Construction Considerations for Geogrid–Segmental Block Mechanically Stabilized Earth Retaining Walls

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The appearance of geogrid segmental block–faced mechanically stabilized earth retaining walls is often a primary reason for their use. Poor construction practice can negate this benefit. Poor control of wall alignment and batter or cracked facing units detract from the aesthetic appeal of these walls. Problems with alignment and cracked facing units are infrequent and of little importance to structural integrity, yet they may be perceived as symbols of instability or failure of the walls. Some common causes of these problems and their solutions are discussed.

The use of geogrid mechanically stabilized earth (MSE) retaining walls using segmental concrete block facing units has grown rapidly since their introduction in the mid-1980s. Initially developed as landscaping walls, segmental block walls had an aesthetic appeal and economy that brought their quick acceptance in the commercial market where walls from 10 to 30 ft high are often required. Their application is now accepted by public agencies, including state departments of transportation.

Geogrid MSE walls use polymer geogrids to reinforce a structural backfill and dry-cast segmental units as facing. The face units typically range between 4 and 12 in. in height, 8 and 18 in. in width, and 8 and 24 in. in depth. Units weigh up to about 100 lb. The units are dry-stacked, and the geogrid is placed between some courses as required for internal stability of the MSE mass and for connection of the facing to the stabilized mass. The various facing systems have different block geometries that allow or require a range of alignment characteristics including batter angles, curves, and corners. The texture and color for the face of the various face units also differ. A fractured, or split, face is popular for its aesthetics.

Aesthetic appeal is often a prime consideration in the selection of a segmental block wall over a conventional MSE wall using precast panels or a cast-in-place concrete wall. This appeal can be diminished by poor construction quality, two results of which are discussed in this paper: variable wall face alignment and cracking of the facing units. These problems generally have not affected the structural stability and performance of either the segmental block–faced walls that are the principle subject of this paper or the conventional precast panel–faced MSE walls with steel or polymer reinforcement that can experience similar problems. The problems have, however, concerned those who perceive a wall face with less-than-perfect alignment or with cracked units as a wall that is failing. This perception of failure can be very important, particularly in high-visibility situations.

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WALL FACE ALIGNMENT

A properly aligned wall will have level blocks set on horizontal courses that are stacked vertically or have uniform setbacks between courses. Each unit face will be in the same plane for straight sections of wall or in the same cylindrical or conical surface for curved sections, within the tolerance specified in the design (typically 15 to 20 mm).

The geogrid reinforcement can affect face alignment. If the geogrids are not well connected to the facing units, the units can move under lateral earth pressures or construction loads. If the geogrids are not uniformly pulled taut to preclude wrinkles, the facing units may move to take up the slack. The combination of variations in the geogrid geometry and thickness and the shape of the facing units may result in nonuniform support and tilting of facing units. Shims are used to prevent tilting.

The first key to proper alignment is construction of the leveling pad. For concrete leveling pads generally used in highway projects, the forms must be accurately placed and surface finished to a smooth and flat plane. Changes in elevation must equal the height of the masonry unit or the height of the masonry unit plus the thickness of geogrid material where reinforcement layers terminate at the step.

The placement of the first course of face units is the next key step. The units should be accurately aligned and uniformly spaced. The batter of the wall must be accounted for in positioning the lower course at the correct offset. String lines or other surveying techniques are essential tools. Where the face units have irregular split faces, as in Figure 1, the back edge of the unit, alignment pins, or lips are better reference points than is the face. Curves in battered walls require special attention since the radius of curvature changes with elevation. Partial compensation can made by spacing the lower course units slightly farther apart on convex curves and closer together on concave curves.

Fill placement and compaction operations can cause the face units to slide or rotate. As with conventional precast panel–faced walls, lightweight compactors should be used within 3 to 5 ft of the face. Any misalignment occurring during this phase of construction will be amplified in successive courses

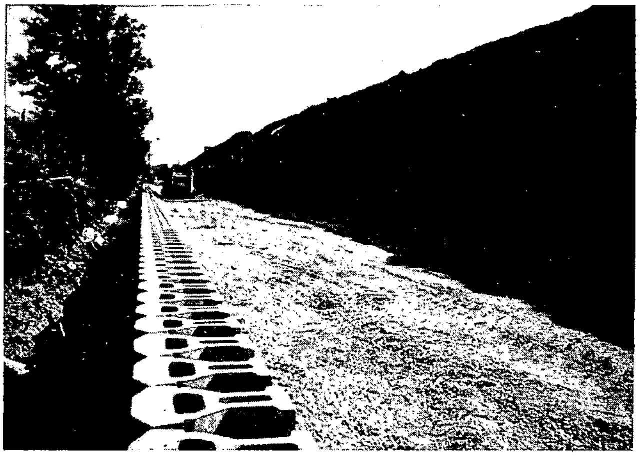

FIGURE 1 Face unit alignment.

if not immediately corrected or compensated for during placement of the next course.

Attempts to compact saturated fill can cause wall face movement. Compaction energy increases pore water pressures within the fill, which reduces the strength of the fill and redistributes tension stresses in the geogrid. Fill material should be placed at water contents within 2 percent of optimum.

Placement of the subsequent face unit courses is aided by the alignment features of the various segmental block systems: pins, tongue, and groove interlocks, or lips. These features aid but do not ensure proper alignment. Slight manufacturing variations in block geometry can alter the horizontal position and tilt of the next course. Any misalignment of the lower course will not be corrected automatically by the alignment feature of the system. Unless the alignment of each course is checked individually and minor misalignments are corrected or compensated for immediately, the misalignments tend to grow.

Curved sections of high, battered walls may require that the facing units be cut to allow for the changing radius of curvature and length of face. If not cut, batter can be lost on concave walls and the wall will "budge out" at the top or the standard overlap of each course will change as the curve is developed. High walls having short radii should be designed to be vertical where possible. If they must have a batter, the face units can be cut to fit, forming a neat vertical construction joint.

Inadequate drainage can be an especially serious problem for any type of wall. Poor drainage has resulted in significant wall face movement and, in some cases, complete failure. MSE walls are not normally designed for hydrostatic pressures in or behind the reinforced soil mass. When the soil becomes saturated, the external and internal driving forces increase while both the frictional strength of the reinforced fill and the interaction strength between fill and geogrid decrease. The result can be movement of the entire reinforced mass or movement within the reinforced mass.

An internal drainage system should be a part of the MSE design unless the reinforced fill is very free draining. The system should be capable of preventing the development of hydrostatic pressure behind the MSE wall mass and development of excess pore water pressure within the reinforced fill. The prism of drainage material traditionally placed immediately behind the facing units is not sufficient where backfill is not free draining. The drainage material should be placed behind the reinforcement so that the water is intercepted before it reaches the reinforced zone.

Internal drainage systems should be designed not only for the postconstruction conditions when surface water is well controlled (e.g., by pavement), but also for anticipated conditions during construction as well. Problems can develop during construction because of inadequate control of surface runoff. Surface water ponded on, or behind, the MSE wall can exceed the capacity of the internal drainage system. It is obviously also very important that the contractor controls surface water to prevent saturation of the MSE mass as prescribed in the specifications.

FLEXURAL CRACKING OF FACE UNITS

In segmental block walls, the masonry units are stacked, without mortar, directly on the previous course of blocks (except where geogrid reinforcement extends over the previous course). Where the rigid facing units are not supported uniformly, the vertical pressures from the weight of the facing units above are concentrated at the isolated points of contact between any single facing unit and the units above and below it. The unit may then be subject to bending and the development of flexural stresses. The tension and shear stresses developed can cause the facing units to crack. Tension cracks are more or less vertical and are usually located in the central portion of the unit. Shear cracks are diagonal and are located near the corners.

This situation is illustrated in Figure 2. In the top part of the figure, the subsidence of the two center facing units in the lower course has resulted in the center unit of the second course being supported at each end. High tension stress in the lower part of the unit can cause the vertical crack through the center of the unit. High shear stress can cause the diagonal crack over the lower corners. In Figure 2 (*middle*) the termination of the layer of geogrid has left a part of the overlying unit unsupported. Here, tension stresses develop in the top of the unit and a crack can form from the top to bottom. A similar situation occurs when the leveling pad step height is less than the height of the face unit [Figure 2 (*bottom*)]. Note that overlying units may also be affected, a fact that can lead to the cracking of several units in a column.

The widths of flexural cracks range from hairline to a few millimeters. The size depends on the degree of misalignment and lack of uniformity of support. In short-radius corners the cracks are wider because of the normal movements of the reinforced mass that occur during construction as the soil and reinforcement mobilize their shear and tension strengths. Since the wall faces move in different directions, the sections of unit on each side of the crack may move relative to each other. Crack widths up to 6 mm occurred in a few units during construction in a 90-degree corner of the north wall at the U.S. Postal Service (USPS) Combined Carrier Facility (*1*).

Flexural cracking allows a redistribution of stress concentrations on, and flexural stresses within, the facing units. After cracking occurs, stresses fall and the system stabilizes under the existing load. If no further load is added, cracks do not

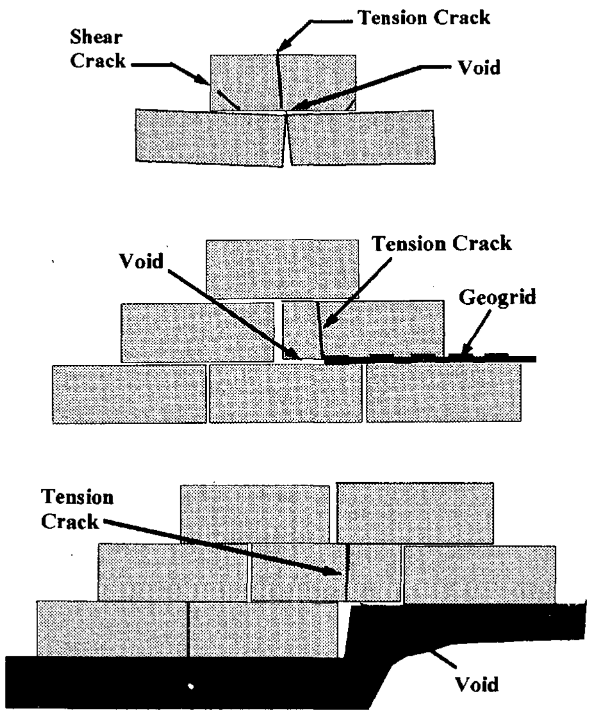

FIGURE 2 Flexural cracking causes and effects: *top*, nonplanar support; *middle*, geogrid termination; *bottom*, leveling pad step.

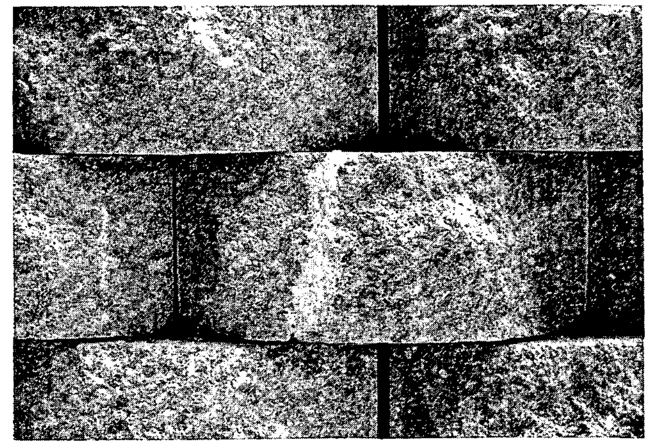

FIGURE 3 Grouted flexural crack.

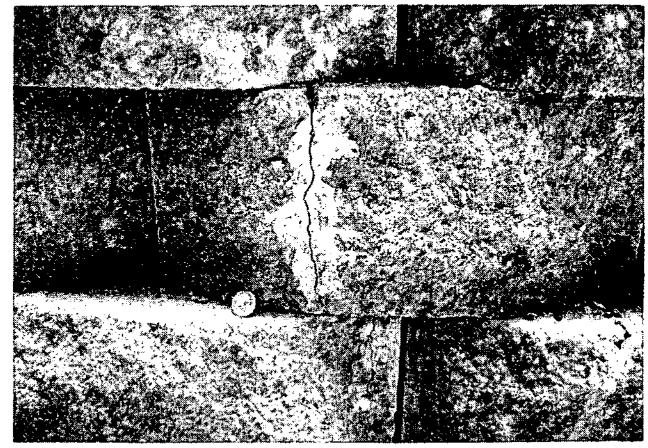

FIGURE 4 Recracked grouted flexural crack.

widen nor do new cracks form. This is shown in Figures 3 and 4, photographs of the USPS Combined Carrier Facility taken in June 1992, 2 years after construction of the wall. Figure 3 shows a unit in the straight section of the wall where it is about 30 ft high. A flexural crack was grouted shortly after the wall was completed. Note that it has not reopened. Figure 4 shows a unit in the 90-degree curve where the crack was 4 to 6 mm wide at the end of construction. It was grouted when the wall was completed. The crack redeveloped but stabilized at 1 to 2 mm when internal stresses reached equilibrium and movements ceased.

Flexural cracks permit a dry-stacked wall facing to adjust to stress concentrations between units and allow internal movements of the reinforced mass that must take place to reach a state of internal stress equilibrium. The cracks result in additional flexibility of the face that is beneficial at corners and for walls subjected to differential settlement. Relative movements between units and sections of cracked units are much less for the small modular units than would occur between large conventional precast panels.

Flexural cracks have not been observed to lead to deterioration of the wall face. The cracks do not grow or radiate, they do not allow loss of backfill, and they do not result in corrosion of rebar as they would in a steel-reinforced face unit.

It is important to note that the frequency of flexural cracking is quite low. A survey of recently completed walls on the Tri-State Tollway in Illinois found only six hairline cracks in a 23-m-long section of 7-m-high wall and no cracks in a similar 23-m section of 5-m-high wall. Nevertheless, because cracks do detract from the appearance of these walls, designers and contractors should make reasonable efforts to minimize their occurrence.

Flexural cracking can be reduced in frequency and severity by reducing stress concentrations. A uniform leveling pad is of prime importance. It must be level and smooth, and elevation change steps must be equal to the face unit height. A good example of a concrete pad is shown in Figure 5.

The wall designer should not terminate grid levels in high walls to avoid the situation illustrated in Figure 2 (*middle*). Where geogrid elevations must change, the change should take place at the edges of facing units and at only one course at a time. The contractor may have to cut the geogrid to achieve a close fit.

The cushioning effect of geogrids between courses is beneficial. The plasticity of the grid compensates for irregularities in the supporting surface. Polymer nets were used successfully as cushions to reduce flexural stress cracks in the higher sections of the USPS wall. A 2-ft-wide strip of net was placed between courses elevations where reinforcing geogrids were not specified. This approach is suggested for dry joints more than 20 ft below the top of wall. The cushion net may also be used where grid layers are terminated, as discussed in the preceding paragraph.

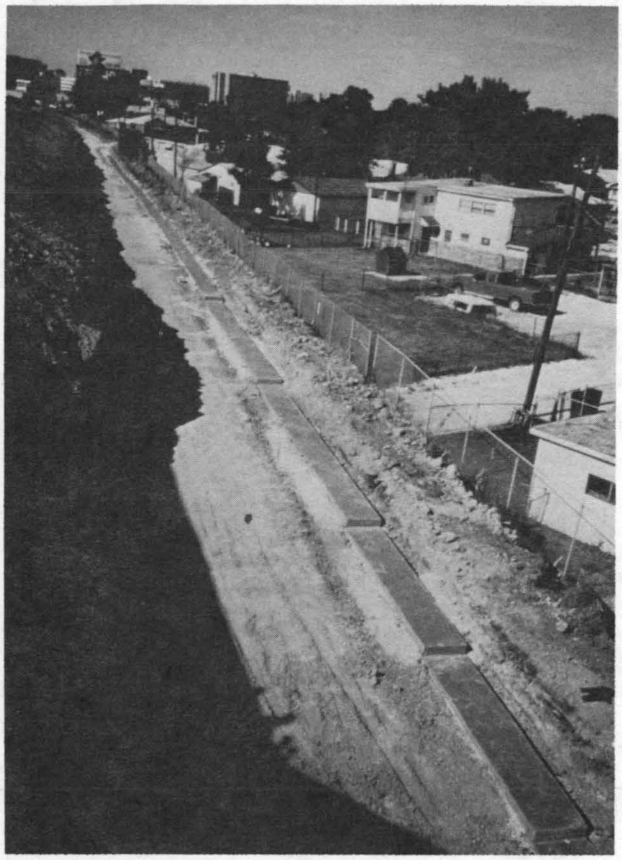

FIGURE 5 Leveling pad for facing units.

SUMMARY

Confidence in structurally sound segmented block walls requires that they appear to be structurally sound. They should be straight, they should be plumb, and they should present a competent face.

Designers can help by understanding the causes of alignment and face cracking problems and reducing them where possible. Careful attention to changes in reinforcement level continuity and leveling pad elevation will help provide uniform support of facing units. Their incorporation of cushion material between courses of high walls can reduce face cracking. Attention to internal drainage of the MSE during, as well as after, construction can help avoid expensive problems during construction.

Close, continuous control of construction operations will always remain necessary to ensure a well-aligned wall and to minimize cracking of the units. This will be the difference between a structure that works okay and one that performs as designed.

REFERENCE

1. Anderson, R. B., F. N. Boyd, and L. Shaw. Modular Block–Faced Polymer Geogrid Reinforced Soil Walls, U.S. Postal Service Combined Carrier Facility. *Proc., Geosynthetics '91 Conference*, Atlanta, Ga., 1991, pp. 889–902.

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