Caltrans / Industry Falsework Advisory Team

Meeting Agenda – January 17, 2024 (Wednesday)

Location: Sacramento/Webex

Time	Topic	Speaker
8:30 – 8:40	Welcome and WebEx Overview (Check you are muted) Introductions	Jim Nicholls

8:40 – 8:55	**Follow up from previous meeting (5/19/2023) action items**
	• Field construction practices manual revised in 2020
	• Draft temporary structure manual not complete yet
	• Section 48-1 *Temporary Structures, General*
	  ○ CBC 1704.6 requires structural observations (Attachment 1)
	  ○ Professional Engineers Act section 6703.1 and 6735.1 allow for construction supervision services (Attachment 1)
	  ○ Email response from Board (Attachment 1)
	  ○ Draft changes to relieve designers from being placed in a superintendence role
	  ○ Draft changes presented to Caltrans management
	  ○ See Attachment 2 for draft changes to 48-1
	  ○ Lanterman Act history PowerPoint
	Minutes:
	• Information in Attachment 1 and 2 was reviewed
	• Team agreed that revising Spec to require engineer to notify in place of stopping the work is an improvement
	• Suggestion that a "competent person" would be better solution
	• Team agreed section 60 should have similar language as 48-1
	• Section 60 uses the term "ensure compliance" which places the responsibility of the means and methods on the engineer
	• Currently subcontracts with temporary structure engineers requires waivers to comply with bonding restrictions
	• Comment made that the cost of the service is not the issue, but the potential liability is
	• As discussed in previous meetings, the resources are also a challenge with engineers in demand
	• Discussed who would be a qualified representative engineer if EOR is not available
	• It was noted the Spec has a list of qualifications for representatives
	• It was suggested that the EOR not be required to certify the qualified representative due to liability
	• The CT Tech team will look at the certification language
	• It was noted that the superintendent may have the expertise to adjust temporary structures but not how to handle unanticipated issues
	• Revisions will be submitted to Spec development for comment
		Jim Nicholls

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8:55 – 9:10	**Caltrans Temporary Barrier** • New barrier name Cal F-23 barrier • Draft standard plans are complete • Standard plans will be published when final test results are received • Do not install K-rail after December 31, 2026 • Cal F-23 barrier will be added to table in 12-3.20C(1) see Attachment 3 **Minutes:** • Discussed table in section 12-3.20C(1) and how each type of barrier performs differently • Temporary structure standard plan drawings will need to address each type of rail • Suggestion that a table, similar to the table in section 12-3.20, could be used in the standard plan sheet so clearance to each type of barrier is addressed • Comment made that RSS that rounds to the nearest inch is seldom approved for used	

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9:10-9:25	**Boussinesq Equation** • Typical Boussinesq formula (strip load): $$F=\frac{2q}{\pi}[\beta - sin\beta cos2\alpha]$$ • Typical methods based on semi-empirical methods of analysis using elastic theory and experiments on non-yielding walls • Computation of lateral stresses due to surcharges is complicated by the lack of rational approach to the distribution of shear stresses in the soil adjacent to a yielding plane • Some software uses 2 for rigid, 1.5 for semirigid, and 1.0 for flexible walls (no reference given) • Caltrans T&S manual uses 2 • Steel Sheet Pile Design Manual use a value of 2 • Railroad uses a value of 2 • Corp or Engineers uses 2 for non-yielding walls and 1 for yielding walls (at failure) • NAVFAC notes conservatively assumes an unyielding wall, and charts use value of 2 • AASHTO BDS uses 2 (notes conservative for flexible walls) • AASHTO GDSBTW uses NAVFAC or other • Appears soil parameters will affect what value less than 2 can be used on a flexible wall **Minutes:** • Team discussed the references above and how they typically do not note when values less than 2 should be used • Noted that values less than 2 are based on engineering judgement • The lack of clear direction is why many sources above default to the more conservative use of 2 in the equation • Soil and wall properties complicate the value to use • The current T&S manual does not address this issue, but is currently being revised and could add a discussion on this topic • This issue is the responsibility of another Tech team and information from this discussion will be forwarded for their use • The issue comes up in the field from time to time and a reference would be helpful to resolve loading discrepancies	Jim Nicholls

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<table>
<tr>
<td>9:25 – 9:40</td>
<td>
Wet Friction Factor for Anchor Blocks

Falsework manual Section 5-5.13 Cable Anchor Systems table values multiplied by 0.67 for wet service conditions
What is considered wet condition?
Table 5-6 below:

Table 5-6. Coefficient of Friction for Concrete Anchor Blocks
<table>
<tr><th colspan="2">Friction of Concrete Anchor Blocks</th></tr>
<tr><th>Base Material</th><th>Coefficient of Friction</th></tr>
<tr><td>Sand</td><td>0.40</td></tr>
<tr><td>Clay</td><td>0.50</td></tr>
<tr><td>Gravel</td><td>0.60</td></tr>
<tr><td>Pavement</td><td>0.60</td></tr>
</table>
Minutes:

Most agreed that standing water around block would require a wet service condition
Suggested that seasonal and geographic conditions should be considered by the engineer
Occasional rain on granular soil would most likely not produce a wet service condition
Team agreed additional direction is not needed in the falsework manual and this should be left to engineering judgement

</td>
<td>Jim Nicholls</td>
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<td>9:40 – 9:55</td>
<td>
Anchor Block (deadmen) Factor of Safety

Falsework manual Section 5-5.13 Cable Anchor Systems does not list a factor of safety for sliding or overturning (FS=1)
Factor of safety of 1.5 typically used for permanent retaining structures
Some temporary structure designs use a FS=1.2 for sliding and overturning of deadmen
AASHTO BDSBTW, Section 2.4.4 Overturning and Sliding, requires a FS=1.5 for sliding and overturning
Should deadmen be designed using a factor of safety greater than 1?

5-5.13A Cable Anchored to Concrete Blocks
Concrete anchor blocks must be proportioned to resist both sliding and overturning. The weight of the anchor block must be reduced by the vertical component of the cable tension to obtain the net or effective weight to use in the anchorage computations.
Minutes:

Comment made that ASCE 7 uses 0.6DL providing a FS > 1
FS=1 is based on wind load from table in Spec which is on the conservative side
Team agreed the method in the falsework manual using a FS=1 is adequate and a change is not needed
Suggestion to add language for clarity to the manual

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<td>Jim Nicholls</td>
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</table>

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9:55 – 10:10	**Pads on Sloping Ground** • Pads typically set on level ground • Stepped pads used on sloping ground • CBC 1809.3 *Stepped footing* 10% max slope for bottom of footing • What are maximum slope pads should be set on? • Should sliding be considered between sloped pads and wedges? **Minutes:** • Discussed sloping pads with corbels wedged plumb • Slopes greater than 10% could pose a sliding issue • At some slope friction would not be enough to resist sliding • Team agreed added language to the falsework manual to consider sliding when slope is in excess of 10% • Some temporary structure standard plan sheets already address sloping pads • Additional measures to prevent sliding do not substantially increase the cost	Jim Nicholls
10:10 – 10:25	**Break**	All

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10:25 – 10:40	**Falsework Manual Revisions** • Version found online is ADA compliant. • Version with updates through September 2023 (Rev 5) is being converted to be ADA compliant, but can be requested by emailing the address below: osc.administration@dot.ca.gov • Revision 6 currently being drafted Published Revision 5: Chapter 4 Revisions An example of dead load redistribution due to longitudinal prestressing is stage construction of continuous bridges with hinges. For these bridges, prestressing will reduce the dead load on the falsework near the center of the suspended span and increase the load on the falsework at the hinge. The forces involved in the dead load redistribution are of considerable magnitude, since up to 3/8 of the total suspended span dead load may be transferred to the falsework at the hinge, assuming the span CALTRANS • FALSEWORK MANUAL CHAPTER 4 4 - 12 CHAPTER 4, DESIGN CONSIDERATIONS JUNE 2022 acts as a fixed-pinned beam. The load due to dead load transfer is shown in the contract drawings and includes the secondary prestress forces. In addition, the dead load of the falsework, calculated in the usual manner, along with the falsework live loads over the deck surface, assuming a fixed-pin beam configuration, will need to be added to the hinge loads provided on the contract plans. ~~must be added to the dead load calculated in the usual manner to obtain the total dead load for the falsework design at the hinge support.~~ Chapter 5 Revisions • Section 5-5.04 *Cable Connector Design* The installation of cable connectors must conform to the manufacturer's requirements. Only forged clips must be used as connectors. Forged clips are marked ***forged*** to permit positive identification, and have the appearance of galvanized metal. Malleable clips shall not be used as connectors. Malleable cable clips appear smooth and shiny. Clips should be labeled with manufacturer's markings and size so installation of the clips can be verified with the manufacturer's instructions in accordance with Contract Specifications, Section 48-2.02B(3)(d) *Manufactured Assemblies*.	Jim Nicholls

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10:40 – 10:50	Draft Revision 6: Chapter 5 Draft Revisions • Section 5-5.06 *Factor of Safety* Therefore, a factor of safety, **FS = 3**, based on the minimum breaking force, **MBF**, is required when determining the allowable design capacity of the cable units. A factor of safety, **FS=2**, based on yield strength, is acceptable for prestressing strand when used in a falsework bracing systems. Chapter 8 Draft Revisions Individual posts may be supported by individual pads, which may be square or rectangular. A row of several posts may be supported by a continuous pad. Falsework pads may consist of a single member or of several members set side by side. Pads are typically set on level ground. When pads are set on ground slopes greater than 10% sliding effects should be investigated. Normally, for continuous pads, a lower cap beam is used to distribute load from the posts to the corbels. **Minutes:** • Team discussed the published revision 5 and proposed revision 6 • Team had no additional comments	Jim Nicholls
10:50 – 11:00	**Specification Changes** • Section 5-1.23 *Submittals* – July 2023 Spec, review time for action submittals when railroad is involved 65 days • Section 48-3.02B *Design Criteria* – Draft minimum horizontal load for temporary supports 10% of supported dead load • Section 51-1.02C(2) *Shop Drawings* – Draft to limit unsupported length to 20 feet for rebar temporary support systems **Minutes:** • Team reviewed the Spec changes above • Team had no additional comments	Jim Nicholls
11:00 – 11:15	**Railroad Required notes on Shop Drawings (UPRR)** • See attachment 4 for required notes • Attachment 4 can be used to develop standard railroad notes in CAD • Required notes will be added to the Excel checklist **Minutes:** • Team commented that the RR (UPRR) continues to ask for more and more notes be added to the plans. • Many of the notes are copies of what is already in the specifications • Suggested that a railroad standard plan sheet be used with required notes • Required notes will be compiled in Jim's Excel checklist	Jim Nicholls

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11:15 – 11:25	**Allowable Soil Bearing for Railroad Submittals** • Previous UPRR required Geotech if over 3000 psf on soil or 6000 psf on AC (Crane pick plan and falsework) • AREMA 28.2.1 investigate as indicated in Part 22 • AREMA Part 3, 3.4.3.2 bearing capacity calculation based on Terzaghi (Attachment 5) • RR wants calculations in addition to soil load test **Minutes:** • Requirement for soil calculations will be added to Excel checklist • This is a new requirement and appears to be expected by one reviewer • Suggested that this calculation be added to all calculation in the future	Jim Nicholls
11:25 – 11:35	**Falsework Lighting Through Railroad Openings** • UPRR/BNSF Grade Separation Guidelines, Section 5.7b, requires lighting for all falsework and shoring areas • SS Section 48-1.01A states: **48-1.01A Summary** Section 48-1 includes general specifications for constructing temporary structures. If a railroad company is involved, falsework, temporary supports, and jacking support systems must comply with any additional requirements of the railroad company. **5.7 Lighting** a. All new or modified Overhead Structures which cover 80 linear feet of track or more shall provide a lighting system to illuminate the track area. However, at the discretion of the Railroad, lighting shall be provided for all structures covering less than 80 linear feet of track in areas where switching is performed or where high vandalism and/or trespassing have been experienced. Care shall be taken in lighting placement such that trains will not mistake the lights for train signals nor shall they interfere with the train engineer's sight distance for existing signal aspects. All lights shall be directed downward. b. Provide temporary lighting for all falsework and shoring areas. c. The minimum lighting design criteria shall be an average of one (1) foot-candle per square foot of structure at the Railroad tracks. Two (2) foot-candle or greater may be required at the discretion of the Railroad. The illuminated area shall extend to the limits of the overhead structure width and the width of the Railroad right-of- **Minutes:** • Comment made by Industry that recently the railroad has required lighting for project where the Spec had not addressed lighting • Lighting through falsework is typically addressed in section 12 • The Spec requirements will be reviewed, and this topic will be discussed at the next FWAT meeting	Jim Nicholls

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11:35 – 11:50	**Round Table** **Minutes:** • Question was raised if temporary structure engineers would be interested in performing the shoring design for emergency contracts to save time • Most were interested in doing the design for emergency contracts • Question raised if the use of steel plates for jacking redundant system would be removed from the Spec. The current Spec does not require steel plates • Brian Mapel has had good results using phenolic resin plates as the redundant system • The use of locking cylinders as a redundant system has not moved forward • Comment made that Caltrans maintenance will most likely not agree to using locking rings • Noted that some projects with minimal access have already used the locking rings as the redundant system • Caltrans will revisit the use of locking rings and it will be on the agenda for the next FWAT meeting	All
11:50	Adjourn	All

Action Items:

Items from Meeting on 5/19/23

1. Caltrans will research requirements of section 48-1 are in accordance with Board of Engineers requirements
2. Brian Mapel will share results of using the phenolic resin plates with CT
3. CT will send the draft chapters of the TSM to the FWAT team for comment

Today's Action Items

1. Caltrans will draft revised language to Spec sections 48-1 and 60
2. Caltrans will revisit locking rings used as a redundant system of support
3. Additional language will be added to the falsework manual addressing sloping pads
4. Caltrans Excel checklist will be updated to include required RR notes and soil bearing calculations

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Attachment 1

CBC 1704.6

1704.6 Structural observations.

Where required by the provisions of Section 1704.6.1, the owner or the owner's authorized agent shall employ a registered design professional to perform structural observations. The structural observer shall visually observe representative locations of structural systems, details and load paths for general conformance to the approved construction documents. Structural observation does not include or waive the responsibility for the inspections in Section 110 or the special inspections in Section 1705 or other sections of this code. Prior to the commencement of observations, the structural observer shall submit to the building official a written statement identifying the frequency and extent of structural observations. At the conclusion of the work included in the permit, the structural observer shall submit to the building official a written statement that the site visits have been made and identify any reported deficiencies that, to the best of the structural observer's knowledge, have not been resolved.

Professional Engineers Act

6703.1. Supervision of construction defined

"Supervision of the construction of engineering structures" means the periodic observation of materials and completed work to determine general compliance with plans, specifications, and design and planning concepts. However, "supervision of construction of engineering structures" does not include responsibility for the superintendence of construction processes, site conditions, operations, equipment, personnel, or the maintenance of a safe place to work or any safety in, on, or about the site.

For purposes of this subdivision, "periodic observation" means visits by an engineer, or his or her agent, to the site of a work of improvement.

6735.1. Civil engineering – no legal duty to provide construction supervision

The signing of civil engineering plans, specifications, reports, or documents which relate to the design of fixed works shall not impose a legal duty or responsibility upon the person signing the plans, specifications, reports, or documents to supervise the construction of engineering structures or the construction of the fixed works which are the subject of the plans, specifications, reports, or documents. However, nothing in this section shall preclude a civil engineer and a client from entering into a contractual agreement which includes a mutually acceptable arrangement for the provision of construction supervision services. Nothing contained in this subdivision shall modify the liability of a civil engineer who undertakes, contractually or otherwise, the provision of construction supervision services for rendering those services.

Hello Jim,

Thank you for your call earlier regarding supervision of a construction site. Yes, if the engineer contracts to provide construction supervision, they would be in breach of contract if they refused. Unless the contract was terminated according to the agreed upon method.

Thank you,

Francesca Domingo La Fleur
Enforcement Analyst/Probation Monitor
Board for Professional Engineers, Land Surveyors, and Geologists
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Attachment 2

48-1.01D Quality Assurance

48-1.01D(1) General

Reserved Stop activity if any unanticipated issues occur.

48-1.01D(2) Temporary-Structure Engineer

The temporary-structure engineer must:

Move item 8 below to this location

1. Be registered as a civil engineer in the State.
2. Have experience in temporary structure design or temporary structure construction inspection.
3. Seal and sign the shop drawings.
4. Be present during all jacking and adjustment activities.
5. Prepare, seal, and sign a daily temporary-structure inspection report during jacking and temporary-structure adjustment activities.
6. The temporary-structure engineer must inspect and certify that:
   - 6.1. Temporary structure is stable before jacking activities o placed.
   - 6.2. Temporary structure complies with the authorized shop
   - 6.3. Materials and workmanship are satisfactory for the work.

Notify temporary structure superintendent and Engineer ....

7. ~~Stop activity~~ if any unanticipated issues occur.
8. ~~Propose revisions to the authorized shop drawings to address any issues. Do not resume temporary structure activities until the proposed revisions are authorized.~~

A representative may be assigned

~~The temporary-structure engineer may assign a representative~~ to perform the temporary structure activities specified in section 48-1.01D. The temporary-structure engineer must submit a letter that is sealed and signed certifying that the representative:

1. Is registered as a civil engineer in the State
2. Has experience in temporary structure design or temporary structure construction inspection
3. Is familiar with the authorized shop drawings and the stresses the members are required to sustain
4. Will attend at least 1 job site visit with the Engineer and your temporary-structure superintendent to discuss the authorized shop drawings

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Attachment 3

Minimum Clear Area Width

Barrier	Configuration	Height differentials 3 feet or less (ft)	Height differentials greater than 3 ft up to 8 feet (ft)	Edge of deck or height differentials greater than 8 feet (ft)	Fixed objects, falsework members, or temporary supports[a] (ft)
12'-6" temporary concrete barrier with "J" hooks	Freestanding	3	4	8	7
	3 stakes per segment traffic side	1	1	2	3
	2 anchor bolts per segment traffic side	1	1	2	3
20-foot temporary concrete barrier with "J" hooks	Freestanding	3	4	8	7
	4 stakes per segment traffic side	1	1	2	3
	3 anchor bolts per segment traffic side	1	1	2	3
50-foot temporary steel barrier	Staked or anchored at both ends only	6	7	9	10
	Staked or anchored every 250 feet	5	6	8	9
	Staked or anchored every 33 feet	1	1	3	4
20-foot Type K temporary railing	Freestanding	2	3	8	7
	2 stakes or 2 anchor bolts per segment traffic side	1	1	3	4
	4 stakes or 4 anchor bolts per segment	N/A	N/A	3	3
Temporary Concrete Barrier with Cross Bolts	Freestanding	1	1	5	4

[a]The minimum clear area width to a falsework or temporary support footing can be 2 feet less than the clear area width shown. Measure clear area width to the footing edge closest to traffic.

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Attachment 4

- Please revise the falsework plan notes to specify the requirements for settlement monitoring outlined in AREMA MRE Ch. 8 Art. 28.6.5.

28.6.5 FALSEWORK CONSTRUCTION (2022)

a. The falsework shall be constructed to conform to the falsework drawings. The materials used in the falsework construction shall be of quality necessary to sustain the stresses required by the falsework design. The workmanship used in falsework construction shall be of such quality that the falsework will support the loads imposed on it without excessive settlement or take-up beyond that shown on the falsework drawings.

b. Falsework shall be founded on solid footings, safe against undermining, protected from softening, and capable of supporting the loads imposed on it. When requested by the Engineer, the Contractor shall demonstrate by suitable load tests that the soil bearing values assumed for the design of the falsework do not exceed the supporting capacity of the soil.

c. When falsework is to be supported on piles, the piles shall be driven until the required pile capacity is obtained as shown on the falsework drawings.

d. For falsework over or adjacent to railroad tracks, all details of the falsework system which contribute to the horizontal stability and resistance to impact, except for bolts in bracing, shall be installed at the time each element of the falsework is erected and shall remain in place until the falsework is removed.

e. Falsework shall be designed to compensate for falsework deflection, vertical alignment and anticipated structure deflection.

f. Contractor shall provide tell-tales attached to the soffit forms and readable from the ground in enough systematically placed locations to determine the total settlement of the entire portion of the structure where concrete is being placed.

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- Please provide additional notes on the plans to contain all pertinent information outlined in AREMA MRE Ch. 8 Sec. 28.6.6.

28.6.6 REMOVING FALSEWORK (2015) R(2022)

a. Falsework supporting any span of a simple span concrete bridge shall not be released before 10 days after the last concrete, excluding concrete above the bridge deck, has been placed in that span and in the adjacent portions of each adjoining span of a length equal to at least ½ the length of the span where falsework is to be released.

b. Falsework for cast-in-place prestressed portions of structures shall not be removed until after the prestressing tendons have been tensioned and released.

c. Falsework supporting any span of a continuous or rigid frame bridge shall not be removed until all required prestressing has been completed in that span and in the adjacent portions of each adjoining span for a length equal to at least ½ the length of the span where falsework is to be removed.

d. Falsework supporting overhangs, deck slabs between girders, and girder stems which slope 45 degrees or more off vertical shall not be removed before 7 days after the deck concrete has been placed.

e. In addition to the above requirements, no falsework for bridge spans shall be removed until the supported concrete has attained a compressive strength of 2,600 pounds per square inch (17.9 MPa) or 80 percent of the specified strength, whichever is higher.

f. When falsework piling are used to support falsework within the limits of the railroad right-of-way, such piling within this area shall be removed to at least 2 feet (0.6 m) below the finished grades or as required by the Engineer.

g. All debris and refuse resulting from the work shall be removed and the premises left in a neat and presentable condition.

- Please provide additional notes on the plans to clearly specify the following:

  a. *Falsework member substitutions are not permitted without express permission from the Falsework Engineer and the Railroad. If permitted, substitutions shall be of equal or higher strength materials in compliance with AREMA and UPRR requirements.*

  b. *Changes in overall design, procedures, means and methods, etc. of this falsework system would require review and approval from the Falsework Engineer and UPRR prior to implementation.*

Required notes:

- *Design, construction, and removal of falsework within the UPRR Right of Way, adjacent to or over the Railroad's operating tracks shall be in accordance with the current edition of the AREMA Manual for Railway Engineering*
- *Railroad review and approval of a detailed work plan from installation of falsework through removal is required prior to commencement of work.*

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- *Construction and removal of falsework shall comply with the AREMA MRE Sec. 28.6.5 and 28.6.6*.

UPRR General Notes Required:

1. *Railroad Flagging Protection is required when:*
   a. *Activities are within 25 feet of the track(s).*
   b. *Equipment has enough height, that if tipped, it has the potential to foul the track(s).*
2. *All equipment, material and personnel shall remain outside the Minimum Construction Clearance Envelope.*
3. *All personnel must clear the area within 25 feet of track centerline when trains pass the work site.*
4. *When trains pass the work site, all work within 50 feet of centerline of track(s) shall cease with all equipment properly secured.*
5. *Equipment under load shall not be supported on track or ballast at any time.*

Requested confirmation:

Please provide written confirmation of understanding and compliance with the following:

1. *The agency is responsible for coordinating with the Railroad's Designated Representative to obtain approval of track curfews prior to commencement of work.*
2. *The agency shall comply with all Railroad requirements and curfew limits.*
3. *The agency shall assume that only naturally occurring track windows are available unless explicitly informed otherwise by UPRR.*
4. *UPRR Structures does not have the authority to approve track curfews. UPRR Structures' review of this submittal does not in any way imply acceptance of track curfews*

Additional notes requested:

All equipment, devices and material shall be staged at sufficient distance from any track to ensure that no apparatus or part of any piece of equipment, device, or material, could under any circumstances reach closer than 25 feet to the centerline of the track.

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Attachment 5

AREMA 3.4.3

3.4.3 SHALLOW FOOTINGS ON GRANULAR MATERIAL (COHESION = 0) (1995)

3.4.3.1 General

a. The allowable soil pressure for a shallow footing on granular material depends on the width B of the footing, the shape of the footing, the depth of foundation D_f, the unit weight of the foundation material, and the position of the groundwater table.

b. The location of the present and/or future groundwater level will noticeably affect the bearing capacity and allowable settlement pressure of the footing. Due consideration should be given to the future groundwater level.

c. Vibrational loads can cause severe settlement of a footing founded on loose to medium granular soils. If future construction in the immediate area will require pile driving, vibratory compaction of subsoil, or other vibrations, then consideration should be given to a more extensive vibratory analysis and a geotechnical engineer knowledgeable in soil dynamics should be consulted.

3.4.3.2 Net Bearing Capacity of a Footing on Granular Material (Cohesion = 0)

a. The net bearing capacity of a footing on sand can be calculated from the following formulae:

For a continuous footing:

$$Q_u = 0.5\gamma BN_\gamma + D_f\gamma(N_q - 1)$$

For a square footing:

$$Q_u = 0.4\gamma BN_\gamma + D_f\gamma(N_q - 1)$$

For a circular footing:

$$Q_u = 0.3\gamma BN_\gamma + D_f\gamma(N_q - 1)$$

where:

Q_u = the net bearing capacity in lb/square foot

B = the footing width in feet

D_f = the footing depth in feet

γ = the unit weight of the sand in lb/cubic foot

$N\gamma$ and N_q = dimensionless bearing capacity factors which are a function of ϕ, the internal angle of friction, or of N, the standard penetration blow count.

3.4.3.3 Allowable Settlement Pressure for Sand

a. An empirical equation by Meyerhof may be used to estimate the allowable settlement pressure, Q_s, of a footing on sand.

(1) For $B \leq 4$ feet:

$$Q_s = \frac{Ns}{8}$$

(2) For $B > 4$ feet:

$$Q_s = \left(\frac{Ns}{12}\right)\frac{(B+1)}{B}$$

where:

Q_s = is in tons/square foot
N = the standard penetration blow count
B = the footing width in feet
s = the allowable settlement in inches

(3) The presence of a water table will have the effect of reducing the allowable settlement pressure as the effective stress is lowered. Therefore the allowable settlement pressure shall be reduced 50% if the water table is at the base of the footing and 0% if the water table is at a depth greater than B. The reduction for intermediate depths can be interpolated.

3.4.3.4 Sizing Footings on Granular Material

A trial footing size is used to determine the net bearing capacity from Article 3.4.3.2 and the allowable bearing capacity described in Article 3.4.1 is calculated by dividing the net bearing capacity by the appropriate safety factor from Article 3.4.2. The trial footing size is used to determine the allowable settlement pressure defined in Article 3.4.3.3. The loads defined in Article 3.2.3 are divided by the trial footing area to give the contact pressure defined in Article 3.4.1. If the contact pressure is greater than either the allowable bearing capacity or the allowable settlement pressure, the footing size must be increased until the contact pressure is less than the allowable soil pressure defined in Article 3.4.1.