FLEXURAL DESIGN

Typically, a continuous slurry wall is reinforced in two directions and spans vertically between supports that consist of bracing members or concrete slabs. Therefore, only minimum horizontal reinforcement is required in accordance with ACI 318-89, Sect. 14.3.3.

For vertical reinforcing, strive for 150-mm (6-inch) spacing, bundle if necessary and do not splice in congested areas. Consider #9 and #11 bars at 150-mm and 30o-mm (6-inch and 12-inch) spacing and compute the ultimate moment capacity *(ØMn)* for the various bar sizes and spacing. This spacing allows for better concrete placement.

The effective depth (d) requires some attention because it greatly affects the amount of reinforcing. ACI 318-89, Section 7.7.1(a) prescribes for "concrete cast against and permanently exposed to earth" a minimum concrete cover for reinforcement of 76 mm (3 inches). Furthermore, a tolerance of 25 mm (1 inch) in placing the steel is prescribed by ACI 117-702 (Tolerances) Section 2.2 (Reinforcement Placement), which is intended for formed walls. Additionally, out-of-plumb tolerance of the wall should be considered and typically not to exceed 25 mm (1 inch) from floor to floor. Finally, bulges and cavities occur typically as a result of slurry wall construction, resulting in loss of cross section and at times, exposed reinforcement.

Taking all the above into account, I recommend computing d as follows (for a 3-foot wall):
[Note: Metric conversions of the following calculations are not provided.]

$d = 36 - 3 \text{ (cover)} - 1 \text{ (rebar tolerance)} - 1 \text{ (other tolerances)} - 1/2 \text{ (\#4 stirrup)} - d^b/2 \text{ (rebar)}$
$\quad = 36 - 5.5 - d^b/2$

for #9 bars, $d = 36 - 5.5 - 1.13/2 = 29.9$ in. for #11 bars, $d = 36 - 5.5 - 1.41/2 = 29.8$ in.

Use d = 29.5 inches. Some may argue that this is too conservative. It is an engineering judgment that should be used on a case by case basis and depends largely on the degree of protection required and the type of structure under study.

Minimum Vertical Reinforcement. This requirement may also be subject to debate. One can rightfully turn to ACI 318, Chapter 14 on walls and determine from section 14.3.2, that the minimum vertical reinforcement required is as follows:

(A_v) min. $= 0.0015(12)(36) = 0.65\ in^2 \div 2$ each face
$= 0.33\ in^2/ft$ (#5 @ 11 inches or #6 @16 inches)

However, bearing in mind the intent of ACI's requirements for walls as being primarily compression members, while a slurry wall is primarily a flexural member, I recommend using section 10.5.2 of ACI which calls for providing reinforcement at least one-third greater than that required by analysis. What is required by analysis could be, as a minimum, the moment capacity of the wall as a plain concrete section determined from the modulus of rupture of concrete (f_r):

$M_{cr} = f_r I_g/y_t$ (ACI Eq. 9-8)
With $fc = 4{,}000$ psi
$fr = 7.5SQR(4000) = 474$ psi (ACI Eq. 9-9)
$M_{cr} = 474(46656) \div (18 \times 12000) = 102.4$ ft-k
$\rho = 0.0022\ (= As \div bd)$
(ACI 10.5.2): $\rho_{min.} = 0.0022(4/3) = 0.0029$
$\Longrightarrow (As)_{min.} = 0.0029(12)(29.5) =$
$1.03\ in^2/ft$ use #9 @ 12 inches ($1.0\ in^2/ft$)

Therefore, if the applied moment is less or equal than 102.4 ft-k, provide minimum reinforcement as computed above along each face of the wall. It is also important to point out on the detailed drawings that the total number of bars provided in the wall should be based on the overall panel length. This is because of the large concrete cover to the vertical bars from the ends of the panel, which can be as much as 9 inches and is dictated by the size of the end stops.

On the other hand, some may consider ACI section 10.5.3 more appropriate for a slurry wall since it is essentially a one-way structural slab of uniform thickness. This is true from the standpoint of width to depth ratio; however, a slab is typically much thinner than a 3-foot slurry wall section, and using section 10.5.3 or $(As)_{min} = 0.0018(12)(36) = 0.78\ in^2$, will result in a moment capacity of 101 ft-k which slightly smaller than the cracking strength of plain concrete *(102.4 ft-k, see above)*, and therefore would not be effective or contribute to the wall's bending resistance. Moreover, besides its own weight, a slab is not normally subjected to a true permanent and uniform loading, and that is the reason why the minimum reinforcement required for slabs is less than that for beams, since an overload as discussed in the Code's Commentary would be distributed laterally and sudden failure would be less likely. A slurry wall on the other hand is permanently subjected to the uniform loading of soil and water (primary loads), and hence for design purposes, my recommendation is to use section 10.5.2.

SHEAR DESIGN

The ultimate shear capacity of the concrete is determined by ACI Section 11.3 as follows:

$ØV_c = 0.85(2)SQR(4000)(12)(29.5)/1000 = 38\ K/ft$

If the shear force V_u is less than 38 kips/foot then no shear reinforcement is required. If V_u is greater than 38 kips/foot, provide minimum stirrups to meet ACI section 11.5.5.3.

In contrast to flexural design, the shear design in this case is quite straightforward, however some disagreement lies in the detailing and placing of the stirrups. The issue is whether to hook the shear reinforcement around the vertical bars (my recommendation) or around the horizontal bars as shown in Figure 3. This recommendation is based on ACI Code sections and are intended to promote further discussion. The ACI requirements are discussed in depth in the original paper.