Illinois Department of Transportation

Reclaimed Asphalt Pavement with Steel Slag Aggregate

Successful Use in Illinois Pavements

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Using recycled materials and by-products in pavements is a sustainable practice that is gaining adoption, particularly for hot-mix asphalt (HMA). HMA materials can be milled off the road surface and recycled.

Reclaimed asphalt pavement (RAP) consists of reprocessed HMA pavement material, such as asphalt and aggregates. RAP often contains high-quality, well-graded aggregates that are coated with asphalt cement but may include steel slag, a by-product of steel making. One approach is to incorporate large quantities of RAP into unbound aggregate base and subbase applications for highway construction.

Problem

Steel slag is an expansive aggregate often added when high frictional properties are required, as in HMA surface courses, particularly when good-quality aggregate is scarce. Steel slag, however, may contain free lime (CaO) and magnesia (MgO), which can react with water and cause the slag to expand.

Volume changes of up to 10 percent or more have been attributed to hydration of the calcium and magnesium oxides in the recycled steel slag aggregate base course, caused by water seeping into the pavement base layer. The amount of expansion depends on the origin of the slag, the grain size and gradation, the hydration of unslaked lime and magnesia, and the age of the stockpile.

PHOTO: ILLINOIS CENTER FOR TRANSPORTATION

Stockpile of slag aggregate.

Solution

Documentation and Research

The Illinois Center for Transportation compiled a synthesis of research results and state highway agency practices (*1*). The findings indicated that pavement structures have used RAP successfully as a granular base or subbase material and that the performance of a RAP base is often comparable to that of a crushed stone base.

The synthesis also revealed that in blending processed RAP materials with virgin aggregates, proper bearing strengths have to be attained, because the RAP bearing capacity is usually less than that of conventional granular aggregate bases. As the virgin aggregate content increases, the dry density and strength properties increase. As a result, characterizing and quantifying the expected range of RAP properties is necessary before application.

Steel slag aggregates often have favorable frictional properties, high stability, and good durability, with resistance to stripping and rutting—therefore they can perform well as base material. The conventional way to control the tendency to expand is to weather the steel slag aggregates in stockpiles until the potentially expansive systems stabilize.

The length of time for stocking depends on the local temperature and rainfall and on the degree of air moisture saturation throughout the year and may range from 3 to 12 months. Most highway departments require at least 6 months for the aging or curing of steel slags. After curing, steel slag can serve as a valuable secondary aggregate.

Project and Findings

The objective of the larger research project was to determine the expansive properties for RAP materials, especially those including recycled steel slag aggregates that could be used as pavement base materials in Illinois (*1*). Additional objectives were to determine the maximum acceptable level of expansion for different RAP aggregate types, the properties and blending proportions with virgin aggregates, and the effects that RAP materials may have on pavement performance.

In the laboratory, researchers applied ASTM Test Method D4792 to 17 Illinois RAP materials and virgin aggregates to determine expansive characteristics. Placed in California bearing ratio (CBR) test molds, the specimens were submerged in a high alkali–cement water solution with a pH of 12 at 70°C; the specimens soaked for up to 60 days to accelerate hydration reactions or until no further expansion was noted.

Some steel slag aggregates showed a potential for expansion of up to 6.2 percent, which is high compared with virgin aggregates, such as siliceous gravel and crushed dolomite, which exhibit minor or almost no expansion (Table 1, right). The lower density RAP materials often exhibited more initial settlement or contraction before any kind of expansion. Surface RAP with 92 percent steel slag aggregates and steel slag RAP recorded maximum expansions of 1.69 percent and 1.46 percent, respectively.

A clear conclusion from the expansion tests was that RAP materials with slag aggregate that was partly coated with asphalt had much lower tendencies to expand than the virgin steel slag aggregates, which showed high expansion potentials. ASTM D2940 limits expansion values to less than 0.50 percent at seven days when materials are tested in accordance with Test Method D4792. Stone matrix asphalt RAP, steel slag RAP, surface binder RAP with 60 percent steel slag aggregates, and surface RAP with 92 percent steel slag aggregates could be used as pavement base course aggregates. Porous and nonporous—that is, virgin—steel slag aggregates, however, should never be used in the bases or subbases without the proper curing specified in ASTM D2940.

TABLE 1 Summary of Average Total Expansion Values for Materials

Material	Average Total Expansion[a] (percent)	Duration of Expansion Test (days)
Virgin Steel Slag Aggregates		
Nonporous steel slag	6.18	49
Nonporous steel slag repeat	5.82	28
Porous steel slag	4.14	49
Steel slag from Illinois District 4	0.28	60
RAP with Steel Slag Aggregates		
Surface RAP (92 percent)	1.69	44
Steel slag RAP, standard composition	1.46	45
Steel slag RAP	1.13	45
Surface binder RAP (60 percent)	0.24	49
Stone Matrix Asphalt RAP	0.93	45

[a]Computed after initial settlement, if any.

Application

Illinois has used steel slag only in HMA surface mixes for years and never has allowed steel slag or RAP containing steel slag in any other layer of the pavement structure because of concerns about expansion. Like most states, Illinois is pursuing environmentally conscious practices and has started applying normal RAP for other aggregate uses, notably in the Chicago area, which has sizable stockpiles of RAP.

The results of this research led to two significant changes in the specifications:

1. Steel slag RAP is allowed in all levels of the HMA mixes.
2. Steel slag RAP can be used wherever normal RAP is used for aggregate applications.

Benefits

Although the changes to the specification are too new to project financial benefits, a few cost savings have resulted. Contractors are now able to stockpile their RAP in a single main stockpile, except when the steel slag RAP will be part of the HMA surface for the beneficial frictional properties. This frees up acreage at the contractor sites for other material.

Before this research, steel slag RAP not used within 2 years was consigned to land fill. Blending steel slag RAP with the other RAP allows the entire HMA pavement to be milled together. The performance of pavement subgrade applications with steel slag RAP is expected to equal that of pavement subgrades built with natural aggregates.

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Slag (*left*) and virgin limestone aggregate side by side.

Reference

1. Deniz, D., E. Tutumluer, and J. Popovics. *Expansive Characteristics of Reclaimed Asphalt Pavement (RAP) Used as Base Materials.* Illinois Center for Transportation Project R27-027 Final Report, Publication No. FHWA-ICT-09-055. Illinois Department of Transportation, Springfield, August 2009. http://ict.illinois.edu/Publications/report%20files/FHWA-ICT-09-055.pdf.

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Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2952; gjayaprakash@nas.edu).