Evaluation of Calcareous Base Course Materials Stabilized with Low Percentage of Lime in South Texas

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Two base course materials commonly used in South Texas—limestone and caliche aggregate—were tested extensively to examine the effect of carbonate cementation due to the addition of small percentages of hydrated lime $Ca(OH)_2$. Testing included mineralogical analyses of the two materials, strength analyses in terms of Texas triaxial strength, Atterberg limits testing, scanning electron microscopy examinations, and resilient moduli determinations of the materials in the laboratory and in the field. Caliche and limestone base materials stabilized with either 1 or 2 percent hydrated lime were compared to control (unstabilized) materials in terms of the analyses listed previously. In addition, the falling weight deflectometer was used to backcalculate the moduli values of the pavement layers using the program MODULUS. The addition of 1 to 2 percent calcium hydroxide significantly increased compressive strength, as measured by the Texas triaxial test, and significantly increased resilient modulus over a wide range of deviatoric stress states. These engineering property improvements (measured in the laboratory were verified in the field through falling weight deflectometer testing.

The objective of this paper is to present the results of research designed to evaluate the effects of low concentrations of hydrated lime [$Ca(OH)_2$] on calcareous aggregates. This research evolves from the work of Graves (*1*), who demonstrated the strength increase of calcareous Florida highway base course materials due to carbonate cementation induced by the addition of lime. According to Graves (*1*), the addition of 1 percent $Ca(OH)_2$ to quartz and calcite sand mixes and cemented coquina base course materials increased strength by supplying more soluble Ca^{2+} ions, which caused the formation of carbonate cement.

Aggregate base courses have been stabilized with lime to upgrade the quality of marginal aggregates. For example, lime is often used in limestone aggregate base courses that have a significant plastic fines content. Caliche soil, which is also known as poor grade limestone, has also been stabilized in south Texas on a routine basis. Lime is used to (a) reduce the plasticity of the fines, stabilizing the consistency of the aggregate base over ranges of moisture fluctuation, and (b) improve strength and stability through pozzolanic reaction between the calcium-rich lime and the silicate-rich and aluminate-rich clay. However, lime stabilization of base course materials is often performed with a low percentage of lime, such as 1 or 2 percent, which, in most cases, is not enough lime to induce significant pozzolanic reactions. Besides, pozzolanic reaction occurs in the presence of clay minerals that are normally not a significant component of limestone and caliche aggregates. It is supposed that the strength and stability increase due to the addition of a low percentage lime in calcareous aggregates with little or no clay content is the result of carbonate cementation. This paper investigates the effect of carbonate cementation due to the addition of small percentages of lime to base courses in south Texas.

LITERATURE REVIEW

The literature typically classifies soil-lime reactions as being the result of the following mechanisms (*2*):

- Cation exchange, where sodium, magnesium, and other cations are replaced by the calcium cations in the lime;
- Flocculation and agglomeration, where flocculation of the clay particles increases the effective grain size and thus increases the strength of the matrix;
- Carbonate cementation, where lime reacts with carbon dioxide from the atmosphere to form calcium carbonate precipitates, which cement the soil particles; and
- Pozzolanic reaction, where the high pH environment created by lime solubilizes silicates and aluminates at the clay surface, which in turn react with calcium ions to form cementitious products primarily composed of calcium silicate hydrates or calcium aluminate hydrates, or both.

Carbonate cementation is of particular interest in this research because commonly used calcareous base course materials in south Texas contain few, if any, clay minerals and are normally stabilized with a low percentage of lime, which is often not sufficient for significant pozzolanic reaction. Calcium carbonate is known to be a natural cement. Because of constant fluctuation of chemical conditions in nature, calcium carbonate is dissolved and reprecipitated as a cementing agent (*1*). The reaction that takes place during the natural carbonate cementation process as suggested by Miller (*3*) is as follows:

$$CO_2 + H_2O + CaCO_3 = Ca^{2+} + H^+ + HCO_3 + CO_3^{2-}$$

This natural tendency toward the carbonation reaction can be enhanced by adding lime to the system, as was shown by Graves (*1*). In the experiments with different base course materials, Graves added 1 percent hydrated lime to dry sand mixes of various quartz and calcite proportions. Compacted specimens of lime and sand

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mixes were then soaked for various lengths of time and tested for Limerock bearing ratio (LBR). The LBR is used by the Florida Department of Transportation for strength measurements of various pavement materials. Cemented coquina materials were also mixed with 1 percent hydrated lime and then compacted, soaked, and tested for LBR strengths in a similar fashion. The LBR data showed significant strength increases of treated materials compared to untreated materials. However, it was observed that the strength gain was much higher for materials having a higher percentage of calcite and a lower percentage of quartz. Lime-treated high carbonate sands demonstrated strength increases as high as 450 percent following a 60-day soaking period. Using scanning electron microscopy (SEM), Graves (*1*) documented the presence of carbonate cement adhering to the carbonate particle surfaces and further demonstrated the lack of bonding of the carbonate material with the quartz particles.

Another experiment was conducted by Graves (*1*) to demonstrate the growth of calcite from a calcium hydroxide solution onto crystals of quartz and calcite. In this experiment, an SEM examination of quartz and calcite crystals (after they were placed in covered petri dishes with a calcium hydroxide solution, removed after 2 weeks, and dried) showed that the calcite precipitates nucleated on the calcite particle surfaces with an outward growth of scalenohedral crystals. On the other hand, the calcite precipitates did not nucleate onto the quartz crystal because the growth was not in contact with the quartz surface but instead nucleated from precipitation in the solution with small crystals growing downward and settling onto the quartz particle surface. This experiment (*1*) proved that the calcite cement formed as a result of carbonation reaction nucleates, which bonds to calcite particles, but not to quartz particles.

SCOPE

Two different base course materials commonly used in south Texas—limestone and caliche aggregate—were extensively tested in this research. The Texas triaxial test (Tex–117–E) was performed as a basic strength test on 48 samples using different lime contents and curing periods. The samples were cured in an environmentally controlled chamber where field conditions were simulated as closely as possible. Another 24 samples were tested for resilient modulus using AASHTO T–274–82. These samples were molded and cured in the same manner as those used for Texas triaxial testing. In addition, Atterberg limits, particle-size distribution, electron microscopy imaging, and X-ray diffraction analyses were performed in the laboratory on lime stabilized and unstabilized materials.

Field evaluation of stabilized and unstabilized base courses was also accomplished on representative pavement sections in two south Texas districts of the Texas Department of Transportation (TXDOT). Ten pavements were selected in these districts, which incorporated stabilized or unstabilized limestone, or stabilized caliche in the base course. No unstabilized caliche base course, however, was available for evaluation in the districts. Nondestructive falling weight deflectometer (FWD) testing was performed to determine in situ layer moduli for the pavements. Deflection data obtained from the FWD test were evaluated and a backcalculation technique was used to predict layer moduli from the deflection basins through the use of a program called MODULUS (*4*) developed at Texas A&M University.

MATERIALS

The two materials used in the study were limestone and caliche aggregates. Limestone was collected from a stockpile in Hearne, Texas, with an original source of Kosse, Texas. Caliche was collected from Corpus Christi, Texas. The two materials were tested in stabilized and unstabilized conditions. Commercially available hydrated lime was used as the stabilizer for both materials.

SPECIMEN PREPARATION AND LABORATORY PROCEDURES

The materials were oven dried at 60°C for 24 hr before moisture-density relationships were determined on aggregate-lime mixtures incorporating 0, 1, and 2 percent lime in accordance with Texas test method, Tex 113–E.

Texas Triaxial

Texas triaxial compression test specimens were prepared at the optimum moisture contents previously determined. Lime was mixed with the dry materials at rates of either 1 or 2 percent by dry weight. Water was then slowly added until the optimum moisture content was reached. After the soil-lime mixtures were thoroughly mixed with water, they were left in bowls covered with wet cloths for 2 hr. This was necessary so that the materials would retain essential moisture and would be uniformly wetted. After a mellowing period, triaxial specimens were molded using an automatic compactor. A 4,540-g hammer was dropped 50 times on each layer of four 50-mm-thick layers to produce a 152-mm diameter and 216-mm-high sample. The specimen heights were maintained as close to 216 mm as possible.

After compaction, each specimen was extruded from the mold with the help of a hydraulic pump. Extreme care was taken during the extraction process to ensure that the specimens remained intact with a constant shape and size. Immediately after extraction, a latex rubber membrane was placed on each specimen, keeping only the top of the specimen open to the atmosphere. This was done with the assumption that during construction in the field, the carbonation reaction primarily occurs when CO_2 from the atmosphere diffuses into the lime stabilized layer through the surface.

The specimens were then placed in an environmentally controlled chamber where a temperature of 25°C and a relative humidity of 80 percent were maintained throughout the entire curing period. Some specimens were cured for 28 days and some for 60 days to observe the effect of curing time and also to evaluate the rate of the carbonation cementation reaction. The specimens were subjected to overnight capillary wetting and were then tested in compression. The Texas triaxial test measures the compressive strength of the moisture conditional samples (through capillary rise) by applying a monotonic load at the rate of 0.38 m^3/sec until compressive failure occurs.

Resilient Modulus

Resilient modulus test specimens were prepared in accordance with AASHTO T274–82 using the same optimum moisture

TABLE 1 Particle Size Distribution and Calcite Content of Limestone and Caliche

Material Type	Particle Size Distribution (mm)			Calcite
	Sand (2-.0074)	Silt (.0074-.002)	Clay (<.002)	
Limestone	72.3	18.7	9.0	31.1
Caliche	55.5	15.7	16.9	23.2

contents and the same compaction energies as those used for the triaxial strength testing. The samples were cured in the same manner as those samples used for triaxial testing. The specimens were subjected to overnight capillary wetting before the resilient modulus test was performed using a materials testing system (MTS) machine, with 200 repetitions applied at each deviatoric stress.

Atterberg Limits

Liquid limits and plastic limits were determined on all stabilized and unstabilized materials following ASTM D4318–84.

Other Tests

Particle-size distribution analyses were performed at the Soil and Crop Science Department of Texas A&M University. In these analyses, bulk samples were dried in a forced-draft oven at 35°C and crushed between electric motor–driven wooden rollers. The soil fines were passed through a 2-mm diameter sieve and mixed, and a representative sample was stored in a liter cardboard carton. Any significant quantities of coarse fragments were soaked overnight in water and washed over a 2-mm sieve and then collected, dried, weighed and related back to the quantity of total aggregates as a percentage by dry weight (*5*). Particle-size distribution was determined in duplicate using the pipette method of Kilmer and Alexander (*6*). Ten gram samples were dispersed in 400 mL of distilled water, which contained 5 mL of 10 percent sodium hexametaphosphate by shaking overnight on a horizontal oscillating shaker. Aliquots of 5 mL were taken at a 5-cm depth following a settling time as given by the Stokes equation (*7*). The percentages of calcite and dolomite were determined using the gasometric procedure of Dreimanis (*8*).

X-ray Diffraction

X-ray diffraction (XRD) analyses were performed at the Geology Department of Texas A&M University. Sample preparation included grinding of material and fractionating into various sizes. Approximately 1 g of the clay-size fraction was applied to a slide with acetone. The XRD spectrum was evaluated to determine the presence of minerals, including calcite, quartz, and clay minerals.

Electron Microscopy

All SEM work was performed at the Electron Microscopy Center of Texas A&M University with a JEOL JSM–6400 Scanning Electron Microscope. The scope has a tungsten filament and a resolution of 3.5 nm, maximum magnification 300,000 ×. All work was conducted in the secondary electron mode. Sample preparation included mounting samples on carbon double-stick tape on aluminum stubs. A carbon glue also was used to improve adhesion and conductivity. The samples were coated with 300 Å of gold/palladium using a Hummer I Sputter Coater.

RESULTS

Mineralogical Analysis

Because the objective of this research was to investigate the strength increase due to carbonate cementation, a mineralogical analysis was performed on representative samples to check for the presence of clay minerals. Particle-size distribution revealed that both materials contained claysize particles (Table 1). However, X-ray diffraction analyses showed that both limestone and caliche materials contained primarily calcite and quartz and no apparent clay minerals. Absence of definable clay minerals indicates that

TABLE 2 Atterberg Limit Test Results for Limestone and Caliche with 0, 1, and 2 Percent Lime

Percent Lime	Limestone			Caliche		
	Liquid Limit	Plastic Limit	PI	Liquid Limit	Plastic Limit	PI
0	27.3	22.9	4.4	39.2	29.3	9.9
1	28.6	26.9	1.7	41.4	37.1	4.3
2	29.1	28.8	0.3	43.4	42.3	1.1

* PI = Plasticity Index

TABLE 3 Texas Triaxial Strength Data for Limestone

Percent Lime	28 Day Curing Period					60 Day Curing Period				
	Strength, MPa		c	ϕ	TC	Strength, MPa		c	ϕ	TC
	CP 0 KPa	CP 100KPa				CP 0 KPa	CP 100KPa			
0	0.65	1.16	0.15	41.2	3.2	0.23	1.13	0.04	52.4	3.2
1	1.10	1.50	0.25	39.9	2.0	1.10	2.00	0.18	53.6	2.0
2	0.80	1.60	0.17	47.0	2.0	0.87	2.00	0.13	55.9	2.0

TC= Texas triaxial classification
CP= Confining Pressure
c = Cohesion
ϕ = Angle of friction

there should be little, if any, pozzolanic reactions between the lime and aggregates.

Atterberg Limits

Atterberg limits test results are presented in Table 2. Liquid limits, plastic limits, and plasticity indexes were determined for limestone and caliche soil treated with 0, 1, and 2 percent lime. Liquid limits and plastic limits tend to increase with the increased percentage of lime, but plastic limits increase more than the liquid limits, resulting in reduced plasticity indexes.

Texas Triaxial Strength

Texas triaxial strength data show substantial strength increase due to lime stabilization. Triaxial strength data with the calculated cohesion and angle of friction for limestone and caliche bases are shown in Tables 3 and 4, respectively. The values for triaxial strength in both tables are the averages of two replicate specimens tested for each condition. Changes in triaxial strengths with percent lime for both limestone and caliche soil are shown graphically in Figures 1 and 2, respectively. Cohesion and angle of friction values were determined by plotting a Mohr-circle diagram. Significant increases in cohesion and slight increases in angle of internal friction were observed in all stabilized specimens. The cohesion and internal friction values determined in Texas triaxial testing are not pure values. This is because test peculiarities, such as the stiffness of the membrane and the nature of confinement affect these parameters. However, the relative values can be effectively used to rank the performance of various materials.

SEM Examinations

SEM images of materials taken from the triaxial samples showed evidence of carbonate precipitates leading to bonding of particles in stabilized samples. Figures 3 and 4 show images of unstabilized and stabilized limestone. Figures 5 and 6 show images of unstabilized and stabilized caliche. All images shown in Figures 3 through 6 are of samples extracted from the triaxial test specimens, which were tested at the same confining pressure.

Resilient Modulus

Resilient moduli values from laboratory tests are summarized in Tables 5 and 6. A typical plot of resilient modulus versus deviatoric

TABLE 4 Texas Triaxial Strength Data for Caliche

Percent Lime	28 Day Curing Period					60 Day Curing Period				
	Strength, MPa		c	ϕ	TC	Strength, MPa		c	ϕ	TC
	CP 0 KPa	CP 100KPa				CP 0 KPa	CP 100KPa			
0	0.14	0.78	0.03	45.9	3.7	0.21	0.81	0.04	44.7	3.7
1	0.48	1.11	0.09	46.5	3.2	0.32	1.07	0.06	48.6	3.2
2	0.63	1.53	0.10	53.3	2.5	0.64	1.57	0.10	53.3	2.5

TC= Texas triaxial classification
CP= Confining Pressure
c= Cohesion
ϕ = Angle of friction

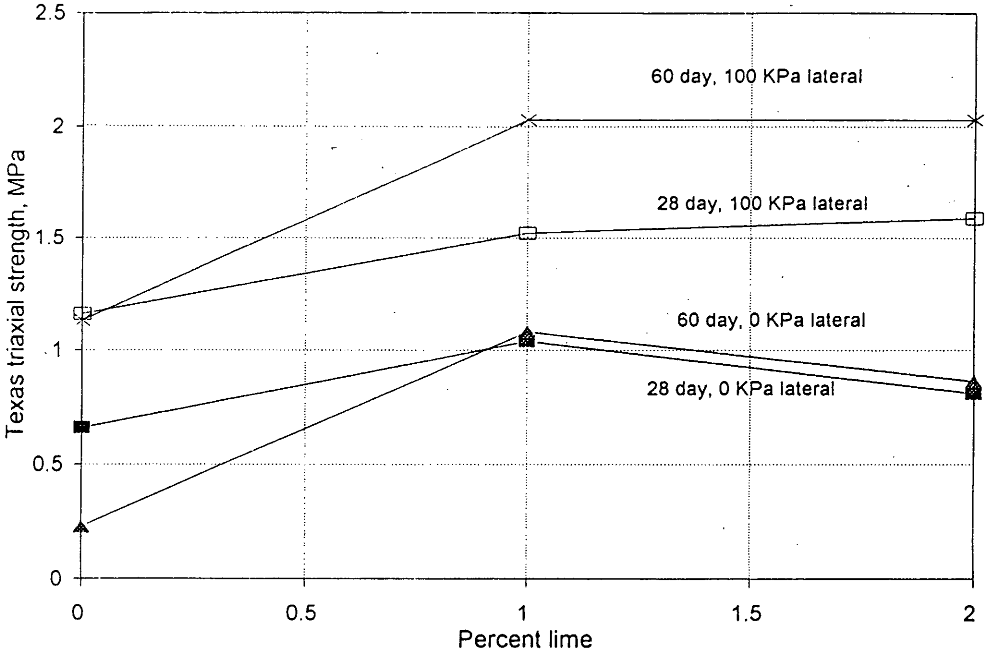

FIGURE 1 Effect of lime stabilization on Texas triaxial strength of limestone.

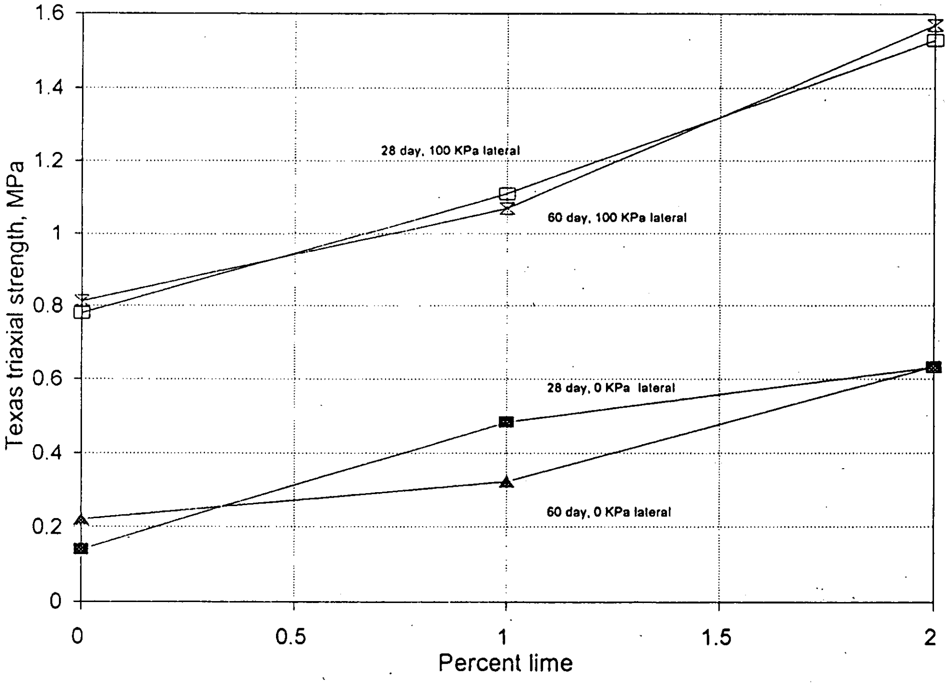

FIGURE 2 Effect of lime stabilization on Texas triaxial strength of caliche.

FIGURE 3 SEM image of unstabilized limestone (×370).

stress is shown in Figure 7. Plots showing the effect of change in deviatoric stress on resilient modulus have almost the same pattern for all specimens. Moduli values increased to a certain level of deviatoric stress and then decreased. Another plot showing the effect of stabilization on resilient modulus for both limestone and caliche soil is given in Figure 8.

Field data

In situ resilient moduli backcalculated from FWD data from 10 pavement sections with either lime-stabilized caliche, lime-stabilized limestone, or unstabilized limestone bases in the Yoakum and Corpus Christi districts are summarized in Table 7. Although the moduli values for all the layers of the pavements were backcalculated from the field data, only the base course moduli are shown in Table 7 because they are of primary interest. All of the caliche base courses have 200 mm of 4 percent lime stabilized natural soil supporting them. On the other hand, two of the limestone base courses have 150 mm of lime stabilized natural soil supporting them, and the third is supported only by natural subgrade.

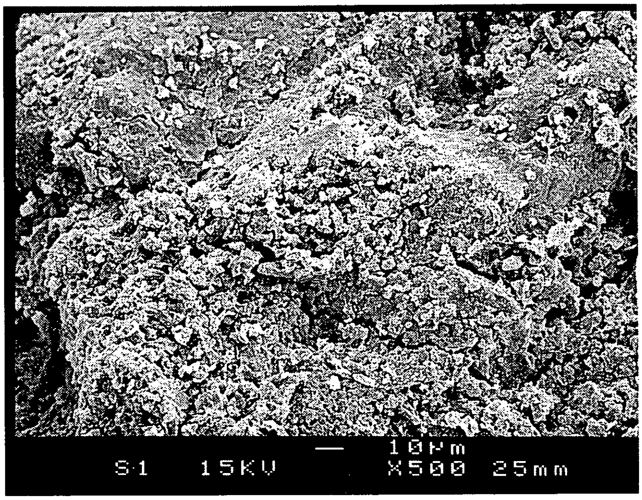

FIGURE 4 SEM image of stabilized limestone (×370).

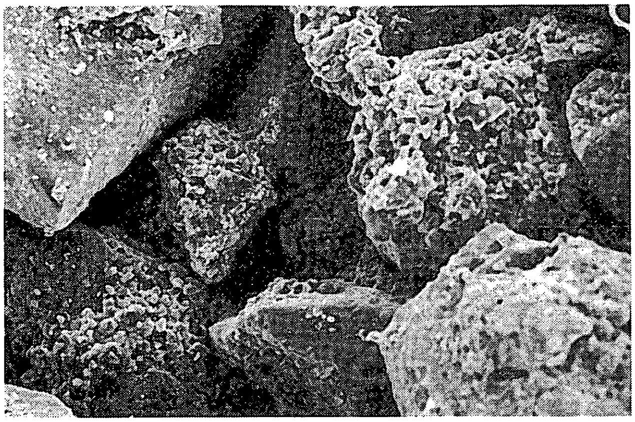

FIGURE 5 SEM image of unstabilized caliche (×370).

DISCUSSION OF RESULTS

It is evident that both of the base course materials tested have some very fine clay-sized particles and hence some degree of plasticity. But as the X-ray diffraction analyses reveal, clay minerals are not present. Therefore, pozzolanic reaction is not likely to occur in either material. The calcite contents of limestone and caliche are only 31.1 and 23.2 percent, respectively. According to the X-ray diffraction analyses, both materials are primarily composed of calcite and quartz minerals, and the percentage of quartz is much higher than calcite in both materials.

Carbonate cementation is substantially more effective with pure carbonate particles than with mixtures of calcite and quartz due to better bonding between carbonate particles and the carbonate cement (*1*). Even so, a significant strength increase is observed in Texas triaxial test data for both the quartz-rich limestone and

FIGURE 6 SEM image of stabilized caliche (×370).

TABLE 5 Laboratory Data of Resilient Modulus for Stabilized and Unstabilized Limestone

% Lime	Confining Pressure (KPa)	Resilient Modulus, MPa Deviatoric Stress (σ_d), KPa							
		7	14	35	70	100	140	170	200
0%	140	807	1040	1390	1630	972	200	159	138
	100	627	986	1250	1390	993	159	117	103
	70	786	876	1220	1280	345	124	97	90
	35	655	765	1070	579	110	90	69	76
	7	689	758	807	103	69	55	48	48
1%	140	827	1180	1760	2410	2490	2520	1770	558
	100	800	938	1740	2210	2300	1920	724	310
	70	724	841	1590	1750	1950	1280	359	221
	35	745	1070	1590	1500	1030	407	179	145
	7	689	910	1250	1140	303	186	117	117
2%	140	703	1080	1600	2670	2890	3590	3340	862
	100	958	1120	1790	2430	3210	2990	2480	1050
	70	945	1050	1700	2340	2780	2530	1980	738
	35	862	1070	1670	2270	2500	2220	1700	579
	7	883	993	1310	1870	1950	1570	545	414

caliche aggregates tested in this study. From Figures 1 and 2, it is obvious that the strength increase of the stabilized limestone has a different trend than that of caliche soil. For limestone, the strength gain is approximately equal for 1 and 2 percent lime treatment levels. The caliche soil continued to gain strength with a higher percentage of lime.

None of the materials showed significant strength increases for the longer curing period, (e.g., a 60-day curing period compared with a 28-day curing period), except that limestone showed a higher strength for 60-day curing when lateral pressure was increased to 100 kPa. According to a work by Wissa and Ladd (*9*), artificial cementation increases the strength of sand due to a large increase in cohesion and a slight increase in friction. This appears to be well-supported by the calculated cohesion and angle of friction values from triaxial strength data. Determination of the Texas triaxial classification of stabilized and unstabilized material showed that stabilization changes poor base materials into fair base materials.

SEM images of unstabilized limestone and caliche soil in Figures 3 and 5 show scattered quartz particles with some calcite on the surface. Voids around the quartz particles indicate a low level of cohesion and friction in these materials. Because of a low percentage of calcite, none of the materials experienced much self-cementation by carbonate reaction as self-cementation is directly proportional to the amount of calcite particles in the material (*1*). In Figures 4 and 6, however, the quartz particles are virtually covered with calcite deposits resulting in a denser matrix. Whereas some bonding might have occurred between the calcite particles and the calcite precipitate, cracks in the precipitate indicate unattached deposits of calcite onto the quartz particles. Thus, the increase in triaxial strength may have been dominated by filling the voids with the precipitate instead of by particle-to-particle cementing action. There is no evidence of fiber-like products of pozzolanic reaction in any of the images. This tends to confirm the strength increase by carbonate cementation only.

Lime-stabilized samples demonstrated laboratory-determined higher moduli than the unstabilized samples regardless of the material type. Backcalculated field moduli of the lime-stabilized limestone base course are higher than those of the two unstabilized base courses evaluated. Because there was no unstabilized caliche base tested, such a comparison is not possible, but the field data provide an idea of the range of moduli values for stabilized caliche base courses. The moduli values obtained were between 138 and 8410 MPa.

TABLE 6 Laboratory Data of Resilient Modulus for Stabilized and Unstabilized Caliche

% Lime	Confining Pressure (KPa)	Resilient Modulus, MPa Deviatoric Stress (σ_d), KPa 7	14	35	70	100	140	170	200
0%	140	140	152	135	129	125	123	119	110
	100	133	145	137	127	116	100	93	90
	70	128	145	132	124	98	90	81	69
	35	125	140	131	119	95	75	53	49
	7	119	138	125	115	48	45	39	36
1%	140	152	200	276	331	290	145	129	125
	100	148	200	262	310	248	142	129	122
	70	131	172	255	310	200	136	102	98
	35	138	165	207	221	159	100	90	89
	7	124	165	186	200	150	99	87	82
2%	140	165	241	283	345	290	195	164	150
	100	152	200	303	317	256	190	151	139
	70	159	205	300	331	218	158	135	126
	35	159	193	255	234	160	140	110	103
	7	145	179	221	214	125	113	95	85

CONCLUSION

The limestone and caliche aggregates evaluated contain 70 to 80 percent quartz and 20 to 30 percent calcite minerals. Although they have some very fine clay-size particles, they do not contain a significant quantity of clay minerals. Fine particles, however, give rise to some degree of plasticity, which tends to decrease with the addition of lime.

Significant strength increases occur in both limestone and caliche aggregates when mixed with a low percentage of lime. Limestone does not show any significant increase in strength when lime content is increased (e.g., 2 percent lime versus 1 percent lime). On the other hand, the caliche aggregate demonstrates a higher strength gain with a higher percentage of lime. The curing period has no significant effect on the stabilization of caliche aggregate, but the limestone shows higher strength for longer curing periods. Cohesion and friction values increased in the stabilized material, which gives rise to the higher shear strength of the material. Stabilization significantly increases the quality of the material according to the Texas triaxial classification scale.

SEM photomicrographs confirm the precipitation of calcite due to carbonate cementation between the calcite particles and between the quartz particles of the stabilized materials. Because of the high proportion of quartz to calcite particles in the materials, it is possible that most strength-gain through lime addition is primarily the result of calcite precipitates filling the voids among particles instead of cementing particles together. Absence of any fiber-shaped mineral likely to be produced during pozzolanic reaction indicates little or no pozzolanic reaction.

Low levels of lime (e.g., 1 to 2 percent) provide very significant strength and modulus improvements for marginal calcareous aggregates due to calcium carbonate formation. The calcareous aggregates used in this study contained significant percentages of quartz minerals. This contamination of parity probably significantly reduced the effect of lime-induced carbonation and bonding with the aggregate particles. A more pure carbonate aggregate should result in a higher level of strength gain and carbonation when lime is added.

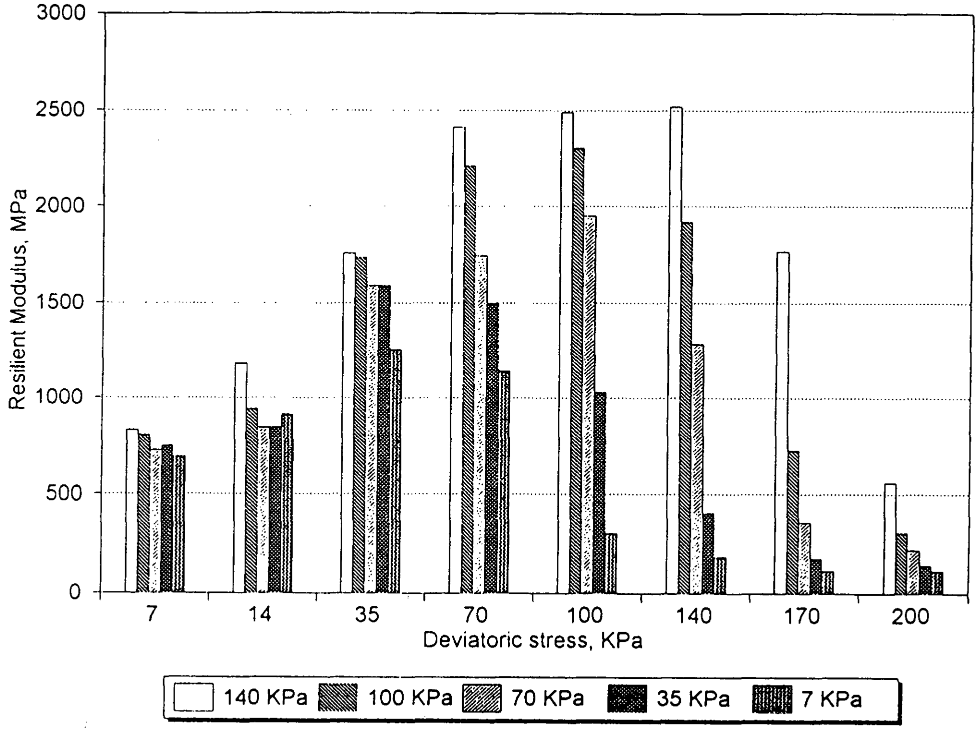

FIGURE 7 Change of laboratory resilient modulus with deviatoric stress for limestone with 1 percent lime.

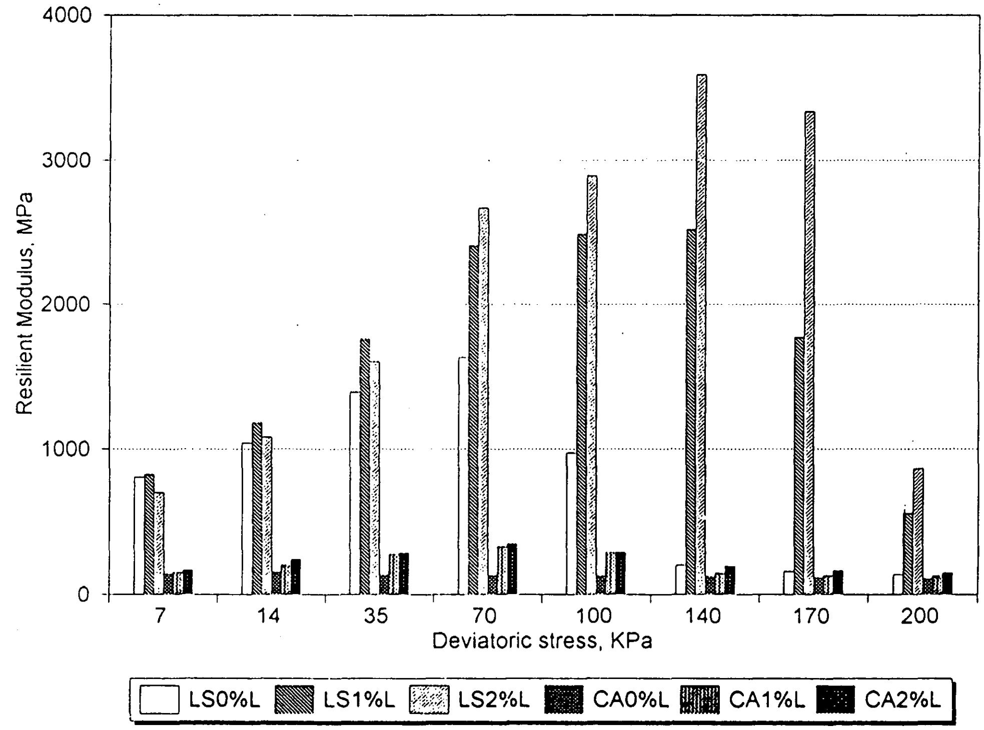

FIGURE 8 Resilient moduli for stabilized and unstabilized limestone and caliche.

TABLE 7 Backcalculated Moduli Values from FWD Data for Stabilized and Unstabilized Base Courses in Yoakum and Corpus Christi Districts of Texas

County	Highway	Description of Base Courses	Number of Deflection Basins	Average Modulus for Base Layers, (MPa)
Matagorda	FM1468	200 mm limestone with 2% lime	33	483
Fayette	SH71	150 mm limestone (unstabilized)	33	207
Nuces	SH286	660 mm limestone (unstabilized)	30	276
Refugio	FM136	150 mm caliche with 1.5% lime	30	138
Jim Wells	US281	300 mm caliche with 1.5% lime	30	207
San Pat.	US77	150mm caliche, 125mm caliche with 1.5% Lime	30	345
San Pat.	FM1069	200 mm caliche with 1.5% lime	30	8410
Nuces	BS-44C	250 mm caliche with 1.5% lime	30	621
Nuces	SH357	200 mm caliche with 1.5% lime	30	276
Nuces	FM24	300 mm caliche with 1.5% lime	24	207

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