Overview of Foundation Stabilization Technologies

RESEARCH PROJECT TITLE
Central Iowa Expo Pavement Test Sections: Phase I – Foundation Construction (InTrans Project 12-433)

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The Iowa Department of Transportation (DOT) worked with its research partners to design comparative pavement foundation test sections at the Central Iowa Expo Site in Boone, Iowa. The project was constructed from May through July 2012. Sixteen 700 ft long test sections were constructed on 4.8 miles of roadway with the following goals:

- Construct a test area that will allow long-term performance monitoring
- Develop local experience with new stiffness measurement technologies to assist with near-term implementation
- Increase the range of stabilization technologies to be considered for future pavement foundation design to optimize the pavement system

This tech brief provides a brief overview of the foundation stabilization technologies used on this project.

Site Conditions

The project site consists of thirteen roads oriented in the North-South direction (denoted as 1st St. to 13th St.) and three roads oriented in the East-West direction (denoted as South Ave., Central Ave., and North Ave.). Re-construction occurred on all roads except 13th St., which was paved with hot-mix asphalt (HMA) earlier in 2012. Construction of test sections required removing the existing chip seal surface and subbase, and 6 to 12 in. of subgrade. The subgrade consisted primarily of wet soils classified as CL or A-6(5). Pore water pressure measurements from cone penetration tests (CPTs) indicated ground water elevations at depths of about 3 to 6 ft below original grade across the site, and at about 12 ft or greater near drainage features.

Sixteen test sections were constructed on the North-South roads that used woven and non-woven (NW) geotextiles at subgrade/subbase interfaces; triaxial and biaxial geogrids at subgrade/subbase interfaces; 4 in. and 6 in. geocells in the subbase layer + non-woven geosynthetics at subgrade/subbase interfaces; portland cement (PC) and fly ash (FA) stabilization of subgrades; PC stabilization of recycled subbase; PC + fiber stabilization of recycled subbase with black polypropylene fibers and white monofilament-polypropylene fibers; mechanical stabilization (mixing subgrade with existing subbase); and high-energy impact compaction. Triaxial and biaxial geogrids were used at subgrade/subbase interfaces at select locations on East-West roads. Individual techs brief provide detailed information for each technology.

All test sections except one were topped with a nominal 6 in. of modified subbase material (MSB) classified as GP-GM or A-1-a (7% fines content); the 6 in. geocell section required 7 in. of MSB. Crushed limestone was used in the MSB layer on all North-South roads, and a mixture of recycled concrete and recycled asphalt was used in the MSB layer on all East-West roads. Six test sections (North and South sections of 6th St., 7th St., and 9th St.) consisted of 6 in. of recycled subbase material classified as SM or A-1-a (14% fines content) between the subbase and subgrade layers.

Foundation Stabilization Technologies

Woven and Non-Woven Geosynthetics

Woven and non-woven (NW) geosynthetics were used on 4th St. South and North segments, respectively, at the interface of subgrade and limestone subbase layers.

The woven geosynthetic material is shown in Figure 1. According to the manufacturer's product sheet, the woven geosynthetic material has an aperture opening size of #30 US sieve, a grab tensile strength of 350 lb, and a water flow rate of 40 gpm/ft^2.

The NW geosynthetic material is made

of a polypropylene, staple fiber, needle-punched material (Figure 2). According to the manufacturer's product sheet, the NW geosynthetic material has an aperture opening size of #70 US sieve, a grab tensile strength of 160 lb, and a water flow rate of 110 pm/ft^2.

Triaxial and Biaxial Geogrids

Triaxial and biaxial geogrids made of polypropylene sheet were used on 5th St. North and South segments, respectively, at the interface of subgrade and limestone subbase layers. The triaxial geogrid (Figure 3) has a triangular aperture shape and has a radial stiffness of 15,075 lb/ft at 0.5% strain. The biaxial geogrid (Figure 4) has a rectangular aperture shape and has an ultimate tensile strength of 880 lb/ft.

Geocell Reinforcement

Geocells are three-dimensional, honeycomb-shaped, soil-reinforcing geosynthetic material used for subbase layer confinement. The 4 in. and 6 in. high geocells used in this study are made of virgin, non-thermally degraded, high-density polyethylene with a perforated cell design.

Geocell test sections were constructed on 3rd St. with 4 in. and 6 in. geocells on the North and South segments, respectively (Figures 5 and 6). A NW geotextile, similar to the one shown in Figure 2, was placed at the interface of the geocell-reinforced base layer and the subgrade to act as a separation barrier. The geocell strips were stretched and stapled to adjacent strips using a pneumatic hog ring

Figure 1. Woven geotextile placed on subgrade as a separation layer

Figure 2. Non-woven geotextile placed on subgrade as a separation layer

Figure 3. Triaxial geogrid placed at the interface of subgrade and limestone base layers

Figure 4. Biaxial geogrid placed at the interface of subgrade and limestone base layers

Figure 5. Installation of 6 in. geocell over non-woven geosynthetic layer placed on subgrade

Figure 6. Close-up of 6 in. geocell over non-woven geosynthetic layer placed on subgrade

tool. After the geocells were stretched, limestone subbase material was placed and compacted using a smooth drum vibratory roller.

Fly Ash and Portland Cement Stabilization of Subgrade

Test sections with subgrade FA stabilization were constructed by mixing a target 10%, 15%, and 20% FA into 12 in. of subgrade on the 12th St. South, 12th St. North, and 11th St. South segments, respectively. The FA used in the 10% section was obtained from the Muscatine and Port Neal power plants, the 15% section was obtained from the Ames power plant, and the 20% section was obtained from the Port Neal power plant. A test section with PC stabilization was constructed by mixing a target 10% PC into 12 in. of subgrade on the 11th St. North segment. Note that the percentages are based on the dry weight of soil.

The FA and PC were distributed onto subgrade (Figures 7 and 8); a soil reclaimer was used to mix the subgrade soil with the stabilizer to target moisture content; and a padfoot roller was used to compact the stabilized soil mixture.

Portland Cement Stabilization of Subbase

The test section with recycled subbase PC stabilization was constructed by mixing a target 5% PC into 6 in. of recycled subbase material placed over subgrade on the 7th St. North and South segments (Figure 9). The process involved placing the recycled subbase material loosely on the subgrade, distributing PC onto the recycled subbase material, mixing and moisture conditioning the subbase material with a soil reclaimer, and compacting the stabilized subbase layer with vibratory smooth drum roller.

Figure 7. Distribution of FA on subgrade for mixing

Figure 8. Distribution of PC on subgrade for mixing

Portland Cement and Fiber Stabilization of Subbase

Test sections with PC and fiber stabilization of 6 in. of subbase were constructed on the 6th St. North and South segments. The stabilization process involved mixing a target 5% PC and 0.5% monofilament-polypropylene (MF-PP) white fibers in the South segment (Figure 10), and target 5% PC and 0.5% PP black fibers in the North segment (Figure 11).

Figure 9. Soil reclaimer mixing PC with recycled subbase material

Figure 10. Mixing white MF-PP white fibers into recycled subbase

Figure 11. Mixing black PP fibers into recycled subbase

A soil reclaimer was used to mix the cement and fibers with the recycled subbase material. The stabilized mixture was compacted using the vibratory smooth drum roller.

Mechanical Stabilization

A test section with mechanical stabilization was constructed on the 2nd St. North and South segments. The process involved scarifying the existing 6 in. of granular subbase layer and the underlying 6 in. of subgrade, mixing them thoroughly with a soil reclaimer (Figure 12), and compacting the mixture with a CS683 vibratory smooth drum intelligent compaction roller (Figure 13).

High-Energy Impact Compaction

A high-energy impact roller (Figure 14) weighing about 19,000 lb (drum weight) was used to rubblize and push down the chip seal coat and the existing granular subbase on the 10th St. North and South segments. The roller is a non-circular shaped tow-behind solid steel mold and was pulled by a tractor. The test sections were compacted using 20 roller passes with the high-energy impact roller and then using the vibratory smooth drum roller.

Cost of Foundation Stabilization

Figure 15 summarizes the combined material and installation costs for the test sections used on this project. The cost data were compiled from all six contractor bidder unit prices as requested in the plans and specifications.

Geosynthetics are at the low end of the cost range, chemical stabilization is in the intermediate range, and special products (fibers and geocell) are at the high-end of the range. The quantities used on this project ranged from about 1,500 ft^2 to 4,500 ft^2.

Figure 12. Mechanical stabilization

Figure 13. CS683 vibratory smooth drum intelligent compaction roller

Figure 14. High-energy impact roller

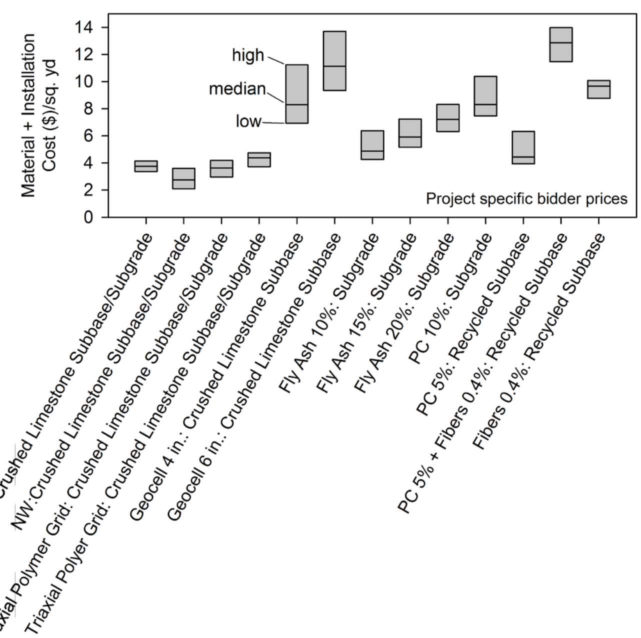

Figure 15. Bid prices for stabilization material + placement based on six bids