Investigation into an MSE Facing Separation Failure

FOCUSING ON DEFORMED WELDED WIRE

SCOBS 2013
PORTLAND, OREGON

BARTON NEWTON
STATE BRIDGE ENGINEER
CALTRANS
The MSE

Proprietary MSE nearing completion Fall 2011
Supporting a new on-ramp, with a barrier slab coping

- Barrier
- Slab with coping
- Concrete facing panels
- Galvanized steel soil reinforcement mats
- Engineered backfill
- Typical underdrain

MSE Facing Separation Failure
The MSE Facing Separation

December 1, 2011
The MSE Facing Separation

Escaped backfill from chimney-shaped hole

- narrow vertical zone immediately behind the facing panels
- Area with known quality issues (hand compaction, thick layers)
Forensics Investigation

At location of failure (30 inches apart)

- Smaller wires, W11 sized, all OK
- Larger wires, W20 sized, all broken and rusted
Forensics Investigation

The MSE was entirely deconstructed
Samples taken from it and 3 other MSE on project

- The backfill was within specifications for gradation, plasticity and electro-chemical requirements.
- Field backfill test reports met the 95% relative compaction requirement
- Backfill soil was slightly damp but not saturated
- Facing panels were dry with no seepage in the joints
- No puddles or wet spots found during deconstruction
Forensics Investigation

Steel sent to Caltrans Translab in Sacramento
Soil reinforcement mats composed of Welded Wire Reinforcement (WWR) typical in reinforced concrete

- Either entirely composed of deformed wires (wire size denoted with a D), or entirely of plain or smooth wires (wire size denoted with a W)
- Deformed and plain wire mats used interchangeably on the project
- Only plain wire mats were denoted on plans
Forensics Investigation

Steel sent to Caltrans Translab in Sacramento

- Minor installation damage but generally no structural damage along mat length except for bends
- Bends for the facing connection cracked or fractured
- Cut numerous samples for a variety of tests
Forensics Investigation

Steel sent to Caltrans Translab in Sacramento

- A single bend radius on plans for all wire sizes (W11, W20, W24, also D11, D20, and D24 on this project)
- Inconsistent with the industry standards (ACI 318)
  “Inside diameter ...shall not be less than 4 nominal wire diameters for deformed wire ...and 2 nominal wire diameters for all other wires.”
  - Only W11 acceptable in detail
  - All other sizes bent tighter than allowed by project specs
Forensics Investigation

Steel sent to Caltrans Translab in Sacramento
Bends for connection to facing panels out of compliance with the plans (Plans depict 90 degrees with no tolerances)

Variable Bends in Plain Wire And in Deformed Wire

MSE Facing Separation Failure
Forensics Investigation

Steel sent to Caltrans Translab in Sacramento
Testing focused on deformed wire samples since no cracks or fractures were observed on the plain wires
Forensics Investigation

Steel sent to Caltrans Translab in Sacramento

- Micro-cracks found at every deformation
- Some cracks had Galvanization within them
Forensics Investigation

Steel sent to Caltrans Translab in Sacramento
Developed a “bent – tensile” test for the fabricated bends to assess the effects of these cracks
Forensics Investigation

Steel sent to Caltrans Translab in Sacramento

- Compared “bent-tensile” test results to the tensile test results of the unbent areas of the same wires in the mat
- The W11, D11 and W20 wires were acceptable
- The D20 wires averaged a 57% loss of tensile capacity
- The D24 wires fractured at 15% of their unbent tensile capacity
Forensics Investigation

Steel sent to Caltrans Translab in Sacramento

- Deformed wires showed patterns typical of brittle shear originating at the inner radius, irrespective of size
- The plain wires displayed the cup and cone pattern typical of ductile behavior prior to fracture

MSE Facing Separation Failure

D20 in Brittle Shear

W20 in Ductile Cup and Cone Fracture
Forensics Investigation

**Additional Note**

- Plain and deformed wire mats cost the same (equivalent diameters supplied, deformed slightly reduced)
- MSE design assumes corrosion loss over time is uniform around the wire
- Corrosion rates are not well defined for cold-worked wire with strain increases at the sites of deformations
- The iron-loss rate probably increased at the deformations
- Thus, the life of MSE with deformed wire may be reduced compared to MSE with plain wire
Conclusion

- **Caltrans will no longer allow deformed WWR as soil reinforcement in MSE**
  
  Due to brittle behavior in-service, equivalent diameters, and poorly defined corrosion characteristics

- **Tight bend radius caused embrittlement**
  1. Numerous Micro-cracks under galvanization
  2. Brittle shear from inner radius Vs ductile necking prior to cup and cone rupture of properly fabricated bends & straight sections
  3. Steel otherwise within specs for chemistry, welding and configuration required by plans

- **QMP will be required of all pre-approved systems on the AML**

  Inconsistent quality control prior to MSE construction

Inconsistent quality control prior to MSE construction
In-Service Investigation

Assessed inventory of the MSE already in-service with the same design and steel

1. Overwhelming majority were built using plain WWR as soil reinforcing mats
2. The few with deformed WWR used primarily the smaller-sized D11 wires
3. Only 8 had D20 or larger, predominately below finished grade
4. All were inspected and found in good condition
5. All in locations with limited/difficult public access
6. Low risk but will be monitored
MSE Facing Separation Failure