07/18/95 13:38 ☎512 465 7486 TXDOT RTT ☑002/002

MS-6051

Technical Report Documentation Page

1. Report No. FHWA/TX-95/+7-2948	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Sulfates in Clays - IH 20 Dallas County		5. Report Date 5/15/95
		6. Performing Organization Code
7. Author(s) Dr. Thomas M. Petry, Ph.D., P.E.		8. Performing Organization Report No. RTT 7-2948
9. Performing Organization Name and Address The University of Texas at Arlington Civil & Environmental Engineering P.O. Box 19145 Arlington, Texas 76019		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. 7-2948
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Transfer Office P.O. Box 5051 Austin, Texas 78760		13. Type of Report and Period Covered FINAL
		14. Sponsoring Agency Code

15. Supplementary Notes

Dallas District - Texas Department of Transportation

16. Abstract

This study was the determination of what has caused the differential movements noted in the roadway of IH 20 between FM 1382 westward to the Dallas county line. The study developed alternative recommendations for treatments, and methods and pavement substructure designs to prevent these movements in the future on the rebuilt pavement structure.

17. Key Words Alternative recommendations pavement substructure	18. Distribution Statement No restrictions

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) No restrictions	21. No. of Pages 40	22. Price

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

SULFATES IN CLAYS -- IH 20 DALLAS COUNTY

by

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Texas Department of Transportation Research Study 7-2948

Sponsored By
Dallas District
Texas Department of Transportation

May 1995

Sulfates in Clays -- IH 20 Dallas County

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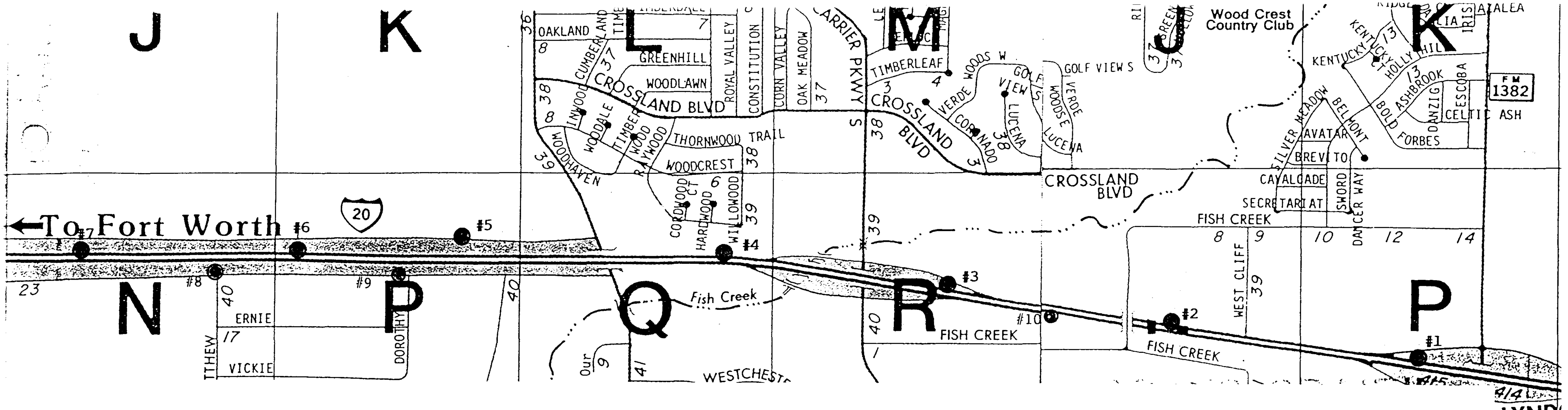
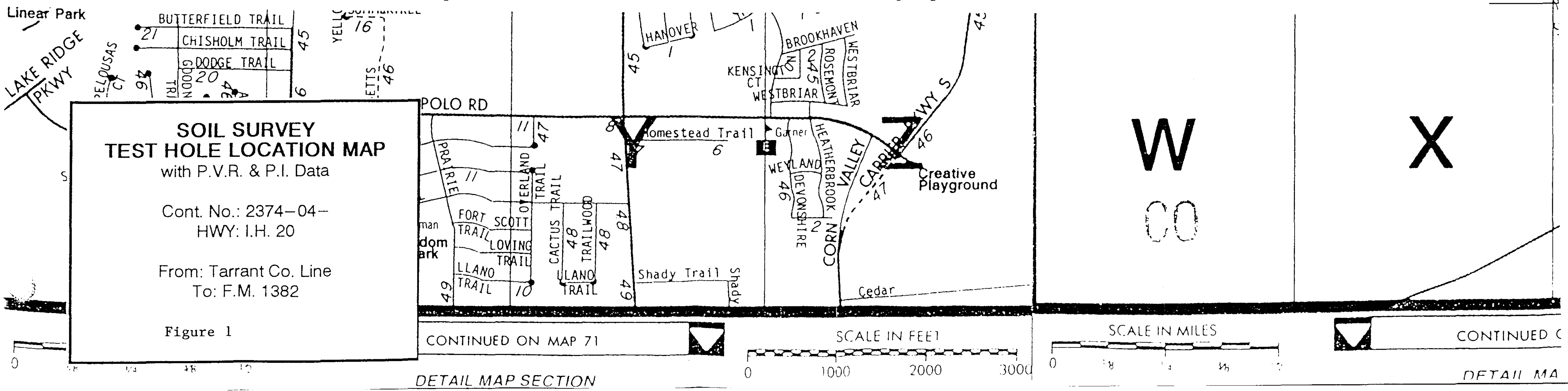


PLASTICITY INDICES AND POTENTIAL VERTICAL RISE

Sta No.	2+50 Cut Section	26+37 Cut Section	45+06 Cut Section	74+65 Cut Section	99+54 Fill Section	121+85 Cut Section	150 +29 Fill Section
Depth							
1 ft.	*	*	23	*	*	*	*
3 ft.	22	42	19	21	23	20	21
5 ft.	38	34	11	12	16	22	28
7 ft.	54	31	35	24	11	53	38
9 ft.	30	28	39	18	19	46	43
PVR, in	1.84	1.71	1.03	0.85	0.39	1.51	1.78
Avg PI	39	35	21	18	18	36	33

PVR values are calculated for a moisture fluctuation depth of 7 ft.

* Road base materials were not tested for soil constants or included in P.V.R. calculations.
Ground surface was assumed to be at the top of natural soil for P.V.R. calculations (see drilling log).



SOIL SURVEY
TEST HOLE LOCATION MAP
with P.V.R. & P.I. Data

Cont. No.: 2374-04-
HWY: I.H. 20

From: Tarrant Co. Line
To: F.M. 1382

Figure 1

Sulfates in Clays -- IH 20 Dallas County

Introduction:

Project 7-2948, "Sulfates in Clays" was designed to assist in the monitoring of sampling, testing, analyses and recommendations for the rehabilitation of IH 20 in South Grand Prairie, from FM 1382 westward to the Dallas County line. Sampling for this project began in October 6, 1994, by the Dallas District laboratory and this project began April 1, 1995. A second sampling was done April 25, 1995, and the testing was complete May 15, 1995. This report provides the results of the sampling which was done, of the testing completed by the Dallas District laboratory, and of the testing accomplished at the geotechnical engineering laboratories of The University of Texas at Arlington (UTA). These results are analyzed and recommendations are provided for the rehabilitation that is to take place.

The current pavement structure of IH 20 between SH 1382 and the Dallas County line has been in place since 1974. When it was constructed it consisted of 8 inches of continuously reinforced concrete pavement, over 6 inches of cement treated base, which was supported by 8 inches of lime treated subgrade, overlying materials weathered from the Eagle Ford shale geologic formation. Immediately following construction, the roadway required asphalt patching and asphalt overlays, and continues to require them today. The existing roadway has from 3 to 12 inches of asphalt overlay, particularly for sections which are in cuts of the natural subgrade. The length of roadway to be rehabilitated is approximately 3 miles. A plan view of the roadway is provided in Figure 1.

The principle objective of this study has been the determination of what has caused the differential movements noted for this section of IH 20, development of alternative recommendations for treatments, methods and pavement substructure designs to prevent these movements in the future for the rehabilitated pavement structure. What follows covers the process used to accomplish this objective and the results of the study.

The functions of the Dallas District were to provide drilling and sampling, testing of materials to determine selected physical properties and reporting of the results to the principle investigator. Samples taken to the UTA geotechnical engineering laboratory were analyzed for their type and selected physical properties. In addition, they were tested for their pH, swell potential, and plasticity. Tests which have been developed at UTA to determine soluble sulfates levels in soils, to ascertain their lime treatment parameters, and to monitor three dimensional swell characteristics of treated clays were utilized, in addition. Using the results of testing conducted at UTA and the Dallas District laboratory, analyses were undertaken to develop alternatives for the pavement subgrade to be used in rehabilitation.

Sampling and Observations:

Initial sampling was done October 6, 1994, at locations along the outer shoulder of the westbound lanes. Seven locations were chosen by James Kern of the Dallas District, approximately one-half mile apart and in areas believed to be representative of the whole. Six borings were advanced, while information for the seventh location was available from drilling done February 27, 1974. Later, on April 25, 1995, a second sampling was done along the outside shoulder of the eastbound lanes. Three locations were chosen, which placed the borings between the stations where the original ones were drilled, and were in cut sections where it appeared that the pavement been affected by significant movements. The locations of all of the ten borings are shown on Figure 1, and logs of the borings are provided in Appendix A.

During the sampling processes, the author and James Kern were present, to identify the materials and analyze the situations found. Samples of materials from the six borings advanced in October, 1994, were identified, sealed in plastic and returned to both the Dallas District laboratory and the UTA laboratory. Samples obtained from the last three borings advanced were identified, sealed in plastic and returned to the UTA laboratory.

Observations were made in field about the locations of significant movements of the pavement system and what types of geotechnical situations existed. It was noted that virtually all the movements of any significance occurred in cut sections along the roadway. The fill sections appeared to be fairly free of evidence of differential movements. The cut sections were estimated to be as deep into the original ground, due to the roadway construction, as 30 feet. One apparent cut section goes through the area of Fish Creek, and the differential movements there appeared to be of less consequence. Generally, the drainage of the roadway structure appeared to be adequate. Due to these situations, it is believed, therefore, that the movements which have occurred may be tied to weathering shale behavior.

It was noted that the materials sampled from the Fish Creek area were different in their level of weathering from those from other areas along the roadway. Everywhere else the subgrade appeared to be fairly typical for a weathering shale formation, but in the Fish Creek area the materials appeared to be much more weathered and like those expected in an alluvial area for this formation. It has been the experience of the author that this difference, alone, may be enough to explain the different behavior noted along this roadway.

As each boring was advanced the asphalt overlays had to be removed first. Their depth confirmed the likelihood that one foot of asphalt overlay was present on the roadway pavement in places. Under the pavement of the shoulder the cement treated base was found in each case. These materials appeared to be of the proper thickness and hardened as expected. There was found no reason to suspect that the cement treated base had contributed to the problem. The lime treated layer, under the cement treated base, was found to be variable in thickness, but there was insufficient evidence to indicate that it was not the proper thickness under the pavement. Either the drilling and sampling methods used or changes of behavior with time made the lime treated layer appear to be more friable or contain less lime than expected. On the other hand, the reaction of these materials to a phenolphthalein solution indicated that their pH was still fairly high, after over twenty years. The lime treated layer was found in each boring, and in only one case did it appear, by visual inspection, to have been affected by sulfate induced heave. Considering what situations were found and the condition of the lime treated layer, it is not believed that the behavior of this layer contributed to the movements found in the roadway.

The materials found below these treated layers were generally found to contain materials at differing states of weathering from the Eagle Ford shale formation. The location where shaley materials was found in most borings was dependent on the depth of the cut originally made and the depth of the boring at any point added together. The deeper the original cut the shallower the shaley materials were found. The apparent deepest cut was located near boring 10, and this boring could not be advanced as far as the rest because of the shaley nature of the subgrade. It is well known that the materials weathered from the Eagle Ford shale formation are generally highly active clays, capable of significant swell and swelling pressure potential. In addition, the more shaley these materials are the slower they express swell behavior and the greater is their swell potential. It is believe, therefore, that the majority of the movements that this roadway system has experienced are likely due to the gradual weathering and swell of these materials.

The aforementioned observations lead the matters of the research study to pursue the swell potential of the subgrades of this roadway, to determine what was needed to enhance their behavior with the addition of lime, to find how they might behave when lime treated, to look for the presence of soluble sulfates which are believed to be present at this location, and to develop other information to support recommendations.

Dallas District Testing:

The report of testing and analyses done by Dallas District personnel has been provided to you in November, 1994. It can also be found as Appendix B to this report. The report includes the location of borings one through seven, the materials identifications made for the six borings advanced in October, 1994, the results of testing done by the Dallas District laboratory, and their analysis of the potential vertical rise left in the subgrade. They found that the materials had liquid limits varying from 26 to 94, with an average of 54. The plastic indexes determined varied from 11 to 54, and had an average of 29. Using a seven foot active layer, they predicted that the potential for vertical rise was from 1.3 to 2.05 inches. In addition, they estimated that a 28 inch cover of non-swelling material could overcome the effects of this swell potential.

It has been the experience of the author that the properties and behaviors of materials weathered from the Eagle Ford shale formation agree well with those found by the Dallas District laboratory personnel. These results support the need for methods and agents of stabilization to be applied to this roadway subgrade as the rehabilitation takes place.

Testing at The University of Texas at Arlington:

Testing done at the UTA laboratory was aimed at determination of the potential of sampled materials to experience sulfate induced heave, of soil pH values, of soil pH response to addition of lime, of natural Atterberg limits and linear shrinkage, of combined sample compaction characteristics, and of sample swell behavior in overburden and three dimensional swell tests. The indicator of sulfate induced heave potential measured was soluble sulfates. The method used for this is very similar to that used by TX D.O.T. and is included in Appendix C. The compaction tests were conducted using the Harvard miniature method because of the small amount of samples available for testing. The other unusual test procedure used was that for the three dimensional swell test. It is given in Appendix C. Other tests were performed using well known and standardized test methods. Most of the results of testing are included in the tables which follow, and all will be discussed in turn.

Soluble sulfates and natural pH were determined for samples obtained from the first six borings made and separately for those from the last three borings. These results are shown in Tables 1 and 2, respectively. Both the average values and ranges of values are presented so that the nature of these results can be determined. In Table 1 the samples taken from shallow depths are given as treated and untreated. These determinations were made in the field using visual identification of the samples. It can be seen that the pH values for the treated materials are fairly high on the average, yet are similar in range to those for materials to five feet deep. The soluble sulfates for all materials to five feet deep from the first six borings are low enough that there should be no difficulties expected. On the other hand, the samples taken from 4 to 10 feet had soluble sulfates values which would present no problem on the average, but would be a problem at the high end of the range. The variation of soluble sulfates shown here is normal for this property, and indicates why caution should be exercised when treating clays for this roadway.

The results provided in Table 2, for samples taken from the last three borings indicate less variance of pH and more potentially hazardous soluble sulfate levels. It is important to note that the samples obtained from depths shallower than five feet were utilized for three dimensional swell testing and, therefore, not tested for these properties. The average values, shown in Table 2 for pH are close to those normally found for these soils, and the ranges shown are relatively small. These materials, as those discussed earlier have somewhat basic pH values. The soluble sulfate levels displayed in Table 2 for materials sampled from five to nine feet have a normal variation, but do not indicate possible problems with sulfate induced heave if they were treated. On the other hand, the soluble sulfate levels presented for materials sampled from nine to thirteen feet have average values which indicate possible problems, and the highest values shown signify the potential for damaging sulfate induced heave, if these materials were to be treated. The fortunate part of this situation is that the potentially damaging sulfate levels have been found fairly deep into the subgrade in materials which will not likely be treated. Unfortunately, the variability of soluble sulfates found and the high values determined in some cases, indicate that potentially problematic levels of soluble sulfates may be present in materials which will be treated as part of the rehabilitation process.

Because of the size the samples that were available which were taken from the first six borings, they were combined by depth to enable further testing. All materials which had been sampled from depths of 1 to 2.5 feet were combined to make up sample C. In a similar fashion the materials from 2 to 5 foot deep were put together into sample D and the soils from 4 to 10 foot depths were combined to make up sample E. These combined samples were then tested for their pH, Atterberg limits and linear shrinkage. Table 3 contains their natural pH values. Sample C probably contained some treated materials so that its pH is significantly higher than that of sample D or E. It is also possible that this is another confirmation of the pH value for shallow materials already discussed. These materials appear to have reducing values of pH with depth, as was the case discussed earlier. The other pH information given in Table 3 is from the results of a Eades and Grim type pH test to determine the optimum amount of lime to add for fixation of the clay. Although the results given are for even percentages of lime, the test was performed using percents lime from 0

TABLE 1
Natural pH and Sulfates-First Six Borings

Property	Shallow Treated	Shallow Untreated	2'-5' Depth	4'-10' Depth
pH (Average)	10.63	9.56	9.34	8.75
Range	9.8-11.3	9.2-10.4	9.0-11.2	7.8-8.8
Sulfates (Average)(ppm)	313	252	307	1220
Range	78-938	54-675	4-1185	12-5626

TABLE 2
Natural pH and Sulfates-Last Three Borings

Property	5'-7'	7'-9'	9'-11'	11'-13'
pH (Average)	8.88	8.87	8.29	8.35
Range	8.5-9.4	8.6-9.4	7.8-8.8	8.2-8.5
Sulfates (Average)(ppm)	479	487	4065	7106
Range	41-757	161-700	383-13,100	1696-14,446

TABLE 3
pH of Combined and Treated Samples

pH	1'-2.5' (C)	2'-5' (D)	4'-10' (E)
Natural	10.48	9.57	8.57
2% Lime Added	----	12.41	----
4% Lime Added	----	12.51	----
6% Lime Added	----	12.55	----

to 7. According to the results of this test, the optimum amount of lime to add to this soil is 6% by dry weight of soil. This agrees with the amount reportedly added during the initial construction of this section of IH 20.

The Atterberg limits information given in Table 4 for these combined samples is in partial agreement with the results provided by the Dallas District laboratory. The one clear exception is the material in sample C. Its Atterberg limits are significantly lower than the average for other samples tested at UTA or the Dallas District laboratory. It may possibly be that this material, which had the uncharacteristically high pH, is somewhat lime modified. The linear shrinkage measured for this sample is higher than those for the other samples tested, which does not match with lime modification. The Atterberg limits and linear shrinkage determined for samples D and E appear to agree well with values measured by the Dallas District laboratory. How these materials respond in the three dimensional swell test will complete the treatment part of the study.

In order to be able to mold treated samples for three dimensional swell testing the compaction characteristics of samples D and E were determined. It was decided to test only these two since they exhibited properties of materials not modified with lime. The tests were done using the Harvard miniature device and procedure to conserve materials. This method uses compacted cylinders which are approximately 1/454 of a cubic foot in size. Sample D was found to have a maximum dry unit weight of 104.1 pcf at an optimum moisture content of 17.0%. The maximum dry unit weight for sample E was determined to be 101.6 pcf at 20.5% water content. The average optimum moisture content for both of these samples is 18.8%. Since the Harvard miniature method results in values similar to those for standard Proctor compaction tests, a value of 19% was used as the optimum for molding of cylinders of natural soils, while 24% was used for molding specimens of lime treated materials. It is generally understood that the addition of lime raises the optimum moisture content for compaction by about 5%. Specimens for three dimensional swell testing were molded, using appropriate compaction energy, to be six inches in diameter and as high as the amount of material would allow them to be, not to exceed 4.5 inches.

Undisturbed samples taken from the last three borings were broken into two groups. The first group was made of those soils from less than five foot deep. These materials were broken down and compacted into test specimens for the three dimensional swell tests discussed later. The rest of the samples were tested for their overburden swell potential. This test is done by cutting the sample to fit a swell/consolidation ring, placing the specimen in the ring with porous stones on top and bottom, inserting this assemblage into a loading frame with dial gauge to measure changes in sample height, putting a load on the specimen which simulates the overburden pressure it has in situ, and inundating the specimen. The dial guage is monitored for swell and when the swell is seen to be complete the specimen is removed and its moisture content is measured. The percent swell is the ratio of the change in height over the original height, times 100%. Table 5 contains the results of the overburden swell tests performed, which had a duration of 11 days. In all cases the swells shown in Table 5 were recorded in less than 9 days, but on two cases 8 days of testing would not have been enough to reach full swell potential. It should be noted that in no case were these materials very dry at the start of the test. It was noted during sampling that much of the materials appeared to have moisture contents near and, in some cases, above their plastic limits. These relatively low swell values, therefore, reflect material behaviors of fairly damp clays.

TABLE 4
Atterberg Limits and Linear Shrinkage

Depth	L.L.	P.L.	P.I.	Lin. Shr. (%)
1'-2.5' (C)	32.1	24.6	7.5	7.5
2'-5'(D)	51.7	27.4	24.3	6.9
4'-10' (E)	47.5	26.8	20.7	6.9

TABLE 5
Overburden Swell Test Results

Depth	5'-6'	6'-7'	7'-8'	8'-9'	9'-10'	10'-11'
Po (psf)	700	800	900	1000	1100	1200
Final M.C.	37.6	34.9	37.3	26.6	37.7	40.3
% Swell	0.21	0.12	0.21	0.45	0.05	0.05

Three dimensional swell tests were conducted on four differing samples of materials and in two states of preparation. The materials combined from samples C and D were used to mold specimens in the natural state at 19% water content, and those treated with 6% lime at 24% moisture content. Similarly, specimens were made using materials from shallower than five feet taken from borings 8, 9 and 10. The total number of specimens was eight. The three dimensional swell tests were conducted using the procedure given in Appendix C. As a part of this procedure each specimen was placed on a porous stone, had its sides covered with a geotextile wicking fabric and a triaxial membrane, was then sealed on all but the bottom with a plastic wrap and placed in a bowl, and water was introduced into the bowl to over the height of the top of the porous stone. Measurements of the specimen's height and diameter are taken periodically, until the change in both height and diameter are determined to have stopped. The final action is to determine the specimen's water content. The UTA geotechnical laboratory has conducted over 500 of these tests on natural and treated clays as a part of ongoing studies related to sulfate induced heave. It has been determined that, when the vertical and/or horizontal swell measured during this test are 1% or less, field swell should be no problem for a pavement system.

The swell values shown in Table 6 illustrate well the behavior improvements which can be obtained for clays when they are lime treated. The vertical and horizontal swell for the natural specimen of combined sample C + D were found to be excessive, in spite of the fact that the specimen was compacted at optimum moisture content. When lime treated these materials exhibited swells which are considered to be nondamaging. Although the natural specimens from borings 8, 9 and 10 did not display excessive vertical swell, their behavior was improved with the addition of lime. This is also true for the horizontal swell exhibited by the lime treated specimen from boring 8. The specimens from borings 9 and 10 displayed horizontal swell in the natural state which is considered excessive. In these two cases lime treatment did not reduce the swell completely to acceptable levels. It is possible that these materials are not as reactive to lime as the others, may be exhibiting slight sulfate induced heave or may have compacted-in tendencies for horizontal swell. The values of horizontal swell in these two cases, although a bit excessive, are not believed to represent situations which would produce significant damage. It is interesting to note that the final moisture contents for the treated materials in three cases were lower than those for untreated materials. The only exception was for the materials which responded best to lime treatment. It is clear that lime treatment will improve the general behavior of these soils.

Stabilization Concepts:

Expansive or highly active clays can be made to behave in an improved or near stable manner by application of methods which will exclude their moisture change or which change their characteristics physicochemically. The slow weathering process of a clay shale will produce volume increase or swell in most cases. This especially true when overburden is removed so that rebound of these highly compressed materials can also occur. The activator of volume increase over the rebound amounts is the introduction of water into the weathering shale. This water is often made more available to the shale, as in the case of the Eagle Ford formation, when the shale has natural cracks and fissures. Another factor is the opening up of these cracks and fissures which occurs when the materials rebound. The reason that the weathering/swell process of these materials takes so long

TABLE 6
3-D Swell Test Results

Soil	C+D	Boring 8	Boring 9	Boring 10
Vert. Swell (%)	1.40	0.80	0.37	0.69
Material Treated	0.77	0.03	0.27	0.36
Horizontal Swell	2.45	0.85	1.86	2.01
(%) Mat. Treated	0.93	0.11	1.42	1.24
Final MC (%)	31.1	27.6	42.7	52.9
Material Treated	35.7	24.3	38.1	39.8

is that it takes time for the clay structure in these materials to open enough to let in moisture, and it takes time for the diagenetic bonds in these clays to release, allowing swell.

The keys to approaching stable conditions in clay shales and clays without the addition of agents are directed at the maintenance of constant moisture conditions. This includes prevention of loss of moisture during construction, establishment of desired levels of moisture during construction and maintenance of moisture levels for the life of the roadway. As these materials are exposed during the rehabilitation process they should be sealed to prevent moisture loss, or watered in such a way to prevent moisture loss. In order to provide as uniform as possible conditions of moisture no water should be allowed to pond nonuniformly on the subgrade and proper positive drainage of surface waters must be maintained. It is believed that the moisture levels in the subgrade, according to the samples tested, are fairly reasonable. It is more important, in moist soil conditions, to maintain or develop uniform moisture conditions withing areas, than build higher moisture levels which cannot be maintained. The long term maintenance of moisture levels in the subgrade of this roadway will, it is believed, necessitate the installation of vertical moisture movement barriers along both sides of the pavement in each direction of traffic. TX D.O.T. has sponsored research into the use of these barriers and has built several of them in the San Antonio area. The person most familiar with these is Malcolm Steinberg, who is currently with The University of Texas at El Paso.

Chemical modification or what is called stabilization of the near pavement subgrade will provide a material without swelling potential. This is predicated on the prevention of sulfate induced heave. Lime is the chemical of choice for clay modification and has the only well proven record of success in these materials. Testing indicates that 6% lime by dry weight of soil will be adequate for this task. In the field, however, it would be prudent to add one percent to 7% for construction inconsistencies. Proper lime treatment of a clay includes scarifying the subgrade, addition of lime, pulverizing/mixing of the lime into the clay, bringing the moisture content to the optimum for the treated material + 5%, mellowing of the mix for at least 24 hours, proper pulverizing/mixing to 100% less than 1 inch and 60% passing the No. 4 sieve, and proper compaction of the material at the optimum moisture content. It has been noted, as part of research that proper pulverization is extremely important to the success of treatment of clays, and that proper moisture contents are required to develop the desired properties of treated clays. Unfortunately, the trends in construction are away from mellowing, proper pulverization and proper moisture levels. It is very possible that the abundance of problems with treated subgrades noted in recent years can be tied to these trends.

The prevention of sulfate induced heave starts with the recognition where potential problems areas exist. Because of the varied nature of the levels of soluble sulfates in clay subgrades it is important to sample and test them for this property as often as economically feasible. It would be possible to begin sampling on a grid of points about 200 feet apart. If significant sulfates are found, then the grid could be made finer. This may be of great assistance, since, if the areas containing significant sulfates were not too large, the materials could be replaced with sulfate free soils. It has been determined that soils with at least 2,000 ppm soluble sulfates pose a potential problem in sulfate induced heave if treated with lime, lime-fly ash, or Portland cement. These potential problems become moderate when the clay contains over 5,000 ppm soluble sulfates, and these possible problems can become severe when the amount of sulfates in the soil exceeds 10,000 ppm.

It is possible to lime treat materials containing significant levels of soluble sulfates when proper procedures are followed. Lime reactive clays with 2,000 to 5,000 ppm sulfates have been successfully treated using prewetting of the soil before treatment to between optimum and optimum +5% for the treated soil for 3 days, followed by addition and proper mixing of at least one-half of the normal percent lime used, followed by light compaction. The next step is to allow at least 7 days for moist mellowing and formation and hydration of ettringite, followed by addition of at least 3% lime or the rest of that normally applied with proper mixing and pulverization. The last step is to compact the mixture properly at the optimum moisture level and moist cure it for at least 7 days before anything is placed on it. There have been situations when the levels of soluble sulfates are this low that the process needed is the same as for normal lime treatment, except the soil must be pretreated with water as described here. When the levels of soluble sulfates in the soil are between 5,000 and 10,000 ppm, the steps described above are even more important. The need for prewetting is greater, it is necessary to add all the normally applied percentage of lime in the first application, and an additional treatment of 3% lime is likely to be needed. There have, also, been occasions when the level of soluble sulfates was moderate and only the single application of all the lime normally applied, coupled with proper prewetting overcame the problem. When the levels of soluble sulfates exceed 10,000 ppm, the situation could present severe problems. Research, so far, indicates a two or three application approach with proper prewetting. More field experience is needed to really prove the procedures to use. It is known that prewetting to moisture levels of at least the optimum for the treated materials is essential, followed by proper application of a full normal percent lime. It is prudent there after to keep the materials at moisture levels at least at the optimum as the compacted materials are monitored for sulfate induced heave. After at least 7 days it will likely be necessary to add more lime and it might be as much as was added the first time. After the second mixing and compaction at the optimum moisture level, monitoring must be done again for at least 7 days to see if the heave occurs once more. If during this moist cure no additional heave occurs, the treated layer can be covered. If more heave occurs, a third treatment of lime at the 3% level will probably overcome the remaining problems. As the time comes for this project to be sent out for bids and be constructed, contact with Dr. Little at Texas A&M University would be prudent, as he will know what procedures have been verified and can assist in perhaps more economical methods.

Summary and Conclusions:

The problems associated with the continued vertical movement of IH 20 from the Dallas County line to SH 1382 are complicated by the differing foundation soils upon which was built. The problems have not been caused by the cement treated base or the lime treated subbase. Only one place was the evidence of possible sulfate induced hampering of the lime treated layer noted, and no roadway movements could be specifically tied to it. The causes of the differential heaves noted are likely the rebound of weathering shale materials as overburden was removed for construction and the gradual heave which has occurred as the weathering shale materials gain moisture and break their diagenetic bonds. The problems appear to have happened in the cut sections of this roadway and were not as serious where the cut was into alluvial clays near to Fish Creek. Understanding of these sort of movements was not fully understood at the time of construction for this section of IH 20 and prediction of these movements would be difficult today, considering the information available.

As indicated by the report of the Dallas District laboratory, it is prudent to stabilize or remove the effects of swell of some of the materials supporting the roadway. Cement treated base or equivalent should perform well to support a new pavement for this roadway, and the thicker this layer the more it contributes to the needed layer of nonswelling material. Lime treatment is the most viable method well proven to date to effectively overcome the swelling potential of these clays. A layer of lime treated clay can be an effective support as a subbase when it is at least one foot thick. The thicker this layer the more it contributes to the nonswelling support for the pavement. In addition, it appears that the weathered shale materials have gained moisture over the twenty years they have been covered with pavement and this moisture must be maintained to prevent shrinkage and its contribution to future damaging movements of the pavement structure, through increased swell later. It would also be prudent to some how lock in the moisture presently in these materials and, if possible, prevent them from becoming damper with the accompanying shrink and swell, respectively. This can possibly be done by installing a moisture movement barrier along the edges of the pavement system. The total effect of all of these measures could be to diminish differential movements of the pavement system in the future. It will be necessary to be careful when applying the Portland cement and lime to the materials used to prevent possible sulfate induce heave.

Recommendations:

It is recommended that a combination of moisture maintenance of subgrade materials, of lime treatment of at least one foot of the natural clays, and of the use of a suitable base of at least one foot thickness be used in rehabilitation of this section of IH 20. It will be necessary to preserve the moisture levels now in the subgrade during construction to prevent shrinkage. A moisture movement barrier system should be installed along the edges of the pavement structure, extending at least slightly under the pavement and at the edges to a depth of preferably 8 feet. This barrier should be made of at 60 mil thick HDPE or HDPP, both of which are currently used as liners for many applications. The exact configuration would depend on the experience of TX D.O.T. and the advice of Malcolm Steinberg. Above this barrier the lime treated clay and the base should be used to support the pavement. It is believed that maintenance of moisture levels in foundation materials will drastically reduce the need for future maintenance of this pavement system, and that the lime treated layer and base further reduce the potential for heave. It is very important, as outlined above, that proper positive drainage must be provided, in addition. This will aid in the maintenance of more uniform and constant moisture levels in foundation soils.

APPENDIX A

Dallas District Laboratory
Texas Department of Transportation

DRILLING LOG

Laboratory No.	18–94–1620 thru 1631	2374	04	
Date Recd.	10–06–94 Date Reported 11–03–94	Contr. No.	Sect. No.	Job No.
Dist. or Res. Engr.	Claude S. Jones, P.E.			
Address	Dallas, Texas	Dallas		I.H. 20
Contractor	Preliminary	County	Fed. Project No.	Highway No.
Sampler	James P. Kern			
Sampler's Title	Geol. Asst. III	Dallas		10–06–94
Sampled From	Auger Test Hole (Pit, Quarry, Car or Stockpile)	District	Req. No.	Date Sampled
Producer		Identification Marks		
Quantity Represented by Sample		Project Charge No.		
Has been used on		Material from Property of	Tx. D.O.T. Right of Way	
Proposed for use as	Subgrade			

HOLE NO.	DEPTH (FT.)	DESCRIPTION OF MATERIAL
4	0.0 – 9.0*	A.C.P. Shoulder
4	9.0* – 12.0*	Soil Cement Base
4	12.0* – 21.0*	Lime Stabilized Subgrade
4	21.0* – 6.0	Brown sandy silty clay w/six inch layers of fine sand at 2'9" and 4' depths
4	6.0 – 10.0	Brown sandy silty clay that becomes lighter in color with depth after 7'
6	0.0 – 7.0*	A.C.P. Shoulder
6	7.0* – 13.0*	Soil Cement Base
6	13.0* – 22.0*	Lime Stabilized Subgrade
6	22.0* – 2.0	Weathered dk. brown and black shale
6	2.0 – 10.0	Brown to reddish brown weathered shale w/thin seams of bentonite and tr. gypsum crystals at 5' This layer becomes lighter in color w/depth
7	0.0 – 6.0*	A.C.P. Shoulder
7	6.0* – 15.0*	Soil Cement Base
7	15.0* – 2.0	Lime Stabilized Subgrade
7	2.0 – 3.0	Black silty clay w/tr. caliche and iron nodules
7	3.0 – 10.0	Lt. brown, tan and gray weathered shale w/thin seams of bentonite throughout and tr. caliche

* Depth in inches

Dallas District Laboratory
Texas Department of Transportation

DRILLING LOG

Laboratory No.	18-74-0251 thru 0255	2374	04	
Date Recd.	02-27-74 Date Reported 11-03-94	Contr. No.	Sect. No.	Job No.
Dist. or Res. Engr.	Claude S. Jones, P.E.			
Address	Dallas, Texas	Dallas		I.H. 20
Contractor	Preliminary	County	Fed. Project No.	Highway No.
Sampler	Ronnie O. McManus			
Sampler's Title	Geologist II	Dallas		02-27-74
Sampled From	Auger Test Hole (Pit, Quarry, Car or Stockpile)	District	Req. No.	Date Sampled
Producer		Identification Marks		
Quantity Represented by Sample		Project Charge No.		
Has been used on		Material from Property of	Tx. D.O.T. Right of Way	
Proposed for use as	Subgrade			

HOLE NO.	DEPTH (FT.)	DESCRIPTION OF MATERIAL
5	0.0 – 0.5	Dark brown w/traces of tan clayey silty sand (topsoil)
5	0.5 – 3.0	Brown sandy silty clay w/powdery and granular caliche
5	3.0 – 6.0	Orange, lt. gray and tan clayey sand This layer becomes sandier and lighter in color w/depth
5	6.0 – 10.0	Lt. gray w/reddish brown and tan shaley clay

* Depth in inches

Dallas District Laboratory
Texas Department of Transportation

SOIL BORING LOG

Date Drilled	April 25, 1995	2374	04	035
Location (Sta.No.)	15+97	Contr. No.	Sect. No.	Job No.
	30' RT of E.B. main lanes	Dallas		IH 20
Elevation	Approx. 6" below E.B. CL	County	Fed. Project No.	Highway No.
Sampler	Tom Petry and James Kern	Tarrant County Line to FM 1382		
Sampled From	Push Barrel	Project Limits		
	(Auger Bore Hole, Pit, Foundation Core Hole, etc.)	Identification Marks		
Depth Samples Taken	0" to 13' 2"	Project Charge No.		
Laboratory No's.	N/A	Material from Property of	Tx D.O.T. Right of Way	
Depth to Groundwater, ft.	11'			

HOLE # 8

DEPTH	MATERIAL DESCRIPTION	P.I.	L.L.
0 – 12"	HMAC		
12" – 16"	Cement Stabilized Base		
16" – 20"	Lime Treated Subgrade		
20" – 3'	Dk. Brown fine grained sand w/organic matter		
3' – 4' 6"	Dk. Brown moist sandy clay w/thin sand seams and organic matter		
4' 6" – 5' 6"	Tan silty clay w/siliceous gravel and bentonite seams		
5'6" – 6' 8"	Tan–grey mottled silty clay w/bentonite seams		
6' 8" – 8'	Tan–orange sl. shaley clay. Moisture decreased w/depth in this layer		
8' – 9'	Grey bentonite w/tan clay layers		
9 – 13' 2"	Tan–orange shaley clay w/grey bentonite seams, organic matter, and fossil casts. There is a water bearing sand seam at 11' in this layer		
13' 2"	Top Dk. Grey Eagle Ford Shale		

ADDITIONAL NOTES AND OBSERVATIONS:

This location was drilled in an existing 12' to 14' roadcut.

Dallas District Laboratory
Texas Department of Transportation

SOIL BORING LOG

Date Drilled	April 25, 1995	2374	04	035
Location (Sta.No.)	37+56	Contr. No.	Sect. No.	Job No.
	30' RT of E.B. main lanes	Dallas		IH 20
Elevation	Approx. 6" below E.B. CL	County	Fed. Project No.	Highway No.
Sampler	Tom Petry and James Kern	Tarrant County Line to FM 1382		
Sampled From	Push Barrel	Project Limits		
	(Auger Bore Hole, Pit, Foundation Core Hole, etc.)	Identification Marks		
Depth Samples Taken	0' to 13' 1"	Project Charge No.		
Laboratory No's.	N/A	Material from Property of	Tx D.O.T. Right of Way	
Depth to Groundwater, ft.	N/A			

HOLE # 9

DEPTH	MATERIAL DESCRIPTION	P.I.	L.L.
0 – 20"	HMAC		
20" – 2'	Cement Stabilized Base		
2' – 3'	Lime Treated Subgrade		
3' – 13' 1"	Tan silty and shaley clay w/tr. bentonite seams and limestone shell fragments.		
	The moisture increased from 6' – 7' in this layer. There are thin sand seams		
	and gypsum at 11'		
13' 1"	Top Grey Eagle Ford Shale		

ADDITIONAL NOTES AND OBSERVATIONS:

This location was drilled in an existing 15 to 20' roadcut.
Several asphalt overlays are apparent at this location.
Fish Creek runs adjacent to the W.B. frontage road along this stretch of IH 20.

Dallas District Laboratory
Texas Department of Transportation

SOIL BORING LOG

Date Drilled	April 25, 1995	2374 (Contr. No.)	04 (Sect. No.)	035 (Job No.)
Location (Sta.No.)	109+89			
	30' RT of E.B. main lanes	Dallas (County)	(Fed. Project No.)	IH 20 (Highway No.)
Elevation	Approx. level w/E.B. CL			
Sampler	Tom Petry and James Kern	Tarrant County Line to FM 1382 (Project Limits)		
Sampled From	Push Barrel (Auger Bore Hole, Pit, Foundation Core Hole, etc.)	Identification Marks		
Depth Samples Taken	0' to 9' 11"	Project Charge No.		
Laboratory No's.	N/A	Material from Property of	Tx D.O.T. Right of Way	
Depth to Groundwater, ft.	N/A			

HOLE # 10

DEPTH	MATERIAL DESCRIPTION	P.I.	L.L.
0 – 12"	HMAC		
12" – 1' 6"	Cement Stabilized Base		
1' 6" – 3'	Lime Treated Subgrade. This material contained dk. grey shale fragments, was friable and in generally poor condition.		
3' – 5' 6"	Tan shaley clay w/some grey shale fragments and gypsum		
5' 6" – 9' 11"	Dk. grey w/some orange Eagle Ford Shale w/possible fine gypsum crystals, and fossil shell fragments		

ADDITIONAL NOTES AND OBSERVATIONS:

This location was drilled in the middle of an existing 25' deep roadcut.

APPENDIX B

INTEROFFICE MEMORANDUM

TO: Mr. Claude S. Jones, P.E.
Attn: Craig Miser, P.E.

DATE: November 16, 1994

FROM: Lawrence E. Kelley, P.E.
District Laboratory Engineer

ORIGINATING OFFICE:
Dallas District Laboratory

SUBJECT: Preliminary Subgrade Soils Report
CSJ: 2374-04-
Highway: I.H. 20
Limits: From the Tarrant Co. Line to F.M. 1382
County: Dallas

The subgrade soils on the above project were sampled, tested and classified in accordance with established departmental procedures. The attached results contain soil constants, soil descriptions, potential vertical rise calculations, and maps showing the approximate locations where the test holes were drilled. The triaxial classification and per cent lime required for stabilization are based upon similar soils. The pavement design for this roadway should be based upon the following type of soil:

LIQUID LIMIT:	*54*	*Range 26-94*
PLASTICITY INDEX:	*29*	*Range 11-54*
TRIAXIAL CLASS:	*5.6*	
%LIME REQUIRED:	*5.0*	
CALCULATED AVG. P.V.R.:*	*1.30"*	
MAX. P.V.R. BASED UPON DRY CONDITIONS:*	*2.05"*	

DEPTH OF COVERAGE: 28"*
(Amount of non-swelling material to restrict vertical movement to one inch)

** Based on a moisture fluctuation depth of seven feet.*

SOIL DESCRIPTION:
Brown, black, and grey silty and sandy clay and weathered shale w/bentonite seams, caliche, ferric oxide granules and tr. siliceous gravel

A visual inspection of the subject roadway conducted on August 31, 1994 indicated pavement distress has primarily occurred in the deeper cut sections. Subsequent sampling through the HMAC shoulder along the north side of the main lanes found clays with high shrink-swell potentials to be present in some of the cut sections. Weathered shales and shaley clays with bentonite seams were logged at locations 2,5,6 and 7. These soil types can be highly expansive given fluctuating moisture conditions. The nature and appearance of the pavement distortion led those present at the initial investigation to suspect expansive clays as the cause of damage rather than soluble sulfates. Dr. Tom Petry at U.T.A. is testing sampled cores for the presence of soluble sulfates. Also, changes in the soil stress state caused by removal of overburden during construction of cut sections may have led to soil movement. Cut and fill section endpoints were located using information provided by the SW Area Office.

Moisture and density control should be specified for all embankment, subgrade, and base materials. Backfill materials for bridge abutments should be restricted to materials with a plasticity index of 20 or less.

Additional sampling and testing will be conducted upon request.

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SOILS AND BASE MATERIALS TEST REPORT

Laboratory No.	18–94–1608 thru 1611	2374	04		
		Control Number	Section Number		Job Number
Date Received	10–06–94 Reported 11–03–94	Dallas			I.H. 20
Engineer	Claude S. Jones, P.E.	County	Federal Project No		Highway No
Address	Dallas, Texas	Dallas			10–06–94
Contractor	Preliminary	District	I.P.E. No	Req. No	Date Sampled
Sampler	James P. Kern	Specification Item No.			
Sampler's Title	Geol. Asst. III	Material from Property of	Tx D.O.T.		
Sampled From	Auger Test Hole		Right of Way		
Producer					
Quantity of Sample	,				
Has Been Used On	'	Proposed for Use as	Subgrade		

LAB NO	LL	PI	SL	LS	SR	Class	Soil Binder	WBM % Loss	% Moist.	I.D.
18–94–1608	40	21					98		18.4	
18–94–1609	56	28					96		21.3	
18–94–1610	67	38					91		22.3	
18–94–1611	69	43					95		23.3	

PERCENT RETAINED ON

Lab No	Square Mesh Sieve															Grain Diam in Millimeters				Spec. Grav.
	Opening in inches								Sieve Numbers											
	3	2 1/2	2	1 3/4	1 1/4	7/8	5/8	3/8	4	10	20	40	60	100	200	.05	.005	.002	.001	
18–94–1608							0	tr	1	1		2								
18–94–1609								0	tr	1		4								
18–94–1610								0	1	5		9								
18–94–1611							0	tr	1	3		5								

SAMPLE IDENTIFICATION

Lab No.	Depth, ft.	Location–Properties–Station Numbers	Type of Materials
18–94–1608	3.0	Hole No. 1 – 32' left of the centerline of the	Note Drilling Log
18–94–1609	5.0	IH 20 W.B. lanes at Sta. No. 150+29. The top of	
18–94–1610	7.0	the hole is approximately 1.0' below the centerline	
18–94–1611	9.0	of the W.B. lanes	

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SOILS AND BASE MATERIALS TEST REPORT

Laboratory No.	18–94–1612 thru 1615	2374	04	
Date Received	10–06–94 Reported 11–03–94	Control Number	Section Number	Job Number
Engineer	Claude S. Jones, P.E.	Dallas		I.H. 20
Address	Dallas, Texas	County	Federal Project No	Highway No
Contractor	Preliminary	Dallas		10–06–94
Sampler	James P. Kern	District	I.P.E. No Req. No	Date Sampled
Sampler's Title	Geol. Asst. III	Specification Item No.		
Sampled From	Auger Test Hole	Material from Property of	Tx D.O.T.	
Producer			Right of Way	
Quantity of Sample	,			
Has Been Used On	'	Proposed for Use as	Subgrade	

LAB NO	LL	PI	SL	LS	SR	Class	Soil Binder	WBM % Loss	% Moist.	I.D.
18–94–1612	42	20					97		22.5	
18–94–1613	42	22					99		19.0	
18–94–1614	92	53					99		34.5	
18–94–1615	89	46					100		32.9	

PERCENT RETAINED ON

Lab No	Square Mesh Sieve															Grain Diam in Millimeters				Spec. Grav.
	Opening in inches								Sieve Numbers											
	3	2 1/2	2	1 3/4	1 1/4	7/8	5/8	3/8	4	10	20	40	60	100	200	.05	.005	.002	.001	
18–94–1612								0	1	2		3								
18–94–1613								0	tr	tr		1								
18–94–1614										0		tr								
18–94–1615												0								

SAMPLE IDENTIFICATION

Lab No.	Depth, ft.	Location–Properties–Station Numbers	Type of Materials
18–94–1612	3.0	Hole No. 2 – 32' left of the centerline of the	Note Drilling Log
18–94–1613	5.0	IH 20 W.B. lanes at Sta. No. 121+85. The top of	
18–94–1614	7.0	the hole is approximately 0.5' below the centerline	
18–94–1615	9.0	of the W.B. lanes	

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SOILS AND BASE MATERIALS TEST REPORT

Laboratory No.	18–94–1616 thru 1619	2374	04	
Date Received	10–06–94 Reported 11–03–94	Control Number	Section Number	Job Number
Engineer	Claude S. Jones, P.E.	Dallas		I.H. 20
Address	Dallas, Texas	County	Federal Project No	Highway No
Contractor	Preliminary	Dallas		10–06–94
Sampler	James P. Kern	District	I.P.E. No Req. No	Date Sampled
Sampler's Title	Geol. Asst. III	Specification Item No.		
Sampled From	Auger Test Hole	Material from Property of	Tx D.O.T.	
Producer			Right of Way	
Quantity of Sample	,			
Has Been Used On	'	Proposed for Use as	Subgrade	

LAB NO	LL	PI	SL	LS	SR	Class	Soil Binder	WBM % Loss	% Moist.	I.D.
18–94–1616	43	23					91		19.4	
18–94–1617	36	16					50		14.9	
18–94–1618	28	11					95		17.5	
18–94–1619	41	19					97		19.1	

PERCENT RETAINED ON

Lab No	Square Mesh Sieve															Grain Diam in Millimeters				Spec. Grav.
	Opening in inches								Sieve Numbers											
	3	2 1/2	2	1 3/4	1 1/4	7/8	5/8	3/8	4	10	20	40	60	100	200	.05	.005	.002	.001	
18–94–1616							0	2	5	7		9								
18–94–1617						0	1	11	27	41		50								
18–94–1618							0	tr	1	3		5								
18–94–1619							0	tr	1	2		3								

SAMPLE IDENTIFICATION

Lab No.	Depth, ft.	Location–Properties–Station Numbers	Type of Materials
18–94–1616	3.0	Hole No. 3 – 30' left of the centerline of the	Note Drilling Log
18–94–1617	5.0	IH 20 W.B. lanes at Sta. No. 99+54. The top of	
18–94–1618	7.0	the hole is approximately 1.0' below the centerline	
18–94–1619	9.0	of the W.B. lanes	

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SOILS AND BASE MATERIALS TEST REPORT

Laboratory No.	18-94-1620 thru 1623	2374	04	
		Control Number	Section Number	Job Number
Date Received	10-06-94 Reported 11-03-94	Dallas		I.H. 20
		County	Federal Project No	Highway No
Engineer	Claude S. Jones, P.E.	Dallas		10-06-94
		District	I.P.E. No Req. No	Date Sampled
Address	Dallas, Texas	Specification Item No.		
Contractor	Preliminary	Material from Property of	Tx D.O.T.	
Sampler	James P. Kern		Right of Way	
Sampler's Title	Geol. Asst. III			
Sampled From	Auger Test Hole	Proposed for Use as	Subgrade	
Producer				
Quantity of Sample	,			
Has Been Used On	'			

LAB NO	LL	PI	SL	LS	SR	Class	Soil Binder	WBM % Loss	% Moist.	I.D.
18-94-1620	43	21					100		17.8	
18-94-1621	30	12					99		14.5	
18-94-1622	46	24					99		17.7	
18-94-1623	34	17					98		18.0	

PERCENT RETAINED ON

Lab No	Square Mesh Sieve															Grain Diam in Millimeters				Spec. Grav.
	Opening in inches								Sieve Numbers											
	3	2 1/2	2	1 3/4	1 1/4	7/8	5/8	3/8	4	10	20	40	60	100	200	.05	.005	.002	.001	
18-94-1620									0	tr		tr								
18-94-1621								0	tr	1		1								
18-94-1622								0	tr	1		1								
18-94-1623							0	tr	1	1		2								

SAMPLE IDENTIFICATION

Lab No.	Depth, ft.	Location-Properties-Station Numbers	Type of Materials
18-94-1620	3.0	Hole No. 4 - 44' left of the centerline of the	Note Drilling Log
18-94-1621	5.0	IH 20 W.B. lanes at Sta. No. 74+65. The top of	
18-94-1622	7.0	the hole is approximately level with the centerline	
18-94-1623	9.0	of the W.B. lanes.	

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SOILS AND BASE MATERIALS TEST REPORT

Laboratory No.	18–74–251 thru 260	2374	04	
Date Received	02–27–74 Reported 03–21–74	Control Number	Section Number	Job Number
Engineer	Claude S. Jones, P.E.	Dallas		I.H. 20
Address	Dallas, Texas	County	Federal Project No	Highway No
Contractor	Preliminary	Dallas		02–27–74
Sampler	Ronnie O. McManus	District	I.P.E. No Req. No	Date Sampled
Sampler's Title	Geologist II	Specification Item No.		
Sampled From	Auger Test Hole	Material from Property of	Tx D.O.T.	
Producer			Right of Way	
Quantity of Sample				
Has Been Used On		Proposed for Use as	Subgrade	

LAB NO	LL	PI	SL	LS	SR	Class	Soil Binder	WBM % Loss	% Moist.	I.D.
18–74–251	40	23					95		17.6	
18–74–252	32	19					98		14.2	
18–74–253	26	11					99		15.5	
18–74–254	60	35					93		27.0	
18–74–255	67	39					100		29.4	

PERCENT RETAINED ON

Lab No	Square Mesh Sieve															Grain Diam in Millimeters				Spec. Grav.
	Opening in inches								Sieve Numbers											
	3	2 1/2	2	1 3/4	1 1/4	7/8	5/8	3/8	4	10	20	40	60	100	200	.05	.005	.002	.001	
18–74–251								0	1	3		5								
18–74–252								0	tr	1		2								
18–74–253								0	tr	1		1								
18–74–254								0	4	6		7								
18–74–255										0		tr								

SAMPLE IDENTIFICATION

Lab No.	Depth, ft.	Location–Properties–Station Numbers	Type of Materials
18–74–251	1.0	Hole No. 5 – 4' left of the outside curb of the	Note Drilling Log
18–74–252	3.5	IH 20 W.B. frontage road at Sta. No. 45+06.	
18–74–253	5.0		
18–74–254	6.5		
18–74–255	8.5		

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SOILS AND BASE MATERIALS TEST REPORT

Laboratory No.	18–94–1624 thru 1627
Date Received	10–06–94 Reported 11–03–94
Engineer	Claude S. Jones, P.E.
Address	Dallas, Texas
Contractor	Preliminary
Sampler	James P. Kern
Sampler's Title	Geol. Asst. III
Sampled From	Auger Test Hole
Producer	
Quantity of Sample	
Has Been Used On	

Control Number	Section Number	Job Number
2374	04	

County	Federal Project No	Highway No
Dallas		I.H. 20

District	I.P.E. No	Req. No	Date Sampled
Dallas			10–06–94

Specification Item No.

Material from Property of Tx D.O.T.
Right of Way

Proposed for Use as Subgrade

LAB NO	LL	PI	SL	LS	SR	Class	Soil Binder	WBM % Loss	% Moist.	I.D.
18–94–1624	73	42					99		26.4	
18–94–1625	67	34					99		26.8	
18–94–1626	66	31					99		28.1	
18–94–1627	62	28					98		26.0	

PERCENT RETAINED ON

Lab No	Square Mesh Sieve – Opening in inches								Sieve Numbers							Grain Diam in Millimeters				Spec. Grav.
	3	2 1/2	2	1 3/4	1 1/4	7/8	5/8	3/8	4	10	20	40	60	100	200	.05	.005	.002	.001	
18–94–1624								0	tr	tr		1								
18–94–1625									0	tr		1								
18–94–1626								0	tr	tr		1								
18–94–1627								0	tr	tr		2								

SAMPLE IDENTIFICATION

Lab No.	Depth, ft.	Location–Properties–Station Numbers	Type of Materials
18–94–1624	3.0	Hole No. 6 – 32' left of the centerline of the	Note Drilling Log
18–94–1625	5.0	IH 20 W.B. lanes at Sta. No. 26+37. The top of	
18–94–1626	7.0	the hole is approximately level with the centerline	
18–94–1627	9.0	of the W.B. lanes.	

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SOILS AND BASE MATERIALS TEST REPORT

Laboratory No.	18–94–1628 thru 1631	2374	04	
Date Received	10–06–94 Reported 11–03–94	Control Number	Section Number	Job Number
Engineer	Claude S. Jones, P.E.	Dallas		I.H. 20
Address	Dallas, Texas	County	Federal Project No	Highway No
Contractor	Preliminary	Dallas		10–06–94
Sampler	James P. Kern	District	I.P.E. No Req. No	Date Sampled
Sampler's Title	Geol. Asst. III	Specification Item No.		
Sampled From	Auger Test Hole	Material from Property of	Tx D.O.T.	
Producer			Right of Way	
Quantity of Sample				
Has Been Used On		Proposed for Use as	Subgrade	

LAB NO	LL	PI	SL	LS	SR	Class	Soil Binder	WBM % Loss	% Moist.	I.D.
18–94–1628	47	22					99		22.6	
18–94–1629	71	38					100		29.0	
18–94–1630	94	54					99		36.3	
18–94–1631	59	30					96		27.8	

PERCENT RETAINED ON

Lab No	Square Mesh Sieve															Grain Diam in Millimeters				Spec. Grav.
	Opening in inches								Sieve Numbers											
	3	2 1/2	2	1 3/4	1 1/4	7/8	5/8	3/8	4	10	20	40	60	100	200	.05	.005	.002	.001	
18–94–1628								0	tr	1		1								
18–94–1629								0	tr	tr		tr								
18–94–1630								0	tr	tr		1								
18–94–1631								0	tr	2		4								

SAMPLE IDENTIFICATION

Lab No.	Depth, ft.	Location–Properties–Station Numbers	Type of Materials
18–94–1628	3.0	Hole No. 7 – 33' left of the centerline of the	Note Drilling Log
18–94–1629	5.0	IH 20 W.B. lanes at Sta. No. 2+50. The top of	
18–94–1630	7.0	the hole is approximately 1.0' below the centerline	
18–94–1631	9.0	of the W.B. lanes.	

Dallas District Laboratory
Texas Department of Transportation

DRILLING LOG

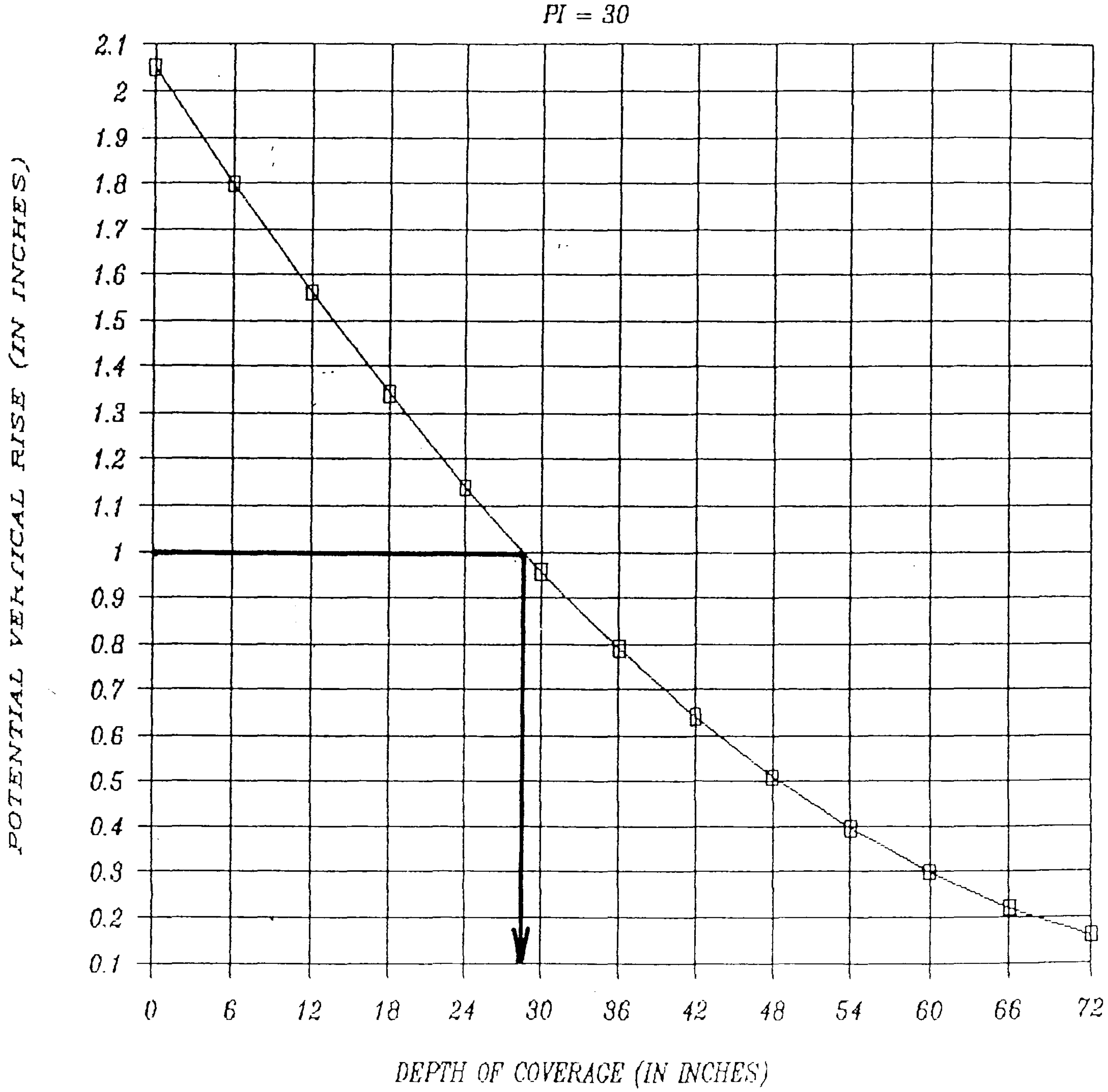
Laboratory No.	18–94–1608 thru 1619	2374	04	
Date Recd.	10–06–94 Date Reported 11–03–94	Contr. No.	Sect. No.	Job No.
Dist. or Res. Engr.	Claude S. Jones, P.E.			
Address	Dallas, Texas	Dallas		I.H. 20
Contractor	Preliminary	County	Fed. Project No.	Highway No.
Sampler	James P. Kern			
Sampler's Title	Geol. Asst. III	Dallas		10–06–94
Sampled From	Auger Test Hole (Pit, Quarry, Car or Stockpile)	District	Req. No.	Date Sampled
Producer		Identification Marks		
Quantity Represented by Sample		Project Charge No.		
Has been used on		Material from Property of	Tx. D.O.T.	
Proposed for use as	Subgrade		Right of Way	

HOLE NO.	DEPTH (FT.)	DESCRIPTION OF MATERIAL
1	0.0 – 6.0*	A.C.P. Shoulder
1	6.0* – 14.0*	Soil Cement Base
1	14.0* – 2.0	Lime Stabilized Subgrade
1	2.0 – 3.0	Brown sandy clay w/tr. caliche and iron nodules
1	3.0 – 4.0	Brown and black silty clay w/tr. caliche and iron nodules
1	4.0 – 5.0	Black silty clay w/tr. caliche and iron nodules
1	5.0 – 10.0	Dark gray silty clay w/caliche and tr. siliceous sand w/iron nodules
2	0.0 – 15.0*	A.C.P. Shoulder
2	15.0* – 22.0*	Soil Cement Base
2	22.0* – 30.0*	Lime Stabilized Subgrade
2	30.0* – 4.0	Brown silty clay w/caliche and iron nodules
2	4.0 – 6.0	Brown, tan and gray sandy silty clay w/tr. iron nodules
2	6.0 – 10.0	Blue and gray weathered shale w/ferric oxide stain and thin seams of bentonite
3	0.0 – 8.0*	A.C.P. Shoulder
3	8.0* – 16.0*	Soil Cement Base
3	16.0* – 2.5	Lime Stabilized Subgrade
3	2.5 – 3.5	Brown and lt. gray sandy clay w/some siliceous fine gravel and caliche, and tr. iron nodules
3	3.5 – 4.0	Dk. brown sandy silty clay w/caliche and some siliceous fine gravel
3	4.0 – 6.0	Lt. brown sandy clay w/caliche and siliceous fine gravel
3	6.0 – 7.0	Black silty clay w/caliche and tr. siliceous fine gravel, siliceous sand, and iron nodules
3	7.0 – 10.0	Brownish black silty clay w/caliche and tr. siliceous fine gravel w/iron nodules

* Depth in inches

CSJ: 2374-04
I.H. 20 From: Tarrant Co. Line
To: F.M. 1382
Engr: Claude S. Jones, P.E.

POTENTIAL VERTICAL RISE



THIS PVR CURVE IS BASED UPON A MOISTURE FLUCTUATION OF 7 FEET

APPENDIX C

3-Dimensional Swell Testing

PROCEDURE:

1. Determine the optimal moisture content and the maximum dry unit weight needed for compaction of the treated soils.

2. Prepare a sufficient amount of treated material such that several 6-inch diameter and 4-inch high specimens can be fabricated. The initial moisture content of the soil should be several percentage points (2% - 4%) below optimum compaction moisture conditions.

3. Compact a test specimen using standard proctor energy. The final specimen should be 4 inches high and 6 inches in diameter. Following compaction, extrude the specimen and hold in an air-tight plastic bag. Record, height, diameter and weight of extruded specimen.

(Optional) 4. Repeat step 3 but at a moisture content which is approximately 3 percentage points higher. Continue this process until the final water content is at least 6 percentage points above optimum.

5. To assemble the test sample, place the extruded specimen on top of a 1/2 x 6 inch diameter porous stone. Top the sample with a similar stone. Wrap the sides of the sample with geotextile fabric capable of wicking. One of the needle-punched non-woven fabrics will be acceptable. Be careful to cut the fabric such that it just fits around the sample. Butt the two ends together and secure with a small piece of tape.

6. A 6-inch diameter x 12-inch long triaxial membrane, which has been cut into two equal lengths (6 inches), is then used to cover the sample. Fold the top end of the membrane down and fix with tape. Keep the folds as flat as practical. The lower end should not cover the end of the porous stone.

7. Wrap the entire specimen, except for the exposed stone with plastic wrap and secure with tape.

8. Place the wraped sample in shallow bowl. The sides of the bowl should hold the sample above the bottom of the bowl by about 1/2 inch or so.

9. Prior to filling the bowl, determine the relative height and diameter of the sample. Use of a PI Tape and some sort of vertical caliber have been found to be quite effective.

10. Fill the bowl with distilled water and allow the sample to swell. Record the relative change in vertical and horizontal dimensions on a routine basis. Discontinue recording information when the rate of change has slowed or stopped.

SOLUABLE SULFATES DETERMINATION

SCOPE

Since the early 1980's sulfate induced heave has been determined to have caused significant distruction to many lightly loaded pavement structures. Numerous extraction methods have been developed and evaluated.

PURPOSE

This procedure presents the methodology for determination of Soluable sulfates in soils. The method given below represents the culmination of a series of studies to determine the most appropriate concentration from which to extract sulfates. The procedure uses a 1:10 dilution process in which 10 grams of dry soil is combined with 100 ml of distilled - demineralized (D-D) water, and extraction of solubles is done with centrifuging. Addition of Barium Chloride in the presence of Hydrochloric acid results in precipitation of Barium Sulfate which is then measured using a gravimetric process.

REFERENCES

The extraction methodlologies used herein are believed to reflect standard soil chemistry processes. The determination of sulfates is as outlined in the 17th edition of Standard Methods for the Examination of Water and Wastewater, edited by Clesceri, Greenberg and Trussell, 1989.

LABORATORY REQUIREMENTS:

The student is expected to prepare samples of unknown sulfates concentrations and determine those concentrations. A spiked specimen will be added to the list of unknowns to evaluate the students technique.

EQUIPMENT

Reagents:

Concentrated Hydrochloric Acid
Barium Chloride Solution
- 100 g $BaCl_2$ - $2H_2O$ in 1000 ml D-D water
Silver Nitrate-Nitric Acid Reagent
- 8.5 g $AgNO_3$ and 0.5 ml HNO_3 in 500 ml D-D water

Special Supplies:

Filter paper: acid-washed, ashless hard finish - Whatman No. 541
Membrane Filter: Gelman Science HT-450 (pore size 0.45 um)
Vacuum Filtration Apparatus

Common Equipment

Balance (0.0001 gram and 0.01 gram)	Glass Funnels and Flasks
Drying Oven (105 - 110 degrees C)	Shaker
Microwave	Centrifuges
Desiccator	Filtering Apparatus
Timer (Second)	D-D Water Source
Tare Cans - Aluminum disposable	Beakers

PROCEDURE

1. A representative sample of the soil weighing at least 100 g is broken down by hand to pass a U.S. No. 4 sieve.' The sample is thoroughly mixed and repeatedly quartered to a suitable size.

2. Determine the water content of a small portion of the soil sample. Either microwave or conventional ovens may be used for this purpose. Be sure to exercise proper care if using the microwave to limit overheating of the soil sample and thereby limit destruction of organics or other heat sensitive materials.

3. Wet the membrane filter with D-D water. Place the membrane filter on an aluminum dish and dry to constant weight in a 110° C conventional oven. Cool in desicator and weight the membrane filter and dish. These now constitue a set which will be kept together throughout the remainder of the test.

4. Select a representative specimen from the original sample (item 1) that weighs 10 grams equivalent dry weight. Weigh and record the weight to the nearest 0.01 g.

5. Disperse the sample in a 250 ml bottle with 100 ml of D-D water. A swirling motion has been found to limit formation of dry masses at the bottom of the bottle.

6. Place bottle on Eberbach shaker table or equvalent and agitate for 30 minutes at high speed.

7. Remove the bottle and transfer to the large Universal floor model centrifuge or equivalent. Centrifuge at 4500 rpm for 15 minutes.

8. Filter the supernatant across the Whatman No. 541 filter. Use of hot D-D water will facilitate this operation.

9. If the filtrate is not clear then transfer the filtrate to a suitable High Speed Centrifuge container. Use the table model IEC-HT centrifuge or equivalent to continue the reduction process. Spin specimens at 60% power (12,000 rpm) for 15 minutes.

10. Pour off supernatant from high speed centrifuge and dilute to 200 ml with D-D water in a 250 ml beaker.

11. Add 2 ml concentrated HCl. The pH of the mixture should be acidic.

12. Bring the mixture to boiling slowly while stirring gently. Warm the Barium Chloride solution and add slowly to the boiling filtrate mixture. Upon adding to the mixture, a precipitant will be observed. Continue adding the Barium Chloride until the precipitation process is complete, then charge with and excess of 2 ml of Barium Chloride. Experimentation has shown that at least 10 ml of Barium

Soluble Sulfate Determination (1:10 method)

1. 10 g equivalent dried soil + 100 ml D-D water
2. Shake for 30 min. at high speed
3. Centrifuge at 4500 rpm for 15 min.
4. Filter the supernatant with hot D-D water and filter paper
5. If the filtrate is clear, then go to next step. | If the filtrate is not clear, then use high speed HT centrifuge for 15 min. at 60% max. speed
6. Dilute the supernatant to 200 ml with D-D water.
7. Add about 2 ml HCl
8. Heat slowly to boiling and, while stirring gently, add about 10 ml Barium Chloride.
9. Digest precipitate at 80 to 90 degrees C, preferably overnight
10. Wash precipitate with hot D-D water until the washings are free of Chloride
11. Dry and weigh the membrane filter with aluminum dish
12. Calculations and results