Independent Facing Panels for Mechanically Stabilized Earth Walls

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Analysis, design, and testing of independent reinforced concrete facing panels for mechanically stabilized earth (MSE) walls are reported. Panels are intended for use as full-height facing for a variety of mechanical reinforcements for fills, including geotextiles, polymer geogrids, and steel mesh. Panels provide a forming surface and permanent facing for MSE walls, but are independent of the reinforced fill. Panels are attached to stable MSE constructions with flexible anchors that limit the earth pressures that can act on panels. Loads on panels are minimal, and panel size and appearance may be tailored to the requirements of individual projects and sites, offering options in construction and in appearance of the finished wall not previously available. Independent facing was tested in a prototype MSE wall using Ottawa sand fill reinforced by a nonwoven geotextile. In the test, flexible anchors performed as expected; earth pressures on panels were bounded by anchor yield loads; and, beyond an initial loading determined by anchor strength, earth pressures on panels did not increase with added surcharge. The basis for design of independent facing systems, methods for stress analysis of independent facing panels, an outline of construction procedures for MSE walls with independent facing, options for anchors and panels in independent facings, and a test of a prototype independent facing panel are presented.

Mechanically stabilized earth (MSE) walls are used in many applications in highway projects. Their economy and performance, and the increasing familiarity of highway engineers with the technology are combining to make MSE walls more accepted and more widely used. But greater acceptance brings demands for greater adaptability in MSE designs. For example, the aesthetics of a wall are often important. Block facings and stacked panel facings are attractive, but some projects may need walls with monolithic fronts not broken by horizontal joints. In such cases, full-height facing units are required.

For block facings and stacked panel facings, each facing unit is attached to a few (typically two) layers of fill reinforcement. Full-height facing panels used in a conventional MSE wall are attached to all reinforcement layers. For full-height facing panels fabricated in reinforced concrete, attachment to all reinforcing layers can result in significant stresses in the panel. The high stresses, in turn, lead to designs with relatively heavy panels.

High stresses in full-height facing panels result from a deformation demand. During construction, deformation occurs naturally as reinforcements in the fill are mobilized. Deformation-driven stresses can be avoided if facing is able to move. This is the concept of independent panel facing. In this paper, a design for independently anchored facing panels is presented. Independent facing systems use flexible anchors to accommodate wall deformations and thereby reduce earth pressures on panels. Independent facings are compatible with many types of earth reinforcements, including geotextiles, geogrids, and woven wire products. The performance of an independent facing system is demonstrated in load testing of a laboratory prototype.

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FACING SYSTEMS

Facings for MSE walls protect fill reinforcements, anchor the tension in reinforcements, and contain the fill at the front of the wall. In anchoring tension and containing fill, facings are a structural design solution for the front boundary of the wall. The designs of block facing and panel facing systems are determined by these structural functions. The size and shape of facing units are adapted for simple, positive connection to fill reinforcement and for efficient construction. Wrapped-front geotextile walls use no units for facing but are still designed to anchor tensions and contain fill.

The comparison of block facing and wrapped-front facing reveals that the role of facing in MSE walls is a matter of design. Block facings, by design, perform all three roles of protection, anchoring, and containment. Wrapped fronts do not rely on facing units for anchoring and containment. The facings have different forms but equivalent functions. A rational approach to design of facing systems then is to identify the desired functions of the facing, to check that the facing is compatible with the load and deformation demands that will be placed on it, and to ensure that strength requirements of the MSE wall are satisfied.

The development of independent facing follows from a statement of function. First, to reduce the time required for a crane in MSE wall construction, it is desired that all facing panels be placed in a single operation not tied to the progress of the construction of the reinforced fill. The panels serve as a forming surface for the fill. Second, to achieve a monolithic appearance for walls, the elimination of horizontal joints in the facing is desired. Both requirements could be met by full-height panel facings.

Facing used as a front-forming surface for reinforced fill must be able to accommodate horizontal deformations as fill reinforcements are mobilized. The facing must have a mode of articulation to accommodate gradual, outward movement of the facing during construction. In block facings, articulation is the product of minor slips and rotations at joints.

Full-height panels have no joints and therefore no articulation in the manner of block facing. A second mode of articulation is available, however. Facing may tilt about its base. By tilting, facing can accommodate horizontal movement but will not conform to the reinforced fill. Because facing will not conform, the link between facing and fill must be flexible to preclude large restraining forces. This implies that a full-height facing panel should not be attached to fill reinforcements but instead should use flexible anchors that extend into the reinforced fill. Because panels are not attached to the fill reinforcements, facing is said to be independent of the reinforced fill. Tensions in reinforcements not anchored by facing must be anchored by other means such as a wrapped front. MSE walls with independent facing therefore comprise

- A stable reinforced fill, typically with a wrapped front;
- Independent facing allowed to tilt about its base but anchored to the reinforced fill; and
- Flexible connections between panels and the fill to limit restraining forces on the facing.

Proceeding from these, standard designs of reinforced concrete panels and deformable steel anchors for panels for walls 3.1, 4.6, and 6.1 m (10, 15, and 20 ft) high have been developed. The design examples presented in this paper are all reinforced concrete panels, although panels may be designed in other materials following the methods presented here.

INDEPENDENT FACING SYSTEMS

An MSE wall constructed with an independent facing is shown in Figure 1. This wall has full-height reinforced concrete panels tied to a reinforced fill with flexible steel anchors. Steel anchors are two-part loop bar anchors that accommodate vertical and horizontal deformation in the fill. Inelastic bending of the loop bars gives the two-part anchor an elastic or perfectly plastic tension response under increasing outward movement. Because the independent facing is not attached to fill reinforcements, the design of facing is effectively divorced from the design of the reinforced fill. The specific strength and deformation characteristics of a reinforced fill do not, within broad limits, influence the design of an independent facing system.

Structural Design of Panels for Facing

Facing panels are subject to earth pressures from the reinforced fill. Apart from loads in panels during handling and placement, earth pressures are the significant load demand on independent facing. The total thrust on independent facing is controlled by the yield load of anchors. Once the anchors reach their yield load, the facing panel will tilt and will not accept higher pressures. For stable reinforced fills, deflections cease once the fill reinforcement is mobilized.

Independent facing panels are designed for moments and shears due to earth pressures. The thrust on facing panels is known from anchor yield loads, but the distribution of earth pressures is needed to compute section forces. Here, it is noted that pressure distributions assumed in design often do not match actual pressure distributions in MSE walls. Where pressures on facings have been measured by load cells or could be computed from tension force in fill reinforcements, it is observed that earth pressures may have a triangular distribution, or may show a peak value near the midheight of a wall, or may show low pressure at midheight with higher pressures at the top and bottom of the wall (*1–7*). Therefore, to establish a design basis for independent facings, it is necessary to consider pressure distributions that satisfy statics, that provide conservative estimates of section forces in facings, and that are reasonable in terms of both accepted design methods (*8*) and the pressure distribution observed in experiments.

Three forms of pressure diagram are considered: a triangular pressure distribution, a rectangular distribution, and a parabolic distribution (Figure 2). For each pressure distribution, bending moments in independent facing panels are computed. In the figure, facing panels are height H and width b and are secured by four anchors placed in pairs at distances $H/4$ and $3H/4$ from the bottom of the wall. The peak lateral earth pressure for each diagram P_{Max} is determined by the yield load A of the anchors for facing panels. The value of P_{Max} is computed by using a moment balance about the base of the panel. The maximum earth pressure depends on the anchor yield capacity only, not on properties of the fill. For this value of maximum earth pressure, a restraining force R at the base of the panel must be present to satisfy equilibrium of horizontal forces. For a triangular earth pressure distribution, it is found that

$$R = 2A \qquad (1)$$

And the maximum bending moment in an independent facing panel subject to a triangular earth pressure is

$$M_{Max} = 0.27AH \qquad (2)$$

Similar procedures computing P_{Max}, R, and M_{Max} are followed for rectangular and parabolic pressure distributions (Figure 2). A triangular pressure distribution leads to the highest estimate of bending moment in panels. The triangular pressure distribution is

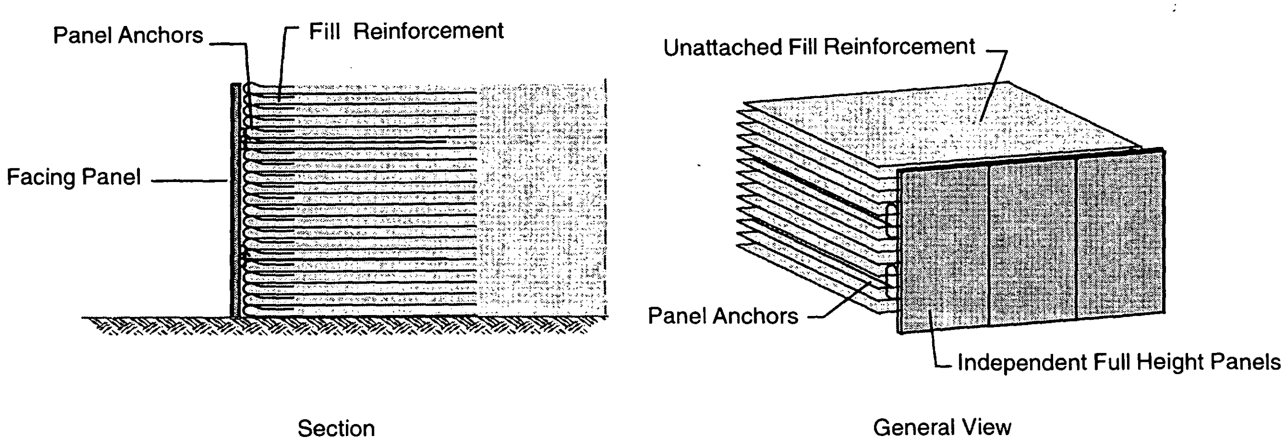


FIGURE 1 Independent facing system.

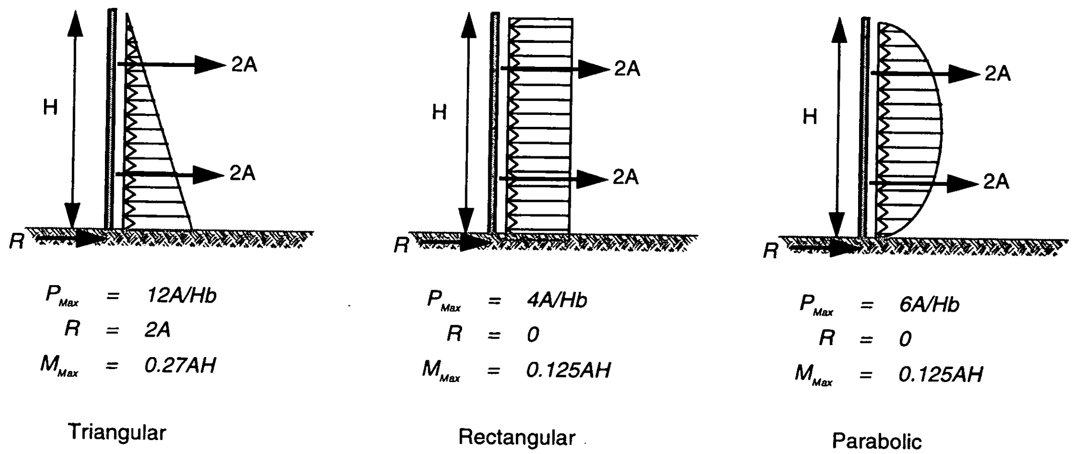


FIGURE 2 Trial soil pressure diagrams for design of facing panels.

adopted as a conservative design basis for facing panels in an independent system.

Taller panels use more anchors. For a vertical spacing of 1.5 m (5 ft) between anchors, panels at heights of 3.1, 4.6, and 6.1 m (10, 15, and 20 ft) use 4, 6, and 8 anchors, respectively. An increase in panel height corresponds to a fixed value of maximum earth pressure and an increase in maximum moment in panels. For all heights, moments and shears in facing panels are controlled by the yield load of the anchors. Results are shown in the "Statics" column of Table 1.

Structural Design of Anchors

Anchors for independent facing must allow movement of panels at moderate earth pressure, and must provide a permanent attachment of facing to the reinforced fill. The requirement for panel movement imposes an upper bound on anchor force that controls the earth pressures on facing panels. The need for permanent attachment of facing panels under self-weight, wind loads, and incidental loads imposes a lower bound on force in anchors. These two requirements may be met by anchors that yield at moderate load, that are capable of large movement during yielding, and that provide elastic response under external loading.

Three designs of anchors for panels have been developed (Figure 3). The first is a two-part design using a straight anchor bar in the reinforced fill attached to a loop bar on the facing panel. The straight anchor does not move; the loop bar provides articulation. The loop bar yields for outward tilt of facing panels. The vertical length of the loop bar allows the straight anchor to slip as fill settles. The loop bar may be bolted through a sleeve at the front of facing panels or may be attached to a plate at the vertical joint between panels. The bolted attachment allows an outward adjustment of panels that may be needed to correct the alignment of facing panels after wall construction is complete.

Figure 3 also shows two other designs for flexible anchors. The blind anchor is a two-part anchor in which the loop bar is welded to a plate embedment in the facing panel. This design offers no adjustment of panel position. The gooseneck anchor is a one-part anchor. The neck in the anchor bar yields to allow outward movement of the facing panel. Gooseneck anchors have limited tolerance for vertical settlement of the reinforced fill.

The tensile load capacity of anchors is determined by the plastic bending strength of the loop bar or gooseneck. Considering the two-part anchors, the minimum yield capacity of the anchor can be computed as

$$A = 4M_p/l \tag{3}$$

where M_p is the plastic bending capacity of the loop bar and l is its length. A two-part anchor will have its minimum strength when the straight anchor is located at the midheight of the loop bar. The anchor capacity will be higher when the straight portion is not at midheight. If the straight portion of the anchor is located at a distance l_a from the near end of the loop bar, the yield capacity of the two part anchor is

$$A = 2M_p\left(\frac{1}{l_a} + \frac{1}{l - l_a}\right) \tag{4}$$

In service, anchors may not be located at midheight of loop bars due to settlement of the backfill, and due to normal construction tolerances. It is necessary to recognize two estimates of strength of flexible anchors. The minimum anchor strength is used for design against external loads on panels. A higher estimate of anchor load using an assumed attachment at $l_a = l/4$ is used to compute earth pressures and to design the facing panels.

TABLE 1 Statical Relations and Design Data for Panels

Panel Height (m)	Anchors (count)	Statics P_{Max} (kPa)	Statics R (N)	Statics M_{Max} (N-m)	Anchor Force (N) Tilt A_{Stabl}	Anchor Force (N) Wind A_{Wind}	Anchor Force (N) Ult. A_u	P_{Max} (kPa)	Moments in Panels (N-m) Tilt M_{Stabl}	Moments in Panels (N-m) Wind M_{Wind}	Moments in Panels (N-m) Earth P. M_P	Moments in Panels (N-m) Ult. M_u	Panel Thick. (mm)	Rebars Gr 60 (Two Way)
3.1	4	$3.9\,A/b$	$2A$	$0.82A$	56	2,670	3,540	5.7	-27	-1,020	2,920	3,240	127	#4@305 mm
4.6	6	$3.9\,A/b$	$3A$	$2.0A$	67	2,670	3,560	5.7	-33	-1,020	7,300	8,110	152	#4@203 mm
6.1	8	$3.9\,A/b$	$4A$	$3.5A$	67	2,670	3,560	5.7	-33	-1,020	12,800	14,200	152[a]	#4@203 mm

[a]Panel with two 254 mm deep webs.

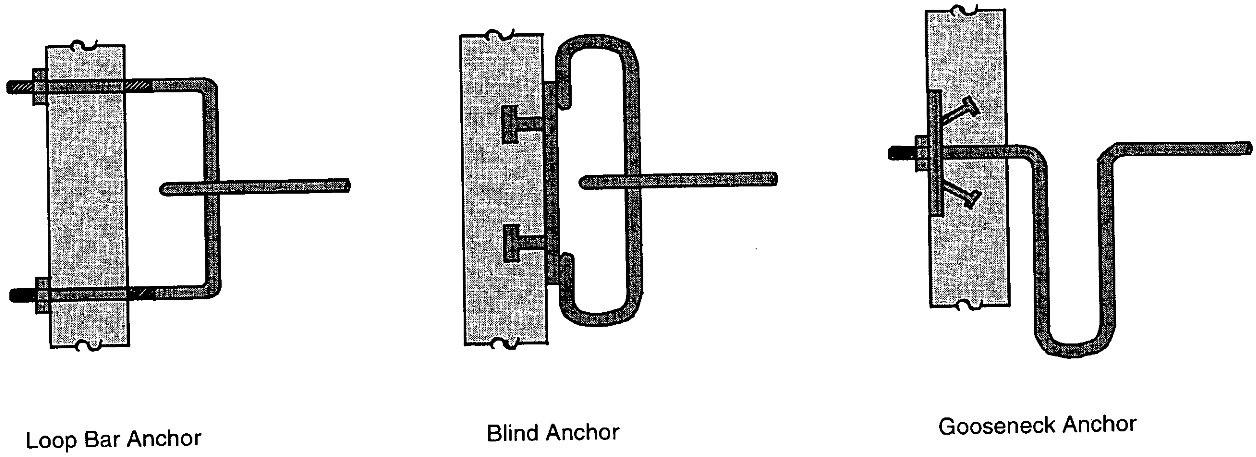


FIGURE 3 Flexible anchors for independent facing systems.

External load demand on anchors are wind and accidental eccentricity of panels. Wind load demand on a single anchor, A_{Wind}, is computed as

$$A_{\text{Wind}} = wbH/n \tag{5}$$

where

w = design wind pressure,
b and H = panel width and height, and
n = number of anchors connected to the panel.

If panels are eccentric (tilted) and if the eccentricity is outward, then a force in the anchors A_{Stabl} is required to maintain stability of the facing. Figure 4 shows three conditions of panel eccentricity: a 3.1-m (10-ft) tall full-height panel tilted outward by an amount e, a 6.1-m (20-ft) tall full-height panel tilted outward by an amount e, and a 6.1-m (20-ft) tall stacked panel system displaced in the first tier. For full-height panels, the anchor force required for stability is computed as

3.1-m (10-ft) panel using four anchors

$$A_{\text{Stabl}} = \frac{We}{4H}$$

6.1-m (20-ft) panel using eight anchors

$$A_{\text{Stabl}} = \frac{We}{8H} \tag{6}$$

where W is the dead weight of the facing panel. Using an estimate of e/H as 1/100, the anchor loads for stability can be expressed as

3.1-m (10-ft) panel using four anchors

$$A_{\text{Stabl}} = \frac{W}{400}$$

6.1-m (20-ft) panel using eight anchors

$$A_{\text{Stabl}} = \frac{W}{800} \tag{7}$$

Design of anchors for independent facing proceeds by computing the required minimum anchor loads for wind and eccentricity loads and selecting an anchor with a yield capacity that exceeds these demands by an adequate margin of safety. In this study, the strength design provisions of the AASHTO specifications are followed (*9*). The yield capacity of anchors is then used to compute the earth pressures on facings. Example designs are presented in Table 1. The columns labeled "Anchor Force" show the load demands and design load for anchors. The wind load is taken as 1.4 kPa (30 psi), and panels are assumed to be normal weight concrete panels 2.4 m (8 ft) wide. Panels are 127 mm (5 in.) thick for 3.1 m (10 ft) height, and 152 mm (6 in.) thick for 4.6-m (15-ft) and for 6.1-m (20-ft) panels. Wind load controls the strength design of anchors. Table 1 lists bending moments in panels for tilt, for wind, and for anchor-controlled earth pressures. The table also lists rebar requirements for concrete panels. For panels, a concrete compres-

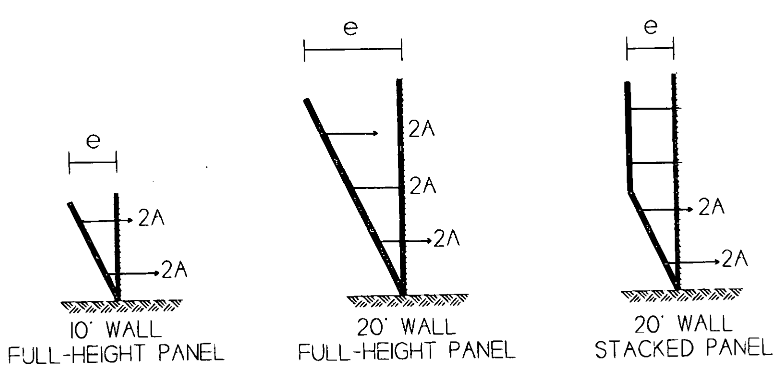


FIGURE 4 Stability of independent facing systems.

sive strength of 35 MPa (5,000 psi) and a rebar tensile strength of 413 MPa (60 ksi) are assumed.

Structural Design of Reinforced Fill

Independent facing panels are not attached to reinforcements in the fill, do not provide an anchorage for tensions in fill reinforcements, and offer only a limited capacity for retaining fill at the front of an MSE wall. MSE wall constructions may take advantage of facing panels as a forming surface during construction, but otherwise MSE walls using independent facing panels must be stable within themselves. Standard design procedures are available to ensure that MSE walls have adequate margins of safety against external failure mechanisms (i.e., sliding, bearing failure, and overturning) and against internal failure mechanisms, including rupture, pullout, and degradation of reinforcements. In addition, methods and analyses are available for designing MSE walls to satisfy limits on defections.

Construction of Independent Facing Systems

Construction of MSE walls with independent facing follows a sequence shown in Figure 5. Here, footings for panels are placed, and facing panels are moved into position and braced. Panels are keyed into footings, but there are no other attachments and no rebars across the joint. Bracing at the front of panels is removed when there are a sufficient number of anchors in place to support the facing.

Panel movement during construction may result in an unacceptable facing alignment. Two measures in construction offer remedies. At initial placement, facing units should be battered in anticipation of a horizontal deformation. Inward batter on the order of 50 to 75 mm (2 to 3 in.) per 3.1 m (10 ft) of wall height is typical. After wall construction is complete, anchor connections may be loosened at the front of the wall and panels pulled forward if necessary to improve alignment.

Laboratory Demonstration of Independent Facing for MSE Walls

A full-height independent facing panel was used in the construction and load testing of two prototype walls in the laboratory. The prototypes were geotextile-reinforced walls approximately 3.1 m (10 ft) tall, 1.2 m (4 ft) wide, and 2.4 m (8 ft) deep. The prototypes each represent a slice of a wall of large lateral extent. The test fixture is a plexiglass box supported by steel strongbacks. It is equipped with greased membranes along the sidewalls to allow the fill to move with little side friction. Details of the test fixture are reported elsewhere (*10*). A general view of the prototypes is provided in Figure 6. The wall tests had two purposes: a demonstration of the performance of an independent facing system, and an investigation of the use of MSE walls with unwrapped reinforcement at the front. Fill reinforcements in these tests were neither attached to facing panels nor wrapped.

The two tests differed in fill material and in the sequence of loading. The first test used an Ottawa sand fill and the application of surcharge in several steps to a maximum of 138 kPa (20 psi). This test demonstrated the performance of independent facing and flexible anchors. The second test used a fill of Colorado DOT Class 1 road base. Surcharge was again applied in steps, but at each new loading the nuts restraining the flexible anchors were loosened and the wall was allowed to stand for a time. The repeated loosening of anchors was part of an effort to observe equilibrium in a fill with unwrapped,

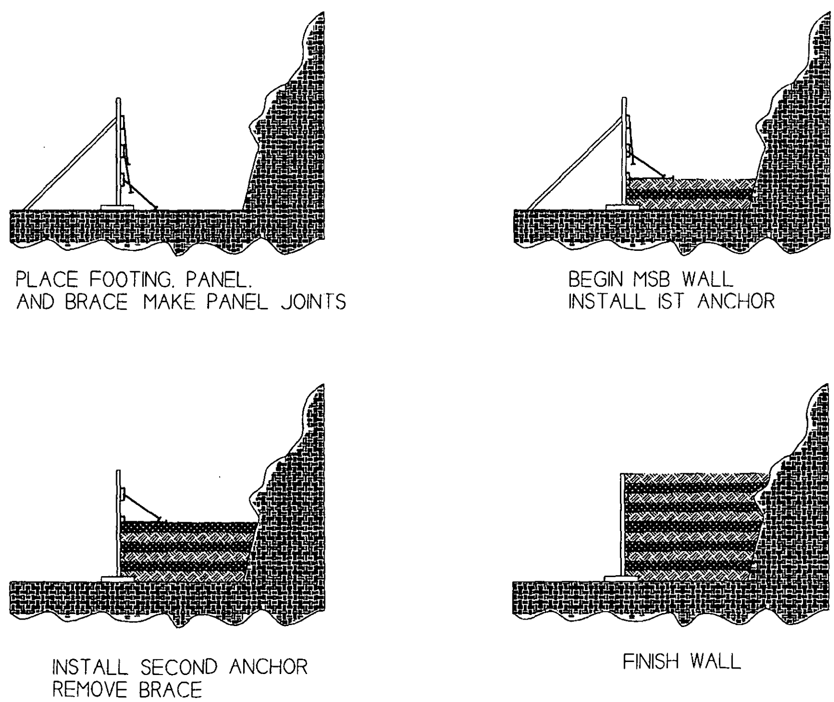


FIGURE 5 Construction sequence of independent facing systems.

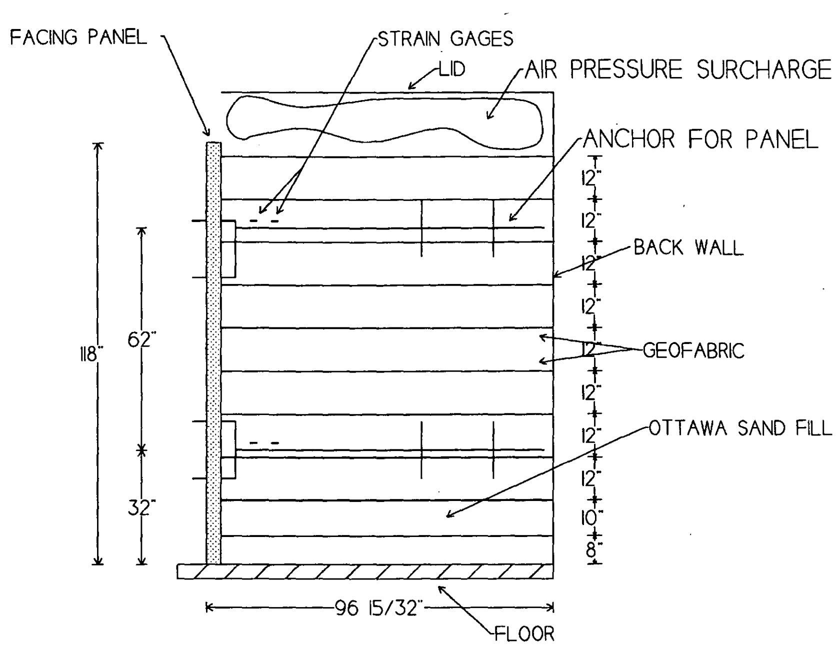


FIGURE 6 Prototype MSE wall with independent full-height facing.

unattached fill reinforcements. Only the first, Ottawa sand, test will be considered in this paper. Additional detail on the testing program can be found elsewhere (*11*).

Properties of fill reinforcements are listed in Table 2. The facing panel was a reinforced concrete panel approximately 3.1 × 1.2 × 102 mm (10 × 4 × 4 in.) with a two-way mat of #4 reinforcing bars at 127-mm (5-in.) spacing. The compressive strength of the concrete was 34 kPa (5,000 psi). Concrete reinforcing steel had a yield stress of 413 MPa (60 psi). The panel was provided with sleeves to accommodate adjustable loop-bar anchors. Loop bars were 13 mm (½ in.) in diameter and 305 mm (12 in.) long fabricated from smooth round bars. The straight anchor bars extended 2.1 m (7 ft) into the reinforced fill. Straight anchors were fitted with steel disks to improve pullout strength. Steel for anchors and loop bars had a yield strength of 289 MPa (42 ksi). Ottawa sand used for fill had a specific gravity of 2.65 and maximum and minimum unit weights per ASTM D-854 of 1 795 kg/m^3 and 1 560 kg/m^3 (112.2 pcf and 97.5 pcf) respectively. The sand reached a compacted density of 1 712 kg/m^3 (107 pcf).

Loading on the wall was a surcharge made up of a 407-mm (16-in.) layer of sand and an additional air pressure applied at the top of the wall by a rubber bladder reacting against the lid of the test fixture. Loads applied by air pressure could be held constant over time to observe creep. The execution of loading on test walls included the application of air-pressure surcharge at 7-kPa (1-psi) and 35-kPa (5-psi) increments, and the maintenance of surcharge. Loads were increased until some portion of the wall or the test setup failed. Failures included the seals around the panel and the air bag applying the surcharge.

Instrumentation for the tests included resistance strain gauges on all four anchors, six earth pressure cells mounted in the facing panel, resistance strain gauges on selected geotextile layers, dial gauges at five locations on the front surface of the facing panel, and a scribed grid on the sidewall membranes of the prototype. To monitor the performance of the facing panels and the anchors, the information needed is provided by strain gauges on anchors and by dial gauges on the panel.

Strain gauges on anchors were mounted in pairs on the straight-bar portion of each anchor near connections to loop bars. The pair of active gauges were wired in a full bridge with two additional gauges mounted on an unloaded length of steel round stock to serve as temperature compensation. For the Ottawa sand test, a single pair of strain gauges was mounted on each anchor. The gauges on one anchor failed during the test.

Four dial gauges were mounted at the corners of the facing panel and a fifth dial gauge was mounted at the middle of the top edge of the panel (Figure 7). From this pattern of gauges, it is possible to compute the translation, tilt, and twist of the panel.

In testing of the wall with Ottawa sand fill, air-pressure surcharges was applied at pressures of 7, 35, 69, and 138 kPa

TABLE 2 Properties of Geotextile Reinforcement for Prototype Test

Unit weight (ASTM D-3776)	1.93 N/m^2
Grab tensile (ASTM D-4632)	890 N
Elongation at break (ASTM D-4632)	60 %
Modulus at 10 % elongation (ASTM D-4632)	4.45 KN/m
Coefficient of permeability	1.99*10-4 cm/sec
Nominal thickness	0.508 mm

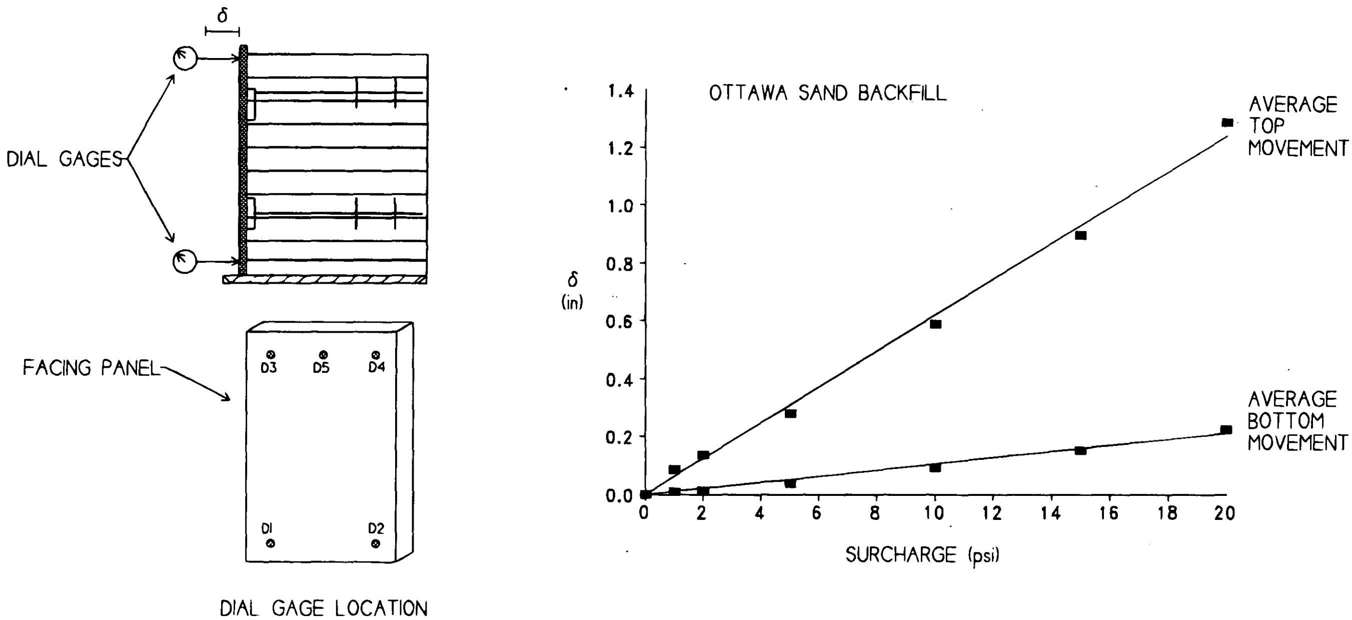


FIGURE 7 Dial gauge locations and deflection of panel versus surcharge.

(1, 5, 10, 15, and 20 psi). The test was stopped after the failure of a seal between the facing panel and the sidewall of the test fixture. The 7-kPa (1-psi) surcharge was held for approximately 75 hr. The 35-kPa (5-psi) surcharge was held for 30 min. The 69-kPa (10-psi) surcharge was held for 12 hr. The 103-kPa (15-psi) surcharge was held for 30 min. The 138-kPa (20-psi) surcharge was held for only a few minutes before a gasket at one vertical edge of the facing panel began to leak fill. The load history of the test is listed in Table 3.

The average movement at the top and at the bottom of the panel are plotted against surcharge in Figure 7. Loads in anchors are plotted versus surcharge in Figure 8. The anchor loads are determined directly from strain gauge readings. The strain gauges on Anchor No. 4 failed early in the test. From these figures several aspects of the performance of independent facing may be noted.

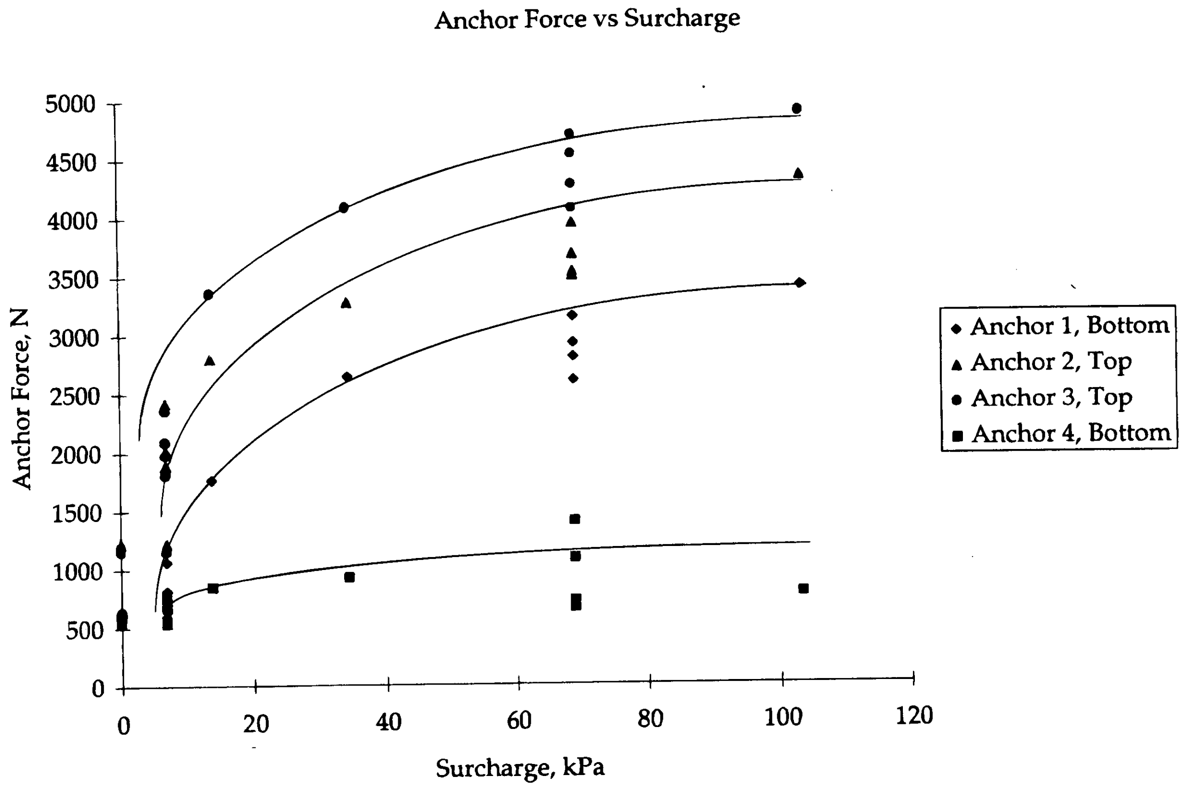
- Under surcharge, panel movement occurs by a combination of tilting and sliding. Panel deflection shows an essentially linear response to surcharge.
- Anchors exhibit a yielding response to increasing surcharge. Forces in two (of three) anchors show an upper bound load of about 3.6 kN (800 lb). The third anchor showed an upper bound load slightly greater than 4.5 kN (1,000 lb). All anchors exhibit greater stiffness initially, followed by a softening response at increasing surcharge (Figure 8). This softening response is the intended yielding of anchors to limit earth pressures on facing panels.
- Anchor forces did not appear to vary with time at constant surcharge. However, two surcharge levels were maintained for periods of less than 1 hr. Long-term behavior of the wall with unwrapped reinforcement was not established in this test.
- Anchor forces exhibit a yielding response as a function of panel displacement (Figure 8). It is found that the anchor loads exhibit a softening behavior for the linearly increasing panel deflections. Again, this is the intended yielding behavior of anchors.

Analysis of Panels and Anchors in Prototype Tests

Following the procedures developed for design of panels, anchor loads are used to compute peak earth pressures for triangular pressure distributions at each level of surcharge. The results are plotted in Figure 9. Peak lateral earth pressures on panels are as high as 15 kPa (2.2 psi) for a surcharge of 138 kPa (20 psi). This peak pressure is substantially lower than the active earth pressure that would be computed for an MSE wall with reinforcements attached to facing. The lateral pressure on independent facing are not linear with surcharge. Moreover, lateral earth pressures are indeed bounded by the yield capacity of anchors for facing panels. The computation of

TABLE 3 Loading Sequence and Dial Gauge Readings for Test with Ottawa Sand Fill

Step	Time (hrs)	Action	Surcharge (kPa)	Dial 1 (mm)	Dial 2 (mm)	Dial 3 (mm)	Dial 4 (mm)	Dial 5 (mm)	Trans (mm)	Tilt (mm)
1	0	Wall completed	0	0	0	0	0	0	0	0
2	39.7	Applied 7 kPa	7	0.05	0.08	0.28	0.36	0.0	0.19	0.14
3	115.6	Additional 28 kPa	34	0.89	1.02	7.21	7.19	6.96	4.06	3.56
4	116	Additional 34 kPa	69	2.06	2.24	14.02	14.07	13.67	8.13	6.60
5	137.2	Additional 34 kPa psi	103	3.61	4.09	22.48	23.04	22.83	13.21	10.41
6	137.8	Additional 34 kPa	138	5.18	6.35	32.77	32.77	32.64	19.30	14.99



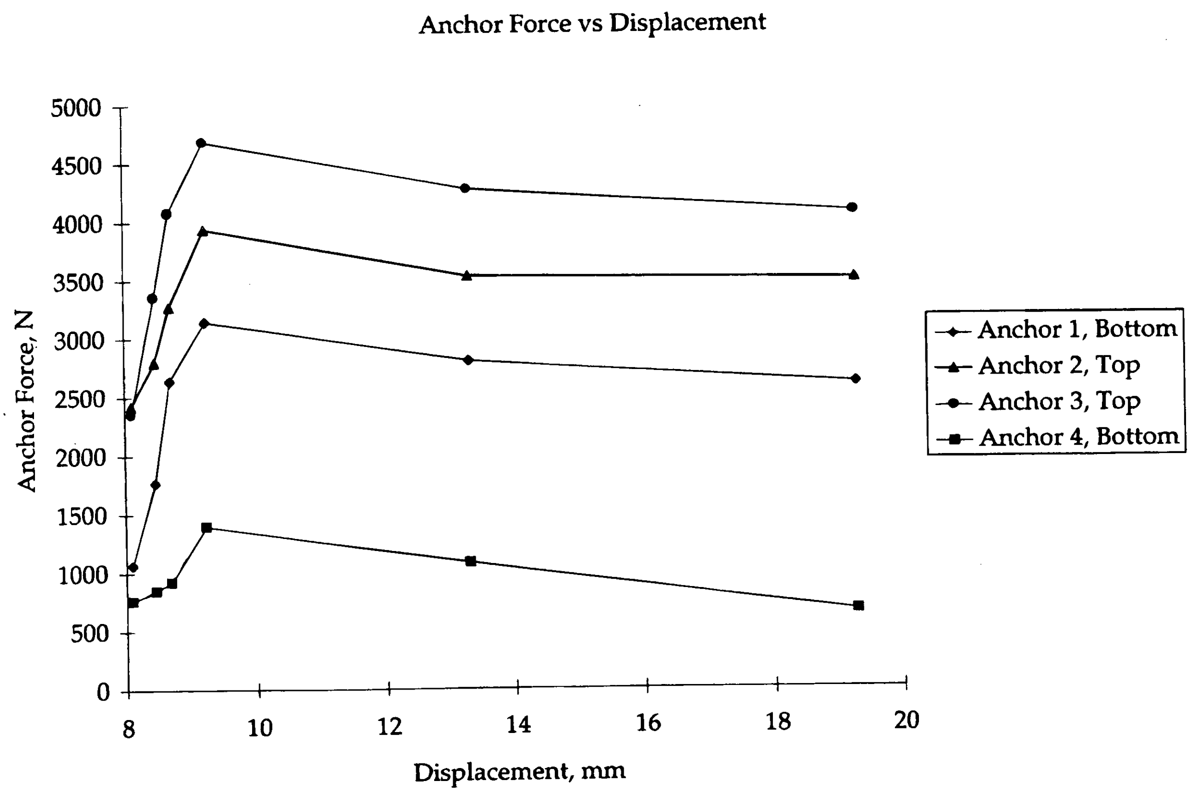
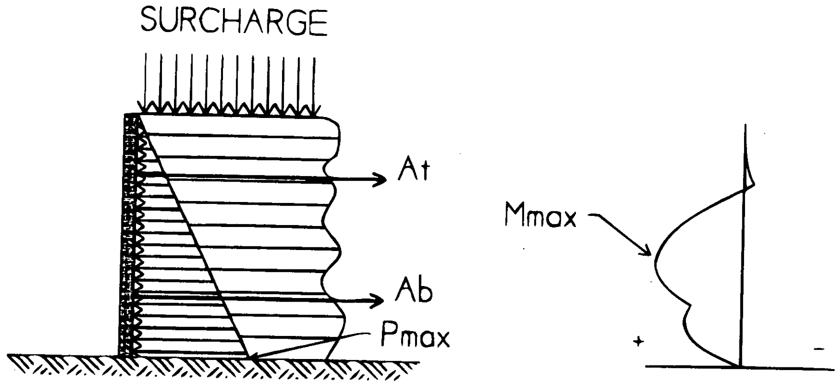


FIGURE 8 Anchor loads versus surcharge and versus displacement.



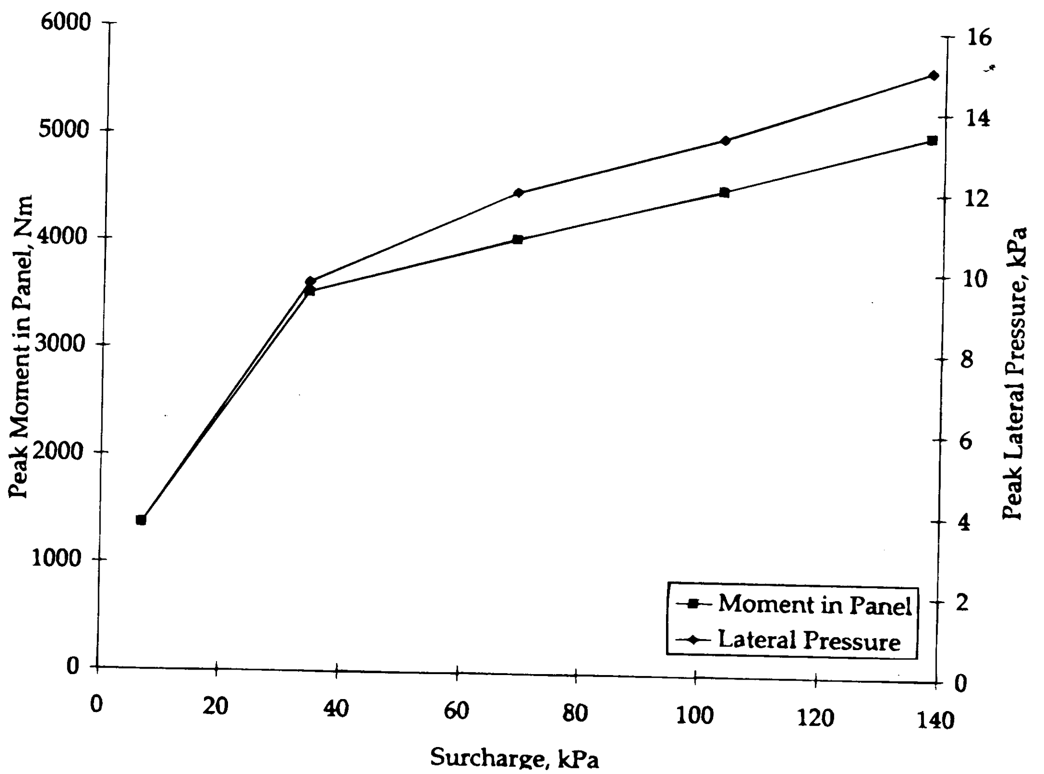


FIGURE 9 **Maximum soil pressure and bending moment versus surcharge.**

bending moments in panels follows directly from the computation of earth pressures. The highest bending moment in the panel is just over 60 kN-m (44,000 ft-lb) at a surcharge of 138 kPa (20 psi). Bending moments are also limited by the yield capacity of anchors.

CONCLUSION

Independent facing for MSE walls offers important options in design, construction, and aesthetics. Independent facing panels enjoy an articulation by a combination of sliding and tilting. Anchors for panels provide an upper bound load associated with the yield capacity of the loop bar. Once yielding is initiated, anchor forces do not continue to increase with increasing surcharge or increasing panel movement. Yielding anchors impose an upper bound on the magnitude of lateral earth pressures acting on panels. Anchors are designed to provide adequate support of facing panels and at the same time to protect panels against high earth pressures. The design basis for independent facing computes maximum bending moments in panels as a function of panel dimensions and anchor yield load.

Independent facing and flexible anchors performed as expected in tests of prototype walls. It was observed that anchors yield smoothly with increasing surcharge and increasing displacement and that anchor loads reach a limiting yield load beyond which additional surcharge will not produce higher anchor forces. A 3.1-m-tall

(10-ft-tall) prototype wall with full-height independent facing was subject to an air pressure surcharge of 138 kPa (2,880 psf). At this surcharge, the maximum lateral earth pressure acting on facing panels was only 15.2 kPa (317 psf). Flexible anchors protected the facing from higher earth pressures.

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