Recurrent Pavement Damage from Underlying Expansive Soil Deposits – Idaho Experience

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Bhaskar C. S. Chittoori, Ph.D., P.E.
Assistant Professor,
Department of Civil Engineering
Boise State University
Boise, ID 83725
Phone: 208-426-3794
Email: bhaskarchittoori@boisestate.edu
(Corresponding Author)

Debakanta Mishra, Ph.D.
Assistant Professor,
Department of Civil Engineering
Boise State University
Boise, ID 83725
Phone: 208-426-3710
Email: debmishra@boisestate.edu

Daris Bruce, PE
Resident Engineer, District 3
Idaho Transportation Department
Boise, ID
Email: daris.bruce@itd.idaho.gov

John Ingram, PE
Geotechnical Engineer
Head Quarters
Idaho Transportation Department
Boise, ID
Email: john.ingram@itd.idaho.gov

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ABSTRACT
A section of US-95 just North of the Oregon/Idaho border (MP 0 to 18.5) has experienced recurrent heaving-related distresses over several years. Research studies were undertaken in the past to investigate the mechanisms contributing to the excessive heaving and to evaluate the feasibility of implementing different stabilization techniques for the subgrade. These studies have indicated the presence of high liquid limit (ranging from 45% to 150%) soils with free swell index values greater than 100%. One-dimensional swell tests performed on both disturbed and undisturbed soil samples showed that the remolded (disturbed) soil samples exhibited swelling as much as 30% and swell pressures up to 0.57 MPa (6 tsf). The undisturbed soils on the other hand did not exhibit any swelling characteristics. Lime stabilization was suggested as the most suitable alternative to minimize or delay swelling along with hydraulic barriers (both vertical and horizontal). After rehabilitation work performed in 2005, the pavement sections performed well except for few sections between milepost 16.7 and 18.5, which have since showed heave-related distress. This paper presents a summary of past studies, their recommendations and the experiences thereafter. Details of the subgrade properties established for this stretch of the pavement section thorough subsurface exploration and laboratory characterization are reported in this paper along with inferences on factors that could contribute to the recurrent heaving problem. Potential rehabilitation and stabilization methods are discussed, and details of an ongoing study to identify the active zone for this expansive subgrade between milepost 16.7 and 18.5 are presented.

Keywords: Expansive Soils; Pavement Heaving; Active Zone; Lightly Loaded Structures; Lime Stabilization;
INTRODUCTION AND OBJECTIVES

Expansive soils have been a major concern for several decades now. Their shrink/swell characteristics have deteriorated many overlying structures, such as roads, residential buildings and other lightly loaded structures (1-3). Significant volume changes observed in expansive soils upon fluctuations in moisture content can be attributed to the presence of the heaving mineral, Montmorillonite, which has an expanding lattice, and undergoes significant expansion when exposed to water. Soils rich with these minerals are abundant in arid and semi-arid regions (4). A study sponsored by the National Science Foundation (NSF) reported that expansive soils cause more damage to light buildings and pavements compared to any other natural disaster including earthquakes and floods (5). Through a detailed review of expansive soils, Gromko (6) estimated that the annual cost of damage from these soils in the United States alone is $2.3 billion. This number is likely much higher in the present date.

There is a wealth of research performed by various state and local transportation agencies such as Texas Department of Transportation, Colorado Department of Transportation and California Transportation Department to name a few that involved expansive soil characterization and stabilization (7-9). Predominance of expansive soils in these states, and resulting damages to overlying structures have led to the development of several guidelines by the respective transportation agencies. As expansive soil deposits are not very common in the state of Idaho, the Idaho Transportation Department (ITD) currently does not have specific guidelines to address problems arising from such problematic soils. However, recurrent damage caused to a particular stretch of US-95 just north of the Oregon-Idaho border has led ITD to pursue extensive characterization of the subgrade soils with an objective to explore different stabilization alternatives that can minimize the costs associated with recurrent maintenance and rehabilitation activities.

University of Idaho under the leadership of Prof. Hardcastle (now deceased) undertook the original research study targeted at investigating the recurrent heaves observed along this stretch of pavement. In this study (10), a series of laboratory tests were performed including conventional geotechnical tests such as Atterberg limits, and 1-D swell tests, along with tests such as X-Ray Diffractions (XRD) and Cation Exchange Capacity (CEC) that are aimed at mineralogical characterization of these soils. Harcastle (10) also evaluated different stabilization methods, and recommended swell remediation and prevention techniques for existing and new constructions. ITD implemented these recommendations during reconstruction of this stretch of highway, which resulted in partial success. While most sections performed satisfactorily after treatment, a few sections continued to exhibit pavement distresses resulting from subgrade heaves. A portion of this pavement section is scheduled for reconstruction in 2018. To facilitate the implementation of sustainable stabilization/remediation techniques that can extend the service life of the reconstructed pavement, ITD has initiated another research study with Boise State University involving extensive subsurface characterization, and recommendation of suitable stabilization methods. Detailed background on this problematic pavement section is presented in this paper through a summary of data collected, analyses performed, and recommendations made by past studies. The ultimate objective is to document ITD’s experience with pavement damage resulting from expansive subgrades, and initiate a technical dialogue to facilitate sustainable reconstruction of this problematic pavement section.
DIFFERENT METHODS TO ASSESS THE SWELL POTENTIAL OF SOILS

Some of the factors influencing the expansive behavior of soils are: soil composition, dry density, soil fabric, confinement and premeability (2). These intrinsic properties of expansive soils govern their behavioral characteristics, and contribute to volumetric strains (swelling and shrinkage) with fluctuations in moisture content. Past researchers developed different chemical, physical, and index tests to assess the swelling potential of a particular soil type. Brief discussions on some of these tests are presented in the following sub-sections.

Chemical Test Methods

The magnitude of swelling is a function of the types and amounts of clay minerals present in the soil (1; 11-13). Clay minerals that often contribute to volume changes in soils are: Smectites, Vermiculites, and some mixed layers of these minerals. Establishing the soil mineralogical composition helps identify different elements present in a clay particle. Different methods used to establish the mineralogical composition of clay particles include: XRD, Differential Thermal Analysis, Vibrational Spectroscopy, and X-Ray Absorbance Spectroscopy. The original work by Hardcastle (10) involved XRD testing of the subgrade soil found underneath this particular problematic stretch of US-95.

Index Test Methods

Basic soil index properties such as Atterberg limits (Liquid Limit, Plastic Limit, and Shrinkage Limit) are commonly used to assess the expansive nature of soils (2). Plasticity Index (PI), defined as the difference between the liquid and plastic limits of the soil, can be used as an indicator of soil expansion potential. A PI value of less than 25% is considered to represent low swelling potential, 25% to 35% corresponds to medium swelling, and PI> 35% is considered high swelling. Several methods were developed to classify soils as low, medium and high expansive soils. Rao (14) presented a detailed description of such methods developed to categorize soils by their expansion potential (low, medium, or high expansion potential). These methods primarily rely on soil properties such as Atterberg limits, colloidal content and soil suction, to determine the severity of swell or swell potential of a given soil.

Physical Test Methods

Swelling pressure, determined from oedometer tests, is one of the most important parameters used to quantify the expansion potential of soils. Swelling pressure is defined as the pressure in an oedometer test required to prevent the soil sample from swelling after being saturated (15). Various loading and surcharge pressures were used to represent in-situ conditions. Loading and wetting sequence, surcharge pressure, sample disturbance, and apparatus compressibility all play integral roles during the performance of oedometer tests. Although Oedometer tests are widely used to quantify the swell potential of expansive soils, environmental factors such as drainage and lateral earth pressure effects cannot be simulated during these tests (16). Another disadvantage of this test involves the long period of time the samples take to achieve equilibrium. This makes conducting this test tedious, and expensive. Two types of oedometer tests commonly used for testing the expansion potential of soils are (i) consolidation-swell test and (ii) constant volume or swell pressure test (2).
PROJECT BACKGROUND AND CHRONOLOGY OF RECONSTRUCTION

US-95 runs north-south from the western border of Idaho with Oregon to British Columbia. The problematic stretch of pavement under consideration lies in Owyhee County, which starts from the Oregon line to Elephant Butte (approximately MP 0 to 18.5). Figure 1 presents an aerial map of the location highlighting the section under investigation. The construction history for this 18.5-mile long section of the highway was presented elsewhere (10). The original highway was built in the 1940s, following which several projects to reconstruct and/or realign the first 18.5 miles of US-95 were carried out resulting in the current alignment. A brief summary of the project construction history is given below.

In 1972, US-95 was rebuilt from the Oregon/Idaho state line to mile marker to 6.36. Expansive soils were treated by compacting embanked soils at slightly above optimum moisture content and using an asphalt treated membrane to control moisture. The segment between mile markers 6.36 to 18.5 was realigned in the early 1980s. Due to the varying subgrade materials encountered, different measures were employed to control and mitigate problems related to expansive soils. Between mile markers 6.36 and 13.2, the embankment and in-situ subgrade soils were lime-stabilized to a depth of 38 cm (1.25 ft.). Soils between mile markers 13.2 and 16.7 were determined to have negligible expansion potential, and were therefore not treated. In the segment between mile markers 16.7 and 18.5, a deepened structure section, 99-cm or 3.25-ft. deep, was employed.

In 1989, the segment between mile markers 16.7 and 17.9 was reconstructed by removing the 107-cm (3.5-ft.) thick ballast previously installed. The exposed subgrade was lime-stabilized to a depth of 38 cm (1.25 ft.), and a new 107-cm (3.5-ft.) thick structural section was installed. In 1992, the segment between mile markers 0.0 and 5.3 was reconstructed, and the subgrade was lime-stabilized to a depth of 38 cm (1.25 ft.).
In 2003, ITD maintenance personnel installed an experimental section, 61-m (200-ft.) in length at mile marker 17.2. The test section was constructed using an impermeable membrane to partially encapsulate the previously placed subgrade. A new roadway ballast section with a thickness of 41 cm (1.35 ft.) was placed over the encapsulation. 3-m (10-ft.) deep longitudinal trench drains were installed on both sides of the highway. Geogrid reinforcing in the transverse direction was also placed at the mid-height of the structural section, and was extended to a distance of 3 m (10 ft.) beyond the experimental section. The paved surface was rehabilitated between mile markers 0 and 16.7 in 2010. Table 1 lists the major reconstruction activities along with the corresponding stabilization activities (if any) performed during each.

Table 1: Construction/Reconstruction activities over the life of the project

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
<th>Stabilization Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>Reconstruction - MP 0.0 to MP 6.36</td>
<td>Subgrade soils compacted wet of optimum moisture content (OMC)</td>
</tr>
<tr>
<td>Early 1980’s</td>
<td>Construction of new alignment – MP 6.36 to MP 18.5</td>
<td>1.25 ft. of lime-stabilized subgrade</td>
</tr>
<tr>
<td>1989</td>
<td>Reconstruction – MP 16.7 to MP 17.9</td>
<td>1.25-ft. of lime-stabilized subgrade</td>
</tr>
<tr>
<td>1992</td>
<td>Reconstruction – MP 0.22 to MP 5.33</td>
<td>1.25-ft. of lime-stabilized subgrade</td>
</tr>
</tbody>
</table>

**Area Geology**

Nottingham (17) presented a detailed description of the area geological setting. As per his description, soils in Owyhee County are composed of geologic formations such as Colluvium and Terrace gravels, Jump Creek Rhyolite, and the Sucker Creek and Poison Creek formations. According to Ulrich (18), both the Sucker Creek and Poison Creek formations have high potential for Montmorillonite mineral content. Hardcastle (10) identified that the expansive clay strata found in these areas are presumably weathering products of the ashflow tuffs found in these formations, as well as transported and sedimented materials eroded from the weathered ignimbrites. Nearly all of the host rock in the area, including the rhyolite beds, have experienced some degree of alteration to clays which include Smectites (Montmorillonite), Illites and the Kaolin group, as well as mixed layer clays.

In the eastern parts of the region, the Smectites tend to be Beidellite and mixed-layer clays (19), whereas in the western part of the region which includes the US-95 soils, the predominant Smectite mineral is Montmorillonite. Both of these 2:1-layer, expanding-lattice clay minerals are common argillic weathering products of basalts and other mafic (rocks rich in magnesium and iron) rocks weathering under arid and semi-arid climates (20).

**HISTORY OF THE PROBLEM AND PAST STABILIZATION EFFORTS**

The US-95 section under consideration was first reported to have an expansive soils issue between MP 0 to 6.5. High-plastic soils with liquid limits values exceeding 125% were reported (10). Treatment aimed at mitigating the effects of these problematic soils involved compaction at water contents slightly above OMC, use of impermeable asphalt membranes, and higher than usual ballast thicknesses to apply increased surcharge loads. The first comprehensive geotechnical study for the “Oregon line to Elephant Butte” pavement section was performed by the Federal Highway Administration in 1979 by Ulrich (18). Hardcastle (10) lists the different
geotechnical studies conducted on this section of highway, along with the corresponding recommendations remediation, prevention of the excessive heaving problems.

These reports (17; 18; 21) detected the presence of moderate to high amounts of expansive soils in the subgrade, and lime stabilization and/or membrane encapsulation as the most suitable alternatives to arrest the swell-shrink behavior. Nottingham (17) advocated lime stabilization using 5 percent quick lime (Calcium Oxide, CaO) by dry weight of the soil, and further recommended that care should be taken during the pavement reconstruction to maintain the stabilized subgrades in a condition as close to saturation as possible. He also recommended that an asphalt (impermeable) membrane should be placed on top of the treated subgrade. A subgrade thickness of 38 cm (1.25 ft.) was treated with lime, and compacted to 95 percent of maximum dry density established using the standard compaction method (AASHTO T-99). An asphalt membrane (CRS-2R) was placed on top of the lime-stabilized subgrade.

As of 1999, some of the reconstructed sections started exhibiting heaving-related distresses. This led ITD to initiate a project with the University of Idaho (Hardcastle) and Boise State University to study the subgrade soils, evaluate the root cause of the heaving distress, and suggest recommend alternatives to stabilize the pavement subgrade. The study results and the recommendations made thereof, are presented in the following sections.

**Hardcastle’s Study**

The objectives of this study were to identify and quantify the mechanisms and factors contributing to the heave development in the pavement section under consideration. The study also aimed to recommend treatment methods for subgrade stabilization for both new construction and rehabilitation/reconstruction activities. For this purpose, 14 boreholes were drilled and sampled at various depths; retrieved samples were tested in the laboratory physical and mineralogical characteristics. The sampling equipment available for the project was ITD’s CME continuous sample tube system. With this system, the soil sample is retained inside a plastic linear with an inside diameter of 8.3 cm (3.25”) and a length of 76 cm (2.5 ft.). The liners fit inside a 152-cm (5-ft.) long split-tube barrel sampler, which has an outside diameter of 10 cm (4.0 in.). The non-rotating liner and split-tube barrel are pushed into the soil just ahead of the bit of the rotating hollow-stem auger. Samples recovered with these tools cannot be considered to be undisturbed due to the combined wall thickness of the liner and split-tube barrel of 9.5 mm (0.375 in.), which results in a kerf (or area ratio) of 51 percent. Recommended values for open-drive undisturbed sampling in fine-grained soils are less than 10 to 15 percent (22).

**Summary of Characterization Studies**

Different categories of laboratory tests were performed for extensive characterization of the soil samples. These tests are listed below in the form of bullet items.

i. **Category One:** This included methods for indirect assessments of soil mineralogy using common soil index properties tests such as Atterberg limits.

ii. **Category Two:** This included tests targeted at establishing soil properties such as Cation Exchange Capacity (CEC) that quantify the ion exchange locations on the surface of the clay particles. The CEC value is a direct indicator of swelling potential of the soil.

iii. **Category Three:** Laboratory tests that yield swelling indices such as Free Swell Index are included in this category. These tests are physical indicators of the swelling nature of the soil, but cannot be used to calculate heaves or settlements for field applications.
iv. **Category Four:** The last category of tests involved direct measurement of the expansion of the soils from a relatively dry condition to a saturated condition. This was performed as per ASTM D 4546 specifications.

Note that tests included in the first three categories provide an indication of the presence of expansive clay minerals in the soil and possible significance of the swelling soil problem. Only tests included in the last category are aimed at directly assessing the expansion potential of the soil under loading and environment conditions that may exist in the field. Some observations from the laboratory characterization efforts are listed in the following sections.

The first and most commonly used index properties correlated with swelling potential of soils are the “consistency limits”. Plasticity limits are only indirect measures of the presence of expansive clay minerals in soils, and by themselves are usually insufficient to predict the actual amount of swelling that can be expected. The amount of swelling in the field can be predicted only when the initial soil condition of interest is identical to the one that was used in the original development of the swell prediction relationship. This is rarely the case.

Plasticity properties established for the Owyhee county soils are presented in Figure 2 and Figure 3. As can be seen from the figures, the liquid limit values ranged from 44% to 185% while the PI values ranged from 25% to 136%. As already mentioned, high PI values often correspond to high swell potentials. Accordingly, the Atterberg limit tests indicate that the Owyhee county soils have high swell potentials, and can cause significant damage to pavement structures.

![Figure 2 Summary of Liquid Limit data performed by Hardcastle (10). Note: Data labels indicate the depth (in ft.) at which the samples were tested (1 ft. = 30 cm)](image-url)
Qualitative swelling tests such as the one proposed by Holtz and Gibbs (23) were also performed in this study. This test consists of a simple comparison of the bulk volume of 10 mm\(^3\) of air-dry minus 40 mesh (material finer than 0.420 mm) and the bulk volume of the same quantity of air-dry soil after it is sedimented in 100 mm\(^3\) of distilled water. Both volume measurements are made in a standard 100 mm\(^3\) graduated cylinder. Free swell, in percent, is defined as the ratio of the wet bulk volume to the dry bulk volume. Holtz and Gibbs (23) suggested that soils with free swells greater than 100 percent have the potential to cause considerable damage to lightly loaded structures. Soils with free swells in excess of 50 percent could present swell problems in the field. A summary of the free swell indices for the Owyhee county soils is presented in Figure 4. As shown in the figure, these soils have high potential for swelling corroborating inferences drawn from the Atterberg limit values.
The test procedure described in ASTM D 4546 was used to quantify the swelling behavior of expansive soils under conditions that closely represent the field conditions. As per this procedure, there are three different methods to conduct this test. In Method A, the test specimen is allowed to expand after being inundated under a 1.0 kPa vertical stress. The change in the specimen height expressed as a percentage of the original height is defined as the “free swell.” After free swell is complete, the specimen is loaded incrementally as in a conventional one-dimensional compression test setup until the specimen height is equal to or smaller than its original height (usually 2.5 cm or 1.00 in.). The swell pressure is defined as the vertical stress required to bring the specimen back to its original thickness.

Method B is similar to Method A, except that the initial vertical stress under which the specimen undergoes its free swell is selected by the operator. In Method C, the test specimen is inundated, and increments of vertical stress are applied as required to prevent the specimen from changing its thickness after inundation. This procedure requires an adjustable oedometer. The swell pressure is the smallest vertical stress that has to be applied to prevent any swelling.

Methods A and B of ASTM D4546 were used in this study. Figure 5 presents results from one-dimensional swelling tests performed on the soils sampled in drill holes adjacent to US-95 in Owyhee County. As can be seen from the figure, the maximum swell percent observed from the test matrix was 5%, and the maximum swell pressure observed was around 0.8 tsf (76.6 kPa). This indicates that the swelling of the soils following inundation at their current natural moisture contents was either very small or nonexistent. This result is contrary to the high swelling potentials inferred from the soil index properties.

![Figure 5 Summary of one-dimensional Swell test results for “undisturbed” samples performed by Hardcastle (10). Note: Data labels indicate the depth (in ft.) at which the samples were tested. Empty spaces indicate no measurable vertical movement for a particular sample](image)

(1 ft. = 30 cm; 1 tsf = 95.8 kPa)

Subsequently, tests were performed on re-compacted soils from each borehole location to study the swelling potential under disturbed conditions. These results are summarized in Figure 6. Data corresponding to three borehole locations, marked as mileposts 2.3E, 17.0E and 17.6W, have been presented in Figure 6. Samples were remolded to lower and higher relative compaction values compared to the maximum dry density established using the standard
compaction method (AASHTO T-99). As shown in Figure 6, the re-compacted samples exhibited higher swell percentages compared to the undisturbed samples, and the maximum swell percent recorded for the re-compacted samples was 31 percent (milepost 2.3E). Similarly, the swell pressures recorded for the re-compacted samples were higher than those for the undisturbed ones, with the highest value being 6 tsf (574.5 kPa). Such swell behavior can be detrimental to pavement section, and hence lime stabilization was recommended to reduce the expansion potential of these soils especially after re-compaction.

The contrasting swelling behavior between the undisturbed and remolded soils observed here could be due the unusual origin of the Owyhee County soils. These soils are believed to have developed from the subaerial hydrothermal alterations and devitrification of, welded to slightly welded ash flow tuffs (ignimbrites). The retention of bonds from the initial welding and post-weathering cementation in the undisturbed, intact material could explain the absence of significant swelling in the more or less intact subsurface samples. Other possible reasons for the reduced swelling of the highly colloidal more or less intact materials include their typically low unit weights and high initial natural water contents as compared to the water contents and dry unit weights produced by compacting the soils.

![Figure 6 Summary of one-dimensional Swell test results for re-compacted samples performed by Hardcastle (2003). Note: Data labels indicate Relative Compaction (RC) percentages. (1 tsf = 95.8 kPa)](image)

**Overall Observations and Recommendations**

Hardcastle made several important observations concerning the distress locations along this pavement section. Note that not all soils encountered and sampled along this section of US-95 showed high expansion potential. Correspondingly, not all locations along this pavement section exhibited heaving-induced distresses. It appears that swelling-related distresses primarily occurred at the transitions between the cut and fill sections as at Milepost 2.3. Moreover, locations close to natural ground surface in relatively flat areas underlain by incoherent coluvial soils (10) also exhibited significant amounts of distress. The hypothesis is that despite
specification requirements concerning the use of imported non-expansive borrow material for the fill sections, there is a high probability that potentially expansive soil adjacent to the cut sections are used to construct the fill sections at the transition locations. The higher initial suction of the compacted expansive soil and increased exposure to surface water at the grade points could be the primary factors leading to increased pavement distresses at these locations.

As a measure to reduce or delay swelling in existing pavement sections it was recommended that a continuous horizontal membrane be placed from the surface of the pavement to the bottom of the ditch by utilizing shoulder and ditch paving in cut sections. This would delay water access to the expansive soils underneath the pavement sections. An alternative recommendation was to install deep vertical moisture barriers at the outside edges of the paved shoulders. For cases where the pavement section would be reconstructed, it was recommended that the subgrade material be removed to the intact rock surface, and refilled with non-expansive backfill. Alternatively, the exposed soil could be stabilized with hydrated lime with dosages as high as nine percent.

Finally, recommendations were also made for the base and ballast materials that used in new construction over expansive soils. It was recommended that these materials be well-graded with non-plastic fines having hydraulic conductivities less than $10^{-6}$ cm/s. If such materials were not available resulting in the use of conventional free-draining base and ballast materials, placement of an impervious asphalt or geosynthetic membrane on the surface of the subgrade prior to placing any base or ballast was recommended.

**ONGOING STUDIES**

Even though lime stabilization was previously implemented in an effort to minimize expansive soil related issues, problems persisted especially with sections between MP 16.7 to MP 18.5. One of the concerns was that the depth of treatment (38 cm or 1.25 ft.) implemented was insufficient to restrict swelling in these soils. To further evaluate the problem and identify governing mechanisms for the heaving-induced distresses, ITD has initiated a new project with Boise State University. The main objective of this study is to characterize these soils to assess the depth of active zone, and determine the depth of treatment required. For this purpose, ten boreholes were drilled and sampled in June, 2015. The borehole locations were selected such that four out of ten boreholes were directly on top of the heave locations in the pavement; four more holes were drilled adjacent to the previous holes where there was no heaving. This was done to facilitate comparison and contrast between stratigraphic conditions that lead to swelling. The final two boreholes were drilled in locations where no swelling distress was observed; soil samples from these two boreholes would serve as the “control” samples during this project.

The drilling and sampling procedures were similar to the ones followed in Hardcastle’s study as explained earlier in this paper. Drilling and sampling was performed by ITD personnel, and boxed/cored samples were delivered to Boise State. The laboratory test matrix includes the following tests:

1. Atterberg limits (Plastic Limit and Liquid limit) – ASTM D 4318
2. One-Dimensional Swell tests – ASTM D 4546 (Method A/Method B)
3. Soluble Sulfate Content
4. Cation Exchange Capacity (CEC)
5. Specific Surface Area (SSA)
Results from the Atterberg limit tests will be used to calculate the Potential Vertical Rise (PVR) values at each of the borehole locations. PVR calculations will provide insights into the maximum possible vertical rise at the surface based on soil plasticity and other environmental factors. This will also help establish the depth of treatment for restricting the PVR to acceptable values.

Soluble sulfate content tests will help in evaluating if sulfate heaving is a concern for the soil underlying this particular section of US-95. Presence of sulfates in expansive soils can lead to the formation of high swelling minerals like Ettringite and Thaumasite when treated with calcium-based stabilizers like lime and cement. It is therefore very important to evaluate the soil sulfate content prior to deciding on the type of chemical stabilize to be applied. CEC and SSA tests are being conducted to determine the concentration of the swelling mineral Montmorillonite present in these soils. The laboratory test program is currently underway and the results from these tests will be presented in future publications. Results from physical and chemical characterization of the soils will be used to recommend suitable remediation/stabilization alternatives to ITD.

SUMMARY

A section of US-95 between Oregon Line and Elephant Butte (MP 0 to 18.5) is experiencing severe heave-related pavement distress. Several studies have been conducted since the 1970s to characterize these soils, and develop suitable mitigation/remediation alternatives. This paper summarized the observations made from these studies, and presented an overview of the outcome of different rehabilitation and reconstruction activities over the years. Results from one particular study conducted at the University of Idaho were presented in details, and the corresponding data was used to draw inferences regarding the expansive behavior of soils underlying these pavement sections. Primary observations from the previous studies are listed below:

1. It was noted that the pavement distress in these sections is due to the presence of swelling mineral Montmorillonite in the soil. Atterberg limits tests confirmed that the soils are highly plastic in nature, with liquid limits ranging from 44 to 185% and plasticity index ranging from 25 to 136%. Other swell indicator tests such as free swell index tests and cation exchange capacity tests corroborated these findings.

2. One-dimensional swell tests performed on undisturbed soils on the other hand showed minimal to no swelling. However, re-compacted samples exhibited considerable swelling behavior. This contrasting behavior could be due to the unusual origin of the Owyhee County soils, which were believed to develop from subaerial hydrothermal alterations and devitrification of, welded to slightly welded ash flow tuffs (ignimbrites). Other possible reasons for the reduced swelling of the highly colloidal more or less intact materials include their typically low unit weights and high initial natural water contents as compared to the water contents and dry unit weights produced by compacting the soils.

Different hypotheses were presented to explain the ineffectiveness of implemented stabilization approaches towards arresting the swell-shrink behavior. Finally, the objectives and scope of a current study being undertaken at Boise State University were outlined. Results from the ongoing study will be reported in future publications.
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