Hearn, G., Abu-Hejleh, N., McMullen, M., and Zornberg, J.G. (2003). "MSE Walls with Independent Full-Height Facing Panels." Proceedings of the *82nd Annual Meeting of the Transportation Research Board*, Washington D.C., January (CD-ROM).

MSE WALLS WITH INDEPENDENT FULL-HEIGHT FACING PANELS

George Hearn
Civil Engineering
University of Colorado
Boulder, CO 80309

Naser Abu-Hejleh
Colorado DOT
1325 S Colorado Blvd
Empire Pk B606
Denver, CO 80222

Michael McMullen
Colorado DOT
4201 E Arkansas
Denver, CO 80222

Jorge G. Zornberg
Civil Engineering
University of Colorado
Boulder, CO 80309

ABSTRACT

In 1996, the Colorado Department of Transportation (CDOT) completed the construction of a mechanically stabilized earth (MSE) wall with independent full-height facing (IFF) in Denver, Colorado. The wall has three major components: 1) a self-stable welded wire fabric (WWF) reinforced soil mass with uneven reinforcement lengths, 2) full-height concrete facing panels not attached to the soil reinforcements (i.e. independent), and 3) anchors to secure the facing panels and allow displacements needed to limit earth pressures on panels. This paper reports the design, construction and performance of a MSE/IFF wall. Wall performance and design are assessed in terms of measured movements of facing panels and measured loads in fill reinforcements and facing anchors.

INTRODUCTION

MSE walls offer advantages that include low cost, simple and fast construction, good seismic performance, and the ability to tolerate large total and differential settlements without distress. Block facings and stacked panel facings are attractive, but some projects need full-height facing panels to create monolithic fronts not broken by horizontal joints. Lateral stresses acting on full-height facing panels for MSE walls can be minimized if the facing is independent of soil reinforcement and if facing is allowed to move as needed to keep facing earth pressure low. This is the concept of MSE/IFF walls, first explored in CDOT-sponsored research (*1*)(*2*). Independent facing panels carry limited lateral pressure from fill, and panels are slender, lightweight, and relatively easy to handle during construction.

In 1996, CDOT built a MSE/IFF wall for a two-lane ramp connecting northbound Interstate 25 to Interstate 70 in Denver, Colorado (Figures 1 & 2). The wall is 1400 ft long and ranges in height from 5.7 ft to 18.8 ft. The MSE/IFF wall is an extension of an existing cantilever reinforced concrete retaining wall. The MSE/IFF system was selected to match the monolithic appearance of the existing wall. The I-25 wall combines a self-stable, welded wire fabric (WWF) reinforced soil mass with full-height, independent prestressed concrete facing panels. WWF reinforcement layers are shorter in the lower zone of the wall to reduce excavation, and longer in the upper zone of the wall. Excavation was a concern at this site because subsoils may be contaminated. Facing panels are anchored by deformed steel bars. Anchors are designed to accommodate panel movement and to minimize lateral pressure on facing panels. Traffic on I-25 was not disrupted during construction.

The I-25 wall was the first MSE/IFF wall in Colorado to carry highway traffic, and consequently it was experimental. A comprehensive instrumentation and monitoring program was incorporated in the project. Wall performance is assessed in terms of measured movements of facing panels and measured loads in fill reinforcements and facing anchors. Detailed information on the I-25 wall, its materials, construction, monitoring program, collected performance data and analysis, design assessment, and recommendations for future MSE/IFF applications are presented in Abu-Hejleh (*3*).

THE I-25/IFF WALL

The I-25/IFF wall is a construction of prestressed concrete facing panels and earth fill reinforced by steel welded wire fabric. Panels are anchored by epoxy coated steel reinforcing bars embedded in the reinforced fill. Anchors for facing panels are epoxy coated rebars. Each anchor is bent to form a six-sided shape that approximates one half of an ellipse (Figure 3a). Embedment of anchors is 8 ft. Typical vertical spacing is 5.33 ft with the lowest anchor placed at the ground surface before placement of fill. For attachment to facing panels, the threaded ends of facing anchors engage steel plates that bear on armored edges of panels (Figure 3b). Bearing plates distribute anchor forces to both adjacent panels.

MSE/IFF wall construction begins by placing panels in a shallow trench supported by flowfill, and installing temporary bracing at the front (Figure 4). The trench and bracing support panels during construction. All panels are erected before fill and reinforcements are placed. The panels define the front of the wall and provide a forming surface for fill. Panels are battered inward (toward the fill) initially in anticipation of outward movements that may occur during construction. Initial batter is about 2 inches per 10 feet of panel height.

Placement of fill and WWF reinforcements proceeds in a normal fashion. A lift of fill is placed and compacted, WWF sheets are installed and another lift of fill is placed and compacted. WWF reinforcements are not attached to facing panels. Compaction of fill causes outward tilts of facing panels. Control of compaction and monitoring of panel tilt are important tasks during construction. Fill movement is a necessary for mobilization of reinforcements, but too much movement can result in poorly aligned panels in the finished wall.

Permanent anchors for facing panels are installed as the reinforced fill advances. When the wall is complete, temporary bracing is removed. The trench remains in place, of course, but it is no longer needed for support of panels.

MONITORING PROGRAM FOR THE I-25 WALL

Two sections of the I25 wall were instrumented and monitored during construction. Instrumentation included strain gages on WWF reinforcements, strain gages on anchors for panels, tilt meters in the fill, thermistors, and survey targets on facing panels. Each instrumented section included a width of wall equal to eight facing panels. Finished wall height was 13.1 ft at one section and 15.2 ft at the other. Details on the instrumentation and monitoring program are provided by Abu-Hejleh, et al. *(3)*. Data from survey targets on panels are reported by Christina and Wu (*4*).

The major findings of the monitoring program are listed below.

Panel tilt, displacement, and settlement

Panel tilt during construction averaged 0.00125 radian per foot of completed fill. For a 15 foot panel height set in a 2ft trench, the outward movement at the top during construction is 3 inches. Panel movement is mostly tilt, with near zero outward translation at the base of panels. Vertical settlement of facing panels averaged 0.07 inch per foot of completed fill.

Forces in WWF reinforcements

The design of WWF reinforcements followed FHWA design guidance (5) for MSE walls with inextensible reinforcements. Measured tensile forces in WWF were below 50% of the tensile yield stress. This tensile force is tolerable, but it is higher than tensile force estimated in design. The location of maximum tensile force line based on strain data is farther behind the wall facing than anticipated. However, embedment length in the resistance zone and pullout resistance of WWF remain adequate. Pullout resistance is not less than 280% of maximum measured tensile force in WWF reinforcements, and averages 900% of measured WWF forces.

Anchors and Lateral Earth Pressure

Lateral earth pressure on facing is estimated from measured anchor forces. The average lateral earth pressure from anchor strain gages is 32 psf, close to the design earth pressure of 30 psf. For anchors near the bottom of panels, measured forces are less than the predicted pullout capacities. For anchors at the middle to top of panels, measured forces are close in value to pullout capacities, and exceed capacities at several anchors. These anchors apparently slipped during construction. Slip is a desired response of anchors as it prevents higher lateral pressures from acting on the panels.

Facing Panels

Panels are designed for bending moments due to handling and due to wind during construction, and for moments due to lateral earth pressure in service. For a 20-ft tall facing panel, the moment at the trench due to 8psf wind loading during construction is 1600 ft-lb/ft. The controlling moment strength of panels for vertical bending during construction is 4300 ft-lb/ft. Earth pressures in service produce moments of 188 ft-pound/ft in vertical bending and 480 ft-lb/ft in transverse bending. These are below the corresponding moment strengths of 7800 ft-lb/ft and 2000 ft-lb/ft.

CONCLUSION

MSE/IFF walls combine self-stable reinforced fill, full-height facing panels not attached to fill reinforcements, facing anchors that accommodate panel movement during construction, and a trench with flow fill and bracing for the temporary support of facing panels during construction. The MSE/IFF wall system offers rapid construction and an appearance similar to monolithic walls.

CDOT built an MSE/IFF wall in 1996 along I-25. The I-25 wall uses two tiers of reinforcement lengths: short, 8 ft length in the lower zone, and long, 20 ft length in the upper zone. After six years, the I-25 wall continues in service with no signs of distress or alignment problems. During construction, the wall facing was allowed to move outward sufficiently to mobilize tensile resistance in the fill reinforcements and keep lateral earth pressure on facing panels low. The average lateral pressure on facing panels is 32 psf. Design concerns in the upper zone of the wall include lower pullout capacity of facing anchors, and larger than anticipated deformations, tensile loads in reinforcements, and size of potential failure zone. The CDOT research study panel has recommended the development of standard worksheets for the design and construction of MSE/IFF walls.

References

1. Hearn,G., Myers,S. and Barrett,R.K. (1995). Independent Facing Panels for Mechanically Stabilized Earth Walls. TRB *Trans. Res. Rec. 1474*, Washington, DC, p13-22.

2. Hearn,G. and Myers,S. (1994). *Independent Facing for MSE Walls*. Colorado Transportation Institute CTI-CU-6-94, Denver. 83p.

3. Abu-Hejleh,N., McMullen,M., Hearn,G. and Zornberg,J. (2001). Design and Construction Guidelines for MSE Walls with Independent Full-Height Facing Panels. Colorado DOT, CDOT-DTD-R-2-001-5. Denver. 120p.

4. Christina, C.W. Ma, and Wu, J.T.H. (1999). "Performance of a Full-Height Facing MSE Wall Constructed at I-25 and 38th Avenue, Denver, Colorado." Internal report to the Colorado Department of Transportation, Research Branch.

5. Elias, V., Christopher, B.R., and Berg, R.R. (2001). *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes*. Publication Number FHWA NH-00-043, March 2001, NHI-FHWA.

Figure 1- Picture of the Completed I-25/I-70 MSE Wall with Independent Full-Height Facing in Denver, Colorado. Note that smooth panel is stacked next to four grooved panel.

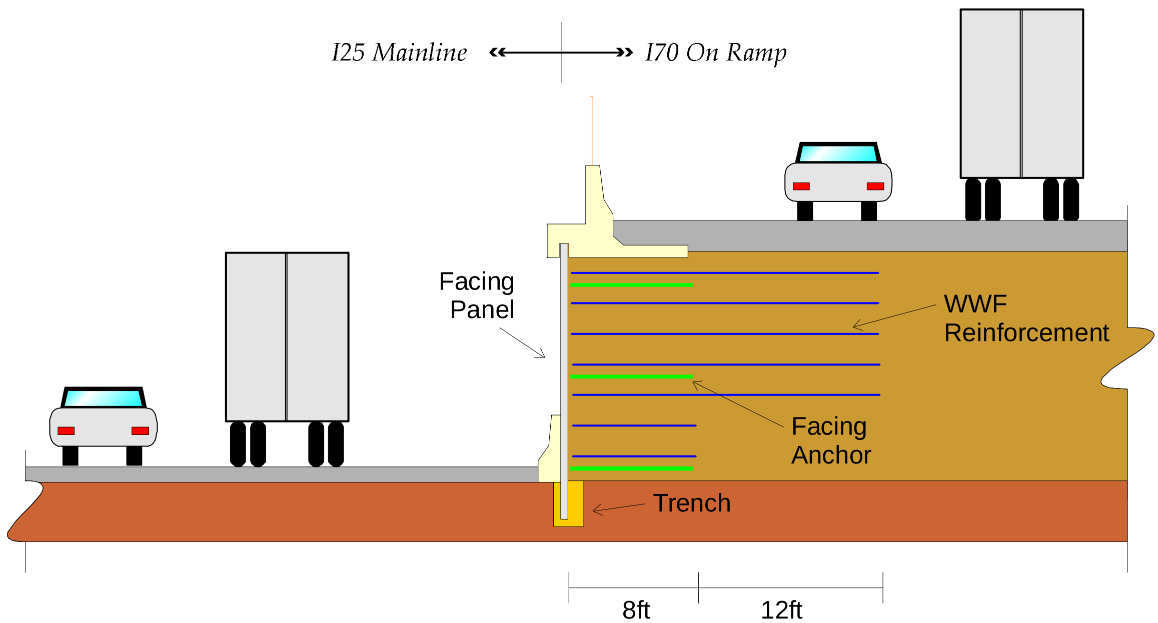

Figure 2 – Section of the IFF/MSE Wall

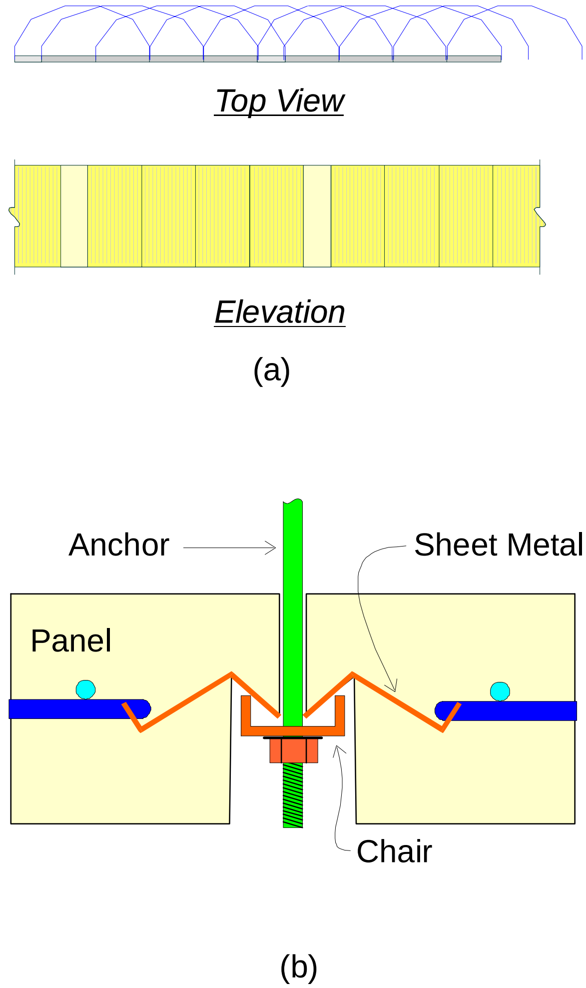

Figure 3 - Anchors for Panels (a) Pattern of overlapping anchors. (c) Anchor Attachment to IFF Panel

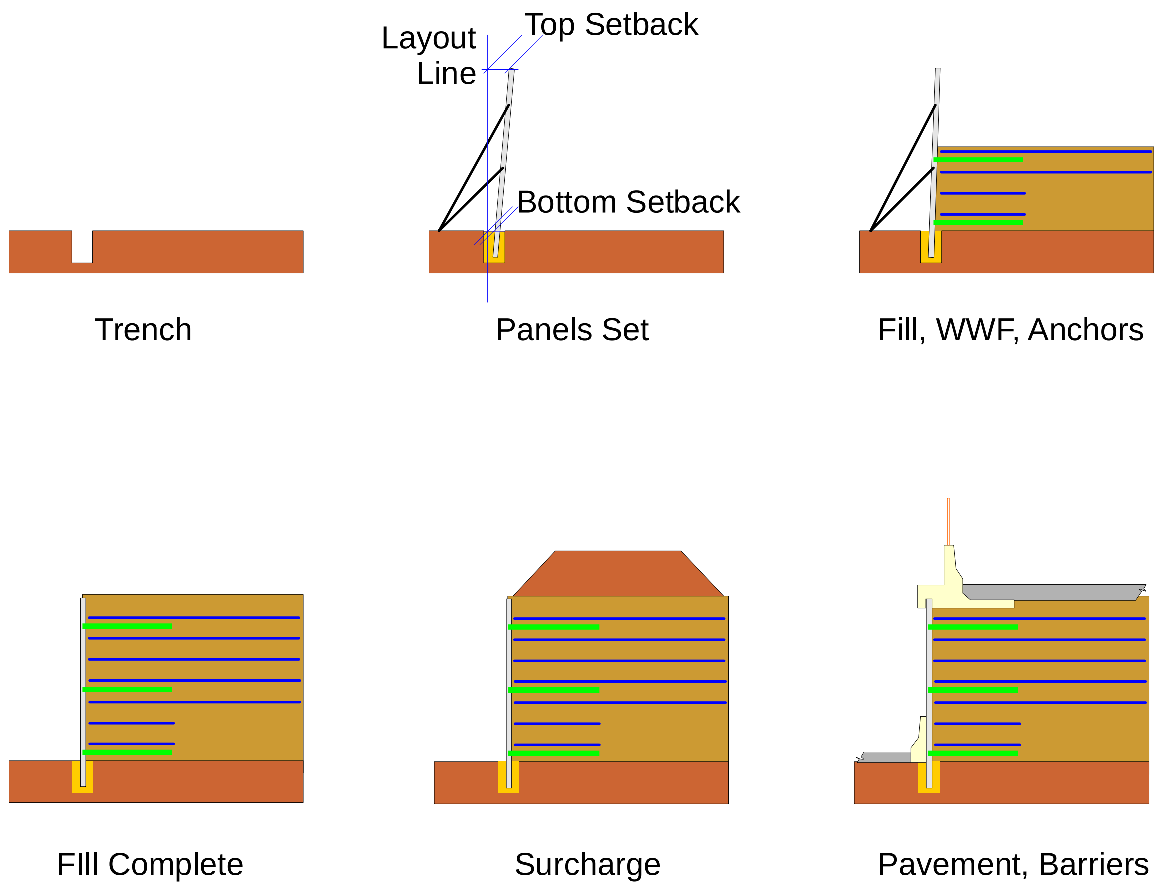

Figure 4 - MSE/IFF Wall Construction