CENTER FOR TRANSPORTATION RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

Project Summary Report 0-4177-S
Project 0-4177: Use of Recycled Asphalt Pavement and Crushed Concrete as Backfill for Mechanically Stabilized Earth Retaining Walls
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PROJECT SUMMARY REPORT

Potential Use of Crushed Concrete and Recycled Asphalt Pavement as Backfill for Mechanically Stabilized Earth Walls

Mechanically stabilized earth (MSE) walls (Figure 1) have been used throughout the U.S. since the 1970s. The popularity of MSE systems is based on their low cost, aesthetic appeal, simple construction, and reliability. To ensure long-term integrity of MSE walls, select backfills consisting predominantly of granular soils have been used. However, with increasing environmental and sustainability concerns, interest in the use of recycled materials as backfill for MSE walls has grown. Some of the most commonly available recycled materials are crushed concrete (CC) and recycled asphalt pavement (RAP), and these materials are being considered for use as backfill in MSE walls in Texas. This Project Summary Report (PSR) summarizes the results from the Texas Department of Transportation (TxDOT) Project 0-4177, as related to the evaluation of crushed concrete (CC) and recycled asphalt pavement (RAP) for use as select backfill for MSE walls.

What We Did...

An extensive laboratory investigation was conducted to evaluate the potential use of CC and RAP as backfill in MSE walls. The laboratory investigation involved a geotechnical evaluation of the materials, as well as a corrosion evaluation that assessed whether these materials will cause excessive corrosions of the metallic reinforcement embedded in MSE walls backfill. For all of these tests, the results from CC and RAP were compared with results from a conventional fill material (CFM) consisting of crushed limestone.

The geotechnical evaluation of CC and RAP involved a suite of laboratory and field tests to characterize the important properties of these materials as they pertain to MSE walls. The index tests performed included grain size distribution, specific gravity, and Atterberg limits. The compaction characteristics of CC and RAP were assessed with standard TxDOT laboratory compaction tests, and field tests were performed to assess field compaction control of CC and RAP. The potential for poor performance of CC when the source concrete had previously suffered sulfate attack of alkali-silica reaction (ASR) was assessed by a suite of expansion tests. Shear strength testing was performed in the laboratory using a 4-in. diameter triaxial device, as well as a 20-in. by 20-in. large-scale direct shear box. Hydraulic conductivity tests and collapse potential tests were also performed. The pullout resistance of typical steel reinforcing strips was assessed using pullout tests performed in the large-scale direct shear box. Finally, constant-stress creep tests were performed on RAP using the triaxial device.

The corrosion evaluation of CC and RAP consisted of evaluating the performance of plain- and galvanized-steel straps embedded in the three different backfill materials with exposure to cyclic water and chloride-ion solution applications. Samples were fabricated and exposed to the different environments for approximately 11 months. After the exposure period the samples were evaluated for mean corrosion rates using mass loss data. Corrosion rates of the metallic reinforcement straps were used to estimate the service life of

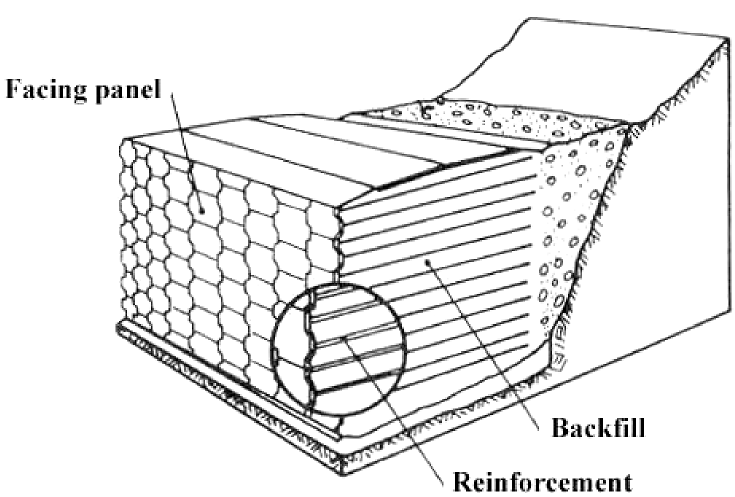

Figure 1. Schematic of MSE wall (Schlosser and Delage 1988)

MSE wall structures. In addition, the research team attempted to correlate short-term solution test results with the long-term test results such that, when necessary, other backfill materials could be assessed over shorter durations (~ 1 month).

What We Found...

Crushed Concrete (CC)

Gradation and Compaction: The gradation of crushed concrete provided by commercial producers in Texas meets the TxDOT Item 423 Type B backfill gradation specification, which is the gradation generally designated for permanent MSE walls. Crushed concrete exhibited compaction characteristics similar to CFM.

Durability: Expansion of compacted CC samples was monitored over a period of 70 to 100 days under various detrimental conditions. The samples included commercial CC and CC derived from concrete that had previously suffered ASR or sulfate attack. The expansion of most samples was negligible except for the samples that had experienced sulfate attack. These samples experienced up to 4 percent volumetric expansion over 70 days when exposed to water.

Strength: The results from consolidated-drained shear strength tests indicate that crushed concrete has strength characteristics comparable to those of conventional fill materials. Using the combined results from triaxial testing and large-scale direct shear testing, the derived effective shear strength parameters for CC were: $c'=9$ psi, $\phi'=46°$. The CFM, which also met TxDOT backfill gradation specifications, displayed very similar shear strength parameters ($c'=10$ psi, $\phi'=46°$).

Drainage properties: Falling-head, rising-tail hydraulic conductivity tests were performed on CC specimens in a triaxial apparatus. The hydraulic conductivity of CC ranged from 10^{-4} to 10^{-5} cm/s over confining pressures of 5 to 50 psi. The hydraulic conductivity of the CFM was close to 10^{-3} cm/s. The low hydraulic conductivity of CC is a concern.

Collapse Potential: The collapse potential tests showed that collapse upon wetting is not a concern for CC if the materials are compacted at water contents that represent saturation levels of 70 to 80 percent.

Pullout testing: Pullout tests were performed in the 20-in. by 20-in. shear box using steel ribbed reinforcement embedded in crushed concrete. Measured values of pullout force were used to evaluate F*, the pullout resistance factor or friction-bearing factor, which is used to predict the ultimate pullout resistance of reinforcement for MSE wall design. The measured F* values at different confining pressures were all greater than those predicted by the design procedures from the Federal Highway Administration (FHWA), indicating that the traditional predictive equations for F* can be used for CC.

Corrosion testing: Various backfill material characteristics were assessed. The pH and resistivity values are commonly used to indicate the corrosion potential of backfill materials. It was determined that the CC used in this investigation does not meet the current pH and resistivity TxDOT specifications for MSE wall backfill. However, the results showed that the average mass loss (and average corrosion rates) of the plain-steel reinforcement embedded in CC was less than the average mass loss of the same reinforcement embedded in the CFM (crushed limestone) when exposed to a non-chloride solution environment. For galvanized-steel reinforcement, the CC and the CFM exhibited similar mass loss values when exposed to a non-chloride solution environment. Although the comparative performance of the metallic material embedded in the CC and CFM backfill materials exhibited similar results for the chloride solution exposure, average corrosion rates were very high for both cases. No correlation between the short- and longer-term testing was observed. The service life times of galvanized reinforcement embedded in CC and CFM, based on the measured average corrosion rates from the longer-term tests, are shown in Figure 2 and indicate that the service life for CC is longer than for CFM.

Recycled Asphalt Pavement (RAP)

Gradation and Compaction: The gradation of RAP provided by commercial producers in Texas meets the TxDOT Item 423 Type B backfill gradation specification, which is the gradation generally designated for permanent MSE walls. RAP exhibited adequate compaction, although it could not hold

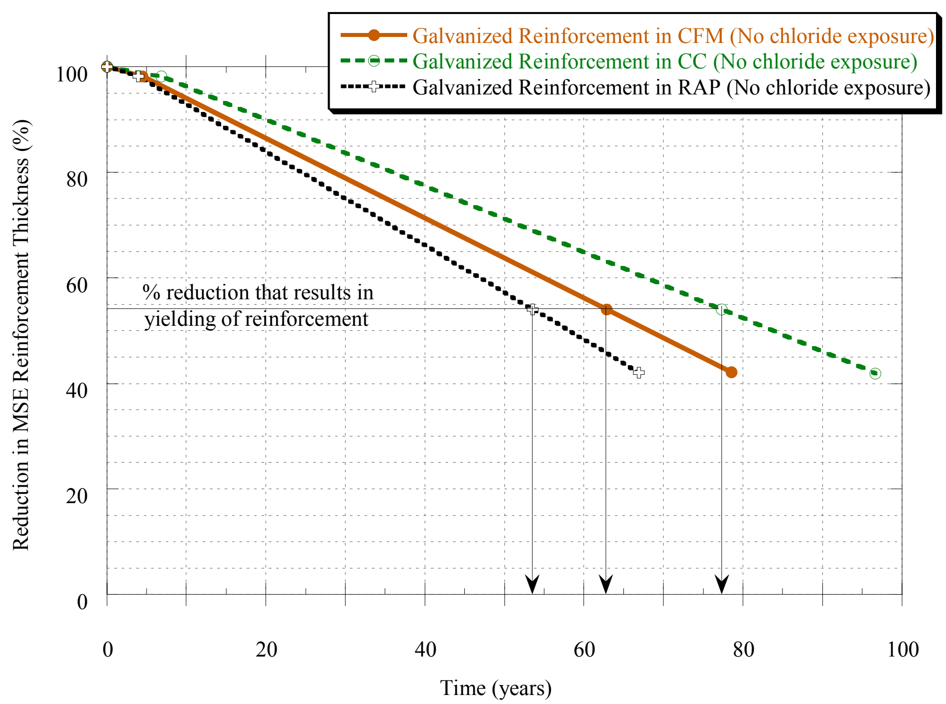

Figure 2. Estimated service life times for galvanized MSE strips embedded in CFM, CC, and RAP using average corrosion rates.

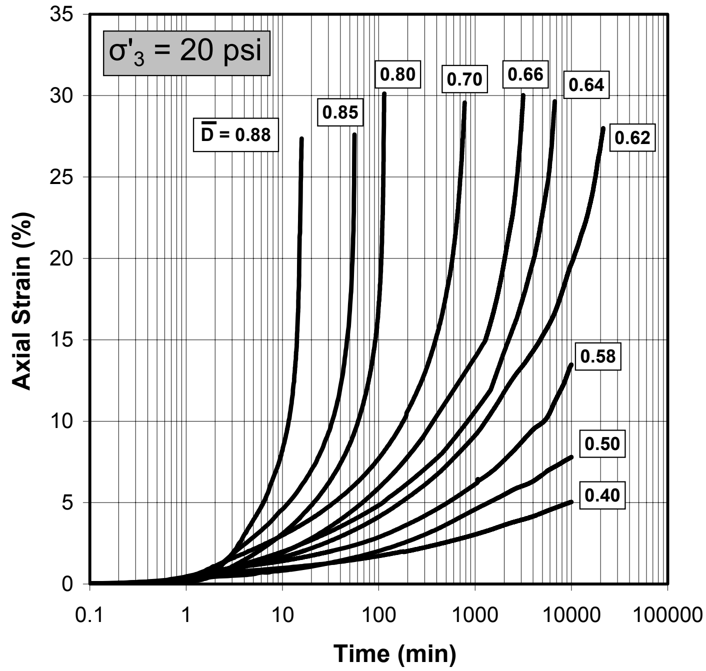

Figure 3. Axial strains developed over time at different deviatoric stress levels ($\overline{D}$) in creep tests.

significant water because of the bitumen coating on the particles.

Strength: The results from strain-controlled consolidated-drained triaxial tests indicate that RAP has acceptable, although somewhat marginal, strength characteristics comparable to those of CFM. The derived effective shear strength parameters for RAP were: c' =8 psi, ϕ' =37°. Because these tests were strain controlled, they do not include the effects of creep. The large-scale direct shear tests, which are force controlled, could not be successfully performed on RAP because of the creep deformations.

Drainage properties: Falling-head, rising-tail hydraulic conductivity tests were performed on RAP specimens in a triaxial apparatus. The hydraulic conductivity of RAP ranged from 0.5x10^{-3} to 4x10^{-3} cm/s over confining pressures of 5 to 50 psi. These values indicate that RAP is a free-draining material.

Collapse Potential: The collapse potential tests showed that collapse upon wetting for RAP is larger than for CC and CFM. This finding stems from the fact that RAP cannot hold significant amounts of water, and thus it is compacted at lower saturation levels. Nonetheless, the collapse potential was only slight and not a concern for RAP.

Pullout testing: Pullout tests were performed in the 20-in. by 20-in. shear box using steel ribbed reinforcement embedded in RAP. The force-controlled pullout tests experienced significant creep deformations, with the deformation limit of 0.75 in. being reached before shear failure along the reinforcement-soil interface. Nonetheless, derived F* values at the deformation limit were similar to those predicted by design procedures, except at larger confining pressures.

Creep testing: A series of constant stress, deviatoric creep tests were performed under drained conditions in a triaxial apparatus. Tests performed at larger deviatoric stress levels ($\overline{D} = (\sigma'_1 - \sigma'_3)/(\sigma'_1 - \sigma'_3)_{ult}$) experienced significant strains and creep rupture within 1 week of testing (Figure 3). These results indicate that the creep potential in RAP is significant, and its creep behavior is similar to that of clays under undrained conditions. Additionally, creep rupture is a concern and the creep potential of RAP appears to be most severe at smaller confining pressures.

Corrosion testing: The longer-term corrosion test results using RAP indicate that the corrosion of MSE metallic reinforcement (both galvanized and plain) embedded in this backfill material results in higher average corrosion rates than in the CFM specimens. These higher corrosion rates can lead to reduced service life values for MSE walls. As with the CC testing, no correlation was observed between the data from the shorter- and longer-term corrosion test programs, and the shorter-term testing is not recommended for assessing the corrosion activity of metallic materials embedded in different backfill materials. The service life time of galvanized reinforcement embedded in RAP was shorter than for CC and CFM (Figure 2).

The Researchers Recommend...

The results from the geotechnical and corrosion studies of crushed concrete (CC) indicate that this material displays adequate gradation and compaction characteristics, shear strength, pullout resistance, and corrosion performance, although it displays low hydraulic conductivity and may experience significant expansion if the source concrete suffered sulfate attack. Based on these results, CC is recommended for use as backfill for MSE walls. However, the following issues must be considered:

1. MSE walls with crushed concrete backfill should include adequate drains and high permittivity filter fabrics behind the wall to avoid drainage problems.
2. Concrete structures that have suffered sulfate attack cannot be crushed and used as backfill in MSE walls.
3. pH and Resistivity specifications for MSE wall backfill materials should be waived for crushed concrete.

The results from the geotechnical and corrosion studies of recycled asphalt pavement (RAP) indicate that this material displays adequate gradation, strength, and hydraulic conductivity properties. However, RAP displays a significant potential for creep deformations, and these creep deformations may lead to excessive deformation in a MSE wall. Additionally, corrosion testing indicated that RAP caused more corrosion than either CC or CFM. Based on these results, RAP is not recommended for use as backfill for MSE walls.

For More Details...

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The research is documented in the following reports:

0-4177-1, *Recycled Asphalt Pavement and Crushed Concrete Backfill: State-of-the-Art Review and Material Characteristics*

0-4177-2, *Recycled Asphalt Pavement and Crushed Concrete Backfill: Results from Initial Durability and Geotechnical Tests*

0-4177-3, *Evaluation of Crushed Concrete and Recycled Asphalt Pavement as Backfill for Mechanically Stabilized Earth Walls*

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