4.1 Introduction

This Chapter deals with the study of designing of Formwork for the flat slab of residential building used as a case study which consists of four floors with an area (2377.6 ft.sq). The study includes design for Sheathing, Joist, Stringer and Shore, according to the requirements of the ACI Committee 347. And the design calculations have been done through excel spreadsheets program following the design steps mentioned in chapter three.

4.1.1 Case study

The plan of the case study used, is shown in Figure (4.1) and in the following there are more details and assumptions about it:
Concrete construction building with building area 2377.6 fit square (202.5 m²) for the purpose of Design, assume the formwork used to support flat slab floor of a thickness of 7.9 inches (20 cm) and conventional density concrete.
Sheathing will be ply-wood that has the following characterize
- Type : APA B-B ply-form class 1 with species group of face ply = 2 (sanded panels ).
- Dry Conditions.
- Thickness = $1 \frac{1}{8}$ in (2.85 cm)
Figure (4.1): Case Study

In the following there are design calculations for the elements of formwork of flat slabs as formulated in the excel spreadsheet.

4.2 Manual Design:

4.2.1 Design Loads:

*Dead load = weight of concrete + weight of the formwork

\[
= 7.9\text{ in} \times 150 + 5.0 \text{ (assumed)}
\]

\[
= 98.75 + 5 = 103.75 \text{ lb/ft}^2
\]

*Live load = 75 lb/ft² (according to ACI = 347).

*Total vertical load = 75 + 103.75 = 178.75 lb/ft²
4.2.2 Sheathing:

* Thickness = $1\frac{1}{8}\text{ in}$. (Sanded panels)

* from Table (3.12) to (3.14) we get the following properties:

Grade stress Level S-2

$A = 3.854\text{ in}^2$

$(KS) = 0.820\text{ in}^3\text{/ ft}$

$I = 0.548\text{ in}^4$

$\frac{lb}{Q} = 9.883\text{ in}^2\text{/ ft}$

$F_b = 1200\text{ psf}$

$F_v = 140\text{ psf}$

$E = 1.5\times10^6\text{ psf}$

* Consider 1-ft strip. It carries a load of $178.75\times1 = 178.75\text{ lb/ ft}$

From Table (3.15), using 3 or more spans:

**Bending:**

$$w_b = \frac{120F_b(KS)}{l_1^2}$$

$$178.75 = \frac{120\times1200\times0.82}{l_1^2}$$

get

$$= 25.70\text{ in}$$

**Shear:**

$$w_s = 20F_v\frac{lb/}{Q} l_2$$

$$178.75 = \frac{20\times140\times9.833}{l_2}$$

$$= 154.027\text{ in}$$
Deflection:

\[ \Delta = \frac{w l^4}{1740 EI} \]

\[ < \frac{l_3}{360} \]

\[ \frac{l_3}{360} = \frac{178.75 * l_3^4}{1740 * 1.5 * 10^6 * 0.548} \]

\[ = 28.12 \text{ in } l_3 \]

Bending governs. Allowable span = 25.70 in
joist spacing = 25.70 / 12.5 = 2.056 ft.

4.2.3 Joists:

From Table (3.6) to (3.8), we can get the following values for Redwood (select-structural):

= 1350 psi \( F_b \)

= 80 psi \( F_v \)

= 650 psi \( F_{\text{r\perp}} \)

\[ E = 1.4 * 10^6 \text{ psi} \]

Temperature factor \( C_f = 1.0 \)

Load duration factor \( C_D = 1.25 \)

Shear stress factor \( C_H = 2.0 \) (no split case)

Choose 2×6 Redwood which has the following characteristics:

\( A = 8.25 \text{ in}^2 \)

\( S = 7.563 \text{ in}^3 \)

\( I = 20.8 \text{ in}^4 \)

\( d = 5.5 \text{ in} \)

\( C_f = 1.20 \)

Load/ ft of joist = 178.75 \( \times \) 2.056 = 367.51 lb/ft
Bending:

\[ F_b' = F_b(C_f)(C_i)(C_D) \]

\[ = 1350 \times 1.2 \times 1.0 \times 1.25 = 2025 \text{ lb/ft} \]

From Table (3.16)

\[ l = 10.95 \left( \frac{F_b' \times S}{w} \right)^{\frac{1}{2}} \]

\[ = 10.95 \left( \frac{2025 \times 7.563}{367.51} \right)^{\frac{1}{2}} \]

\[ = 70.686 \text{ in} = 5.654 \text{ ft} \]

Shear:

\[ F_v' = F_v(C_m)(C_i)(C_D) \]

\[ = 80 \times 2.0 \times 1.0 \times 1.25 = 200 \text{ psi} \]

\[ l = 13.3 \left( \frac{F_v' \times A}{w} \right) + 2 \times d \]

\[ = 13.3 \times \frac{200 \times 8.25}{367.51} + 2 \times 5.5 \]

\[ = 70.712 \text{ in} = 5.657 \text{ ft} \]

Deflection:

\[ E' = 1.4 \times 10^6 \text{ psi} \]

\[ \Delta < \frac{l}{360} \]

\[ l = 1.69 \left( \frac{EI}{w} \right)^{\frac{1}{3}} \]

\[ = 1.69 \left( \frac{1.4 \times 10^6 \times 20.8}{367.51} \right)^{\frac{1}{3}} \]

\[ = 72.587 \text{ in} = 5.80 \text{ ft} \]

Shear governs. Span of joists = 70.686 in \( \approx 5.654 \) ft (OK)
4.2.4 Stringers:

Load on a stringer is $= 178.75 \times 5.654 = 1010.65$ Ip/ft

Use 2×8 (tow stringers)

$b = 1.5$ in
$d = 7.25$ in
$I = 47.63$ $in^4$
$A = 10.88$ $in^2$
$S = 13.14$ $in^3$
$E = 1.4 \times 10^6$ psi
$C_f = 1.2$

**Bending:**

$$ F_b' = F_b(C_f)(C_i)(C_D) $$

$$ = 1350 \times 1.2 \times 1.0 \times 1.25 = 2025 \text{ psi} $$

$$ l = 10.95 \left( \frac{F_b' \times S}{w} \right)^{\frac{1}{2}} $$

$$ = 10.95 \left( \frac{2025 \times 13.14 \times 2}{1010.65} \right)^{\frac{1}{2}} $$

$$ = 79.45 \text{ in} \quad = 6.36 \text{ ft} $$

**Shear:**

$$ l = 13.3 \times \left( \frac{F_s' \times A}{w} \right) + 2 \times d $$

$$ = 13.3 \times 200 \times (10.87 \times 2 \text{ twostringers}) $$

$$ = \frac{13.3 \times 200 \times (10.87 \times 2 \text{ twostringers})}{1010.65} + 2 \times 7.25 \text{ in} $$

$$ = 71.719 \text{ in} \quad = 5.74 \text{ ft} $$

**Deflection:**
\[ \Delta < \frac{l}{360} \]

\[ l = 1.69 \times \left( \frac{1.4 \times 10^6 \times 47.63 \times 2}{1010.65} \right)^{\frac{1}{3}} \]

= 86.04 in = 6.88 ft

Take stringer spacing = 5.74 ft

* Check for crushing (joist on stringer):

Force transmitted from joist to stringer is equal to load of joist/ft multiplied by the span of the joist, force = 5.654 \times 367.51 = 2077.90 lb

Area through which this force is transmitted = 1.5 \times 3 = 4.5 \text{ in}^2

Crushing stress = \frac{2077.90}{4.5} = 461.75 \text{ lb/ in}^2

From Table 3.6a, we get the following properties:

\[ = 650 \text{ lb/in}^2 F_{c\perp} \]

Bearing area factor = 1.25 (b = 1.5 in)

Temperature factor = 1.0

\[ F'_{c\perp} = F_{c\perp} (C_b)(C_t) \]

\[ = 650 \times 1.25 \times 1 = 812.5 \text{ psi since } 461.75 < 812.5 \text{ (safe in crushing)} \]

**Shore strength:**

Required shore spacing = (stringer span)

Shore strength = span of stringer \times load of stringer

\[ = 5.74 \times 1010.65 = 5801 \text{ lb} \]

So we use shores strength is larger than 6000 lb
Design by Microsoft Excel:

4.3 Input Data [See Figs. (4.2) - (4.4)]

Fig.(4.2): Excel Spread Sheet Menu.

Fig.(4.3): Input data Menu.
4.3.1 Slab Input

\[ \text{thickness of slab} = 7.9 \text{ in} \]

**Sheathing:**

\[ \text{thickness of sheathing} = 1 \frac{1}{8} \text{ in} \quad \text{(Sanded panels)} \]

From Tables (3.12) to (3.14) (Appendix B), we get the following properties:

Grade stress Level = S-2

\[ A = 3.854 \text{ in}^2 \]

\[ (KS) = 0.825 \text{ in}^3/\text{ft} \]

From tables (3.12)
$I = 0.548$
$BQ = 9.883$ in²/ft

$F_v = 1200$ psf
$F_i = 140$ psf from tables (3.14)
$E = 1500000$ psf

**Joists:**
Select type of wood - from tables 3.3 to 3.8(Appendix B), we can get the following values for Redwood

(Select-Structural:

$k_b = 1350$ psi from table (3.3)
$F_v = 80$ psi from table (3.3)
$F_i = 650$ psi from table (3.3)
$E = 1400000$ psi from table (3.3)

Temperature factor $C_t = 1.0$ from table (3.8)
Load duration factor $C_D = 1.25$ from table (3.7) (no split case)
Shear stress factor $C_H = 2$ from table (3.4d)

Choose (2 *6) Redwood which has the following characteristics : (from table 3.2)

$A = 8.25$ in²
$S = 7.563$ in³
\[ \begin{align*}
I &= 20.8 \text{ in}^2 \\
d &= 5.5 \text{ in} \\
C_f &= 1.2 \\
b &= 1.5 \text{ in}
\end{align*} \]

Temperature factor \( C_t = 1.0 \) from table (3.8)

Load duration factor \( C_d = 1.25 \) from table (3.7)

Shear stress factor \( C_h = 2 \) (no split case) from table (3.4d)

Choose (2*6) Redwood which has the following characteristics (from table 3.2):

\[ \begin{align*}
A &= 8.25 \text{ in}^2 \\
S &= 7.563 \text{ in}^3 \\
I &= 20.8 \text{ in}^4 \\
d &= 5.5 \text{ in} \\
C_f &= 1.2 \\
b &= 1.5 \text{ in}
\end{align*} \]

Shore:

Bearing Area Factor = 1.25 from table (3.9) (b=1.5 in)

Temperature Factor = 1.0 from table (3.8)

\[ \text{4.3.2 Design Load on formwork} \]

Weight of concrete (Ib./cubic foot) = 98.75

Weight of formwork (Ib./cubic foot) = 5

Dead Load (Ib./cubic foot) = 103.75
Live load (lb/cubic foot) = 75 (according to ACI = 347)

Total vertical load = 178.75 lb/ft²

Figure (4.5): Slab Form Components

4.3.3 Design of Sheathing

* Consider 1-ft strip. It carries a load of = 178.75 lb/ft²

From table 3.15, using 3 or more spans:

Bending:

\[ l_1^2 = 660.5874 \]
\[ l_1 = 25.70 \text{ in} \]

Shear:

\[ l_2 = 154.81 \text{ in} \]

Deflection:
\[ l_i^3 = 22226.57 \]
\[ l_i = 28.12 \text{ in} \]

Joists spacing = \[ 25.70 \text{ in} \]
Joists spacing = \[ 2.056 \text{ ft} \]

### 4.3.4 Design of Stringer

Load on a stringer is  = \[ 1010.79 \text{ ip/ft} \]

**Bending:**

\[ F_b = 2025 \text{ psi} \]
\[ l = 79.45 \text{ in} \]
\[ = 6.36 \text{ ft} \]

**Shear:**

\[ l = 71.764 \text{ in} \]
\[ = 5.74 \text{ ft} \]

**Deflection:**
4.3.5 Design of joists

Load / ft of joist = 367.537 lb/ft

Bending:

\[ F_b^* \equal{} 2025 \text{ lb/ft} \]

From Table 3.16

\[ l \equal{} 70.70826 \text{ in} \]
\[ = 5.675 \text{ ft} \]

Shear:

\[ F_s^/ = 200 \text{ psi} \]

\[ l = 70.70826 \text{ in} \]
\[ = 5.657 \text{ ft} \]

Deflection:

\[ l = 72.55825 \text{ in} \]
\[ = 5.80 \text{ ft} \]
span of joists = 5.655 ft

4.3.6 Design of Shore

Check for crushing (joist on stringer):

force transmitted from joist to stringer is equal to load of joist/ft multiplied by the span of the joist,

force = 2078.33 lb

Area through which this force is transmitted:

\[ 1.5 \times 3 = 4.5 \text{ in}^2 \]

Crushing stress = 461.851 lb/in²

from Table 3.6a, we get the following properties:

\[ F_{c} = 650 \text{ lb/in}^2 \]

Bearing area factor = 1.25 from table 3.9

Temperature factor = 1.0 from table 3.8

\[ F'_{c} = 812.5 \text{ psi safe in crushing} \]

Shore strength

Required shore spacing = (stringer span)

Shore strength = span of stringer * load of stringer

= 5803.04 lb

So we use shore strength is larger than 5804 lb
4.4 Distribution of Joist & Stringers:

4.4.1 Distribution of Joist For length 13.5m (Figure 4.1):

Joist spacing = 2.056 ft/3.28 = 0.626 m

Span 5 m (net span = 4.7 m)

No of joist = 4.7/0.626 = 7.5 joists
Spacing between joist = 4.7/7.5 = 0.63 m

Span 4.25 m (net span = 3.95 m)

No of joist = 3.95/0.626 = 6.3 joists
Spacing between joist = 3.95/6 = 0.66 m

4.4.2 Distribution of Stringers For length 17 m (Figure 4.1):

Stringers spacing = 5.741 ft/3.28 = 1.75 m ≈ 2 m

Span 4 m (net span = 3.7 m)

No of Stringers = 3.7/2 = 1.85 ≈ 2 Stringers
Spacing between Stringers = 3.7/2 = 1.85 m

Span 4.25 m (net span = 3.95 m)

No of Stringers = 3.95/2 = 1.97 ≈ 2 Stringers
Spacing between Stringers = 3.95/2 = 1.97 m

Span 4.75 m (net span = 4.45 m)

No of Stringers = 4.45/2 = 2.2 ≈ 3 Stringers
Spacing between Stringers = 4.45/3 = 1.48 m
4.5 Desiccation

- Design for 1ft strip
- Design Load for square foot of decking = 178.75 lb/ft²
- The type of Sheathing sanded panels (4×8 in) & thick. \( \frac{1}{8} \) in
- The safe spacing of Joist = 2.056 ft
- No of Joist for length 13.5m figure 4.1 = 20 Joists
- Select joist type Red wood (select- structural) carry load = 367.537 lb/ft
- Select stringers (2×8) tow stringer. carry Load = 1010.79 lb/ft and spacing = 5.74 ft
- No of Stringers for length 17m figure 4.1 = 9 Stringers
- Force on Shore = 2078.33 lb & shore spacing = stringers span
Table (4.1): Comparison between Manual Design & Design by Excel

<table>
<thead>
<tr>
<th></th>
<th>Manual Design</th>
<th>Design by Excel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Load</strong></td>
<td>178.75 lb/ft</td>
<td>178.75 lb/ft</td>
</tr>
<tr>
<td><strong>Sheathing</strong></td>
<td>Load = 178.75 lb/ft, Joist Spacing = 2.056 ft</td>
<td>Load = 178.75 lb/ft, Joist Spacing = 2.056 ft</td>
</tr>
<tr>
<td><strong>Joist</strong></td>
<td>Load = 367.51 lb/ft, Span of Joist = 5.654 ft</td>
<td>Load = 367.537 lb/ft, Span of Joist = 5.655 ft</td>
</tr>
<tr>
<td><strong>Stringers</strong></td>
<td>Load = 1010.651 lb/ft, Stringer Spacing = 5.74 ft</td>
<td>Load = 1010.79 lb/ft, Stringer Spacing = 5.74 ft</td>
</tr>
<tr>
<td><strong>Shore</strong></td>
<td>Force = 2077.90 lb, Cruching stress = 461.75 lb/in², Shore Strength = 5801 lb</td>
<td>Force = 2078.33 lb, Cruching stress = 461.851 lb/in², Shore Strength = 5803 lb</td>
</tr>
</tbody>
</table>
Figure (4.6): Distribution of Joist

Figure (4.7): Distributions of Stringers