Outline

- Types of earth retaining structures
- Types of Mechanically Stabilized Earth walls (MSE walls)
- Criteria for approving wall system
- MSE Wall project design review
Types of Earth Retaining Structures

Wall Development

- Reinforced concrete (rigid) structure – gravity wall
Types of Earth Retaining Structures Wall Development

- Cantilever wall: semi-gravity
Types of Earth Retaining Structures Wall Development

- Mechanically Stabilized Earth wall includes three components:
  - Structural backfill
  - Reinforcement
  - Facing
Types of MSE Wall Category

- Precast concrete panel type of MSE wall with extensible or inextensible reinforcement
  - Inextensible reinforcement
  - Extensible reinforcement

Note: Current Indiana specification only allows inextensible reinforcement.
- **Types of MSE Wall Category**
  - Modular block wall with typical extensible reinforcement
    - Dry-cast block
      - Dry-cast block wall without reinforcement – gravity wall
      - Dry-cast block wall with reinforcement – MSE wall
  - Wet-cast block
    - Large-size block without reinforcement – gravity wall
    - Large-size block with reinforcement – MSE wall
Massive Block Wall vs. MSE Wall

Precast panel MSE wall
- Steel Reinforcement
- Economical in fill areas
- Lighter in weight
- Tolerate more settlement

Massive block wall
- No reinforcement
- Economical in cut areas
- Heavier in weight
- Tolerate relatively less settlement

Conclusion: Large block wall shall follow gravity wall design.
Comparison

- Precast panel MSE wall
  - Steel reinforcement
  - Tested mechanical connection strength
  - Settlement tolerance 1/100
  - Need evaluation for approval to use

- Wet-cast block wall with reinforcement
  - Geosynthetic reinforcement
  - Wrap around blocks or pure friction
  - Settlement tolerance 1/200
  - Need evaluation for application

Conclusion: Evaluation needed before wet cast block wall with reinforcement could be used.
Block Wall Criteria

- INDOT criteria for using modular block walls:
  - Maximum wall height without reinforcement: 5 Feet
  - Reinforced block wall height limit: 15 Feet
  - Modular block walls could be used only for non-critical application
Other State’s Criteria

- Minnesota DOT:
  - Wet-cast gravity block walls maximum height without reinforcement: 8 feet
  - Gravity block walls shall not support traffic
  - Reinforced block wall height limit: 18 feet
Wall Design Height (Hd)
Effect of Settlement on Wall

- Longitudinal settlement along wall facing: Panel may crack, gap between panels exposed.
- Settlement perpendicular to wall front face: The reinforcement connection may be overstressed.
Typical MSE Wall Problems
Typical MSE Wall Problems
Typical MSE Wall Problems
Typical MSE Wall Problems
Criteria for Approving Wall System

Approval MSE walls system:
- Precast reinforced concrete panel
- Galvanized steel reinforcement
- Mechanical connection
Criteria for Approving Wall System

- Link to the website of wall approval list:
Criteria for Approving Wall System

- Benefits of establishment of pre-approval list of MSE wall:
  - Past successful experience of the system in public transportation projects, if any.
  - Information of possible failure/disadvantages of the system.
  - Structural strength of the components.
  - Reliable system components’ configuration.
  - Project design review.
Criteria for Approving Wall System

Indiana Test Method 806, No. 14, Procedure J requires the following:

- Highway Innovative Technology Evaluation Center (HITEC) Evaluation Report
- Pullout tests to confirm pullout performance is in lieu of the performance of reinforcement in AASHTO LRFD Bridge Design Specifications Figure 11.10.6.3.2-1
Criteria for Approving Wall System

- Indiana Test Method 806, No. 14 Procedure J requires (cont’d):
  - Conditional approval with two-year monitoring program
  - Other information requested by Office of Geotechnical Services
  - Type A Certification
  - Shop drawings and design samples with hand calculation verification
Criteria for Approving Wall System

- Revisions to approval criteria:
  - An alternative approach to HITEC Evaluation Report: evaluation report from independent evaluators
  - Conditional approval with two-year monitoring program
  - Pullout test procedures
Criteria for Approving Wall System

- HITEC evaluation
  - It accepts both high-tech and low-tech products.
  - The evaluation includes multiple consultant’s evaluation and each of them may request additional documentation and/or product test results.
Criteria for Approving Wall System

- HITEC evaluation report includes:
  - Features which may NOT meet AASHTO Standards.
  - Both design and construction of subject wall system.
  - All components of wall system and performance of the wall as a structure.
Criteria for Approving Wall System

HITEC to expert’s evaluation report:

- Alternate to HITEC
  - HITEC transition.
  - After discussing with other states and FHWA.
  - Maintain HITEC evaluation quality while reducing the costs and time.
Criteria for Approving Wall System

Criteria for selecting evaluators:
- HITEC panelist and/or consultants
- AASHTO T-15 (Retaining Wall Subcommittee) Technical Advisors
- National Highway Institute (NHI) MSE Wall design and construction course instructors and FHWA MSE Wall Manual authors/technical consultants
- Selected as evaluators by other states
- Publications in retaining wall industry
Criteria for Approving Wall System

- INDOT list of wall system evaluators:
  - Ryan Berg
  - Barry Christopher
  - James Collin
  - Dov Leshchinsky
Criteria for Approving Wall System

Recent changes to approval criteria:

- Two-year monitoring program for two projects.
  - Daily readings during construction, weekly monitoring after completion of construction for 12 weeks, then monthly readings for 24 months.
Criteria for Approving Wall System

Possible future revisions to approval criteria:

- Pullout tests requirement to determine friction factor $F^*$
  - Factors affecting $F^*$ values:
    - Test scale
    - Structural backfill grain sizes
    - Steel dilation
  - Details about pullout test procedures – under research
Typical MSE Wall Problems
MSE Wall Project Design Review

- Establish project requirements
  - Wall geometry
  - Loading conditions
  - Performance criteria
MSE Wall Project Design Review

- Loading conditions
  - Soil surcharge
  - Live load
  - Dead load
  - Seismic
  - Traffic barrier impact
MSE Wall Project Design Review

- Traffic barrier impact verification
  - AASHTO 11.10.10.2 specify that traffic barriers, constructed over or in line with the front face of the wall, shall be designed to resist overturning moments by their own mass.
  - INDOT Spec: When traffic barriers are constructed above a MSE Wall or reinforced backfill envelope, the wall shall be designed for extreme event II limit state.
- MSE Wall Project Design Review
  - Wall design
    - External stability
    - Internal stability
    - Global stability
MSE Wall Project Design Review

- Wall external stability
  - Bearing capacity
  - Sliding
  - Limiting eccentricity (overturning)

Bearing Capacity  Direct sliding  Eccentricity
MSE Wall Project Design Review

- Wall internal stability
  - Tension rupture
  - Connection strength
  - Pullout
MSE Wall Project Design Review

- Wall internal stability
  - Coherent gravity method
  - Simplified method
  - Structure stiffness method

\[ T_{\text{max}} \leq \phi T_{al} R_c \]

Demand (Factored Load) \quad \downarrow \quad \text{Capacity (Factored Resistance)}
MSE Wall Project Design Review

- Wall external and internal stability
- Capacity vs. demand ratio should be always no less than 1.0 (CDR $\geq$ 1)
MSE Wall Project Design Review

- Wall global stability
- Factor of safety
- **MSE Wall Project Design Review**
  - Shop drawings
    - AASHTO LRFD bridge design specification
    - INDOT approved wall system configurations
MSE Wall Project Design Review

- Corrosion of galvanized steel
  - Corrosion calculation for wall steel reinforcement and connectors: Theoretical structural strength – is that always reliable?
MSE Wall Project Design Review

- Pullout friction factor $F^*$ values
  
  All MSE Wall system shall refer to AASHTO Figure 11.10.6.3.2-1 for pullout friction factor $F^*$. 
MSE Wall Project Design Review

- Structural backfill properties
  - Internal friction angle shall be 34 degree for internal stability analysis.
  - Unit weight shall be at least 120 lbs/ft$^3$.
  - Free of organics (1% max.)
Typical MSE Wall Problems
Typical MSE Wall Problems
Typical MSE Wall Problems
Typical MSE Wall Problems
- **MSE Wall Project Design Review**
  - Design redundancy should be ensured by construction quality control.
Construction Quality

- Coarse aggregate compaction
- Geotextile
- Steel reinforcement get around obstruction
Typical MSE Wall Problems
Typical MSE Wall Problems
Get Around Obstruction
Recommendations for Future

- Possible use of geosynthetic reinforcement in MSE walls.
- Possible raising modular block wall height limit.
- Possible use of modular block walls for critical application not supporting any structures.
- Develop a list of approved modular block wall systems.
- Use Only Simplified Methods for design
- CDR to be provided for each reinforcement elevation
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Questions?