APPENDIX-A: CALCULATION OF THE ULTIMATE LOAD FOR BARE STEEL FRAME AND DESIGN OF THE CONNECTIONS

The aim of this section is to determine the collapse load \( W_u \) at the failure, plastic moment of resistance for a given frame size and design the connections, weld size, diameter of bolts, size of base plates etc.

A.1. To find, plastic moment of the section-

To find out numbers of plastic hinges required to form mechanism.

Total No. of unknowns = 3 x 2 = 6

Total No. of equilibrium equation = 3.0

Hence no.’s of redundant = 6-3 = 3

One more hinge is required to form the mechanism,

Max. Hinge = 3 + 1 = 4 Nos.

Only sway mechanism is possible because only lateral load is applied at the beam level from left to right.

As per Figure A.1.1, plastic hinges are at connections A, B, C, and D points.

![Figure A.1.1 Bare steel frame](image)

To find out plastic modulus \( Z_p \) of the section is shown in Figure A.1.2.
Zp = A1.Y1 + A2.Y2

Such as A1 = A2 = A/2

Y1 and Y2 are the centroids of the area above and below N.A.

Zp = (50 x 3 x 1.5 + 50 x 3 x 1.5) = 450 mm³

Zp = (50 * 3 * 1.5)² = 450 mm²

$M_p = \sigma_y \times Zp$

$\sigma_y = 338.2 \text{N/mm}^2$, $M_p = 450 \times 338.2 = 152190 \text{ Nmm}$

A.2 To find out collapse load ($W_u$)

(a) The collapse load is calculated by using plastic theory,

External work done due to ultimate load,

$W_EU = W_u \Delta = W_u (H0)$  \hspace{1cm} (1)

Internal work done due to hinge rotation,

$W_IH = 4M_p\theta$  \hspace{1cm} (2)

External work done = Internal work done,

$W_u = 4M_p/H$, $H=400 \text{ mm}$

$W_u = 1521.9 \text{ N} = 1.52 \text{ kN}$
(b) To find out reaction at support-

(1) \( \sum H = 0.0 \)

\[ H_A + H_D = W_u, \quad H_A = H_D = \frac{W_u}{2} \]

\[ H_A = H_D = \frac{1521.9}{2} = 760.95 \text{ N} \]

(2) For vertical reaction taking moment @ A

\[ V_D \times 600 = W_u \times 400 \]

\[ V_D = \frac{(400 \times 1521.9)}{600} \]

\[ V_D = 1014.6 \text{ N} \]

Same magnitude of reaction at A but opposite in direction.

\[ V_A = 1014.6 \text{ N (\uparrow)} \]

A.3. Designing connection -

The design of various connection are summarized below,
Beam to column connection (Butt Weld), as shown in Figure A.3.1.

Figure A.3.1 Beam to column connection

Mp = 152190 N mm.

To find out thickness of weld:-

We know that, \( f_b = \) Permissible stresses in weld (Butt) = \( M / Z \)

Here \( M = \) Mp

As per I.S. 816-1969 permissible stresses in butt weld is taken same as that for parent metal would be applicable.

Mp = 152190 N mm.

\( Z_p = \frac{M_p \times y_{mo}}{\sigma_y} = \frac{152190 \times 1.1}{338.2} = 495 \) mm³

\( Z = \frac{Z_p}{1.14} = \frac{495}{1.14} = 434.21 \) mm³
Hence $Z = \frac{t \times b^2}{6}$; Here $b = 50$ mm

Hence, $434.21 = \frac{(t \times 50 \times 50)}{6}$

$t = 1.042$ mm.

As plate thickness is $= 6$ mm. So weld thickness should be provided as 6 mm.

**A.4. Column to base plate connection (fillet weld)**

The connection is shown in Figure A.4.1,

![Column to base plate connection](image)

**Figure A. 4.1 Column to base plate connection**

Here by formula,

$f_b = \frac{M}{Z}$

Where, $f_b = f_{ut} / (\sqrt{3} \times y_{mw}) = 493.33 / (1.732 \times 1.25) = 227.86$ M Pa (Permissible stresses in fillet weld), $M_p = 152190$N mm.

$S =$ size of fillet weld $= 6$mm, $L_w =$ Length of fillet weld

$M = M_p / 1.14 = 152190 / 1.14$N mm $= 133500$ N mm

$227.86 = 133500 \left(\frac{L_w}{2}\right) / [2x(L_w)^{3/2}x0.7] / 12$
So L_w = 20.45 mm

Provide full 50 mm length.

**A.5. Design of base plate-**

(i) Plate length and width

Assume concrete base as provide actually.

Bearing stresses in concrete = 0.45 \times 15 = 6.75 \text{ N/mm}^2,

Area required = \frac{1014}{6.75} = 150.22 \text{ mm}^2

Minimum length of plate required as 20 mm dia. bolts are used due to their availability in market.

L = 6 (thickness of column) + 2 [21.5 (diameter of hole)] + 4 \times 32 (edge distance),

L = 176 mm, But available size of plate was 180 mm.

(ii) By elastic analysis,

As per details illustrated in Figure A.5.1,
Hence $C_1 = T_1$

Compression Force = Tension Force

Depth of N.A. \( 'n' = \frac{d}{1 + \left(\frac{f_b}{m \cdot f_c}\right)} \)

Where, \( f_b = 120 \) N / mm\(^2\)

\( d = 230 - 56 = 174 \) mm.

\( n = \frac{174}{1 + \left(\frac{120}{(18 \times 4)}\right)} \), \( n=65.24 \) mm, lever arm = \( d\cdot n/3 \)

\( = 174.0 - 65.24 / 3, \)

Lever arm = 152.25 mm.
Taking moment about the action of tensile force,

\[ C \times 152.25 = 1014.6 \times 59 + 152190 \]

\[ C = 1392.78 \, N \]

Equating \[ C = \frac{1}{2} \times b_1 \times n \times f_c \]

\[ 1392.78 = \frac{1}{2} \times b_1 \times 65.24 \times 4.0 \]

\[ b_1 = 10.674 \, \text{mm}. \]

But due to providing 2 nos. of bolts in one row,

Minimum width required = \( 2 \times 21.5 + 26 \) (pitch) + \( 2 \times 32 \) (edge distance) = 133 mm.

Size available in the market is 150 mm. Hence size of base plate in plan = (150x150)

(iii) Thickness of base plate

Consider 1 mm wide strip. For safer side moment at critical is taken for full bearing strength

\[ = \left[ \left( \frac{1}{2} \right) \times 6.75 \times 90 \times \left( \frac{2}{3} \right) \times 90 \right] = 18225 \, N \, \text{mm} \]

\[ Z = \frac{Z_p}{1.14} = \frac{669.63}{1.14} = 587.4 \, \text{mm}^3 \]

Hence \( Z = \frac{t^2}{b} ; \) Here \( b = 150 \, \text{mm} \)

\[ 18225 = \left( \frac{\sigma_y}{\gamma_{mo}} \right) \left( \frac{t^2}{150} \right) / 6 \]

\[ t = 1.54 \, \text{mm}. \]

As it is assumed that there may be in future experiments will be done on the same foundation and availability in market provides \( t = 10 \, \text{mm} \)

Hence final size of base plate = 150 x 150 x 10 mm

A.6. Design of bolts -

(i) Diameter of Bolts:-

Hence \( C_u = T_u \)
\[ T_u = T \times \text{load factor} = 1392.78 \times 1.5 = 2089.17 \text{ N} \]

Strength of bolt in single shear = \( 0.462 f_u (n_n \times A_{nb}) \)

\[ = 0.462 \times 400 \times 0.78 \times (314)/1000 = 45.26 \text{ kN} \]

Strength of bolt in bearing = \( 2.5 d_n \ t_p \ f_u = 2.5 \times 20 \times 10 \times 400/1000 = 200 \text{ kN} \)

Bolt value = 45.26 kN (least of single shear and bearing)

Required number of bolts at one side = \( T_u / (2 \times \text{Bolt value}) = 2576.64 / (2 \times 45.26 \times 1000) \)

Required number of bolts at one side = 0.023

Which is very less at least provides 4 bolts of 20 mm each side.

As the 110 mm length is embedded in concrete and 90 mm for 2 nuts of base plate.

Total length of bolt = 110 + 90 = 200 mm. Here, provided 4 nos. of bolt on each column of size 20 mm dia. and 200 mm length. Total nos. of bolts = 8 nos.

**A.7. Design of foundation** -

The foundation details are shown in Figure A.7.1.

![Figure A.7.1 Foundation details](image-url)
Taking moment about toe,

Overturning moment = stabilizing moment

\[ Wu \times 400 = \text{(wt. of concrete)} \times 500 \]

\[ 1521 \times 400 = (1000 \times 500) \times d_1 \times 500 \times 25 \times 10^{-6} \]

Depth of footing \( d_1 = 96 \text{ mm} \), provided as 300 mm.

Size of footing = \((1000 \times 500 \times 300) \text{ mm}\).
### APPENDIX B: MATERIAL PROPERTIES FOR THE STEEL FRAMES

(a) Details of steel used for frame

<table>
<thead>
<tr>
<th>Part</th>
<th>Property</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>Area of mild steel flat specimen</td>
<td></td>
<td>25 x 6 =150</td>
<td>mm²</td>
<td>Measured</td>
</tr>
<tr>
<td>Frame</td>
<td>Length of specimen</td>
<td></td>
<td>5.64√Area of flat = 69</td>
<td>mm</td>
<td>Measured</td>
</tr>
<tr>
<td>Frame</td>
<td>Yield stress of mild steel flats</td>
<td>σy</td>
<td>338.2</td>
<td>N/mm²</td>
<td>Tensile test Py =50.73 kN, Figure 4.1</td>
</tr>
<tr>
<td>Frame</td>
<td>Ultimate stress of mild steel flats</td>
<td>f_{ut}</td>
<td>493.3</td>
<td>N/mm²</td>
<td>Tensile test Put=74 kN, Figure 4.1</td>
</tr>
<tr>
<td>Frame</td>
<td>Full plastic moment of the section</td>
<td>M_p</td>
<td>1, 52,190</td>
<td>N-mm</td>
<td>Measured/estimated</td>
</tr>
<tr>
<td>Frame</td>
<td>Plastic modulus</td>
<td>Z_p</td>
<td>450</td>
<td>mm³</td>
<td>Measured/estimated</td>
</tr>
<tr>
<td>Frame</td>
<td>Area of cross section</td>
<td>A</td>
<td>300</td>
<td>mm²</td>
<td>Measured/estimated</td>
</tr>
<tr>
<td>Frame</td>
<td>Width of frame</td>
<td>b</td>
<td>400</td>
<td>mm</td>
<td>Measured</td>
</tr>
<tr>
<td>Frame</td>
<td>Height of frame</td>
<td>h</td>
<td>600</td>
<td>mm</td>
<td>Measured</td>
</tr>
</tbody>
</table>
(b) Details of infill
Steel wires and High grade mild steel bracing

<table>
<thead>
<tr>
<th>Part</th>
<th>Property</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infill</td>
<td>Area of steel wires</td>
<td>$A_s$</td>
<td>3.14</td>
<td>mm$^2$</td>
<td>Measured</td>
</tr>
<tr>
<td>Infill</td>
<td>Area of square bracing bar</td>
<td>$A_{sb}$</td>
<td>100</td>
<td>mm$^2$</td>
<td>Measured</td>
</tr>
<tr>
<td>Infill</td>
<td>Yield stress of mild steel bracing bars</td>
<td>$\sigma'_y$</td>
<td>240</td>
<td>N/mm$^2$</td>
<td>Tensile test</td>
</tr>
<tr>
<td>Infill</td>
<td>Allowable bending tensile strength of bracing bars</td>
<td>$\sigma_{bt}$</td>
<td>$0.66 \times 240 = 158.4$</td>
<td>N/mm$^2$</td>
<td>Literature</td>
</tr>
<tr>
<td>Infill</td>
<td>Design stress of reinforcing wires</td>
<td>$\sigma_{dw}$</td>
<td>$0.8 \times \frac{410}{328}$</td>
<td>N/mm$^2$</td>
<td>Tensile test/Literature</td>
</tr>
</tbody>
</table>

The value of N and N1 is obtained from Figure 5.7.

(c) Brick masonry

<table>
<thead>
<tr>
<th>Frame No.</th>
<th>Average Ultimate compressive strength of brick masonry $\sigma_{bm}$ (N/mm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B6A</td>
<td>2.5</td>
</tr>
</tbody>
</table>

(d) Concrete

<table>
<thead>
<tr>
<th>Frame No.</th>
<th>Average Ultimate compressive strength of concrete $\sigma_c$ (N/mm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B6,B10,B11 and B12</td>
<td>19.5</td>
</tr>
<tr>
<td>S1,S2,S3 and S4</td>
<td>22</td>
</tr>
</tbody>
</table>

(e) Cement mortar

<table>
<thead>
<tr>
<th>Frame No.</th>
<th>Average Ultimate compressive strength of cement mortar $\sigma_{cm}$ (N/mm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B6C</td>
<td>17.7</td>
</tr>
</tbody>
</table>
APPENDIX C: MATERIAL PROPERTIES FOR THE R.C.FRAMES

(a) Details of R.C. Frames

<table>
<thead>
<tr>
<th>Part</th>
<th>Property</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>Area of cross section</td>
<td>A</td>
<td>60 x 100</td>
<td>mm$^2$</td>
<td>Measured/estimated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>= 6000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame</td>
<td>Average Ultimate compressive strength of concrete</td>
<td>$\sigma_c$</td>
<td>24.2</td>
<td>N/mm$^2$</td>
<td>Compression test</td>
</tr>
<tr>
<td>Frame</td>
<td>Full plastic moment of the section</td>
<td>$M_p$</td>
<td>972840</td>
<td>N-mm</td>
<td>Measured/estimated</td>
</tr>
<tr>
<td>Frame</td>
<td>Plastic modulus</td>
<td>$Z_p$</td>
<td>90000</td>
<td>mm$^3$</td>
<td>Measured/estimated</td>
</tr>
<tr>
<td>Frame</td>
<td>Partial safety factor for concrete</td>
<td>$\gamma_c$</td>
<td>1.5</td>
<td></td>
<td>Literature</td>
</tr>
<tr>
<td>Frame</td>
<td>Width of frame</td>
<td>B</td>
<td>400</td>
<td>mm</td>
<td>Measured</td>
</tr>
<tr>
<td>Frame</td>
<td>Height of frame</td>
<td>H</td>
<td>600</td>
<td>mm</td>
<td>Measured</td>
</tr>
</tbody>
</table>

The characteristic strength of 8 mm and 6 mm tor steel is 419 and 350 N/mm$^2$ respectively.

(b) Details of infill

High grade mild steel bracing

<table>
<thead>
<tr>
<th>Part</th>
<th>Property</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infill</td>
<td>Area of square bracing bar</td>
<td>$A_{sb}$</td>
<td>100</td>
<td>mm$^2$</td>
<td>Measured</td>
</tr>
<tr>
<td>Infill</td>
<td>Yield stress of mild steel bracing bars</td>
<td>$\sigma'_y$</td>
<td>450</td>
<td>N/mm$^2$</td>
<td>Tensile test</td>
</tr>
<tr>
<td>Infill</td>
<td>Allowable bending tensile strength of bracing bars</td>
<td>$\sigma_{bt}$</td>
<td>0.66 x 450 = 297</td>
<td>N/mm$^2$</td>
<td>Tensile test/Literature</td>
</tr>
</tbody>
</table>

The value of $N_1$ is obtained from Plate 5.1.
(c) Concrete

Average Ultimate compressive strength of concrete, $\sigma_c = 24.2$ (N/mm$^2$)
APPENDIX D: CALCULATION OF THE ULTIMATE LOAD FOR THE INFILLED STEEL FRAMES

(a) For frame B1

\[ W_u = 4M_p / H \]

\[ M_p = \sigma_y \times Zp \]

\[ Zp = A1 \cdot Y1 + A2 \cdot Y2 \]

Such as \( A1 = A2 = A/2 \)

\( Y1 \) and \( Y2 \) are the cancroids of the area above and below Neutral axis

\[ Zp = (50 \times 3 \times 1.5 + 50 \times 3 \times 1.5) = 450 \text{ mm}^3 \]

\[ Zp = (50 \times 3 \times 1.5)2 = 450 \text{ mm}^2 \]

\( \sigma_y = 338.2 \text{ N/mm}^2 \), \( H = 400 \text{ mm} \), \( M_p = 152190 \text{ Nmm} \)

\[ W_u = 1521.9 \text{ N} = 1.52 \text{ kN} \]

(b) For frame B2 and B3

\[ W_u = 5.33M_p / H \]

\[ W_u = 2.03 \text{ kN} \]

(c) For frame B4

\[ W_u = 5.6M_p / H \]

\[ W_u = 2.13 \text{ kN} \]

(d) For frame B5

\[ W_u = 5.33M_p / H \]

\[ W_u = 2.03 \text{ kN} \]

(e) For frame B6\(_A\), B6\(_B\), B6\(_C\)
\[ W_u = \left[ 5.33 \frac{M_p}{H} \right] + F_c \left[ 1 - \left( \frac{2 C_x}{3 H} \right) \right] \cos \alpha \]

For brick masonry, \( F_c = 0.4 \sigma_{bm} \cdot t'_w \cdot W_c \)

For Concrete, \( F_c = 0.4 \sigma_c \cdot t'_w \cdot W_c \)

For Cement Mortar, \( F_c = 0.4 \sigma_{cm} \cdot t'_w \cdot W_c \)

\( \sigma_c = 22 \text{ N/mm}^2, t'_w = 25 \text{mm}, W_c = 2C_x \sin \alpha, B = 600 \text{mm} \)

\( \sin \alpha = 0.554, \tan \alpha = 0.66, \cos \alpha = 0.832 \)

For cement mortar, \( \sigma_{cm} = 17.7 \text{ (N/mm}^2\text{)}, C_x = 3.5 \frac{H}{B} \)

For concrete, \( \sigma_c = 19.5 \text{ (N/mm}^2\text{)}, C_x = 5.5 \frac{H}{B} \)

For brick masonry, \( \sigma_{bm} = 2.5 \text{(N/mm}^2\text{)}, C_x = 7.5 \frac{H}{B} \)

<table>
<thead>
<tr>
<th>Frame</th>
<th>Infill</th>
<th>( W_u )</th>
</tr>
</thead>
<tbody>
<tr>
<td>B6A</td>
<td>Brick Masonry</td>
<td>2.06 kN</td>
</tr>
<tr>
<td>B6B</td>
<td>Concrete</td>
<td>2.39 kN</td>
</tr>
<tr>
<td>B6C</td>
<td>Cement Mortar</td>
<td>2.48 kN</td>
</tr>
</tbody>
</table>

(f) For frame B7, B8, B10, B11

\[ W_u = \left[ 5.33 \frac{M_p}{H} \right] + F_c \cos \alpha \]

Where the value of \( F_c \) for various partial infills are;

For Cement Mortar, \( F_c = 0.4 \sigma_{cm} \cdot t'_w \cdot W_c \)

For Concrete, \( F_c = 0.4 \sigma_c \cdot t'_w \cdot W_c \),

\( W_c = 2C_x \sin \alpha \)

For cement mortar, \( \sigma_{cm} = 17.7 \text{ (N/mm}^2\text{)}, C_x = 1.2 \frac{H}{B}, 2.5 \frac{H}{B} \)

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For concrete, $\sigma_c = 19.5 \text{ (N/mm}^2\text{)}, C_X = 1.0 \frac{H}{B} . 1.5 \frac{H}{B}$

<table>
<thead>
<tr>
<th>Frame</th>
<th>Infill</th>
<th>$W_u$</th>
</tr>
</thead>
<tbody>
<tr>
<td>B7</td>
<td>Cement Mortar</td>
<td>2.16 kN</td>
</tr>
<tr>
<td>B8</td>
<td>Cement Mortar</td>
<td>2.3 kN</td>
</tr>
<tr>
<td>B10</td>
<td>Concrete</td>
<td>2.14 kN</td>
</tr>
<tr>
<td>B11</td>
<td>Concrete</td>
<td>2.2 kN</td>
</tr>
</tbody>
</table>

(g) For frame B9, B12

$W_u = 5.6M_p/H + F_c \cos \alpha$

The value of $C_y = C_X \cdot \tan \alpha$ and the value of $C_X$ is $3 \frac{H}{B}$ and $1.5 \frac{H}{B}$ for cement mortar (B9) and concrete (B12) partial infill frames respectively. For Cement Mortar $F_c = 0.4\sigma_{cm} \cdot t_w \cdot W_c$

For Concrete, $F_c = 0.4\sigma_c \cdot t_w' \cdot W_c$

$W_c = 2C_X \sin \alpha$

For cement mortar, $\sigma_{cm} = 17.7 \text{ (N/mm}^2\text{)}, C_X = 3.0 \frac{H}{B}$

For concrete, $\sigma_c = 19.5 \text{ (N/mm}^2\text{)}, C_X = 1.5 \frac{H}{B}$

<table>
<thead>
<tr>
<th>Frame</th>
<th>Infill</th>
<th>$W_u$</th>
</tr>
</thead>
<tbody>
<tr>
<td>B9</td>
<td>Cement Mortar</td>
<td>2.46 kN</td>
</tr>
<tr>
<td>B12</td>
<td>Concrete</td>
<td>2.31 kN</td>
</tr>
</tbody>
</table>

(h) For frame S1, S2, S3 and S4

$W_u = 4M_p/H + F_c [(H - C_X \tan \alpha)] \cos \alpha /H$
For reinforced concrete (S1)
\[ F_C = 0 \cdot 67 \sigma_c t_w W_C + \sigma_{dw} A_s N \cos \alpha \]

For BRC infill (S2, S3 and S4)
\[ F_C = 0 \cdot 67 \sigma_c t_w W_C + \sigma_{dw} A_s N \cos \alpha + \sigma_{bt} A_{sb} N_1 \]

The values of N and N1 are shown in Fig. 5.10. \( W_C = 2C_X \sin \alpha \).

<table>
<thead>
<tr>
<th>Frame</th>
<th>N</th>
<th>N1</th>
<th>Cx</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>2</td>
<td>-</td>
<td>35 H/ B</td>
</tr>
<tr>
<td>S2</td>
<td>2</td>
<td>1/4</td>
<td>37.5 H/ B</td>
</tr>
<tr>
<td>S3</td>
<td>2</td>
<td>1/2</td>
<td>45 H/ B</td>
</tr>
<tr>
<td>S4</td>
<td>2</td>
<td>1</td>
<td>50 H /B</td>
</tr>
</tbody>
</table>

Where for S4, \( W_C = 2C_X \sin \alpha \)
\[ F_C = 0 \cdot 67 \sigma_c t_w W_C + \sigma_{dw} A_s N \cos \alpha + \sigma_{bt} A_{sb} N_1 \]
\( \sigma_c = 22 \text{ N/mm}^2 \), \( t_w = 50 \text{ mm} \), \( W_C = 2C_X \sin \alpha \), \( B=600 \text{ mm} \), \( H=400 \text{ mm} \)
\( C_X = 50 \frac{H}{B} = 50*400/600 = 33.33 \text{ mm} \), \( \tan \alpha = 0.66 \), \( \cos \alpha = 0.832 \),
\( W_C = 36.97 \text{ mm} \), \( A_s =3.14 \text{ mm}^2 \), \( N=2 \), \( \sigma_{dw} =0.8*410=328 \text{ N/mm}^2 \)
\( \sigma_{bt} = 0.66 * 240 = 158.4 \text{ N/mm}^2 \), \( A_{sb} = 10 \times 10 = 100 \text{ mm}^2 \), \( N_1 = 1 \)
\( W_u = 1521.9 + (27251.49 + 1713.89 + 15840) \times 0.79 = 36918.15 \text{ N} = 37 \text{ kN} \)

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Frame</th>
<th>Type of Infill</th>
<th>( W_u )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>R.C.C.</td>
<td>18.2 kN</td>
</tr>
<tr>
<td>2</td>
<td>S2</td>
<td>R.C.C.</td>
<td>22.3 kN</td>
</tr>
<tr>
<td>3</td>
<td>S3</td>
<td>R.C.C.</td>
<td>28.5 kN</td>
</tr>
<tr>
<td>4</td>
<td>S4</td>
<td>R.C.C.</td>
<td>37.0 kN</td>
</tr>
</tbody>
</table>
APPENDIX E: CALCULATION OF THE ULTIMATE LOAD FOR THE INFILLED R.C. FRAMES

(a) For frame R1

\[ W_u = 4M_p / H \]

\[ M_p = [(0.67) \sigma_c / \gamma_c * Z_p] \]

Average Ultimate compressive strength of concrete, \( \sigma_c = 24.2 \text{ (N/mm}^2 \text{)} \)

Full plastic moment of the section, \( M_p = 972840 \text{ N-mm} \)

Plastic modulus, \( Z_p = 90000 \text{ mm}^3 \)

Partial safety factor for concrete, \( \gamma_c = 1.5 \)

Height of frame, \( H = 600 \text{ mm} \)

\[ W_u = 9.71 \text{kN} \]

(b) For frame R2, R3, R5, R6

\[ W_u = 4M_p / H + F_C \{(H + H_2)/2\} \cos \alpha / H \]

For braced R.C. frames,

\[ F_C = \sigma_{bt} A_{sb} N_1 \]

For concrete partial infill,

\[ F_C = 0 \cdot 67 \sigma_c t_w W_c + \sigma_{bt} A_{sb} N_1 \]

\( \cos \alpha = 0.832 \), \( t_w = 50 \text{ mm} \), Area of square bracing bar \( A_{sb} = 100 \text{ mm}^2 \)

Area of square bracing bar \( A_{sb} = 100 \text{ mm}^2 \)

Yield stress of mild steel bracing bars \( \sigma'_y = 450 \text{ N/mm}^2 \)

Allowable bending tensile strength of bracing bars \( \sigma_{bt} = 0.66 \times 450 = 297 \text{ N/mm}^2 \)

Average Ultimate compressive strength of concrete \( \sigma_c = 24.2 \text{ (N/mm}^2 \text{)} \)
The values of N1 are shown in Plate 5.1.

(c) For frame R4, R7

\[ W_u = 4M_P/H + F_C [(H - C_X \tan \alpha)] \cos \alpha/H \]

For braced R.C. frames

\[ F_C = \sigma_{bt} A_{sb} N_1 \]

For concrete infill

\[ F_C = 0.67 \sigma_c t_w W_C + \sigma_{bt} A_{sb} N_1 \]

\[ W_C = 2C_X \sin \alpha. \quad , \sin \alpha = 0.554 , \cos \alpha = 0.832 , t_w = 50 \text{mm} \]

Area of square bracing bar \( A_{sb} = 100 \text{ mm}^2 \)

Yield stress of mild steel bracing bars \( \sigma_y = 450 \text{ N/mm}^2 \)

Allowable bending tensile strength of bracing bars \( \sigma_{bt} = 0.66 \times 450 = 297 \text{N/mm}^2 \)

Average Ultimate compressive strength of concrete \( \sigma_c = 24.2 \text{ (N/mm}^2) \)

<table>
<thead>
<tr>
<th>Frame</th>
<th>N1</th>
<th>( C_X )</th>
</tr>
</thead>
<tbody>
<tr>
<td>R4</td>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>R7</td>
<td>0.9</td>
<td>50 B/H</td>
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</tbody>
</table>

The values of N1 are shown in Plate 5.1. The value of \( W_C = 2C_X \sin \alpha. \)
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Frame</th>
<th>Type of Steel bracing</th>
<th>Concrete infill</th>
<th>Theoretical Ultimate Load kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R1</td>
<td>-</td>
<td>-</td>
<td>9.71</td>
</tr>
<tr>
<td>2</td>
<td>R2</td>
<td>Corner</td>
<td>-</td>
<td>22.84</td>
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<td>3</td>
<td>R3</td>
<td>Central</td>
<td>-</td>
<td>30.38</td>
</tr>
<tr>
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<td>R4</td>
<td>Diagonal</td>
<td>-</td>
<td>39.36</td>
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<tr>
<td>5</td>
<td>R5</td>
<td>Corner</td>
<td>Partial</td>
<td>28.68</td>
</tr>
<tr>
<td>6</td>
<td>R6</td>
<td>Central</td>
<td>Partial</td>
<td>38.17</td>
</tr>
<tr>
<td>7</td>
<td>R7</td>
<td>Diagonal</td>
<td>Full</td>
<td>84.76</td>
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</tbody>
</table>