Durability and Maintenance of Lime-Stabilized Bases

A motor grader mixes lime with the dry base material in the construction of an access road at Fort Sam Houston, Texas, in 1951. (Photo courtesy of Fourth Army Headquarters.)

Conrad M. Kelley

I recently made a detailed field study in the Southwest of numerous lime-stabilized military roads that have been in service for 25 years or longer. The main objectives were to determine the durability of lime stabilization, to ascertain the extent of maintenance during the period, and to develop guidelines for using lime stabilization in modern pavement design.

In highway construction today, the problems of reduced budgets, inflation, material shortages, and energy have brought recycling of pavements to the forefront. Yet, in the late 1940s and early 1950s recycling was used extensively by the Fourth Army Engineers in rebuilding more than 160 km (100 miles) of roads and streets at military bases in its five-state command. I was directly involved in the program, having been in charge of the Army materials laboratory at Fort Sam Houston, where we developed design recommendations.

At that time the road system at the southwest military bases was in dire need of repair—no small wonder since many of the roads were built during World War II, often on an emergency basis and with inexperienced personnel using marginal base materials and minimal pavement design. To rebuild all of the failed roads with new materials was beyond the military budget, so our laboratory investigated the feasibility of stabilizing the existing materials, a process that was then in its infancy.

Stabilizers studied included portland cement, asphalt, asphalt emulsion, and hydrated lime, the latter being a newcomer. During field investigations of the failed roads,

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The author retired in 1976 after serving as highway engineer for the National Lime Association for 21 years. He is a charter member of the TRB Committee on Lime Stabilization, which most recently authored TRB Circular 180, State of the Art: Lime Stabilization.

we determined that the instability was largely due to highly plastic clay, either being present in the original aggregate base material or having been pumped up by traffic from the underlying clay subgrade or both. Since laboratory tests indicated that hydrated lime was particularly effective with these highly plastic materials (plasticity indexes of 12 to 50+), we designed most of the renovation projects with lime (a few with the combination of lime and portland cement).

In stabilizing clay, lime performs two basic functions: (a) flocculation-agglomeration, which reduces the plasticity index and makes the soil workable and (b) cementation, which is a slow reaction that occurs after compaction and increases the soil strength and stability many times. The latter reaction helps create a firm working table during construction but, even more important, provides for durability and low maintenance during the life of the pavement.

The construction procedure used by the Fourth Army Engineers was relatively simple, consisting of the following steps:

1. Scarify existing distressed pavement to a depth of 15 to 20 cm (6 to 8 in) and pulverize old asphalt surfacing so that it can be incorporated in the reworked base course;
2. Spread hydrated lime, either bulk or bags, using 3 to 4 percent lime by weight;
3. Mix lime and aggregate, adding water as needed and using disk harrow, grader, or rotary mixer (windrow mixing with grader was popular then);
4. Compact layer at optimum moisture content, usually with light pneumatic rollers in thin lifts;
5. Moist cure for 4 to 7 d; and
6. Apply single or double asphalt surface treatment [or 4 to 5 cm (1.5 to 2 in) of hot-mixed asphaltic concrete for major arteries].

This method proved to be low cost since in-place aggregate materials were used, thus eliminating excavation and wastage, and only small percentages of lime were required. The typical lime stabilization cost was 30¢/m^2 (35¢/yd^2) for a 15-cm (6-in) stabilized layer, compared to 63¢/m^2 (75¢/yd^2) for excavating and replacing with specification flexible base material. According to Fuller and Dabney (1), the Fourth Army Engineers saved more than $300 000 in initial cost on road projects constructed from 1948 to 1951 at eight army installations. In retrospect, it is remarkable that the Roads and Railroads Branch was able to carry out so many lime projects, considering that lime stabilization was in its infancy; only the Texas Highway Department used it to any extent. In essence we were pioneers, having little experience to draw on.

That recycling-via-lime stabilization paid off in the long run is indicated from recent investigations of the old roads and by interviews with personnel familiar with road performance and maintenance. Projects visited were located at Fort Sam Houston and Fort Hood in Texas, Fort Chaffee in Arkansas, Fort Polk in Louisiana, and Fort Sill in Oklahoma. The following are brief comments on selected typical projects.

Fort Sam Houston

Zinn Road was the first lime project. Two blocks long, it was stabilized in 1948 with a 15-cm (6-in) reworked gravel base and single asphalt surface treatment. Several years later it was overlaid with 4 cm (1.5 in) of hot-mixed asphalt. When the road was recently widened, untreated base material was used, and some edge failure has developed. The road is still in service, however, and the original stabilized section has required little maintenance in 28 years.

The laundry parking area was stabilized in 1949 and is still in service. V. O. Fritze, retired post engineer, considers this to be the most impressive lime project on the post. It has required no maintenance, although some transverse and longitudinal cracks have developed.

The W. W. White and Nursery roads were rebuilt in 1951 with 10-cm (4-in) stone subbase, 10-cm (4-in) lime-stabilized gravel base, and double surface treatment. The roads were well traveled, are still in good condition, and require little maintenance.

The depot area roads were stabilized with 2 percent lime and 6 percent portland cement; the lime was mixed with the existing clay gravel first to make the soil binder friable for subsequent mixing with cement. The roads originally had single surface treatment and later received a 4-cm (1.5-in) hot-mixed overlay. The roads still give good service and carry heavy truck traffic. Some longitudinal and transverse cracking has developed, but this is characteristic of well-cemented base material.

Fort Chaffee

From 1949 to 1953 about 40 km (25 miles) of roads were renovated by using lime stabilization to depths of 15 to 20 cm (6 to 8 in). Since then, the post was deactivated several times so that for about 16 to 18 years the stabilized roads were on standby and no maintenance was performed. In spite of the latter circumstance (which can be damaging), they are still in good condition and have required only minimal repair and spotty resealing. However, part of the Third Avenue project did fail in 1975, soon after the post was reactivated to accommodate Viet Nam refugees. Failure was due to heavy rainfall pen-

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1 A vibratory roller compacts a lime-treated base at Fort Hood, Texas. This road was built 20 years ago and is still giving good service.

2 Fort Sam Houston, Texas, home of the Army Materials Laboratory where design recommendations for army roads and streets were prepared.

3 Spreading lime on a street at Fort Polk, Louisiana, in 1951, before mixing it into the base.

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etrating the numerous shrinkage cracks developed during the 1965 to 1975 deactivation period. That led to subgrade failure of the underlying clay. Had the road been sealed before the refugee traffic, the distress probably would not have developed. Well-cemented samples of lime-stabilized base taken from the distressed area broke at 11.7 and 12.5 MPa (1690 and 1820 lb/in^2), which is more than 30 times stronger than the original gravel; the material resembled lean concrete. The distressed section was ultimately rebuilt by using a 15-cm (6-in) lime-stabilized subgrade, 7.5-cm (3-in) stone subbase, 7.5-cm (3-in) black base, and double surface.

Fort Sill, Oklahoma

In 1949 the Fourth Army Engineers built one of the earliest lime-stabilized roads in Oklahoma—a 10-km (6-mile) section of North Boundary Range Road in which 15-cm (6-in) reworked base was incorporated. During the past 28 years the road has been sealed twice, but no repair work has been required. A small bare spot appeared near a bridge end, where the asphalt stripped,

but the exposed base showed no erosion. The appearance was like lean concrete.

Similar good performance was exhibited on 3 km (1.84 miles) of Meer's Road, stabilized in 1949, and on 3.2 km (2 miles) of Tower 2 Range Road, built in 1962. The latter has been used for heavy military traffic, including M60 tanks that weigh 48 Mg (53 tons). A similar 1962 project on 3.2 km (2 miles) of North Boundary Range Road showed some edge raveling, but that was due to the big tanks riding on the shoulders.

It is interesting to note that at Fort Sill the stabilized roads have maintained good grade alignment and uniform cross sections, whereas adjacent unstabilized roads have dips and bumps and nonuniform cross sections. There is also a marked difference in ridability detected at 48 km/h (30 mph).

Fort Polk, Louisiana

The first lime-stabilized road was built at Fort Polk in 1951 on a 5-km (3-mile) section of Texas Avenue connecting North and South Polk streets. Two percent lime and 6 percent portland cement was used in reworking the existing asphalt surfaced road to a depth of 23 cm (9 in). A year later engineers carried out a major program in which 265 000 m^2 (317 000 yd^2) of lime was used to stabilize various roads, streets, and parking areas. Then, in 1958 117 000 m^2 (140 000 yd^2) of tank hard stands and motor pool areas were lime stabilized, largely for accommodating 41-Mg (45-ton) tanks (2). Three sections were designed totaling 41 to 51 cm (16 to 20 in) in thickness, depending on subgrade condition. In all sections a 15-cm (6-in) stabilized base was included, for which imported clay gravel was used, and in one section the clay subgrade was stabilized to a 15-cm (6-in) depth.

In all Fort Polk projects (1951 to 1958) double surface treatments were placed. In 1965 the hard stand areas were overlaid with 4 cm (1.5 in) of hot-mixed asphalt. To date, all stabilized areas have performed with a minimal patching, except a 671-m (2200-ft) cut section of Texas Avenue built with lime-cement stabilization. That section developed shrinkage cracks allowing surface water to penetrate the clay subgrade, which failed. That section was rebuilt when 11.3 km (7 miles) of Texas Avenue were overlaid with 10 cm (4 in) hot-mixed asphalt to accommodate M60 tanks and M88 recovery vehicles. The subgrade problem in the distressed section was corrected by lime stabilizing to a 15-cm (6-in) depth and then placing a 30-cm (12-in) gravel subbase, 15-cm (6-in) cement-treated base, and 9-cm (3.5-in) hot-mixed asphalt surface.

Field tests performed on Texas Avenue before repaving revealed that the stabilized base had a California bearing ratio (CBR) of 139+ (reflecting the limit of field-testing equipment), whereas the subgrade CBR varied from 2 to 30. A sample of the original lime-cement stabilized base was recently tested, and it broke at 12.5 MPa (1820 lb/in^2), nearly three times the strength attained in 1952.

Fort Hood, Texas

The first lime project at Fort Hood was built in 1953. In 1958, 80 km (50 miles) of range roads were built on which a 10 to 15-cm (4 to 6-in) lime-treated, shell-aggregate base material was placed on existing open surface gravel or stone roads; the surfacing was a double asphalt treatment. One project, Old Copperas Road, was sealed in 1963, overlaid with 4 cm (1.5 in) of hot-mixed asphalt in 1965, resealed in 1973, and overlaid again in 1976. The road carries heavy traffic and is in excellent condition.

Old Georgetown Road was similarly maintained, except that it received no overlay in 1976; it is also in excellent condition. Post engineers consider this to be remarkable since good maintenance practice requires a seal every 5 years and an overlay every 8 years; yet, this road was not overlaid in 11 years and is still performing well.

West Range Road was also sealed and overlaid twice and was reported to carry as much heavy traffic as many primary roads in the Texas highway system. It is also in excellent condition.

Conclusion

Field investigations in the Southwest of old military roads and streets as old as 28 years indicate clearly that lime-stabilized bases are durable. The stabilized roads, built from recycled asphalt-surfaced pavements, are still in satisfactory to excellent condition, even though many were underdesigned according to current standards. Maintenance has been minimal.

The Fourth Army Engineers proved that recycling pavements by means of lime stabilization is a feasible, low-cost technique, in both initial and ultimate costs. Highway engineers can learn from the pioneering work of the Fourth Army Engineers in recycling pavements and thereby save taxpayers millions of dollars in the rebuilding of the vast highway network.

References

1. M. G. Fuller and G. W. Dabney. Stabilizing Weak and Defective Bases With Hydrated Lime. Roads and Streets, March 1952.
2. C. G. Van Dine. Low Cost Roads and Hardstands: Lime Stabilization Methods and Experience at Fort Polk, Louisiana. Roads and Streets, Sept. 1958.