EXAMPLE 5 PROBLEM STATEMENT:

The subject structural wall panel configurations are excerpts from a set of construction drawings for a large-volume, single-story distribution center. Two reinforced concrete tilt-up wall panels are selected for evaluation as part of this example.

The wall panels serve as the primary structural support for the roof structure as well as comprising the building’s cladding system. The roof system is comprised of open web steel joists and joist girders, both of which derive direct support from the panels (i.e., there is no structural steel framing line of beams and columns directly adjacent to the wall panels). In addition to providing direct support for gravity loading, the panels are also relied upon for lateral stability under wind or seismic loading. A continuous reinforced concrete shallow footing system is constructed to support the wall panels.

The wall panels are designed by the Engineer of Record per the requirements of ACI 318-19. Walls are considered ordinary reinforced concrete shear walls in accordance with ASCE 7-16, and as such are not categorized as special structural walls noted in Table 20.2.2.4(a) of ACI 318-19.

Design Criteria are as follows:

\[ f'_c = 4,000 \text{ psi}, \beta_1 = 0.85 \]
\[ f_y = 60,000 \text{ psi (reinforcing bar yield strength)} \]

Concrete Density = 0.145 kcf, normalweight concrete \( \lambda = 1.0 \)
Clear cover: 1.5” interior face, 2.25” exterior face (1.5” clear +0.75” reveal depth)
Figure 1: Excerpt from contract structural drawings to be used for construction
The example includes the following steps:

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td>Summary of Engineer’s Structural Design Routine and Typical Details</td>
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<td><strong>Step 2</strong></td>
<td>WWR Detailer: Determination of WWR Inclusions and Exclusions</td>
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<td><strong>Step 5</strong></td>
<td>WWR Detailer: Reinforcement Conversion Routine for WP-2</td>
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<tr>
<td><strong>Step 6</strong></td>
<td>WWR Detailing for WP-2</td>
</tr>
</tbody>
</table>
### STEP 1: Summary of Structural Design Routine and Typical Details

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Structural Engineer of Record’s design routine requires reconciliation of both gravity and lateral loading.</td>
</tr>
<tr>
<td>Due consideration is made by the engineer for the eccentric alignment of roof loading relative to the wall panel centerline, which introduces additional flexure in the wall section. Panel out-of-plane mid-height displacement due to thermal bowing is also acknowledged in the form of additional eccentricity applied to the concentrated forces due to roof joists incurred by the panel.</td>
</tr>
<tr>
<td>The panel is restrained at three levels: the roof diaphragm, the slab-on-ground, and the foundation.</td>
</tr>
<tr>
<td>The following figures illustrate design attributes, as well as the resulting content that would be presented on the contract structural drawings.</td>
</tr>
</tbody>
</table>

**Figure 2:**
Designer’s Basic Wall Panel Model with Fixities

**Figure 3 through 6:**
Designer’s “Typical” Details

**Figure 7:**
Designer’s Project-Specific Reinforcement Schedule

**Figure 8:**
Designer’s Project-Specific Panel Elevations

**Figure 9:**
Designer’s General Notes Excerpt
Figure 2: Excerpt from the engineer's design model showing panel proportions and fixities
Figure 3: Engineer’s reference panel elevations, showing typical reinforcement call-outs (continued on next page)
Figure 3 (continued): Engineer's reference panel elevations, showing typical reinforcement call-outs. Note that these elevations are illustrative only and are not necessarily project-specific. Their inclusion in the contract drawings is not only worthwhile to give the contractor clarification on general positioning of the various numbered reinforcement “categories”, but is required as it relates to the trim (9 and 10) and corner (11) reinforcement that will be present in all wall panels.
Figure 4: Engineer's typical detail showing wall panel base anchorage to the foundation level and to the slab. It is important to note that not all wall panels require physical anchorage to the foundation. Generally, foundation connection is limited to those panels that are subjected to overturning forces not capable of being resisted by the weight of the panel itself.

Both the foundation and the slab connections indicated are notable from the WWR detailer's standpoint because they represent reinforcement components that (a) can potentially be furnished in WWR form and (b) must be spatially addressed and resolved as they relate to avoidance of interruption/conflict with other “primary” wall reinforcement mats.
Figure 5: Engineer’s typical detail showing roof framing attachment. This information is notable for the WWR detailer in order to identify embedded anchorage features that could result in spatial conflict with intended positioning of the wall reinforcement. The presence of embedded components requires special attention when WWR mat configurations are being derived to ensure compatible alignment. (continued on next page)
Figure 5 (continued): Engineer's typical detail showing roof framing attachment. This version of the detail shows a formed pocket into which connection hardware and roof framing are ultimately positioned. Again, from the WWR detailer’s point-of-view, these cast-in and embedded components are items that must be acknowledged in the geometry of the WWR mats to be used on the project. (Note that this version of the detail ultimately does not apply to this example.)
Figure 6: Engineer’s typical detail showing panel reinforcing arrangement, used in conjunction with project-specific information in Figure 7 and 8.
### TILT-UP WALL PANEL SCHEDULE

<table>
<thead>
<tr>
<th>PANEL</th>
<th>THICK.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP-1</td>
<td>7.5&quot;</td>
<td>N/A</td>
<td>#4 @ 14&quot; OC E.F.</td>
<td>(4) #5 E.F.</td>
<td>(5) #5 E.F.</td>
<td>#5 @ 14&quot; OC E.F.</td>
<td>#5 @ 14&quot; OC E.F.</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>WP-2</td>
<td>7.5&quot;</td>
<td>#5 @ 14&quot; OC E.F.</td>
<td>#4 @ 14&quot; OC E.F.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### TILT-UP WALL PANEL SCHEDULE NOTES

1. REFER TO TYPICAL TILT-UP WALL PANEL REINFORCEMENT DETAILS AND PROJECT-SPECIFIC PANEL ELEVATIONS FOR REINFORCEMENT TYPES DENOTED IN SCHEDULE. REFER TO TYPICAL TILT-UP WALL PANEL REINFORCEMENT DETAILS FOR REQUIRED TRIM BARS AND CORNER BARS, NOT SCHEDULED HERE.
2. INFORMATION SCHEDULED HERE SHALL BE WORKED IN CONJUNCTION WITH FOUNDATION, FLOOR, AND ROOF SECTIONS/DATIALS TO ENSURE FULLY COORDINATED INSTALLATION OF ALL RELATED EMBEDS, BLOCK-OUTS, AND CAST-IN ELEMENTS.
3. PANELS DENOTED WITH AN ASTERISK (*) SHALL BE FURNISHED WITH HOLD-DOWN ASSEMBLIES SHOWN IN THE TYPICAL TILT-UP PANEL FOOTING ANCHORAGE DETAILS.
4. PANEL LIFT DESIGN AND SEQUENCE IS BY OTHERS. LIFTING HARDWARE AND SUPPLEMENTAL CAST-IN FEATURES SHALL NOT COMPROMISE OR ALTER STRUCTURAL REINFORCEMENT AND STRUCTURAL CAST-IN COMPONENTS DEFINED HEREIN. PANEL LIFTING POINTS AND PROCESS SHALL BE AS REQUIRED TO ENSURE 80% OF THE DESIGN STRENGTHS ASSOCIATED WITH DETAILED REINFORCED CONCRETE ASSEMBLIES HEREIN ARE NOT EXCEEDED.

*Figure 7: Engineer’s project-specific wall panel reinforcement schedule, used in conjunction with Figure 6 and 8.*
Figure 8: Engineer's project-specific wall panel reinforcement elevations. Use in conjunction with Figure 6 and 7.
MILD REINFORCING STEEL

1. DEFORMED REINFORCING BARS (REBAR) SHALL CONFORM TO ASTM A615, GRADE 80. BARS SHALL BE LAPPED IN ACCORDANCE WITH THE REBAR LAP SCHEDULES UNLESS OTHERWISE EXPPLICITLY DETAILED.

2. LONGITUDINAL REINFORCEMENT IN SPECIAL MOMENT FRAME BEAMS AND COLUMNS, AND VERTICAL AND HORIZONTAL REINFORCEMENT IN SPECIAL STRUCTURAL (SHEAR) WALLS SHALL BE ASTM A706 GRADE 60 OR GRADE 80 AS NOTED. TENSILE AND ELONGATION PROPERTIES SHALL BE CONFIRMED THROUGH MILL REPORT DOCUMENTATION PROVIDED AS PART OF THE PROJECT REINFORCEMENT SUBMITTAL.

3. WELDED DEFORMED WIRE REINFORCEMENT SHALL CONFORM TO ASTM A1064 (GRADE 80) AND SHALL BE PROVIDED IN SHEET FORM. REINFORCEMENT SHEETS SHALL BE MANUFACTURED WITH OVERHANG LENGTHS SUFFICIENT TO ACHIEVE A LAP SPLICE LENGTH EQUAL TO THE GREATER OF 12 INCHES OR THE LAP SPLICE DIMENSION SHOWN IN THE REBAR LAP SCHEDULE FOR BAR OF EQUAL (OR GREATER) DIAMETER AND GRADE, UNLESS OTHERWISE NOTED. SHEETS AND ASSOCIATED LAP REGIONS SHALL BE INSTALLED COPLANAR SO AS TO NOT “STACK”.

4. WELDED DEFORMED WIRE REINFORCEMENT OF EQUAL AREA, EQUAL OR LESSER SPACING, AND IDENTICAL CURTAILMENT (HOOKS AND LAP SPLICES) IS PERMITTED AS A SUBSTITUTION FOR DEFORMED REINFORCING BARS, EXCEPT IN THE FOLLOWING STRUCTURAL APPLICATIONS:
   A. LONGITUDINAL STEEL IN SPECIAL MOMENT FRAMES
   B. VERTICAL AND HORIZONTAL STEEL IN SPECIAL STRUCTURAL WALLS

5. ALL REINFORCING STEEL SHALL BE SECURELY TIED AND ANCHORED IN PLACE

Figure 9: Excerpt from contract documents showing the design professional's permissive WWR substitution language
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<thead>
<tr>
<th>ACI 318-19</th>
<th>Calculations</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td><strong>STEP 2: Determination of WWR Inclusions and Exclusions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.2.1.7</td>
<td></td>
<td>Deformed wire sizes between D4 and D31 are permitted.</td>
</tr>
<tr>
<td>20.2.2.4</td>
<td></td>
<td>Welded wire reinforcement is permitted for the tilt-up wall panel application (walls are not “special structural walls”).</td>
</tr>
<tr>
<td>1. The EOR allows for WWR substitution per the Mild Reinforcing Steel General Notes (Figure 9).</td>
<td></td>
<td>The WWR Detailer reviews the structural drawings and identifies notable benchmarks for carrying out the detailing of welded wire reinforcement.</td>
</tr>
<tr>
<td>2. Individual corner bars (Figure 3) will be excluded from the WWR portion of the reinforcement submittal and will remain reinforcing bars.</td>
<td></td>
<td>As is commonly deployed for numerous other cast-in-place concrete structures requiring reinforcement layout flexibility to achieve the intended design, the WWR detailer for this tilt-up wall panel project will rely heavily on single-direction mats (structural wires in one direction with non-structural “holding” wires in the other direction) to resolve the specified configurations of vertical bars and horizontal bars independent of each other. The use of one-directional WWR mats is prevalent throughout the Welded Wire Reinforcement Design and Detailing Guide and can be seen in several other example chapters.</td>
</tr>
<tr>
<td>3. Panel and opening trim bars will be included in the WWR portion of the reinforcement submittal (bars will be converted to wires).</td>
<td></td>
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</tr>
<tr>
<td>4. The tilt-up wall panel schedule (Figure 7) indicates that neither wall panel WP-1 nor WP-2 require mechanical hold-down assemblies as detailed in Figure 4. As such, the reinforcement components of these assemblies will not need to be considered for (a) WWR conversion or (b) spatial conflict resolution.</td>
<td></td>
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<tr>
<td>5. The presence of embed plates noted in the first illustration of figure 5 must be coordinated when WWR mat configurations are derived for WP-1 and WP-2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. The presence of panel openings in WP-1, resulting in somewhat irregular reinforcement layouts, must be coordinated when WWR mat configurations are derived for WP-1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACI 318-19 Calculations</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
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<td></td>
</tr>
<tr>
<td><strong>STEP 3: WWR Detailer: Reinforcement Conversion Routine for WP-1</strong></td>
<td>The following figures illustrate the WWR Detailer’s allocation of panel reinforcement areas into generalized WWR mat regions. **Worth noting is the fact that WWR mat lap splices are not being introduced anywhere in the panel. There exist geometric width limitations related to both transport and manufacture of WWR, with 8’-6” being a maximum width requiring consideration to avoid the extra expense of wide load transport, and 12’-0” being the generally accepted maximum manufactured width of a WWR mat coming off the welding machine at the plant. From a WWR detailing standpoint, one might be tempted to offset the aforementioned geometric limitations by utilizing multiple mats “laced” together by lap splicing, however, this approach could result in the positioning of lap splices in proximity to points of high tensile stress within the panel, a practice that is discouraged in ACI 318-19 and all but prohibited by practicing engineers in the prevailing detailing methodology used on contract structural drawings. While there may be exceptions, it is advisable for lap splices to be avoided unless explicitly detailed and permitted by the Engineer of Record in the original tilt-up wall panel design.</td>
<td></td>
</tr>
<tr>
<td>R25.5.2.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Welded Wire Reinforcement Design and Detailing Guide
### ACI 318-19 Calculations

**Step 3: WWR Detailer: Reinforcement Conversion Routine for WP-1 (continued)**

<table>
<thead>
<tr>
<th>Description</th>
<th>A. <strong>Edge Jamb Mats</strong> - Continuous Verticals. Horizontals spaced per designer requirements directly adjacent to opening. Horizontals spaced as &quot;holding wires&quot; outside of the extents of the opening height.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B. <strong>Center Jamb Mat</strong> - Continuous Verticals. Horizontals spaced per designer requirements directly adjacent to opening. Horizontals spaced as &quot;holding wires&quot; outside of the extents of the opening height.</td>
</tr>
<tr>
<td></td>
<td>C. <strong>Over-Opening Vertical Mats</strong> - Continuous Verticals between top of panel and top of opening. Widely-spaced horizontal &quot;holding wires&quot; throughout.</td>
</tr>
<tr>
<td></td>
<td>D. <strong>Base Horizontal Mat</strong> - Continuous Horizontals, full panel width. Verticals spaced per designer requirements below openings. Verticals omitted outside of the extents of the widths of the openings.</td>
</tr>
<tr>
<td></td>
<td>E. <strong>Over Opening Horizontal Mats</strong> - Continuous Horizontals, full panel width. Widely-spaced vertical &quot;holding wires&quot;.</td>
</tr>
</tbody>
</table>
### ACI 318-19 Calculations Description

<table>
<thead>
<tr>
<th>STEP 3: WWR Detailer: Reinforcement Conversion Routine for WP-1 (continued)</th>
</tr>
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</table>

Jamb mats A and B are configured predominantly with single directional structural vertical reinforcement in, kept “in shape” by widely-spaced horizontal holding wires. The exception occurs in the regions directly adjacent to the panel openings, where the mats include horizontal wires as required to match the engineer’s specified horizontal reinforcement.

Mats A and B will include the vertical trim bars illustrated in Figure 3, located at the vertical edges of the wall panel and at the vertical edges of the openings.
## STEP 3: WWR Detailer: Reinforcement Conversion Routine for WP-1 (continued)

Over-opening vertical mat C is configured with single directional structural vertical reinforcement kept “in shape” by widely-spaced horizontal holding wires. The vertical wires will be duly positioned to suit the alignment of the adjacent vertical trim bars along the vertical edges of the openings, which will be built into previously-described Mats A and B.

| MAT REGION WITH SINGLE DIRECTION WIRES AND MINIMAL NON-STRUCTURAL HOLDING WIRES |
| MAT REGION WITH WIRES IN BOTH DIRECTIONS |
STEP 3: WWR Detailer: Reinforcement Conversion Routine for WP-1 (continued)

Base horizontal Mat D has continuous horizontals running the full width of the wall panel. In the wall regions directly below the two openings, welded vertical wires match the engineer's specified requirements. In the wall regions that align with the previously defined A and B jamb regions, vertical wires are omitted from Mat D.

Mat D will include the horizontal trim bars illustrated in Figure 3, located at the horizontal bottom edge of the wall panel and at the horizontal bottom edge of the openings.
Over-opening horizontal mats E have continuous horizontals running the full width of the wall panel, with widely-spaced vertical holding wires throughout.

E-Mats will include the horizontal trim bars illustrated in Figure 3, located at the horizontal top edge of the wall panel and at the top edge of the openings.
With the allocation process done, it is time to actually generate the physical WWR mat configurations to populate the allocated regions.

Mats A and B are shown here. Notice how both mat configurations contain “design” horizontal wire in the regions directly adjacent to the openings, while the remainder of the lengths of the mats contain only widely-spaced non-structural holding wires to maintain shape. Also note that the WWR detailer has kept the lower extent of the A- and B-Mat free of horizontals, which will help avoid potential wire collision at its interface with the D-Mat. Of equal importance is the exclusion of horizontals in the upper extent of the mat, affording the placers some flexibility to slightly shift the verticals for the purpose of avoidance of embedded anchorage items at the roof framing level.

Both A-Mat and B-Mat contain vertical trim bars. A-Mat was scheduled in Figure 6 to have (4) #5. With two (2) trim bars “built in”, it has a total of six (6) verticals. For the B-Mat, scheduled bars (5) plus trim bars (2) bring the total verticals to seven (7). Half-inch dimensions noted are nominal overhangs required for manufacture.

**A-MAT:**
4 X V2 D31/D20 20" (+0.5",+0.5") X 29'-8" (34, 34)
V2= 34" OH, 68", 60", 64", 6 @ 14", 46" OH

**B-MAT:**
V1 X V2 D31/D20 32" (+0.5",+0.5") X 29'-8" (34, 34)
V1= 0.5" OH, 4", 4 @ 6", 4", 0.5" OH
V2= 34" OH, 68", 60", 64", 6 @ 14", 46" OH
For the C-Mats, vertical reinforcement is originally defined for this region to be #5 @ 14" on center (each face of wall panel).

\[
#5 @ 14" OC = 0.266 \frac{in^2}{ft}
\]

\[
0.266 \times 9 \text{ feet width} = 2.394 in^2
\]

Use (8) D31 wires \((A_s = 2.48 in^2)\)

Eight (8) vertical wires are spaced at 14" on center.

Since the WWR detailer is not capturing any of the horizontal structural reinforcement on this particular mat configuration, the only horizontals used will be non-structural holding wires, and their size will be reduced to suit the manufacturer’s requirements for maintaining shape during handling, transport, and placement.

Finally, note that the overall mat width is still less than the maximum that would require oversize load transport, resulting in a monetary savings.

**C-MAT:**

14 X V2 D31/D12 98" (+0.5",+0.5") X 17'-8" (34, 50)

V2 = 34" OH, 68", 60", 50" OH
So far, Mats A, B, and C have been configured and positioned. The figure to the left shows this arrangement. Note the placement of the C-Mats (blue) symmetrically above the wall panel openings, resulting in a 7-inch offset from the A- and B-jamb mats (red). Also noteworthy is the alignment of the non-structural holding wires; the C-Mats were configured such that holding wire position matched that which was previously established for the A-mat and B-mat.

Roof structure embedment plates are represented by the five (5) rectangles positioned at varying elevations towards the top of the wall panel. Verticals are capable of slight shifting if necessary to avoid conflict with the embedded headed studs associated with the plates.

Non-structural holding wires are not intended to contribute in any way to the structural performance of the reinforced concrete element. As such, once the WWR mats are being positioned in the forms and chaired/bolstered, holding wires can themselves be field cut to allow for added localized adjustment of the structural wire alignment if conflicts with embedded items remain. The permission to field cut non-structural holding wires would be explicitly defined and illustrated by the WWR Detailer on the reinforcement submittal and placement drawings to ensure no confusion.
**ACI 318-19 Calculations**

<table>
<thead>
<tr>
<th>STEP 4: WWR Detailer: WWR Detailing for WP-1 (continued)</th>
</tr>
</thead>
</table>

For the D-Mat, vertical reinforcement is originally defined for this region to be #5 @ 14” on center and horizontals defined to be #4 @ 14” on center. The pattern of vertical wires to replace the vertical bars will match that used in the C-Mats above the openings. The horizontal wires are determined as follows (each face of wall panel):

\[
\#4 \, @ \, 14'' \, OC = 0.171 \, \frac{in^2}{ft}
\]

\[
0.171 \, \frac{in^2}{ft} \times 3 \, \text{feet height} = 0.513 \, in^2
\]

*Three (3) D20 = 0.60 in\(^2\) ...

*But spacing would be \( \frac{36 - 2'' - 2''}{2 \, \text{spaces}} = 16'' \)

*Use (4) D20. Resulting spacing is 10”, 12”, 10”.

Note that panel trim bars are “built in” to the WWR mat configuration.

V1 X V2  D20/D31  32" (+0.5",+0.5") X 24'-8" (27,27)

V1 = 0.5” OH, 10”, 12”, 10”, 0.5” OH

V2 = 27” OH, 7 @ 14”, 46”, 7 @ 14”, 27” OH
STEP 4: WWR Detailer: WWR Detailing for WP-1 (continued)

A composite of Mats A, B, C, and D is shown at left.

While not explicitly noted during the previous configuration exercise for A-Mat and B-Mat, the positioning of the horizontal structural wires on these mats, adjacent to openings, was done in a manner that anticipated the presence of other WWR mats containing the horizontal trim wires at the bottom (shown) and top (subsequent, on E-Mat) of the wall panel openings.

As can be seen, the placement of D-Mat is such that, not only are horizontal trim wires captured thereon, but the engineer’s prescribed 14” spacing is maintained at the “transition” from D-Mat horizontals upward to A-Mat and B-Mat horizontals.

This is where the use of WWR mats can prove to be far superior to placement of individual loose bars. The tilt-up wall panel site fabrication process itself is innately modular, and when coupled with WWR assemblies the labor and time expenditure, as well as the tolerance control, results in an extremely efficient and streamlined construction operation.

One of the keys for both the design professional and contractor is the ever-increasing contributions of highly-skilled and knowledgeable WWR detailers throughout the welded wire reinforcement manufacturing industry. Without the WWR detailing professional, the implementation of WWR into structural projects would be a considerably more arduous undertaking.
## ACI 318-19 Calculations

### Description

**STEP 4: WWR Detailer: WWR Detailing for WP-1 (continued)**

The E-Mat configuration is shown in the figure at the left. Two E-Mats will be used over the openings to complete the panel's primary structural reinforcement arrangement.

E-Mat contains structural horizontal wires to replace horizontal #4 @ 14” on center, with non-structural vertical holding wires positioned to avoid conflict with the structural wires of other mats as well as embedded wall panel items.

Notice that E-Mat contains trim reinforcement, as is readily apparent in subsequent illustrations.

| E-MAT | (8) D20 HORIZONTALS SPACED AT 14", D12 NON-STRUCTURAL VERTICAL HOLDING WIRES AT VARIABLE SPACING. |
### STEP 4: WWR Detailer: WWR Detailing for WP-1 (continued)

<table>
<thead>
<tr>
<th>ACI 318-19</th>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>The full WWR reinforcement assembly is shown at left, with non-structural holding wires of A-, B-, and C-Mats represented by hidden (dashed) lines.</td>
</tr>
<tr>
<td>ACI 318-19 Calculations</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td><strong>STEP 4: WWR Detailer: WWR Detailing for WP-1 (continued)</strong></td>
<td>The full WWR reinforcement assembly is shown at left, with all non-structural holding wires represented by hidden (dashed) lines. Layout of non-structural holding wires is a critical component of the WWR mat detailing process, as it is the WWR detailer’s responsibility to provide “workable” sheets of reinforcement for the crew in the field without compromise to the engineer’s structural design intent nor disruption of intended geometric tolerances. In this regard, not only is the WWR detailing professional required to have a good technical grasp of the structural requirements themselves, but they must also have intimate familiarity with manufacturing capabilities and an artistic yet concise methodology of presenting the detailed information to project stakeholders. Note that within the thickness of the wall, holding wires physically occupy the same plane as structural wires, hence all of the attention paid to their arrangement. The result is that positioning of structural vertical and horizontal reinforcement shown in Figure 6 is maintained. Structural vertical wires are positioned outermost in the panel (nearest the surface), and the horizontal holding wires that are welded to them will occupy the same plane as the structural horizontal wires from the other mats placed in direct contact with said outermost mats. This then leaves the non-structural vertical wires associated with the structural horizontal mats. These non-structural vertical wires simply align to the inside of the structural horizontals and occur in a plane where no other reinforcement is positioned.</td>
<td></td>
</tr>
</tbody>
</table>
The full WP-1 WWR reinforcement assembly is shown at left, with all non-structural holding wires removed from view, and color-coding turned off.

The configuration shown would be placed in each face of the wall panel, and the contractor would be responsible for adding the individual diagonal corner bars noted previously in Figure 3.

In the end, for WP-1, the comparison is as follows (excluding aforementioned diagonal corner bars):

**Reinforcing Bar Solution:**
- Placement and tying of 184 loose reinforcing bars (51 verticals and 41 horizontal, each face)

**Welded Wire Reinforcement Solution:**
- Placement of 16 prefabricated WWR mats

For clarification and transparency, the WWR shop/placement drawings for a tilt-up wall panel project will typically include submittal documentation that quantitatively supports the conversion of reinforcing bars over to welded wire reinforcement mats. For an example of this support documentation, refer to the Shallow Foundations example chapter of this guide.
The following figures illustrate the WWR Detailer’s allocation of panel reinforcement areas into generalized WWR mat regions.

Both WP-1 and WP-2 derive the entirety of their structural restraint from attachment to horizontally-oriented external “planes” (roof diaphragm level and slab level). As such, an individual wall panel, buffered on each of its vertical edges by a flexible control joints that creates physical separation (structural discontinuity) between itself and abutting wall panels, can only reliably span vertically to external supports; it has no quantifiable ability to span horizontally because no such external supports exist along the vertical panel edges. In this regard, the wall panels in this example are truly one-way spanning elements: resolution of the effects of out-of-plane flexural loading is achieved entirely through spanning in the vertical direction.
Because of the presence of openings within the field of Wall Panel WP-1, there is invariably some *internal* resolution of out-of-plane flexure by way of “spandrel” portions of the wall (above/below openings) spanning horizontally between the full height vertical jambs/piers. While the jambs/piers do receive this force by way of horizontal redistribution, in the end they still depend entirely on their own vertical spanning ability to seek out restraint from external horizontal planes.

WP-2, on the other hand, has no internal discontinuities that create the need for horizontal redistribution of out-of-plane flexural effects; the internal flexural load path, then, is entirely vertically-spanning.

The offshoot of this WP-2 behavior is that the horizontal reinforcement is essentially relegated to shrinkage and temperature effects (and in extreme instances, in-plane shear resistance). This shift in responsibility of the horizontal reinforcement may allow for the WWR mats themselves to be spliced in the horizontal direction. With that said, lap splices other than those explicitly illustrated and/or defined by the design professional or record would of course require the designer’s approval, so for this example a solution comprised of mats with lap spliced horizontal wires is not illustrated.

WP-1 relies on vertically continuous portions of the wall to deliver effects of out-of-plane flexural loading to the roof and floor diaphragm. Spandrel portions of the wall rely on horizontal distribution of out-of-plane flexure to the continuous portions of wall, especially in closer proximity to the tops of the wall panel openings.

WP-1 is entirely vertically-spanning. There is no expectation for the wall panel to have any internal horizontal redistribution of out-of-plane flexural effects.
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<th>Description</th>
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<tr>
<td><strong>STEP 5: WWR Detailer: Reinforcement Conversion Routine for WP-2 (continued)</strong></td>
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</table>

A. **VERTICAL MATS** - CONTINUOUS VERTICALS. WIDELY-SPACED, NON STRUCTURAL HORIZONTAL "HOLDING WIRES".

B. **HORIZONTAL MATS** - CONTINUOUS HORIZONTALS. WIDELY-SPACED, NON STRUCTURAL VERTICAL "HOLDING WIRES".

![Diagram of vertical and horizontal reinforcement mats]
### ACI 318-19 Calculations

#### Description

**STEP 5: WWR Detailer: Reinforcement Conversion Routine for WP-2 (continued)**

A-Mats are configured as single directional structural vertical reinforcement kept “in shape” by widely-spaced horizontal holding wires.

Panel vertical trim bars will be configured as part of the mats.

| MAT REGION WITH SINGLE DIRECTION WIRES AND MINIMAL NON-STRUCTURAL HOLDING WIRES |
| MAT REGION WITH WIRES IN BOTH DIRECTIONS |

![Diagram showing material configuration and labels](image-url)
B-Mats are configured as single directional structural horizontal reinforcement kept "in shape" by widely-spaced vertical holding wires.

Panel horizontal trim bars will be configured as part of the mats.
STEP 6: WWR Detailer: WWR Detailing for WP-2

For the A-Mats, vertical reinforcement is originally defined to be #5 @ 14” on center (each face of wall panel).

\[
#5 \text{ @ 14” } OC = 0.266 \frac{in^2}{ft}
\]

\[
0.266 \frac{in^2}{ft} \times 25 \text{ feet width} = 6.65 \text{ in}^2
\]

(22) D31 wires \((A_s = 6.82 \text{ in}^2), \text{required, min.}\)

In configuring the mats, based on the overall wall panel width, it is clear that three mats will be necessary in order to avoid monetary ramifications of oversize transport widths. The solution comes in the form of a three-mat arrangement comprised of one (1) A1 mat with seven D31 wires and two (2) A2 mats, each with eight D31 wires. This results in a total of (23) D31 wires.

Horizontal wires are non-structural, sized as D14 to maintain shape of the WWR and spaced to avoid conflict with the structural horizontal wires on the B-mats.

**A1-MAT:**
V1 X V2 D31/D14 72” (+0.5”,+0.5”) X 29’-8” (56, 62)
V1 = 0.5” OH, 14”, 4 @ 11”, 14”, 0.5” OH
V2 = 56” OH, 70”, 2 @ 84”, 62” OH

**A2-MAT:**
14 X V2 D31/D14 98” (+0.5”,+0.5”) X 29’-8” (56, 62)
V2 = 56” OH, 70”, 2 @ 84”, 62” OH
The A-Mat layout within the wall panel is shown at left. A single A1-Mat is centered in the panel and flanked on each side by an A2-Mat. The symmetrical arrangement of vertical wires minimizes guesswork in the field as the workers place the mats in the forms.

Non-structural holding wire offset from the top of the panel allows for localized flexibility in the event that slight shifting of the verticals is required to avoid spatial conflict with embedded elements.
For the B-Mats, horizontal reinforcement is originally defined to be #4 @ 14” on center (each face of wall panel).

\[
\#4 @ 14" \text{ OC} = 0.172 \frac{in^2}{ft} 
\]

\[
0.172 \frac{in^2}{ft} \times 30 \text{ feet height} = 5.15 \text{ in}^2
\]

(26) D20 wires \((A_s = 5.20 \text{ in}^2)\), required, min.

In configuring the mats, based on the overall wall panel width, it is clear that four mats will be necessary in order to avoid monetary ramifications of oversize transport widths. The solution comes in the form of a four-mat arrangement comprised of one (1) B1 mat with six D20 wires and three (3) B2 mats, each with seven D20 wires. This results in a total of (27) D20 wires.

Vertical wires are non-structural, sized as D14 to maintain shape of the WWR and spaced to avoid conflict with structural vertical wires on the A-mats.

**B1-MAT:**

\(V1 \times V2 \text{ D20/D14} \quad 62" \quad (+0.5",+0.5") \times 24'-8" \quad (50, 50)\)

\(V1 = 0.5" \text{ OH, 14", 12", 12", 14", 12", 14", 0.5" OH}\)

\(V2 = 50" \text{ OH, 68", 60", 68", 60", 68", 60", 50" OH}\)

**B2-MAT:**

\(14 \times V2 \text{ D20/D14} \quad 84" \quad (+0.5",+0.5") \times 24'-8" \quad (56, 62)\)

\(V2 = 50" \text{ OH, 68", 60", 68", 60", 68", 50" OH}\)
### STEP 6: WWR Detailer: WWR Detailing for WP-2 (continued)

The B-Mat layout within the wall panel is shown at left. A single B1-Mat aligns at the top of the wall panel, with the balance of the panel covered by three (3) B2-Mats. The symmetrical arrangement of wires on each mat minimizes guesswork in the field as the workers place the mats in each face of the form.

Non-structural holding wires offset from the embedded item positions allow for localized flexibility in the event that slight shifting of the horizontals is required to avoid spatial conflict with embedded elements.
### STEP 6: WWR Detailer: WWR Detailing for WP-2 (continued)

The full WP-2 WWR reinforcement assembly is shown at left, with all non-structural holding wires represented by hidden (dashed) lines.

Layout of non-structural holding wires is a critical component of the WWR mat detailing process, as previously noted for WP-1.
### ACI 318-19 Calculations Description

**STEP 6: WWR Detailer: WWR Detailing for WP-2 (continued)**

<table>
<thead>
<tr>
<th>The full WWR reinforcement assembly is shown at left, with all non-structural holding wires removed from view, and color-coding turned off.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The configuration shown would be placed in each face of the wall panel.</td>
</tr>
<tr>
<td>In the end, for WP-1, the comparison is as follows:</td>
</tr>
<tr>
<td><strong>Reinforcing Bar Solution:</strong></td>
</tr>
<tr>
<td>• Placement and tying of 100 loose reinforcing bars (23 verticals and 27 horizontals, each face)</td>
</tr>
<tr>
<td><strong>Welded Wire Reinforcement Solution:</strong></td>
</tr>
<tr>
<td>• Placement of 14 prefabricated WWR mats</td>
</tr>
</tbody>
</table>

For clarification and transparency, the WWR shop/placement drawings for a tilt-up wall panel project will typically include submittal documentation that quantitatively supports the conversion of reinforcing bars over to welded wire reinforcement mats. For an example of this support documentation, refer to the *Shallow Foundations* example chapter of this guide.