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Recent Case Histories of Permanent Geosynthetic-Reinforced Soil Retaining Walls

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Permanent geogrid reinforced soil retaining walls – US experience

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Abstract: The technology associated with the design and construction of Mechanically Stabilized Earth (MSE) walls reinforced with geogrids has advanced in the decade since its first use in the United States. Three case histories are presented which document this evolution.

INTRODUCTION

The use of geogrid reinforced soil walls has increased dramatically since their first use less than a decade ago. Major civil engineering structures have been designed and successfully constructed in North America. Three case histories are presented herein. They are: Gaspe Peninsula Reinforced Soil Seawall; Tanque Verde-Wrightown-Pantano Road Reinforced Soil Wall; and Illinois Tollway-Genesis Reinforced Soil Wall.

The summary results of field instrumentation programs for the Gaspe Seawall and Tanque Verde Walls are also presented. The monitoring program for Tanque Verde is a long-term program with data taken over a seven year period to date.

GASPE PENINSULA REINFORCED SOIL SEAWALL

In 1985, the Ministere des Transports, Quebec Canada (MTQ) let a contract for construction of a reinforced soil seawall using high density polyethylene (HDPE) geogrids and concrete facing elements, as part of a major program of road widening of Highway 132. This was the first North American Seawall incorporating geogrid soil reinforcing elements. As such, the Ministere of Transports initiated the Seawall as a trial project. A field monitoring program was

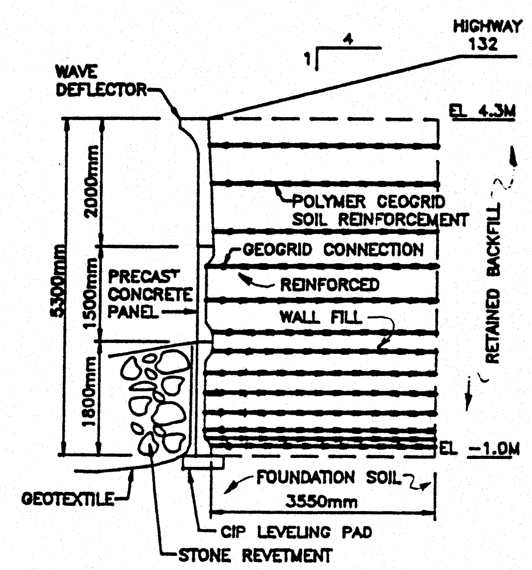

FIGURE 1. SEAWALL CROSS SECTION

established to facilitate evaluation of the performance of the seawall.

The seawall is 5.3m high, 99m long. The facing elements are 1.5 to 2.0m high and 3m wide. The top panels are shaped as wave deflectors (Figure 1). Tensar structural geogrids, SR2, were used as the reinforcement. For details concerning wall design see Berg, et. al. 1987.

Connection Detail

The design of the connection between the facing panel and geogrid reinforcement is a critical issue that must be addressed in order to assure satisfactory long-term performance of the seawall. For this project, short lengths of geogrid (geogrid tabs) were placed into the panels during panel fabrication. During wall erection, the tabs were mechanically connected to the main length of geogrid reinforcement using a pinned (bodkin) connection (Figure 2). Connection strength testing conducted at the same strain rate as ultimate strength tests on the geogrid indicated a connection strength equal to approximately 92% of the geogrid ultimate strengths.

Construction

A cast-in-place leveling pad used to facilitate erection of the precast concrete facing panels. Backfilling operations commenced after erection of the bottom panels. Backfilling operations continued until the elevation of the fill coincided with the first geogrid layer. The geogrid reinforcement was connected to the geogrid tabs using the HDPE connection pipe. The geogrid reinforcement was pretensioned to remove slack in the connection prior to additional fill placement. Pretensioning was

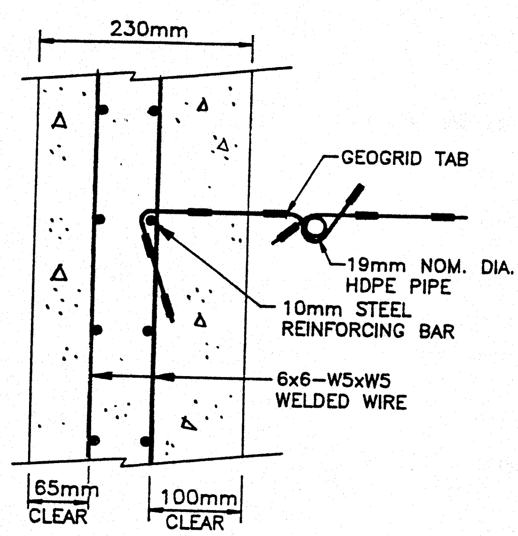

FIGURE 2. CONNECTION DETAIL

accomplished by using steel pry bars at the back edge of the reinforcement. The bars were inserted through the apertures of the geogrid, driven into the ground and then leveraged back. Thus induced tension in the geogrids, removing slack from the connection. Fill was then placed on the tensioned reinforcement. The above procedures were repeated until the wall was complete.

Two difficulties of note were experienced during the construction of this seawall. First placement and compaction of the reinforced fill immediately behind the facing panels was difficult and time consuming. Because of the shape of these panels, compaction equipment could not work effectively immediately behind the back of the panel. The second problem involved consistent pretensioning of the geogrid. A screw type struct braced against the concrete panel with a rake-head has effectively been used since construction of this seawall to provide more consistent pretensioning (Berg et. al. 1986).

Instrumental Monitoring Program

The instrumentation program included the following devices; strain gages on the geogrid, soil extensometers; clamp load cells; total stress cells; piezometers and thermocouples. Figure 3 shows the layout of the instrumentation. For a more detailed description of the monitoring program see Berg et. al. (1987).

Horizontal wall movements measured by surveying the wall face are plotted in figure 4 for level 3 of the two instrumented sections. This figure shows an increase in outward movement during backfilling operations behind the third level of the wall (Aug 1-6, 1985), and a second increase during completion of the roadway.

The horizontal wall movements were also evaluated by means of the extensometers. Assuming that the last anchored plate at the end of the extensometer has not moved, the movement of the wall face could be determined. Figure 4 shows a plot of the extensometer readings based on the above assumption. The general trends of deformation with time obtained by the extensometers and the survey are similar. However, the surveyed movements are larger than those of the extensometer by 11mm. This difference indicates that the back anchor plate, assumed to be fixed, moved outward. This is likely as the filling of a 3 to 4 meter wide space between the reinforced fill and old retaining wall was carried out after wall construction.

The strain gage data was also used to analyze wall movement by integrating the deformation over the lengths of reinforcement. This data is also presented in Figure 4. The movements deduced from the strain gages for level three are appreciably less than either the survey or extensometer. It is possible that this difference is due to slack in the geogrid connections.

Figure 5 shows the strain in the reinforcement as a function of distance from wall face and time. It is interesting to note that the maximum strain is below 1%. However, the long-term allowable strength of the

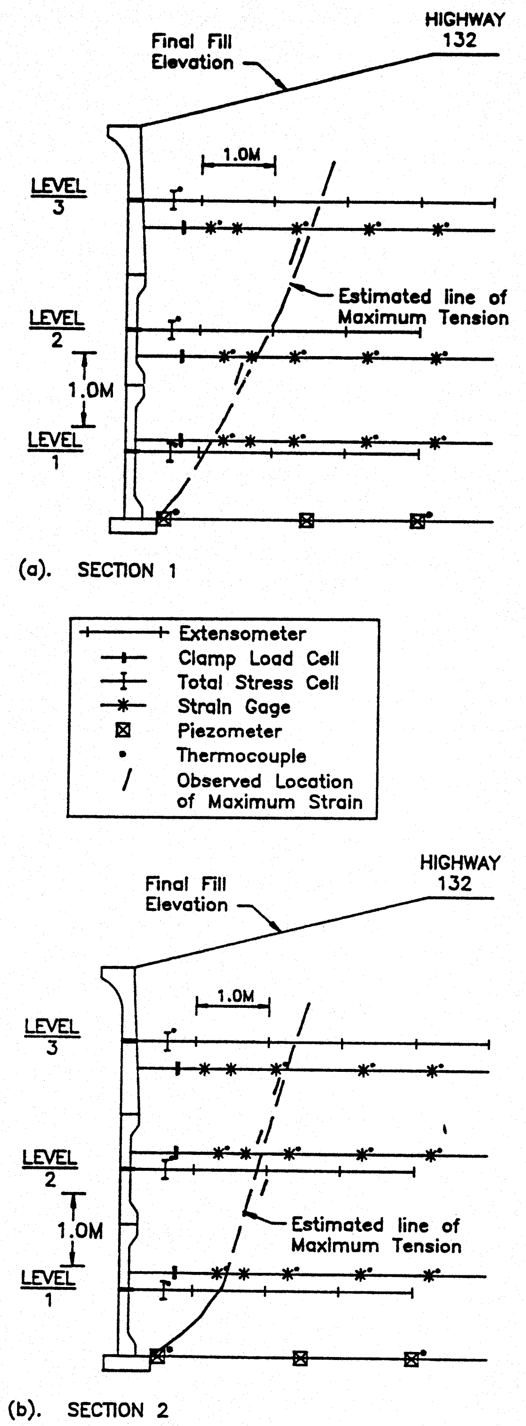

FIGURE 3. INSTRUMENTATION LAYOUT

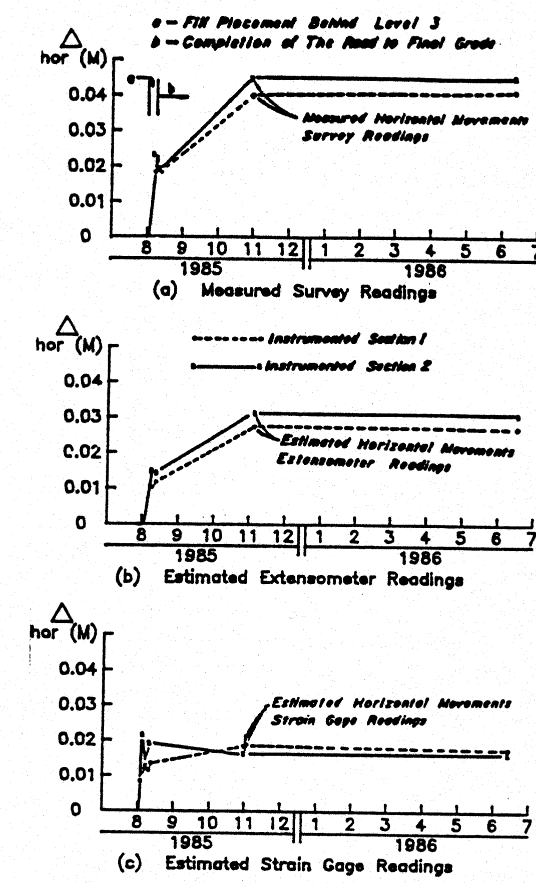

FIGURE 4. HORIZONTAL WALL MOVEMENTS INSTRUMENTATION LEVEL 3

reinforcement is based on an allowable strain of 10%, defined by in-isolation laboratory testing.

TANQUE VERDE REINFORCED SOIL WALL

In 1984 and 1985, forty-three separate geogrid reinforced soil walls were constructed in Tucson, Arizona (Tanque Verde Road project). These walls represent the first use of geogrid

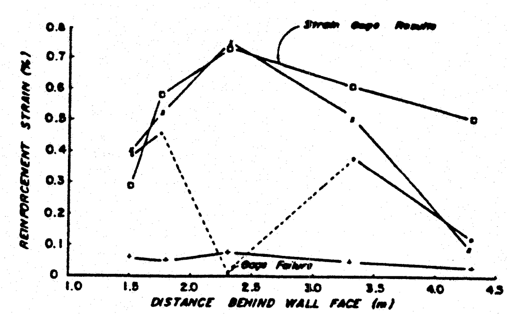

FIGURE 5. SEAWALL STRAIN MEASUREMENTS SECTION 2, LEVEL 3

reinforcement along with precast facing panels in a major transportation related MSE application in North America. This project was considered a demonstration project by the Federal Highway Administration. A construction monitoring and instrumentation program was conducted to evaluate the performance of the system.

The geogrid reinforced soil walls for this project are situated within limited rights-of-way at two grade separated interchanges. The walls extend approximately 1550 lineal meters and vary in height from 0.3 to 6.6 meters. The wall facings on this project are full-height precast concrete panels, 150mm thick and 3 meters wide. Tensar structural geogrids, SR2, made of high density polyethylene were used as the soil reinforcement. The geogrids were mechanically connected to the concrete facing panels.

Figures 6 and 7 show the layout of the monitoring system for the two wall panels that were instrumented. These panels (4.6 meters high) were selected for instrumentation because they are the highest walls sections on the project that are independent of three dimensional effects (i.e. near bridge abutments).

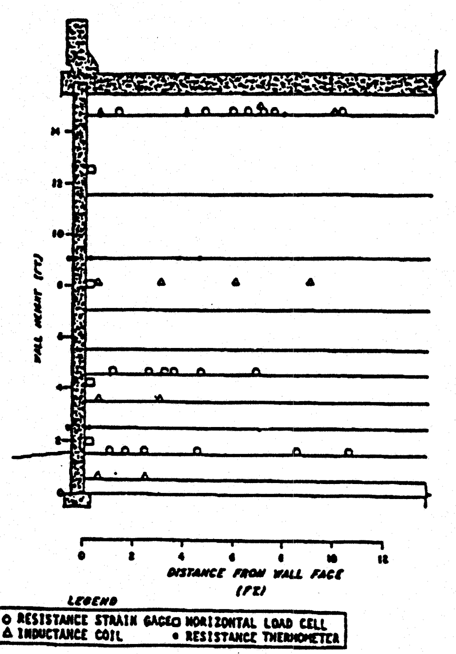

FIGURE 6. SCHEMATIC OF INSTRUMENTED EARTH REINFORCED RETAINING WALL (WALL 26-30)

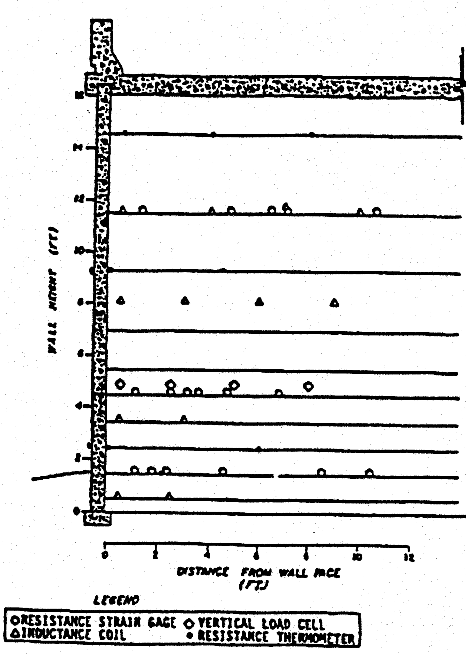

FIGURE 7. SCHEMATIC OF INSTRUMENTED EARTH REINFORCED RETAINING WALL (WALL 26-32)

The goals of the instrumentation program were to determine stresses and strains within the reinforced soil mass, movements of the wall panels, external and internal wall temperature and to make an over all assessment of the performance of the wall.

Construction Detail

The concrete facing panels were attached to the geogrid reinforcement by a connection system illustrated in Figure 8, that was composed of a geogrid tab cast into the facing panel, a PVC pipe connector, and a strip of the main geogrid reinforcement. The geogrid tabs were formed by embedding a short section of geogrid into wall panels during casting such that a "C" shaped tab protruded from the wall face. This connection was specifically designed with the intent of being capable of withstanding differential settlement between the panel and the reinforced fill without over-stressing the facing panel or the geogrid to facing panel connection.

Construction

Concrete facing panels were set on concrete leveling pads. Leveling bolts (Figure 9) were cast into the leveling pads. Panel alignment was achieved by placing the panels such that the leveling bolts penetrated the recesses in the bottom of the panels. The wall panels were held in place with adjustable erection braces. Note braces were used on this project in lieu of the corbels cast on the seawall face panels to facilitate compaction immediately behind this wall face. To minimize differential movement of the panels (due to rotations about the leveling bolts) during construction, the tops of adjacent panels were temporarily clamped together.
Granular wall fill was placed and compacted up to the elevation of the first geogrid layer. Fill within three feet of the wall face was compacted with hand operated lightweight vibratory compactors. At each reinforcement level the geogrid reinforcement was secured to the geogrid tab embedded in the wall using the PVC pipe connector.

The connection to the wall face was pretensioned by placing a timber wedge between the PVC pipe and wall facing to remove any slack. The geogrid reinforcement was also pretensioned by inserting steel "T" forks through the apertures of the geogrid and pulling taut.

Granular reinforced fill was placed on the geogrid and spread with a front end loader. After a lift of fill (200mm loose) was placed, the steel "T" forks and wedges were removed. When the fill height reached approximately 2/3 the height of the wall the erection braces were removed from the outside of the wall. Fill and geogrid placement continued in this manner until the wall was complete.

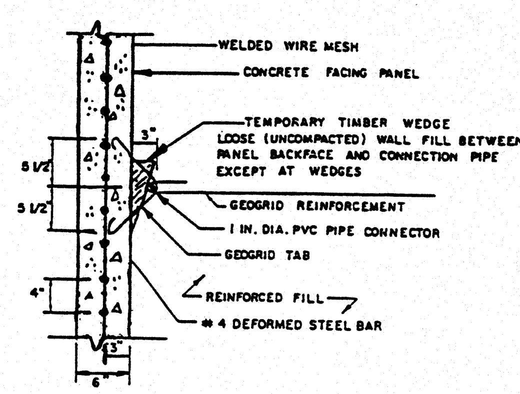

FIGURE 8. GEOGRID LOOPED CONNECTION USED ON THE TANQUE VERDE ROAD PROJECT

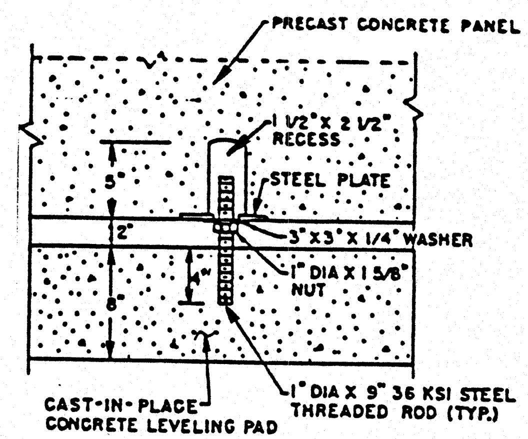

FIGURE 9. LEVELING BOLT FOR THE TANQUE VERDE ROAD PROJECT

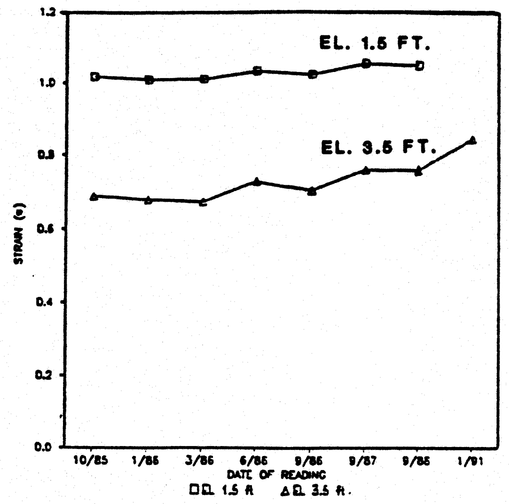

FIGURE 10. GEOGRID WALL FACE CONNECTION STRAIN GAGE DATA (WALL 26-30)

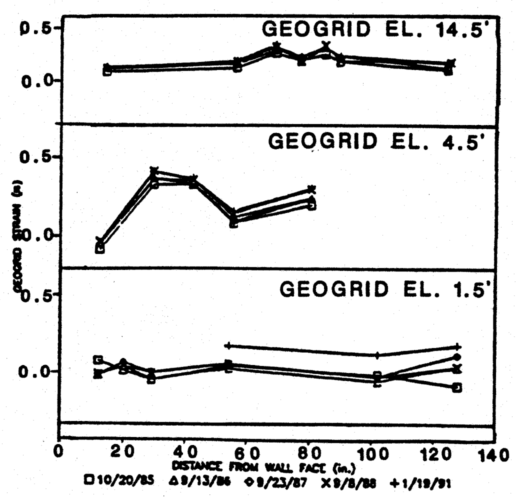

FIGURE 11. GEOGRID STRAIN GAGE DATA (WALL 26-30)

Instrumentation

A long-term performance monitoring program was established for this project, with the objective of measuring strain and corresponding stress in the geogrid reinforcement with time. Preliminary results (at the end of construction), 2 year results and 4 year results are presented by Berg et. al. (1986), FHWA (1989) and Fishman et. al. (1989) respectively.

The strain along the length of the reinforcement as well as the strain at the connection were monitored for this project. Strains were measured with resistance strain gages mounted on the connection tab (Figure 8) loops. Figure 10 presents results from both instrumented wall sections. Geogrid strain measurements were taken with resistance strain gages attached to the geogrids. Results of geogrid strains are presented in Figures 11 and 12. From these figures it is clear that geogrid strains over a seven year period of time are stable. The maximum measured strain in the reinforcement is below 1% for all layers of geogrid for both instrumented wall sections. The maximum strain at the connection between the geogrid reinforcement and wall face also appear to be stable with time, again with a maximum measured strain below 1%. The geogrid reinforcement for this project was designed based on an allowable strain of 10%, defined by in-isolation laboratory testing. After seven years of monitoring on this project the apparent factor of safety with respect to the allowable strain and corresponding stress in the geogrid reinforcement is 10.

ILLINOIS TOLLWAY - GENESIS REINFORCED SOIL WALL

In 1992, as part of a major expansion of Interstate 294 in metropolitan Chicago the Illinois Toll Highway Authority let a contract for the first phase of their expansion program. This contract includes approximately 8,500 square meters of "alternate retaining wall". These walls varied in height from 1.1 to 9 meters. The alternate systems allowed in the bid were; mechanically stabilized earth (MSE) walls reinforced with steel strips and grid, MSE wall reinforced with geogrids and concrete bin gravity retaining walls. The Genesis Highway Wall System™, a geogrid reinforced MSE walls consisting of Tensar structural geogrids and Keystone segmental concrete units was selected for this project (Figure 13).

The contract included 3.3 km of roadway widening and improvements. Five individual Genesis walls were required, totaling just under two kilometers in combined length. Existing embankments for I-294 were as high as 12 meters above adjacent property grade. With the limited right of way it was not possible, to widen the roadway without the use of retaining wall at many locations.

Connection Detail

The connection between the segmental concrete facing units and structural geogrid is shown in Figure 13. The connection strength is a function of the geogrid concrete interaction, geogrid gravel interaction and geogrid pin interaction. Design of the structural capacity of the connection was based on connection strength tests (Chewning and Collin (1991); Collin and Berg (1993)). The ultimate connection strength for this system was approximately twice the long-term design strength of the geogrid reinforcement.

Unlike the connection details for the precast panel walls, the connection for the Genesis Highway Wall System is easy to construct as the precasting of tabs into concrete is eliminated. All slack is readily taken out of the system and uniform compaction is easily achieved immediately behind the wall face.

Construction

The first step in the construction process was to place a 150mm thick concrete leveling pad. The leveling pad served no structural purpose. However, it did provide a means to insure proper placement and alignment of the first course of segmental concrete units.

Perhaps the most critical step in the construction of this wall system is to assure proper alignment of the first course of segmental concrete units. This is generally accomplished by use of a stringline and survey checks. Once this first course is set the segmental concrete units are backfilled with free draining unit fill. Reinforced fill is then placed and compacted behind the unit fill. This procedure is followed until the first layer of geogrid is required.

Geogrid reinforcement, precut to the desired length is placed, with the leading transverse bar of the geogrid hooked over the fiberglass dowels. The geogrid is pulled taut and staked prior to backfill placement. The backfill was compacted and the process continued until the top of the wall was reached.

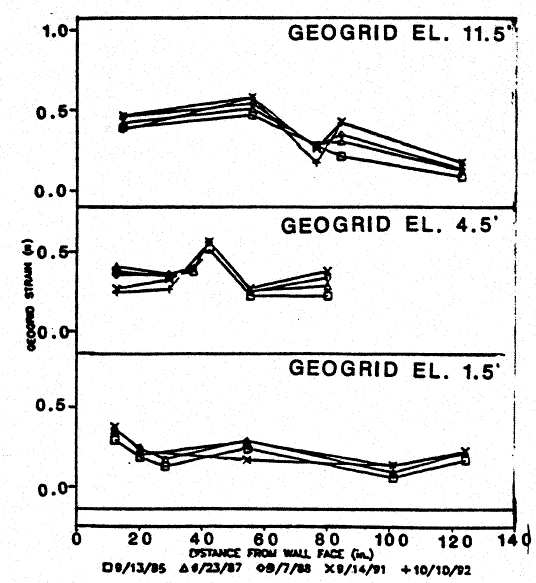

FIGURE 12. GEOGRID STRAIN GAGE DATA (WALL 26-32)

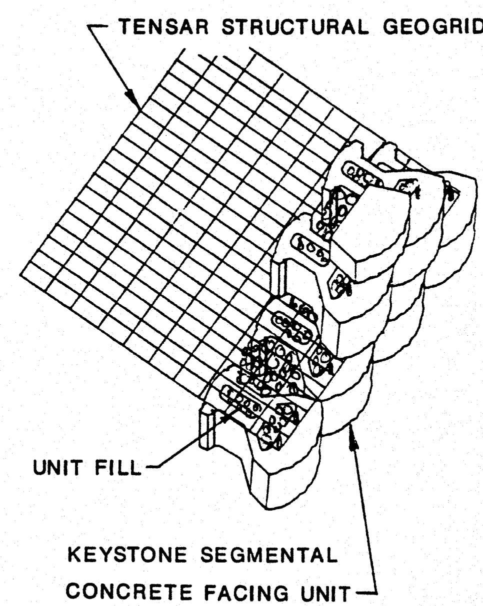

FIGURE 13. GENESIS RETAINING WALL

Conclusions

The use of geogrid reinforced mechanically stabilized earth walls has seen rapid growth in the last several years. This growth is a result of the well-documented performance of geogrid MSE walls and the development of segmental concrete units as the facing for these structures (e.g. Genesis Wall System). The construction of these segmental concrete faced MSE walls as demonstrated by the case history is both simple and fast to erect. No temporary bracing of the wall face is required, compaction immediately behind the wall face is simplified and the connection between the reinforcement and face provides excellent strength while being easy to construct.

REFERENCES

Berg, R.R., LaRochelle, P., Bonaparte. R, and Tanquay, L. (1987) *Gaspe Peninsula Reinforced Soil Seawall - Case History* Proceeding of Soil Improvement - A 10 year update, ASCE - Special Publication.

Berg, R.R., and Bonaparte, R., Chouery, V.C., and Anderson, R.P. (1986) *Design, construction and performance of two geogrid reinforced soil retaining walls* Proceedings of the 3rd International Conference on Geotextiles, Vienna, Austria.

Chewning, R.J., and Collin, J.G., (1991) *Evaluation of Geogrid to Wall Facing Connections for Modular Block Earth Retaining Wall System*, Proceedings XXII Ohio River Valley Soils Seminar, October 18, 1991 Lexington, Kentucky.

Collin, J.G., and Berg, R.R., (1993), *Connection Strength Criteria for MSE Walls* Transportation Research Board, 72nd Annual Meeting, January 10-14, 1993, Paper Number 931034.

FHWA Report No. FHWA-EP-90-001-005 *Tensar Geogrid Reinforced Soil Wall*, January 1989.

Fishman, K.L., Desai, C.S., and Berg, R.R. (1989) *Geosynthetic-Reinforced Soil Wall: 4 Year History*, Transportation Research Record 1330

Link, S. (1992) *Geogrids and Segmental Blocks Replace Steel and Precast Panels on Chicago Interstate* Geotechnical Fabrics Report ISSN 0882-4983, November.