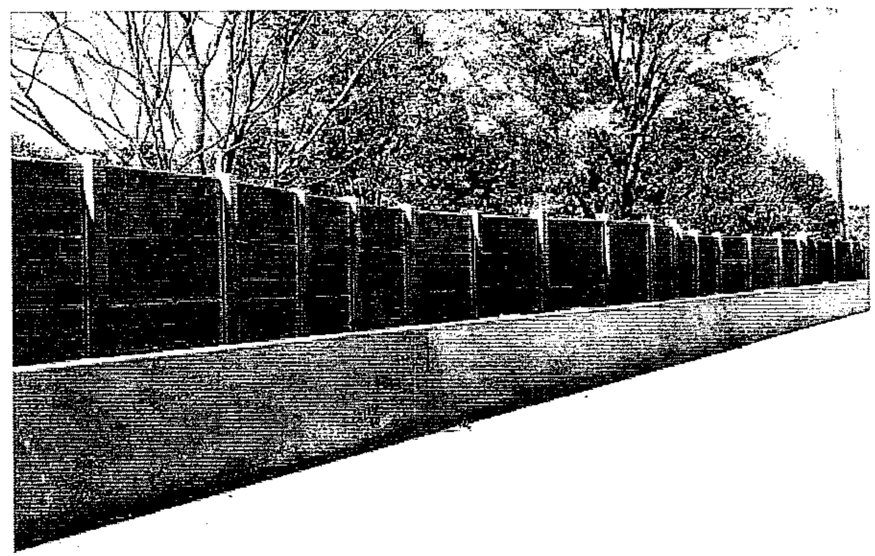
16. Precast concrete posts and stacked panels, Manchester Road, St. Louis, integrally pigmented concrete, slight color variations in panels (2' high) 1998



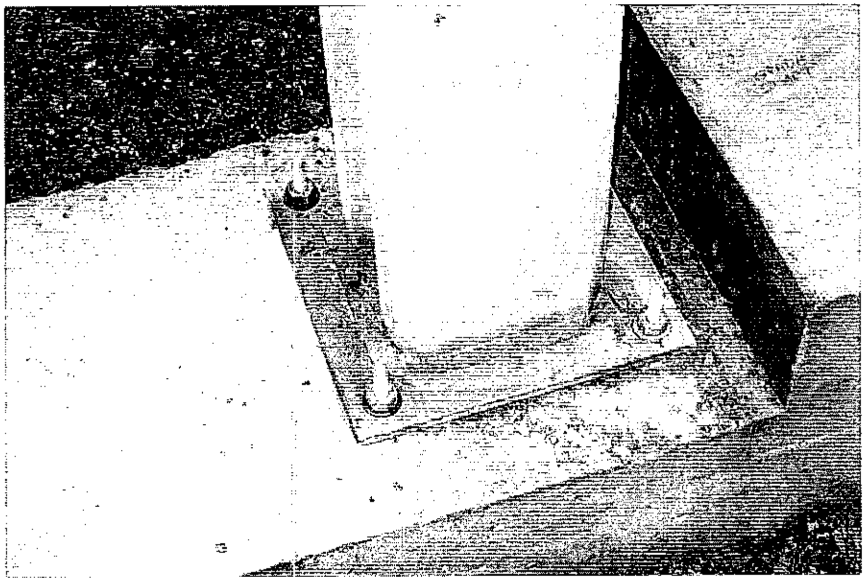
17. Precast concrete posts, Manchester Road, St. Louis, under construction 1998



18. Precast concrete posts and stacked panels, Manchester Road, St. Louis, undulating wall section 1998



19. Precast concrete posts and stacked panels, Manchester Road, St. Louis, undulating wall section 1998



20. Precast concrete post, Manchester Road, St. Louis, base plate connection to continuous wall footing, new construction 1998