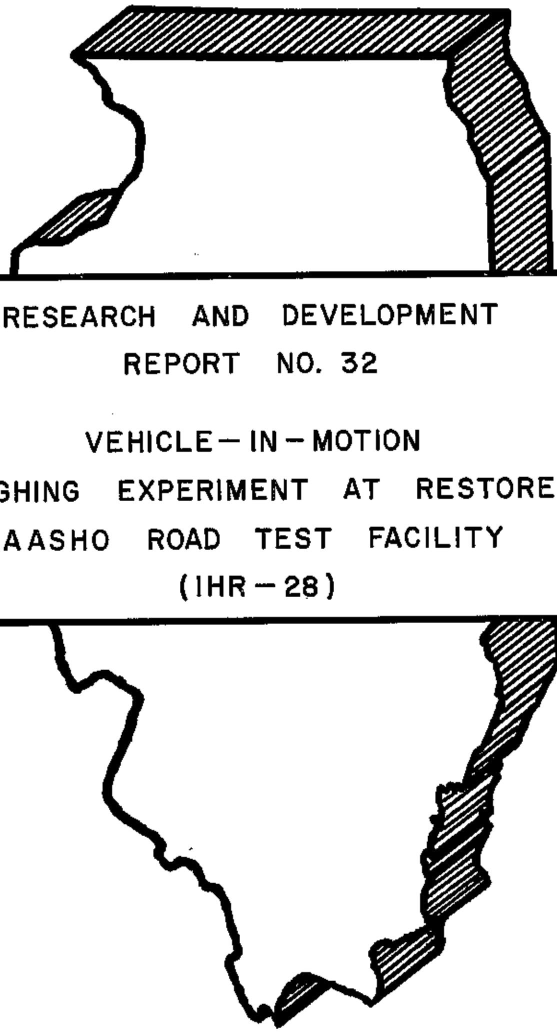
STATE OF ILLINOIS

DEPARTMENT OF PUBLIC WORKS AND BUILDINGS

DIVISION OF HIGHWAYS



RESEARCH AND DEVELOPMENT REPORT NO. 32

VEHICLE-IN-MOTION WEIGHING EXPERIMENT AT RESTORED AASHO ROAD TEST FACILITY

(IHR-28)

RESEARCH & DEVELOPMENT

ILLINOIS DIVISION OF HIGHWAYS

State of Illinois
DEPARTMENT OF PUBLIC WORKS AND BUILDINGS
Division of Highways
Bureau of Research and Development

VEHICLE-IN-MOTION WEIGHING EXPERIMENT AT RESTORED AASHO ROAD TEST FACILITY

(IHR-28)

by

Edward J. Kubiak and Floyd K. Jacobsen

A Research Project Conducted by
Illinois Division of Highways
in Cooperation with
U.S. Department of Transportation
Federal Highway Administration

July 1971

ABSTRACT

During the construction of the AASHO Road Test facility, and in the subsequent restoration of the facility for service as a part of Interstate 80, electronic scales were installed in the pavements to measure the dynamic weights of axles of vehicles traveling at normal speeds in the regular traffic stream. Calibration tests produced inconsistent results, especially at higher speeds, and showed no simple relationship to exist between dynamic and static loadings. Platform vibrations caused serious interference in the oscillograph recordings of axle loads. Several modifications that were made in the system to overcome the interference were unsuccessful. Insurmountable maintenance problems resulting from poor resistance of the scale system to the normal environmental conditions of the site brought about a termination of the study.

SUMMARY

The working committee for the AASHO Road Test project, which had the responsibility for developing specific directions, recognized the need for more information on loads actually being applied to pavements and on the static and dynamic load relationship. As one of the special considerations in addition to the principal objectives of the project, the committee recommended provisions in the project for collecting information on the dynamic characteristics of heavy vehicles in relation to imposed loads, vibration effect, and impact.

In the original construction of the AASHO Road Test facility, one electronic scale system was installed for weighing vehicles in motion. During the rehabilitation construction of 1962, when the test facility was made a part of Interstate 80, this scale system was incorporated in the eastbound pavement and an additional scale system of the same general design was added to the westbound pavement.

The scale system installed in each pavement was Cox and Stevens Traffic Research Scale Model TR-2, supplied by the Electronic Signal Company, Inc., of Jamaica, New York, a subsidiary of the Neptune Meter Company. The Cox and Stevens system consisted of narrow platforms of lane width built directly into the road surface and supported by load cells containing wire strain gages. One cell was placed at each of the four corners of each platform. The system included electronic signal conditioning equipment, and an oscillograph for recording the amplified output of the load cells. Calibration of the system was accomplished by applying a known axle weight to the scale and monitoring the signal output corresponding to the given load.

From the calibration tests that were conducted it was evident that the scale system that was examined was not capable of serving to provide either dynamic weights or acceptable estimates of static weights of axles of vehicles traveling at normal highway speeds.

Induced oscillations of the scale platform that masked the recordings of interest were not removable in the attempts that were made, although a filtering system to compensate for their presence showed promise. Whatever relationship that may exist between dynamic loadings and static loadings proved to be too complex for estimating static weights from dynamic weights by procedures in this study.

Three separate modifications were made in the original scale system in an effort to control the oscillations of the platform. The first attempt involved preloading the scale platform with a known force, but this approach produced no apparent benefit. The second revision included hinging one side of the platform while supporting the other side by two load cells. This only served to decrease the natural frequency of the platform instead of achieving the desired increase. The final modification was the addition of an electronic filter to eliminate the effect of the undesirable oscillations. This refinement appeared to have merit. Possibly the use of a more sophisticated filter circuit would improve the scale system to a greater degree. Physical problems with the system prevented further exploration.

The physical resistance of the scale system under study was not sufficient to withstand the pounding of the normal traffic mix on what can be considered to be a typical heavy-duty highway. Constant displacement of the load cells supporting the scale platform proved to be a problem that was never overcome. Deterioration and failure of the electronic equipment and circuitry in the scale pits from water and brine action proved to be another problem that was never coped with successfully.

VEHICLE-IN-MOTION WEIGHING EXPERIMENT AT
RESTORED AASHO ROAD TEST FACILITY

INTRODUCTION

Conventional roadside scales and portable scales for weighing standing highway vehicles disrupt the flow of traffic, are costly to operate, and often do not permit the attainment of sample sizes that are statistically stable. Furthermore, they offer no opportunity for obtaining information on the loads actually applied to pavements by moving vehicles.

The advantages of a system that can determine the static weight of vehicles automatically without a change in vehicle speed and without driver recognition have encouraged highway engineers to look toward its development for many years. While such a system that could somehow provide information equivalent to that now provided by static weighings has seemed attractive, a realistic look at available techniques and hardware has never been very encouraging.

Alternatively, the development of a lesser system that can provide dynamic weights with a reasonable degree of accuracy could still be advantageous. A very significant improvement could be made in pavement design techniques and in performance evaluations with the kind of information that this system would produce. Additionally, such a system probably could have sufficient accuracy to serve as a culling device by which static weighings could be limited to those vehicles of questionable weight. A system with these capabilities has seemed for many years to be within the immediate realm of possibility.

The Working Committee for the AASHO Road Test project, which had the responsibility for developing specific directions, recognized the need for more information on loads actually being applied to pavements, and on the static and dynamic load relationship. As one of the special considerations in addition to the principal objectives of the project, the committee recommended provisions in the project for collecting information on the dynamic characteristics of heavy vehicles in relation to imposed loads, vibration effect, and impact. In its final report entitled "Statements of Fundamental Principles, Project Elements, and Specific Directions," submitted in 1955, the committee suggested a special study on "The Development of Methods for Determining the Loads Imposed on Pavements." Some studies conducted during the Road Test responding to this suggestion are reported in an article, "Measuring Dynamic Vehicle Loads," by John W. Fisher and Henry C. Huckins, Highway Research Board Special Report 73 (1962), and also in "The AASHO Road Test," Highway Research Board Report 6, Special Studies (1962). The studies with which the present report is concerned also were made in response to this recommendation of the Working Committee, but conducted following conclusion of the Road Test. These later studies were centered on the use of scales located in the pavements of the restored facility for weighing vehicles moving in the regular traffic stream.

In the original planning of the AASHO Road Test facility, two scale installations were proposed for weighing vehicles statically and in motion. One set was to be installed in the south tangent of one test loop for static weighings during the test period, and a second set was to be placed in the north tangent for special dynamic studies involving speed as a parameter. Both scales were to be incorporated later in the pavements of Interstate 80 for the post-test period when the project would be open to normal mixed traffic.

Both scale installations were included in the original paving plans for the Road Test facility submitted to contractors for bids. When the single bid that was received at the initial letting exceeded the amount budgeted for the pavement construction, a number of revisions and deletions were made to reduce the cost of the project. Among the items deleted was the stretch of pavement in which the scale installations were to be located for special dynamic studies, together with the scale set. The other scale installation, needed for static weighings during the controlled traffic tests, was retained, with the thought that it could be used also for a limited program of dynamic testing and calibration where long approach runs by vehicles attaining high speeds would not be necessary. The revised contract was awarded in August 1957. The approximate cost for the scale installation under this contract, exclusive of the construction of the pits and platforms, was $24,000.

During the rehabilitation construction of 1962 when the test facility was made a part of Interstate 80, the electronic scale system installed in the initial construction of the test facility was incorporated in the eastbound pavement, an additional scale installation of the same general design was added to the westbound pavement. The cost of the second scale installation constructed in the westbound pavement was $19,170, exclusive of a cost of $2924 for the construction of the pits and platforms.

The basic design for the scales that were installed followed very closely the design described by O. K. Normann and R. C. Hopkins in the article published in 1952 in Highway Research Board Bulletin 50. The same article also appeared in the April 1952 issue of Public Roads. Normann and Hopkins reported that under the conditions of their study this electronic scale was sufficiently accurate for highway planning purposes. The Working Committee was cognizant of the availability of this type of scale at the time the recommendation was made that dynamic studies be included in the project.

The scale system used for the study was Cox and Stevens Traffic Research Scale, Model TR-2, supplied by the Electronic Signal Company, Inc., of Jamaica, New York, a subsidiary of the Neptune Meter Company. Literature of the supplier indicated that, as a culmination of the project by Normann and Hopkins, the system would provide a practical method of recording axle spacings and weights of vehicles moving at normal traffic speeds. It was believed that weight data obtained by the proposed system would satisfy project needs for collecting information on the dynamic loads imposed by heavy vehicles; and that some fairly simple relationship would be found to exist between static and dynamic weighings.

The Cox and Stevens scale system consisted of narrow platforms of lane width built directly into the road surface and supported by load cells containing wire strain gages. One load cell was placed at each of the four corners of each platform. The system included electronic signal conditioning equipment and an oscillograph for recording the amplified output of the load cells. Calibration of the system was accomplished by applying a known axle weight to the scale and monitoring the signal output corresponding to the given load.

A plan layout of the scales is shown in Figure 1. A two-platform system was placed in the main traffic lane of the eastbound pavement to provide a capability for the static weighing of tandem axles without moving the vehicle. Only the first platform on the traffic approach side was used in weighing moving loads. Single platforms were installed in the passing and traffic lanes of the westbound pavement.

With the knowledge that a considerable amount of field testing with moving loaded trucks would be required in the planned effort to establish correlative relationships between static and dynamic loadings, the original intention was to accomplish most of this testing before the new pavements were opened to through traffic. Unfortunately, malfunctioning of the equipment at critical times, and public pressure for immediate opening of the completed pavements, combined to prevent its accomplishment. Continued malfunctioning of the equipment after the

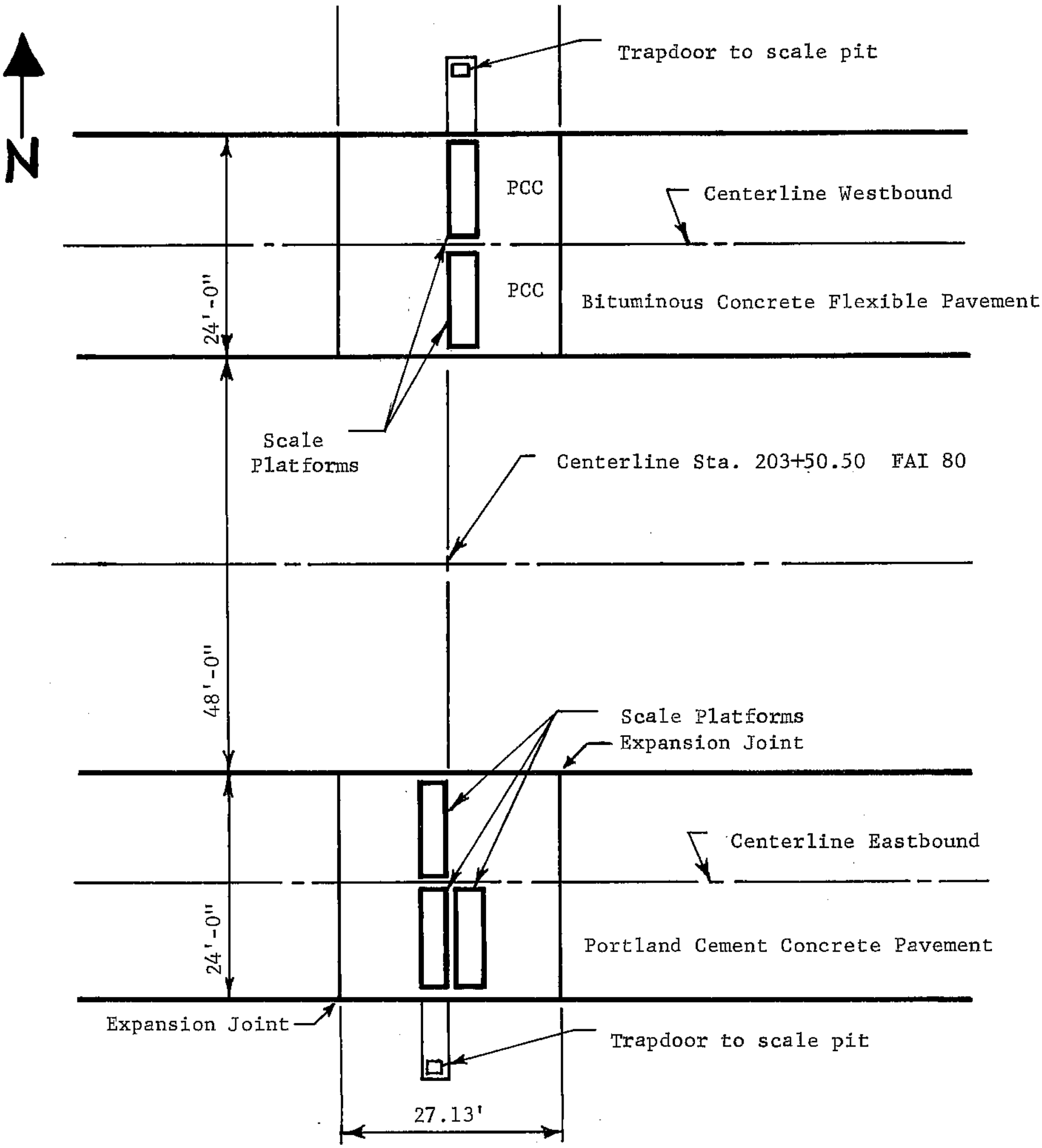


Figure 1. Plan view of electronic weigh scales

highway had been opened to traffic, combined with the difficulties of conducting a load-test program of the scope and type required in the traffic stream of a busy Interstate highway, limited the correlation effort below that which was originally intended. However, a sufficient amount of testing was done to provide a strong indication that no simple relationship exists between static and dynamic loadings. Furthermore, experience showed a lack of capability of both the original equipment and several revised versions to consistently provide realistic values for dynamic loadings over the normal range of highway speeds. Experience also showed the existence of a variety of physical deficiencies under normal climatic conditions, normal usage of pavement de-icing salts, and traffic intensities often equalled or exceeded throughout the country. The deficiencies were of a severity indicating that the system as installed should be removed from further consideration as a candidate for a weighing-in-motion system.

DESCRIPTION

Each scale platform of the system under study was a reinfoced concrete floating slab framed by welded steel channels and mounted flush with the top of the adjacent roadway. A total of five platforms were installed. Each platform measured 11 ft 6 in. long, 3 ft wide, and 1 ft 3 in. thick, and weighed 8000 lbs. A photograph of the platforms in the eastbound pavement is shown in Figure 2.

The load cells used to support the platforms were of the bonded resistance wire gage type, each with a capacity of not less than 10,000 lbs., and each capable of withstanding 200 percent overload without physical damage or change in calibration. The output and input leads were permanently attached to the load cells and all cables and cable fittings were supposed to be impervious to moisture. The load cells were mounted between two ball joints spaced a minimum of 12 in. apart. The upper ball

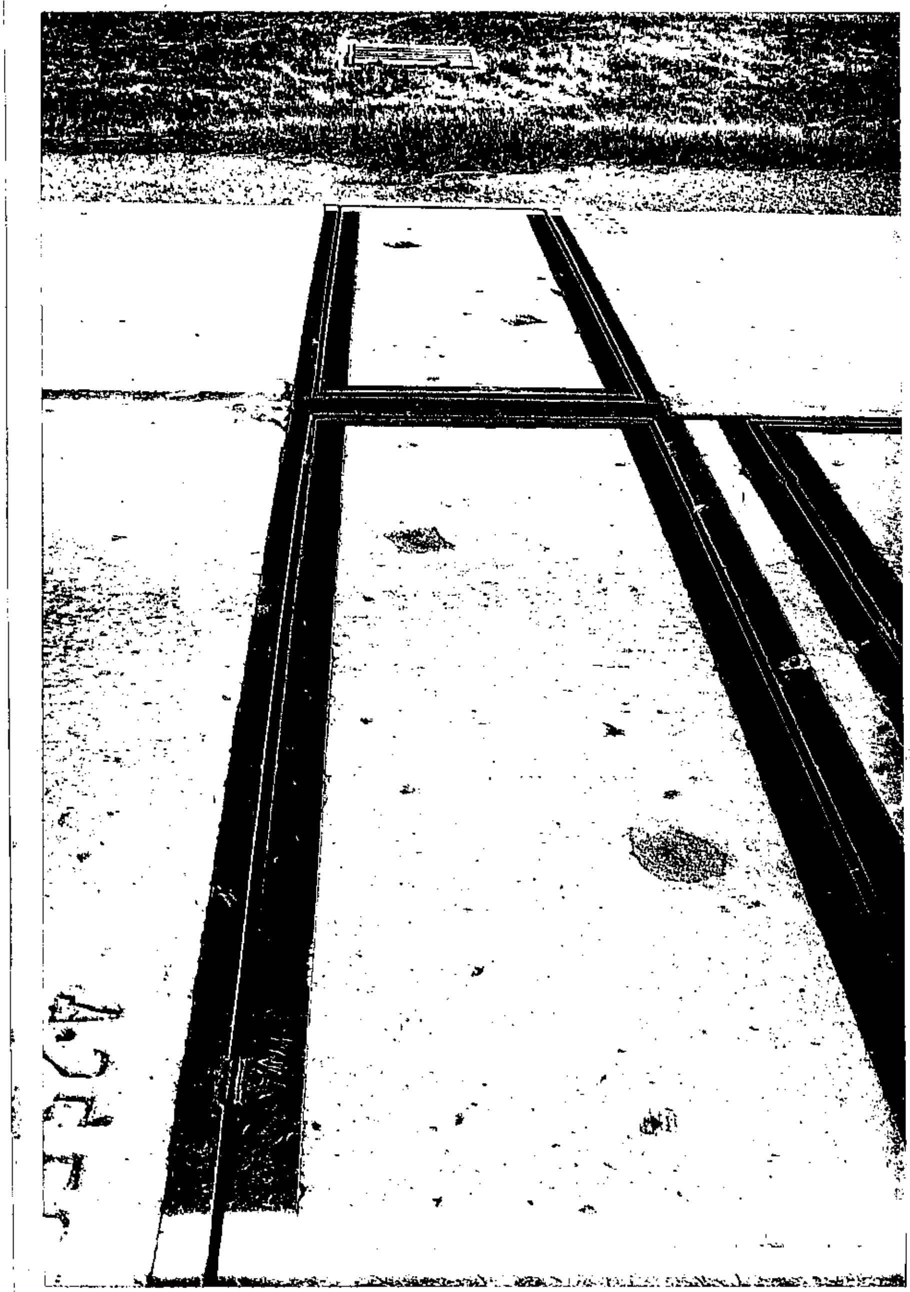


Figure 2. Scale platforms

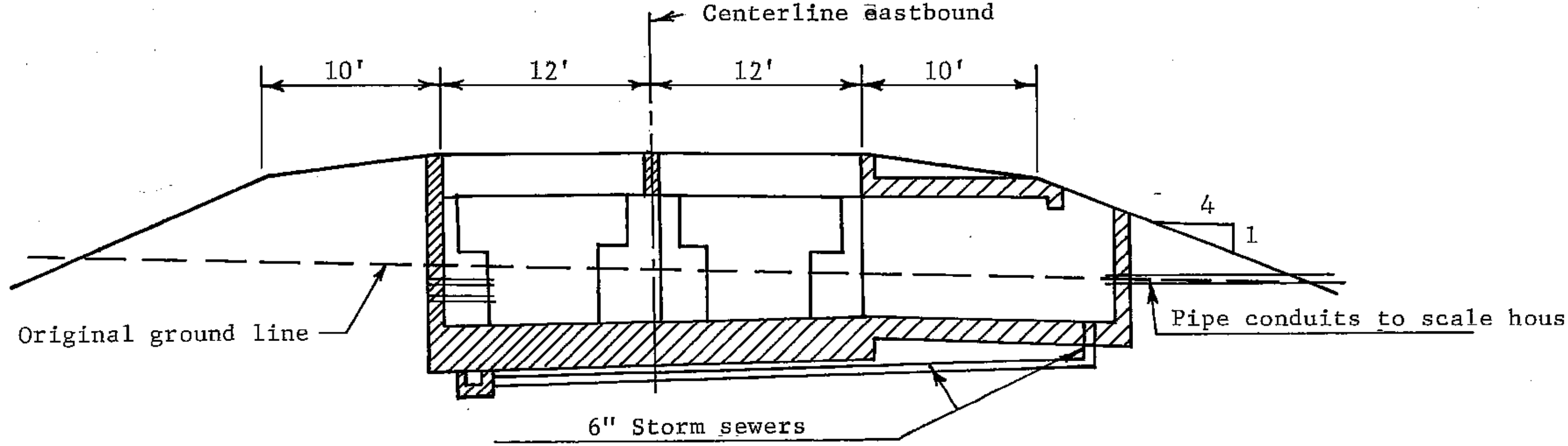
joint was mounted on the underneath side of the weigh platform and the lower ball joint was attached to a steel plate which rested on the foundation pier. Theoretically, the load cells, with the aid of signal conditioning equipment, could be expected to produce electric signals proportional to the forces applied to the platform.

Each scale platform spanned a pit of approximately 3-ft 9-in. clear depth, which provided access to the scale equipment for maintenance purposes. Typical cross sections of the scales and pit for the eastbound lanes are shown in Figure 3. The bottoms of the pits were below the elevation of the roadway drainage ditches, requiring pumps to keep the pits dry.

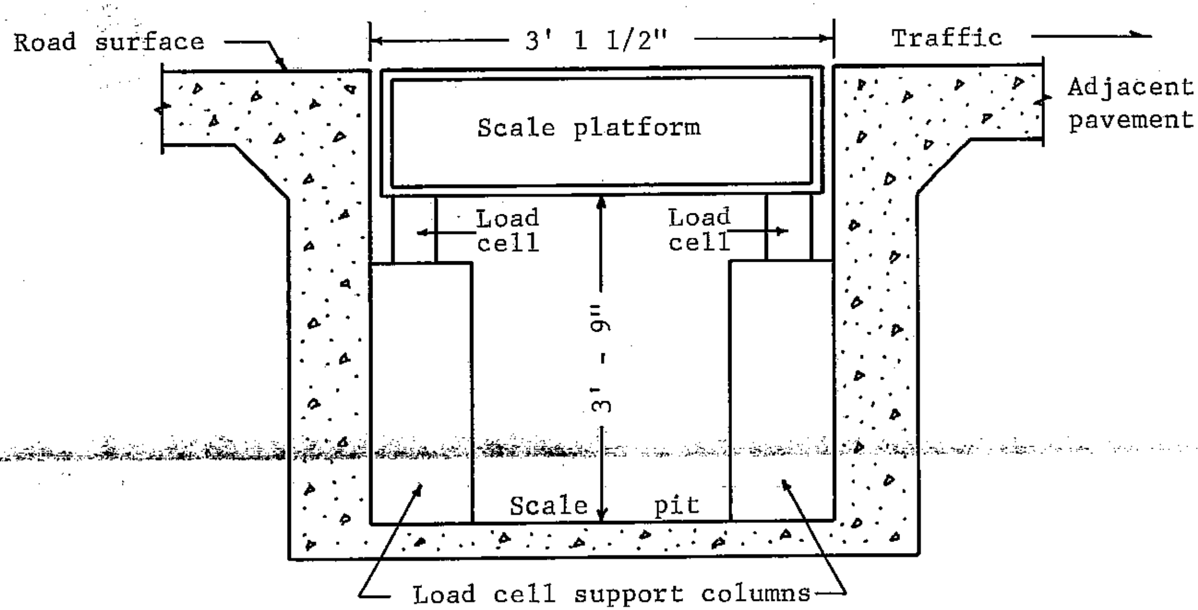
The clearance between the sides of the platforms and the scale pit walls was constructed a minimum of 3/4 in. To prevent horizontal movement of the floating slab, flexure-type check rods were installed to check both longitudinal and transverse motions without affecting vertical movement.

The major components of the electronic system were the load cells, a recording amplifier, an oscillograph, and treadles for activating the oscillograph motor. Three waterproof junction boxes were used to connect the load cell cables to the recording system. One junction box was installed in each scale pit, and the third box was mounted at the outer edge of the eastbound roadway shoulder. The amplifier and oscillograph (Figure 4) were located within a small building situated near the right-of-way line.

The four strain gage load cells supporting each platform were wired to operate independently and collectively as Wheatstone bridges. Use was made of the proportionality that exists between forces applied to load cells and the resistance of the bridge, which was excited by an AC voltage. The output of each load cell was



Scale Pit and Eastbound Roadway (Westbound similar)



Scale Platform and Pit Details

Figure 3. Cross sections of electronic weigh scales

an AC voltage with an amplitude that represented the force applied to the cell. The four load cells supporting a platform were connected in parallel so that the combined output of the cells could be fed into the recording amplifier.

The recording amplifier accepted the AC output voltage of the load cells, converted it to a DC voltage, and fed it to the oscillograph following amplification.

The oscillograph produced permanent recordings through the use of a hot stylus and a heat-sensitive recording paper that turned black at the point of contact with the hot stylus. The stylus of the recorder moved across the paper in proportion to the amplified output of the load cells.

The scales and recording equipment were calibrated through the use of axles of known weights. Axles of the calibrating vehicles were weighed on a commercial scale. The vehicle was loaded to different weights to provide a range in axle loadings. During the calibration process, and at any time static weights were being determined, the vehicle actually was driven at creep speed across the platform to make certain that the platform was properly seated on the load cells and that the cells were functioning properly. Experience showed that this was necessary. The waveform at creep speed could be expected to be essentially a square wave, and any other wave shape could be presumed to indicate a load-cell malfunction.

The recording paper was fed through the oscillograph only for short periods of time covering the recording of axles of individual passing vehicles. This was accomplished automatically through the use of a pressure trip plate placed in the pavement a few feet in advance of the scale platform. The load of the first axle of an approaching vehicle would actuate the paper-feed motor, which was set to remain on for ten seconds, an ample recording period for the longest of vehicles traveling at normal road speeds.

When the scale system was put into operation, its lack of capability for providing accurate static weights from weighings of fast-moving vehicles became evident.

SCALE RESPONSE TO MOVING LOADS

In tests utilizing a truck with known axle weights, the scale system showed good accuracy in weighings at creep speed as compared with static weighings made on a commercial scale. As the speed of the vehicle was increased, however, the recorded data neither depicted the static weights nor showed any consistent relationships from which static weights could be estimated. Even the indicated dynamic weights could be strongly suspected of not truly representing the applied forces.

Typical weight recordings of a two-axle truck with a rear-axle weight of 12 kips over a range of crossing speeds from 10 to 55 miles per hour are shown in Figure 5. Two runs were made at each speed increment shown. It will be noted that the waveforms indicate a pattern typical only for each given speed. Although the waveform for an established axle weight appears repeatable for a given speed, the static weight is not readily discernible as a function of the generated waveform.

The largest amplitude of the waveform always occurred at the beginning of each reading. This would seem to indicate that the roadway approach to the scale platform influenced the smoothness of the waveforms. The occurrence of this distinct peak is indicative of an initial impact load being immediately induced as the vehicle makes contact with the scale. Plots of the initial impact forces as an average of replicate tests for various axle loads and vehicle speeds are shown in Figure 6. The curves indicate that the initial impact in terms of a dimensionless load factor defined as a ratio of the dynamic load to static weight tends to increase with an increase in crossing speed and to decrease with an increase in static weight. The dynamic forces superimposed upon the static weights occurred as an inverse function

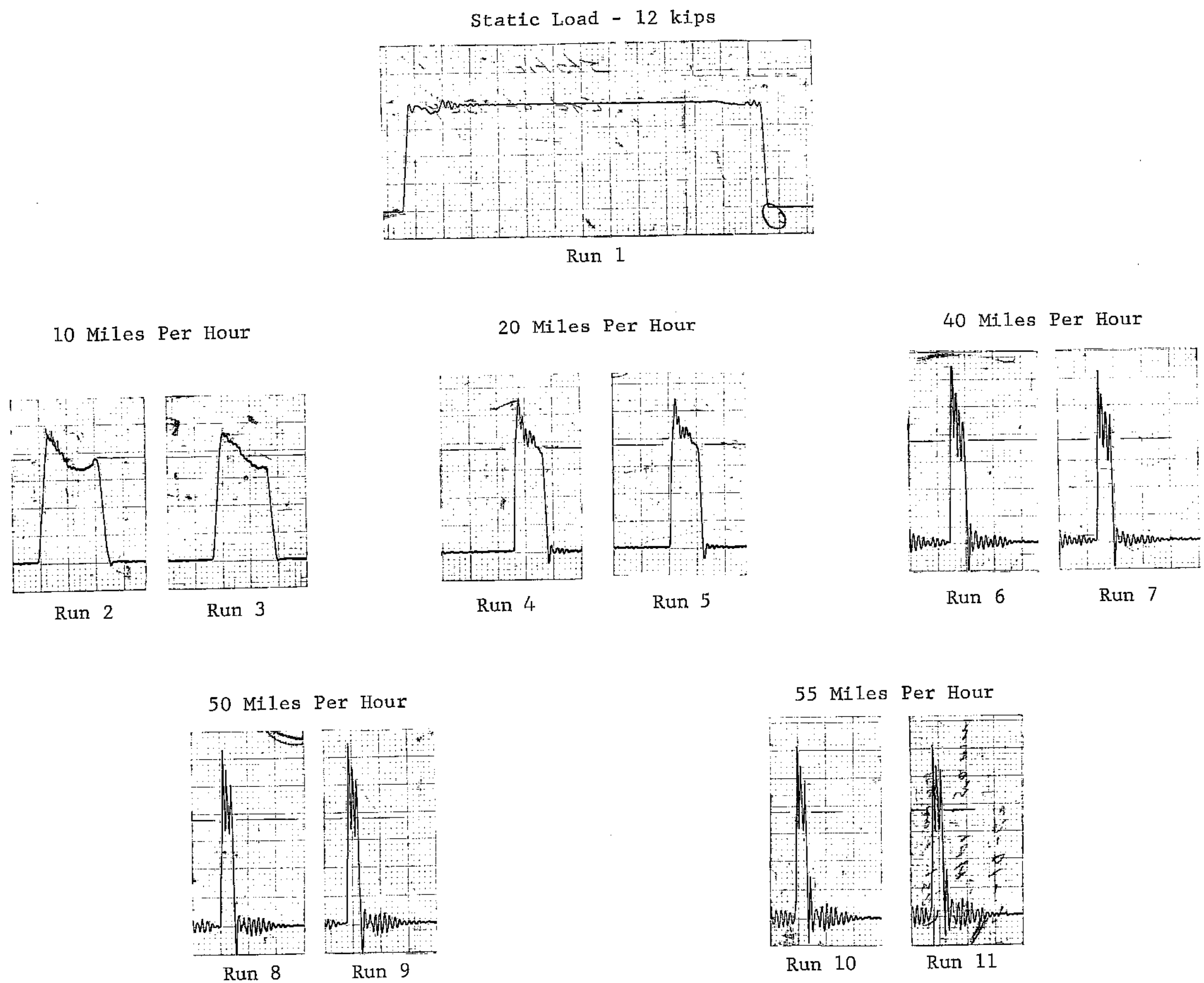


Figure 5. Typical recordings of dynamic load reading versus vehicle speed for static rear-axle load of 12 kips

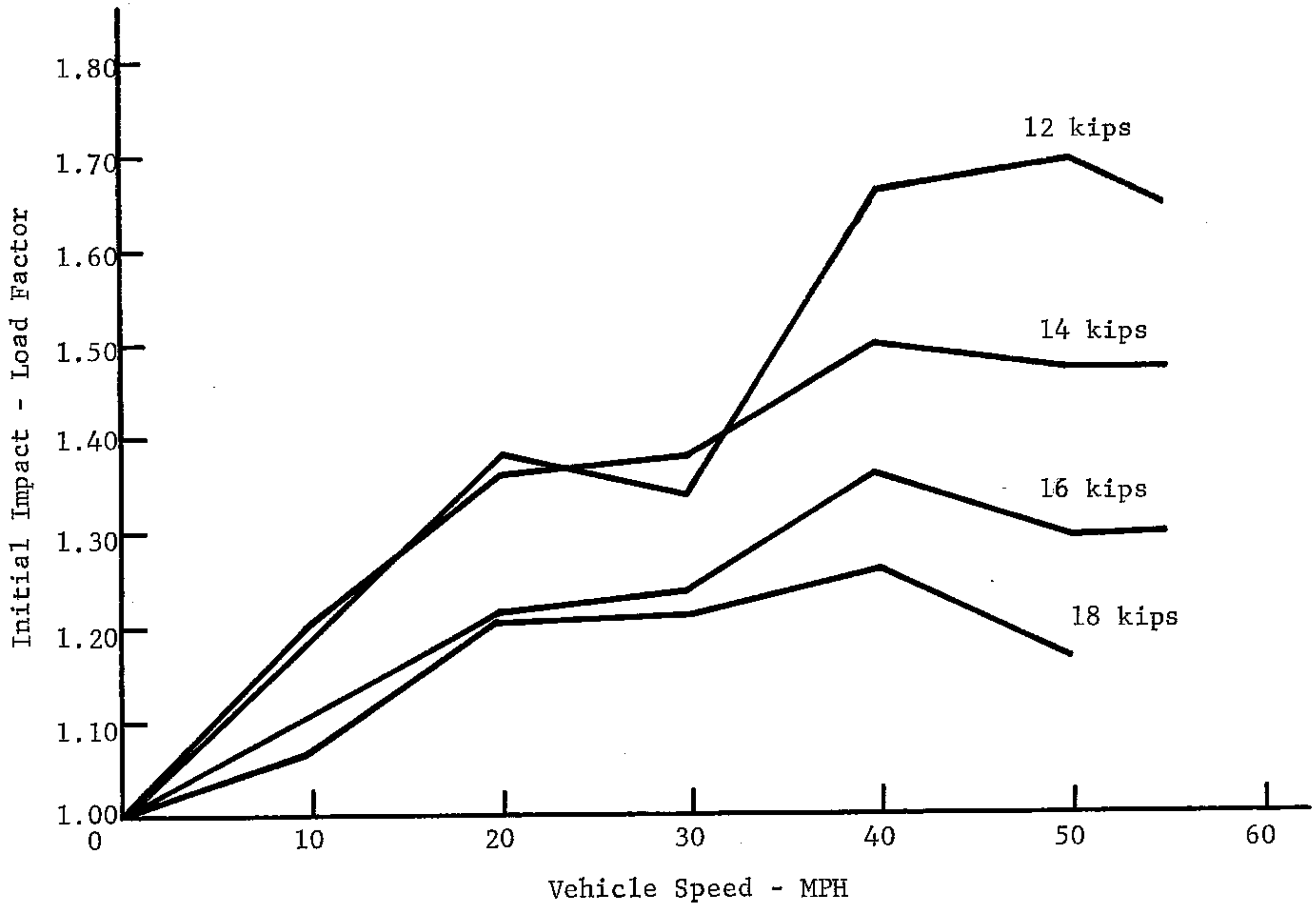


Figure 6. Average initial impact versus static load and vehicle speed

of the static weights that became significantly less for the high load increments, especially at the higher crossing speeds.

Further analysis of the data is shown in Figures 7 to 14. The graphs in Figures 7 to 12 represent plots of the weighted average of the maximum and minimum peak readings of the dynamic forces recorded for axle applications of different weights at varying increments of crossing speed. The curves are also plotted in Figures 13 and 14 to illustrate the comparative values obtained from the analysis. For speeds of 10 to 40 miles per hour, the relative readings of measured weights were consistently higher than the actual static weights and the deviations between the measured and actual weights appeared fairly constant. At the higher speeds, however, the actual static weights were more difficult to determine, as indicated in Figure 14, because a small change in the measured weight represents a larger range of actual static weights. For speeds greater than 40 miles per hour, the deviations are more inconsistent, and the relationship of measured to actual weights is not clearly defined.

The dynamic forces that moving vehicles transmit through the tires to supporting surfaces can be expected to be constantly varying. Even during the short increments of time that the loads are on a scale platform, the applied forces can not be expected to remain constant. A great number of factors, including road surface roughness, wind pressure, tire imbalance, and undoubtedly many others, are responsible for the variations. Scale samplings may be of a varying force, lying at or somewhere above or below the static load.

The oscillograph recordings using the original platform setup typically showed extraneous pen movements that did not appear to be directly related to the applied forces. The extraneous movements were especially evident at higher speeds of travel.

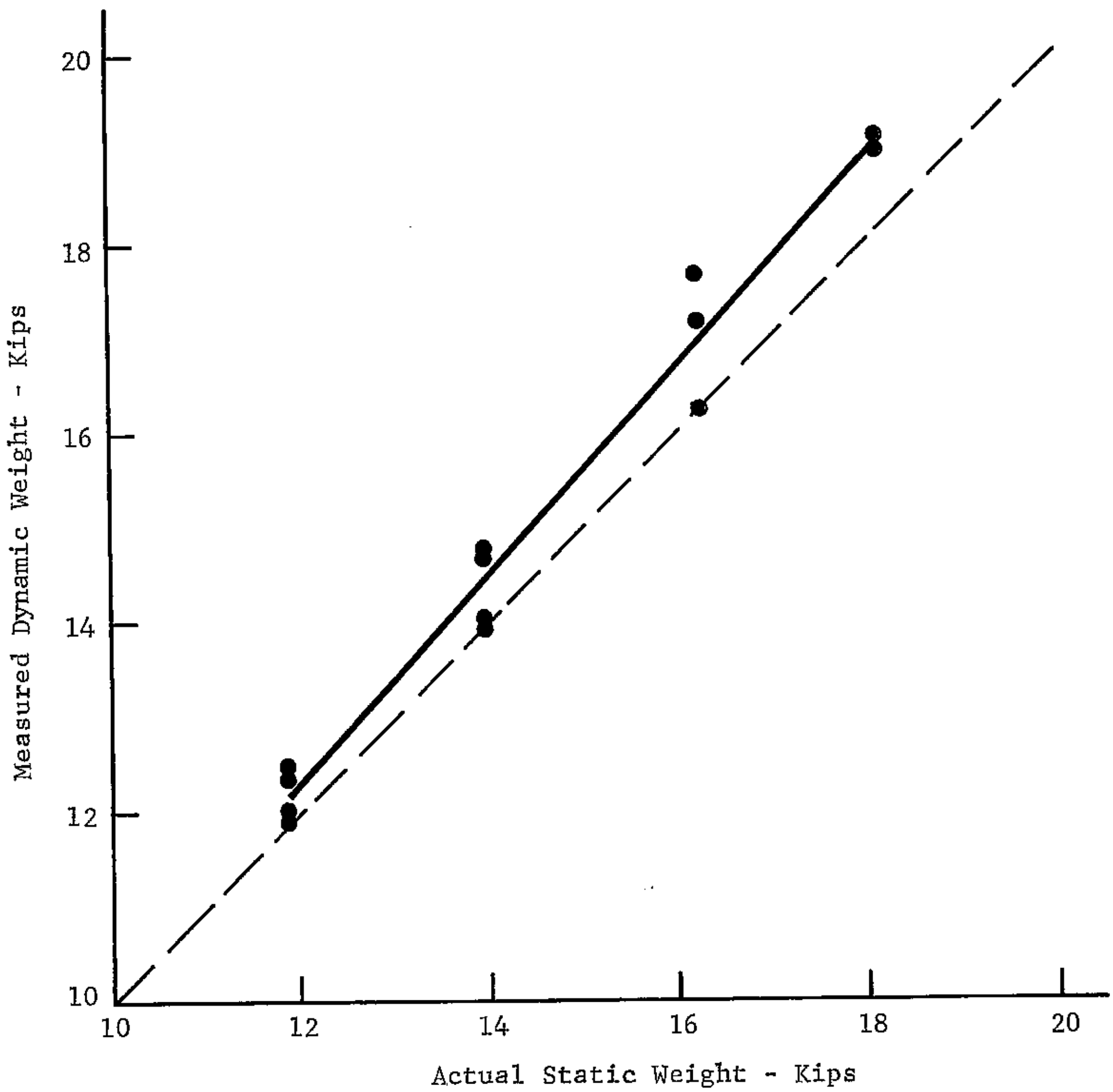


Figure 7. Recorded dynamic weights versus actual static weights for 10 mph

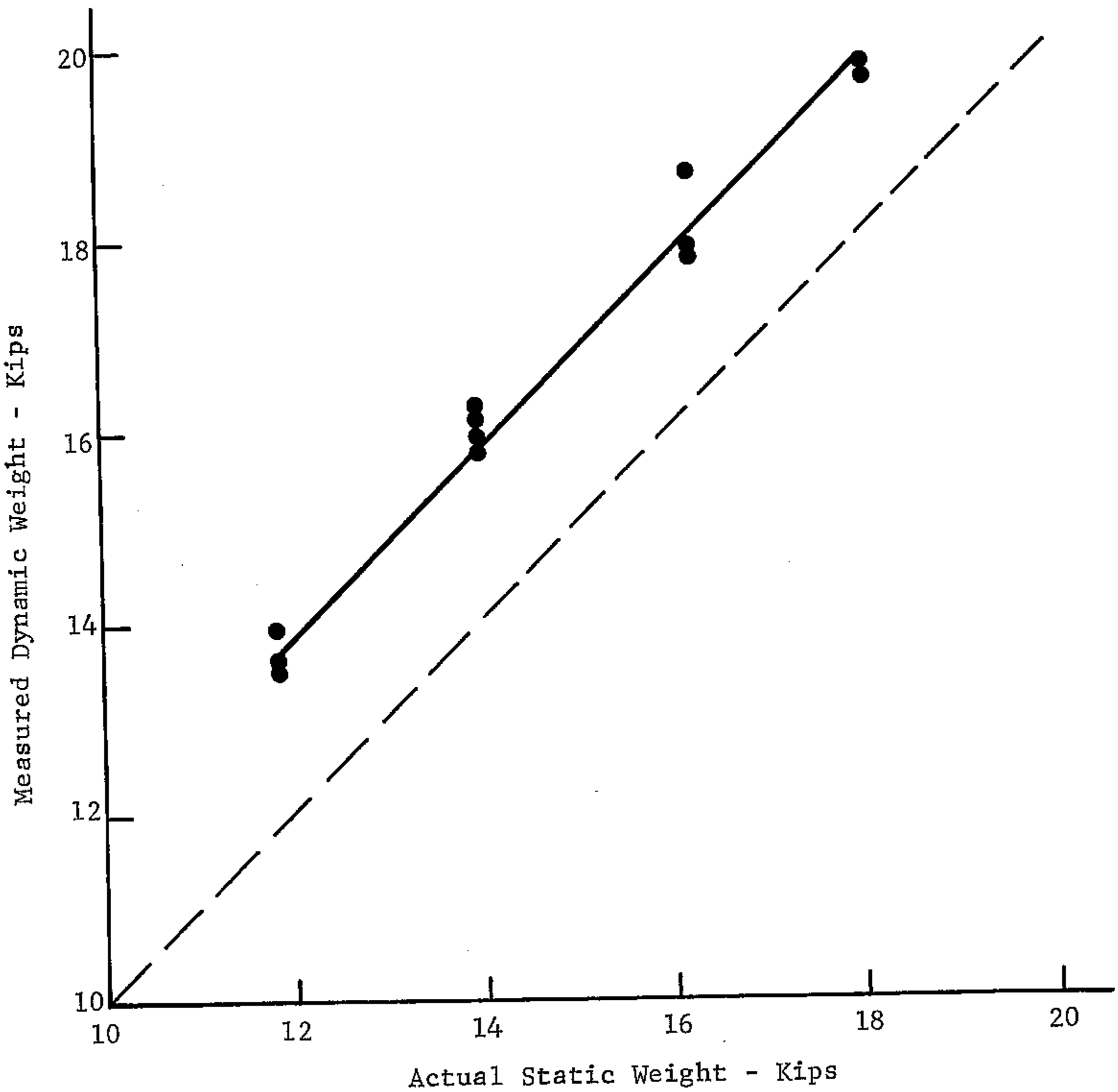


Figure 8. Recorded dynamic weights versus actual static weights for 20 mph

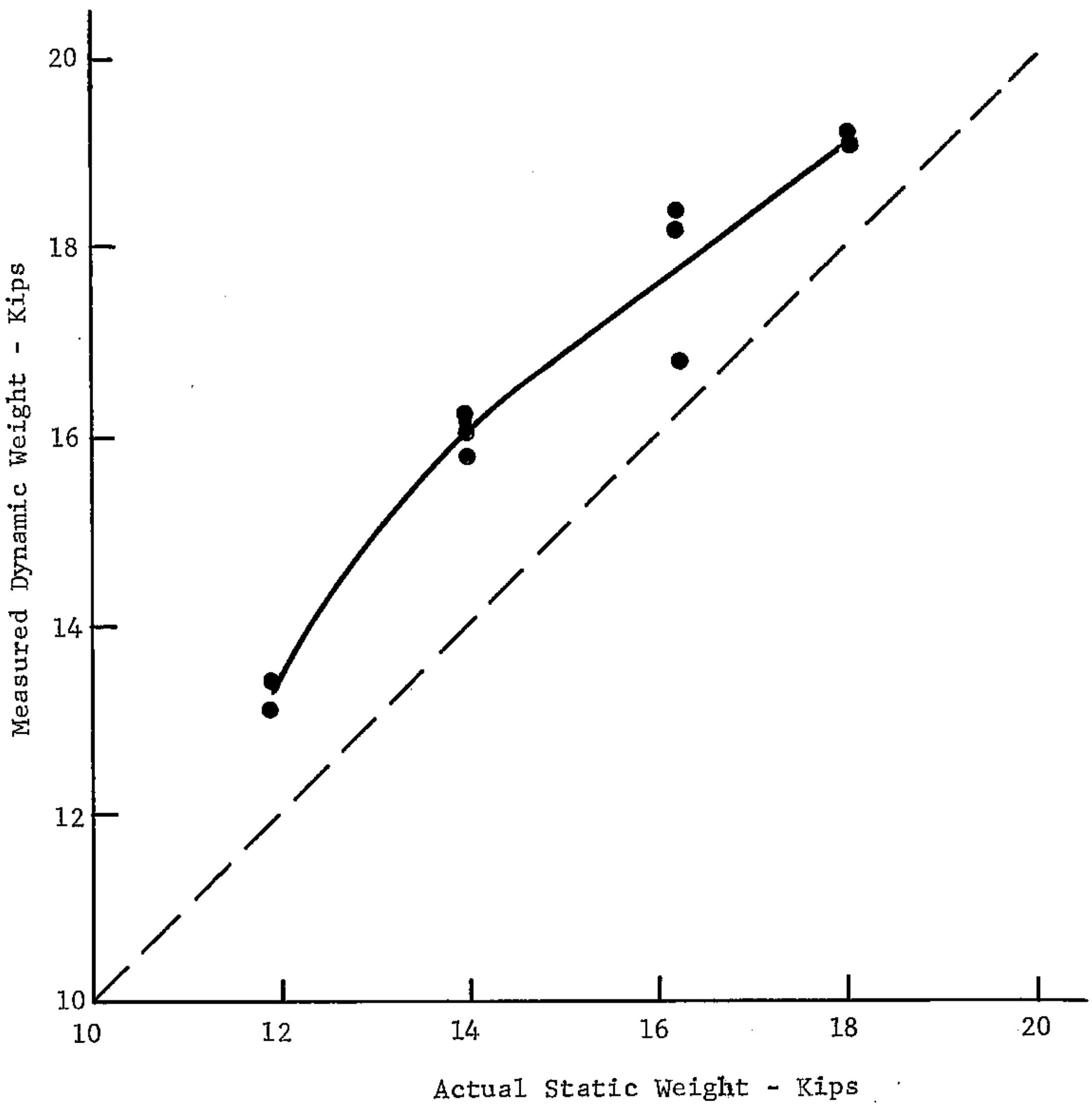


Figure 9. Recorded dynamic weights versus actual static weights for 30 mph

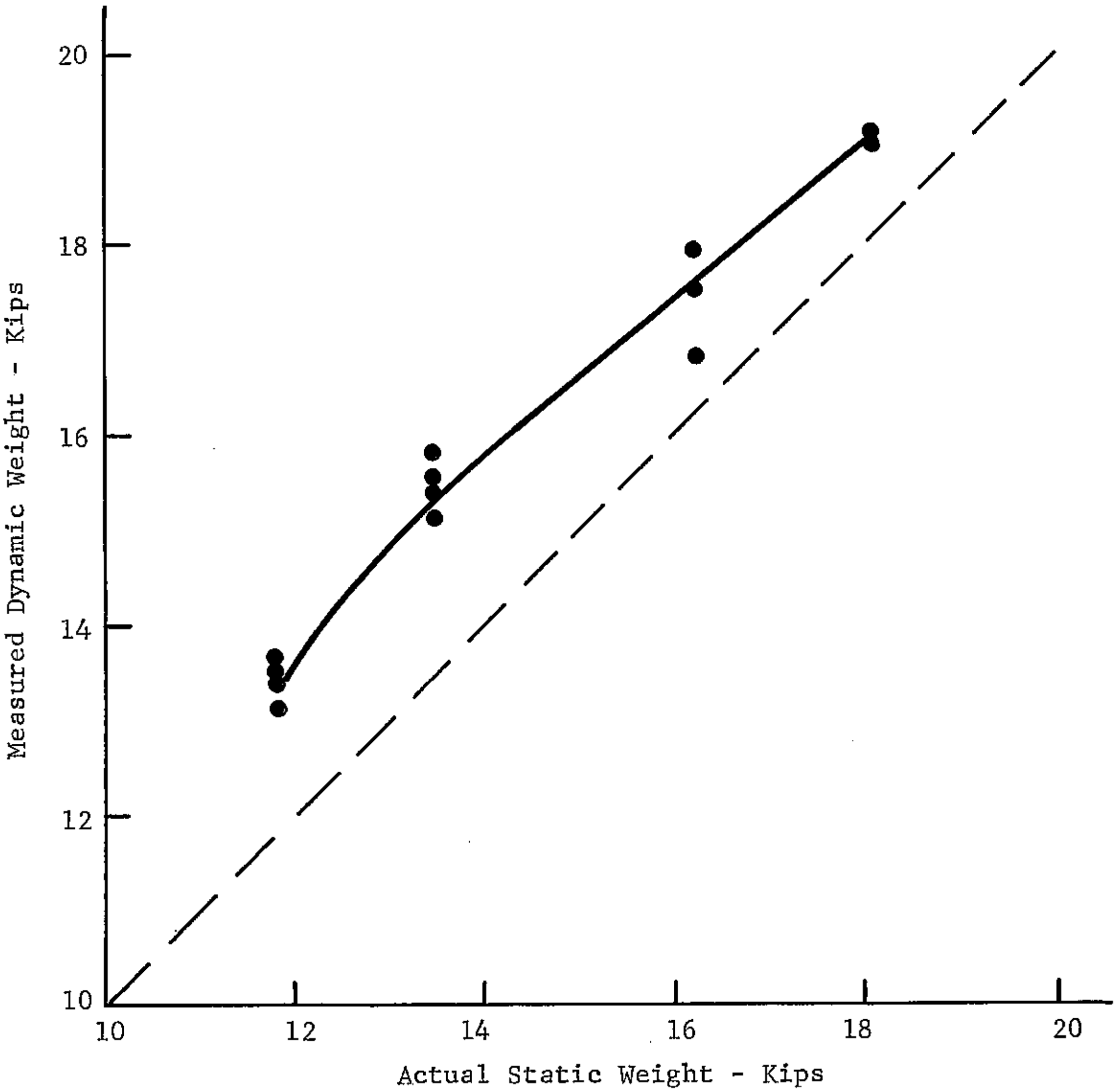


Figure 10. Recorded dynamic weights versus actual static weights for 40 mph

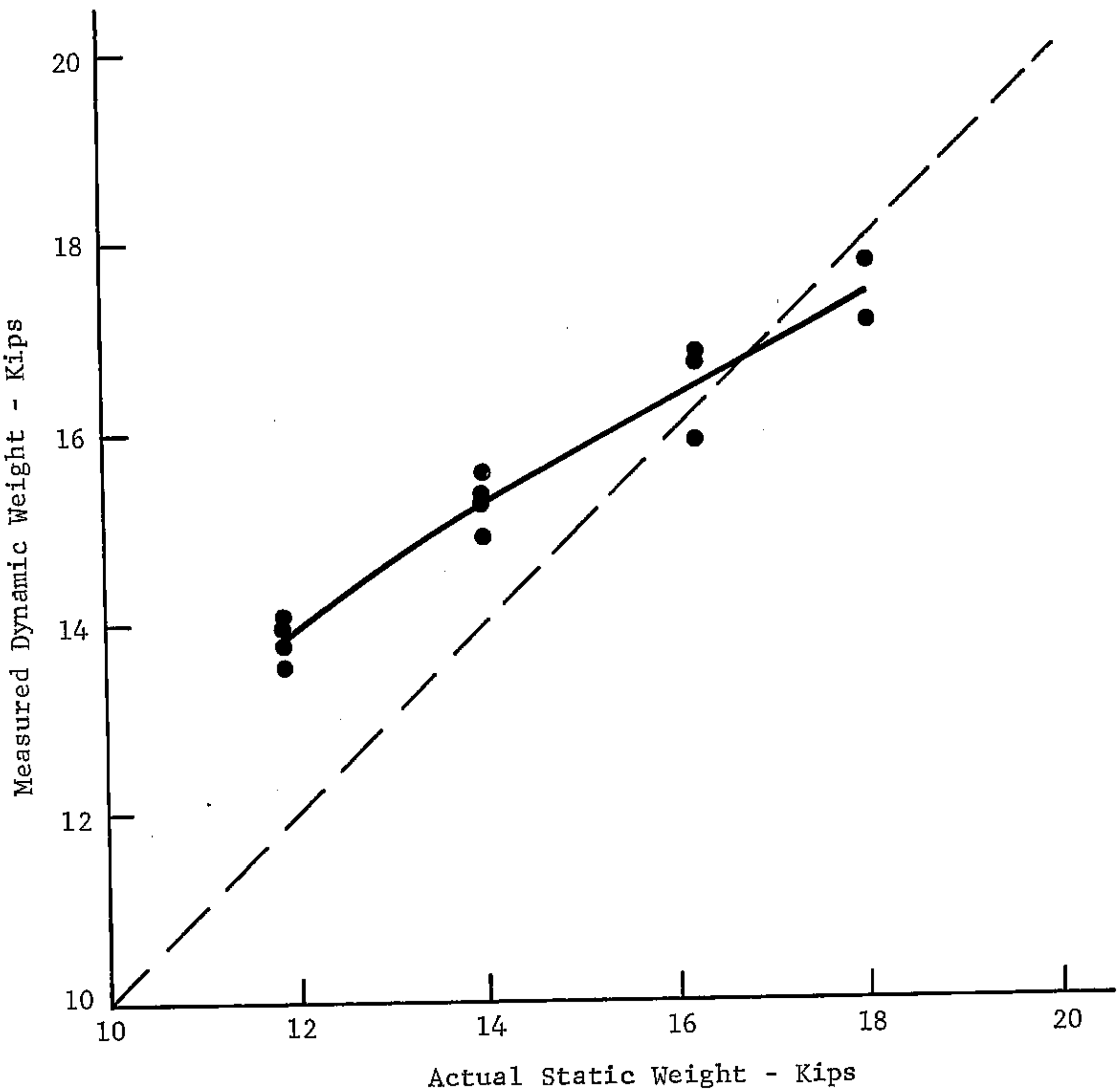


Figure 11. Recorded dynamic weights versus actual static weights for 50 mph

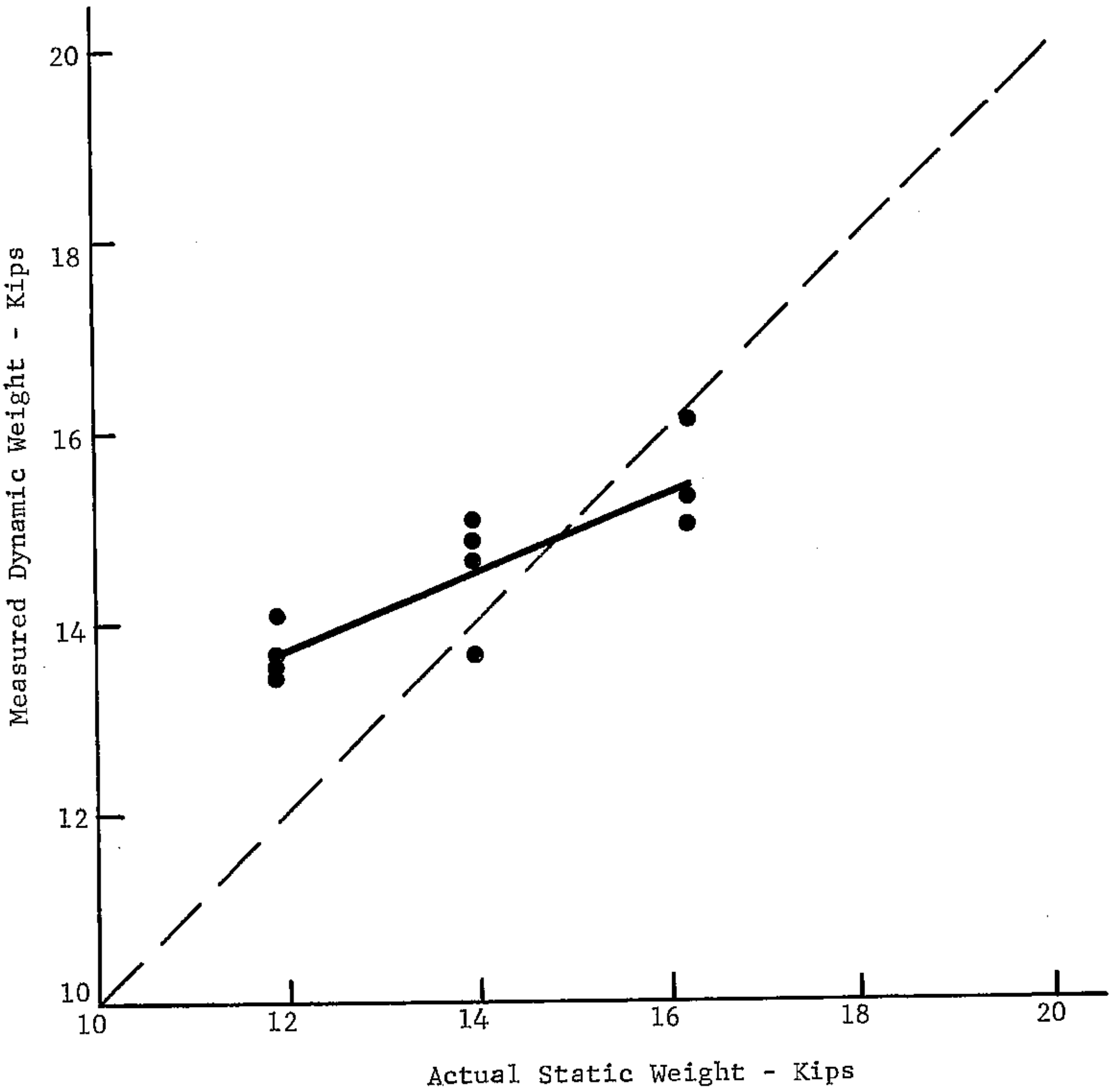


Figure 12. Recorded dynamic weights versus actual static weights for 55 mph

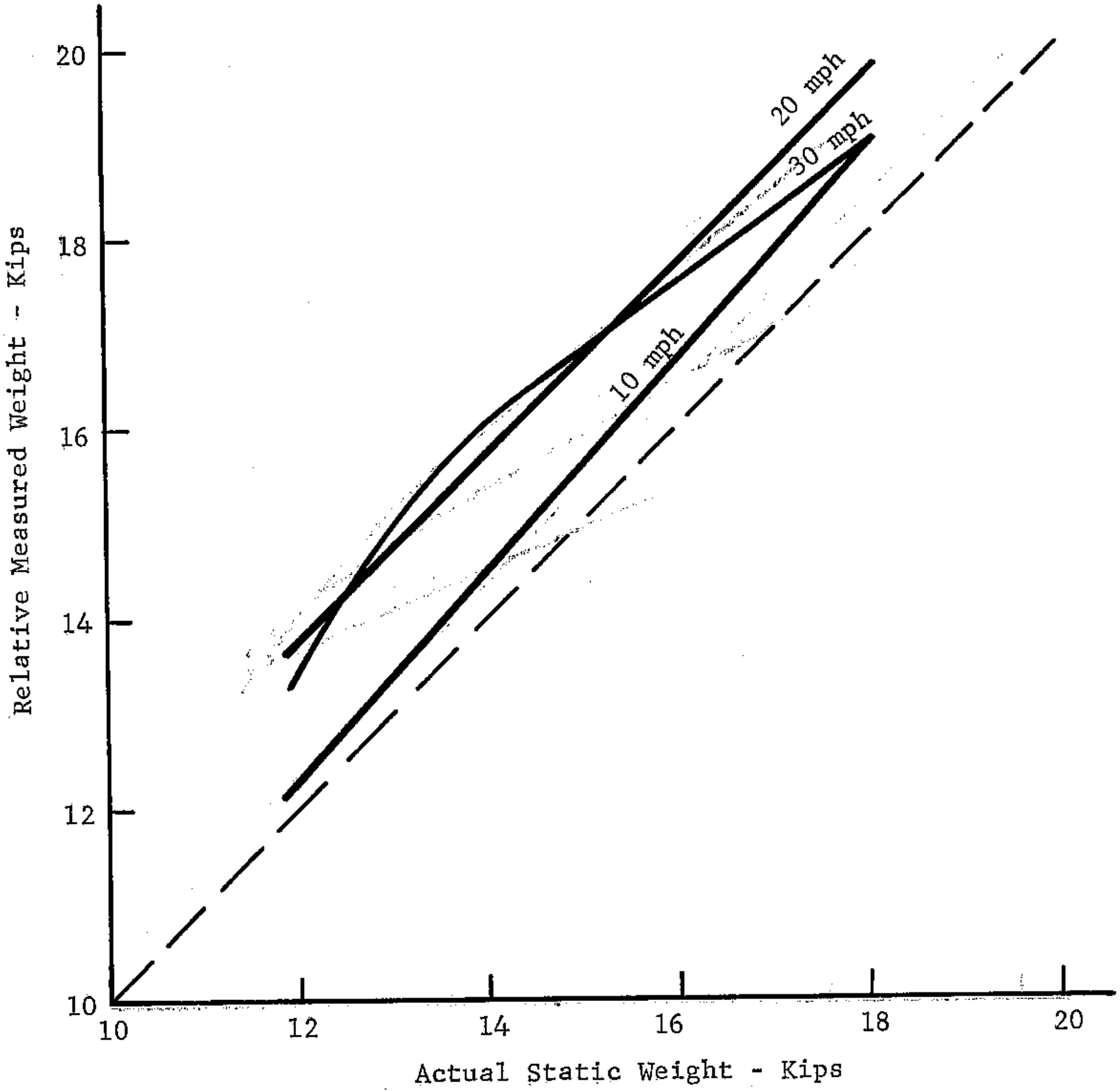


Figure 13. Relative recorded weights versus Actual static weights for 10 to 30 mph

They did not occur at creep speeds. These movements were of a magnitude that interfered with movements of interest in estimating applied loads. The output of an accelerometer mounted on the scale platform, in corresponding to the recorded pen movements during weighings, placed the source of the unwanted vibrations in the platform-load cell assembly.

SYSTEM MODIFICATIONS

Three different system modifications were made in an attempt to remove the extraneous platform vibrations as interfering factors. They were:

(1) preloading the platform;

(2) hinging the platform; and

(3) adding an electronic filter.

Preloading

Normann and Hopkins, in describing their research that has been mentioned previously, reported good success in preloading the scale system to reduce both the vibrations created by the dynamic load and the influence of these vibrations on the platform and recording data. In this subsequent study, preloading of the platform did not achieve the desired effect.

Preloading was accomplished through the use of 1-in. diameter steel bars welded to the steel frame at each of the four corners of the scale platform and fastened to steel plates bolted to the bottom of the scale pit with four 1/2-in. bolts. A known load was placed on each corner of the scale platform by adjusting each set of four bolts. Several tests were conducted with different amounts of preloading being applied and while applying known dynamic weights. Results of the tests indicated that preloading the platform increased slightly the natural frequency of the scale system, reduced the output value of the load cells, and raised slightly the speed at which the platform oscillations began. Without preloading, the oscillation began at a speed of about 12 miles per hour; with preloading, the oscillations started at about 15 miles per hour.

Since preloading produced so little improvement, and because of the difficulties encountered in maintaining known preloading forces, the procedure was discontinued.

Hinged Platform System

The next modification involved changing the corner-support system to a hinged-support system by replacing the two load cells on the upstream traffic side of the scale platform with rockers and hinging the platform to the frame on this side. It was hoped that platform stability could be improved by this means.

The hinged configuration is a variation of the broken-bridge scale favorably tested and reported by Blythe, Dearinger, and Puckett of the University of Kentucky. The broken-bridge scale consists of two similar platforms which are recessed in the roadway and which extend completely across one traffic lane. The outer edge of each section rests on a hinged rocker-type support. The adjacent edges are supported by two load cells. Thus, the hinged platform is essentially one half of the broken-bridge scale. The three platform systems are shown in Figure 15. The hinged system as devised in this study is shown in greater detail in Figure 16.

The major disadvantage of the hinge modification was a reduction of the natural frequency of the platform to about half its former value. The result was more rather than less interference produced in the oscillograph recordings.

It appeared from the study that any effort at correcting the deficiencies of the hinged platform would be impractical, and this approach was discontinued.

Electronic Filter

Because of the almost constant frequency of the scale platform oscillation, of about 94 cps, it appeared feasible to eliminate the effect of the undesirable

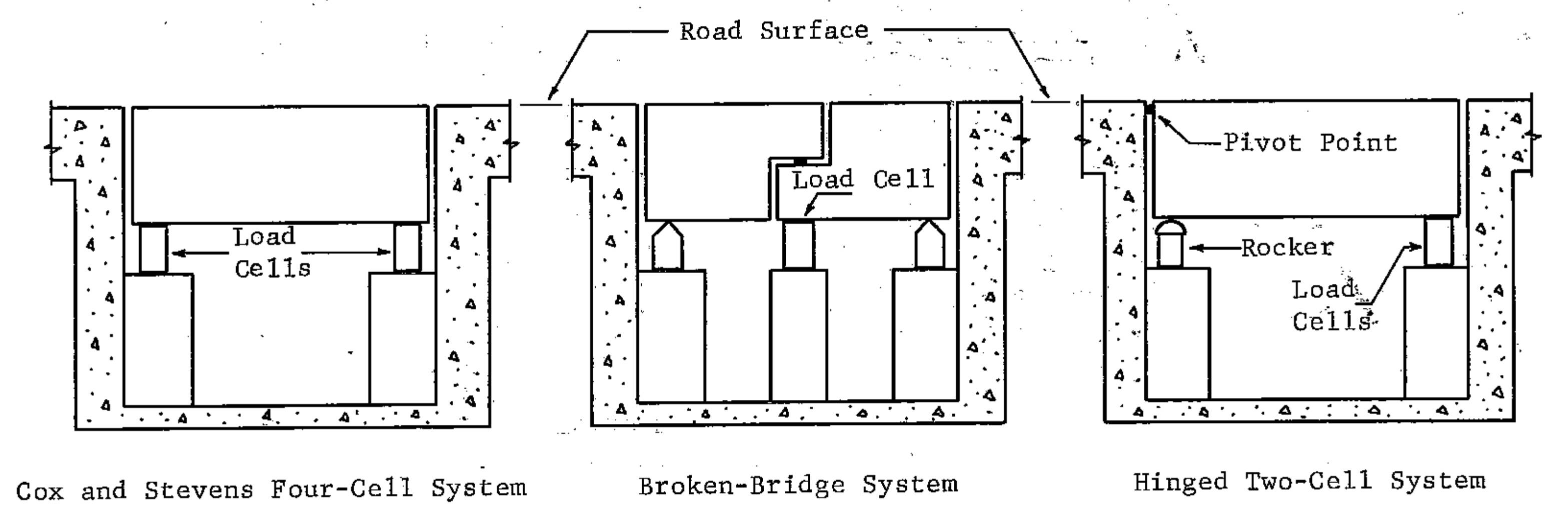


Figure 15. Three platform systems

oscillations by the use of an electronic filter. In an attempt to filter out the oscillations, an LC type filter was designed to reject 94 cps. This filter was installed in the input of the recorder's DC amplifier.

To test the filter's effectiveness, two recording systems were used, one with a filter and one without. Both recording systems shared the same input and each output was connected to an oscillograph. Comparing the two simultaneous recordings revealed that about 80 percent of the vibration interference had been eliminated. Tests under axle loadings of vehicles selected randomly from the regular traffic stream produced recording patterns that were very encouraging. It is believed that a much higher percentage could be eliminated with a more sophisticated filter. Typical recordings made with and without the filter are shown in Figure 17.

Of the three modifications attempted to reduce the extraneous signals affecting the recording equipment, the addition of the filter appeared to show the greatest promise. However, as time passed, the problems of maintaining the scale system in a functioning condition over periods longer than a few days became unmanageable. Continual displacement of the load cells under traffic and frequent damage to the electronic equipment and circuitry in the scale pits by surface water and brine from de-icing operations, and binding of the platforms by expansion of the adjacent pavements, were the most serious problems encountered.

MAINTENANCE PROBLEMS

Displacement of one or more of the supporting load cells, caused mainly by the heavy loading impact and the ensuing platform oscillations, was a common difficulty. The displacement usually began with one of the load cell base plates working out of alignment. As the base plate shifted, the load impact hastened the movement, and the load cell soon worked completely out. With the load cell removed, its corner of the platform was without support. Following additional impacts, more load cells worked loose, causing the scale platform to drop onto the safety piers. As a result, under the direct action of severe pounding, damage to the piers became quite pronounced. A platform with two load cells displaced is shown in Figure 18.

The effect of corrosion from water and de-icing salts was a continuing problem. The scale platform design allowed both water and salt solutions to enter the pit easily, causing damage to the load cells and electrical components. The salt solutions severely corroded the load cells, increasing their eventual damage or subsequent failure. The salt and water also entered junction boxes, outlets, and lighting fixtures. In severe cases, salt water created a shorted circuit which cut off power in the pits, including the pumps. The stoppage of the pumps resulted in flooding of the scale pits. The high degree of rust and corrosion on the metal parts of a load cell assembly is illustrated in Figure 19.

Originally, the scale was designed to use two flexure rods in order to limit the horizontal movement of the scale platform. The rods were fastened between the scale pit walls and the scale platform, thereby confining the platform to vertical movements only. The flexure rods constantly worked loose from both the wall and the platform. In an effort to more effectively restrict the horizontal movement of the platform, the gap between the scale platform and the pit framework was reduced by welding steel spacers or shims to the sides of the platform. This alteration reduced the amount of platform sideplay somewhat, but had little or no effect on load cell displacement.

Movement of the portland cement concrete pavement adjacent to the scale platform proved to be a serious problem with this particular installation. During the summer

Figure 18. Scale platform with load cells displaced

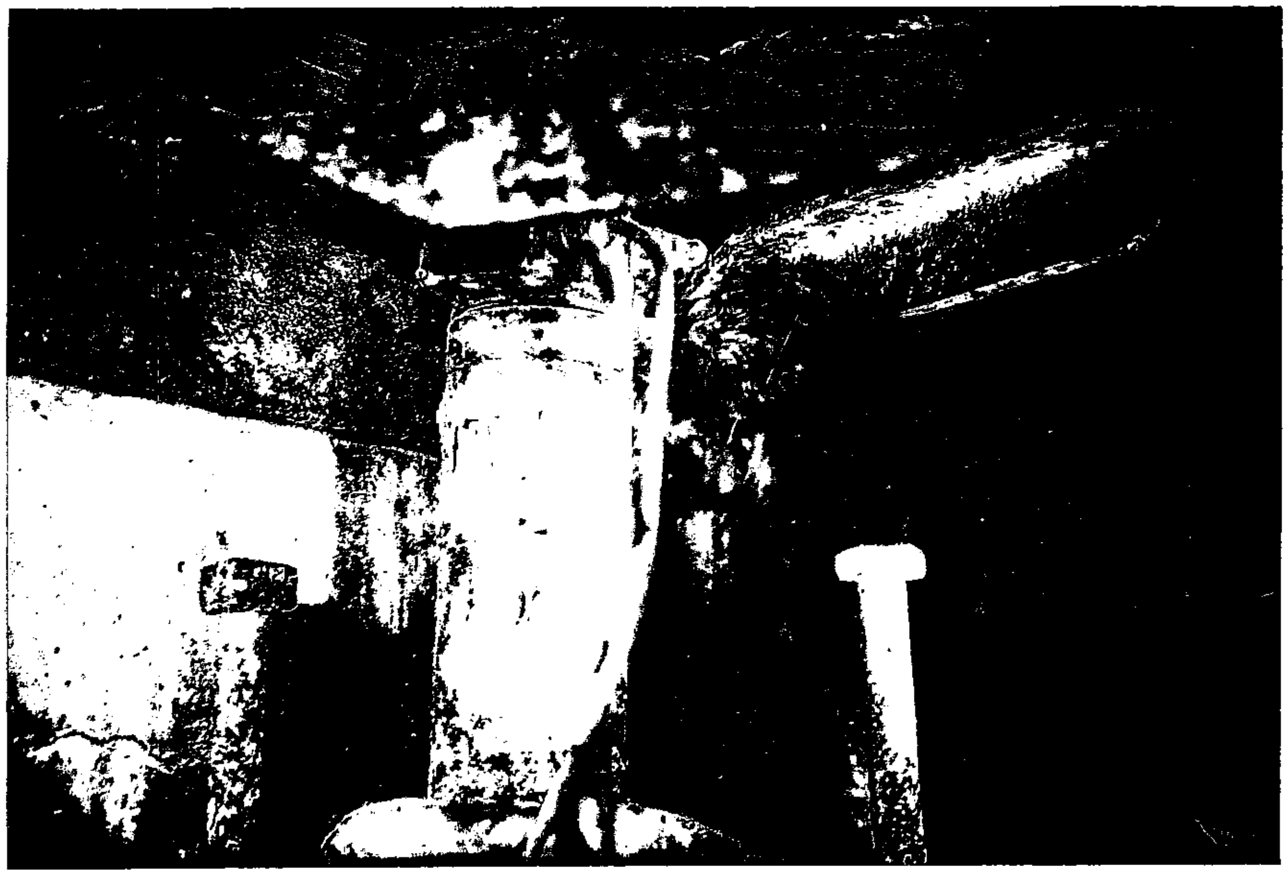


Figure 19. Corrosion of load cell assembly

months, expansion of the pavement was sufficient to force the scale framework inward to wedge the scale platform. Removal of the welded shims would not free the platform. Finally, the platform was jacked up and the sides were ground to provide sufficient clearance. Distortion of the pit framework is shown in Figure 20. The pavement expansion also caused cracking of the platform supporting columns, as can be observed in Figure 21.

CONCLUSIONS

It is evident from the results of this research that the scale system that was examined was not capable of serving to provide either dynamic weights or acceptable estimates of static weights of axles of vehicles traveling at normal highway speeds.

Induced oscillations of the scale platform that masked the recordings of interest were not removable in the attempts that were made, although a filtering system to compensate for their presence showed promise. Whatever relationship that may exist between dynamic loadings and static loadings proved to be too complex for estimating static weights from dynamic weights by procedures in this study.

Three separate modifications were made in the original scale system in an effort to control the oscillations of the platform. The first attempt involved preloading the scale platform with a known force, but this approach produced no apparent benefit. The second revision included hinging one side of the platform while supporting the other side by two load cells. This only served to decrease the natural frequency of the platform instead of achieving the desired increase. The final modification was the addition of an electronic filter to eliminate the effect of the undesirable oscillations. This refinement appeared to have merit. Possibly the use of a more sophisticated filter circuit would improve the scale

Figure 20. Distortion of pit framework

Figure 21. Cracking of columns

system to a greater degree. Physical problems with the system prevented further exploration.

The physical resistance of the scale system under study was not sufficient to withstand the pounding of the normal traffic mix on what can be considered to be a typical heavy-duty highway. Constant displacement of the load cells supporting the scale platform proved to be a problem that was never overcome. Deterioration and failure of the electronic equipment and circuitry in the scale pits from water and brine action proved to be another problem that was never coped with successfully.

IMPLEMENTATION

No further use of, or experimentation with, a scale of the specific design and hardware components of that covered in this study is recommended.

REFERENCES

(1) Fisher, J. W. and Huckins, H. C., Measuring Dynamic Vehicle Loads, Special Report 73, Highway Research Board, 1962.

(2) The AASHO Road Test, Report 6, Special Studies. Highway Research Board, 1962.

(3) Puckett, R. E. and Gover, J. E., Comparison of Two Methods for Preloading Electronic Scales, Vol. 32, No. 8, Public Roads, June 1963.

(4) Dearinger, J. A., Dynamic Weighing of Vehicles, Vol. 31, No. 10, Public Roads, Oct. 1961.

(5) Hopkins, R. C. and Boswell, H. H., A Comparison of Methods Used for Measuring Variations in Loads Transferred through Vehicle Tires to Road Surface, Vol. 29, No. 10, Public Roads, Oct. 1957.

(6) Normann, O. K. and Hopkins, R. C., Weighing Vehicles in Motion, Vol. 27, No. 1, Public Roads, April 1952.

(7) Normann, O. K. and Hopkins, R. C., Weighing Vehicles in Motion, Highway Research Board Bulletin 50, 1952.

(8) Puckett, R. E., Selecting the Best Scale for In-Motion-Weighing, Vol. 33, No. 3, Public Roads, August 1964.

(9) Edholm, S., Methods of Traffic Measurements - Determination of Number and Weight of Vehicles, Highway Research Board Bulletin 338, 1962.

(10) Lee, C. E., A Portable Electronic Scale for Weighing Vehicles in Motion, Highway Research Record 127, 1966.