CHAPTER 5: PROPOSED ANALYTICAL METHOD

5.1 Opening remarks

Before discussing the details of design and other things, it is necessary to know about "Plastic theory". As per Sir John Baker and Jacques Heyman (2008), it is appropriate approach to design steel structures. It serves two functions "Economy as well as simplicity". In elastic design, the factor of safety is provided on the basis of yield stress which is not a consistent indication of safety with respect to ultimate capacity of a member, in other words if yield point attained at a single point does not means collapse of member. Steel has a unique quality called ductility, due to which it is able to absorb large deformations beyond the elastic limit without fracture. Due to plastic deformation of strain hardening of the material, particle which is less stressed will be brought into action, so structure is able to resist larger loads. The method which utilizes this reserve strength is called plastic method of analysis. The fundamental aspect is that the margin of safety is same as in case of elastic theory. In the following paragraphs the proposed methods for various frames are discussed.

5.2 Method 1: Proposed methods for bare steel frame (B1)

The proposed analytical model to calculate theoretical ultimate lateral load capacity is on the basis of the experimental observations and formation of plastic hinges for bare steel frame.

Here, Wu can be easily found out by using mechanism method, (i.e. based upon upper bound theorem) as shown in Figure 5.1.

![Figure 5.1 Idealization for proposed method 1(B1)](image)
Let virtual displacement, corresponding to sway mode be represented by ‘$\Delta$’ at B and C and hinge rotation ‘$\theta$’ at A, B, C and D.

Applying virtual work method,

External work done due to ultimate load,

$$W_EU = W_u \Delta = W_u (H0) \quad (5.1)$$

Internal work done due to hinge rotation,

$$W_H = 4Mp\theta \quad (5.2)$$

External work done = Internal work done,

$$W_H = W_EU$$

$$W_u = \frac{Mp}{H} \quad (5.3)$$

5.3 Methods for braced frames - In the following Para proposed methods for braced and partial infilled steel frames are discussed.

5.3.1 Method 2: Proposed methods for top corner and top central braced frame (B2, B3)

While applying the load, particularly on the frames with corner and central braced, it was observed that though failure mechanism was predominantly the sway mechanism but plastic hinges are formed at base of column and at junction of column and the bracing. The top has deflected less in comparison to braced horizontal member. To develop a mathematical model, certain assumptions were made:

1. Plastic hinges are formed at column base and column – bracing junction.
2. The mode of collapse is sway mechanism for all frames.
3. For braced frames, perfect initial fit exists.
4. Small deformation theory is applicable.

The idealization of the proposed method is illustrated in Figure 5.2. As per the assumptions, the failure mode is sway mechanism with plastic hinges at P, Q, R, and S.
Let virtual displacement, analogous to sway mode be represented by ‘Δ’ at Q and R and hinge rotation ‘θ’ at P, Q, R and S.

External work done due to ultimate load,

$$W_{EU} = W_u \Delta = W_u \left(\frac{3}{4}H\theta\right)$$  \hspace{1cm} (5.4)

Internal work done due to hinge rotation,

$$W_H = 4Mp\theta$$

External work done = Internal work done,

$$W_u = 5.33Mp/H$$  \hspace{1cm} (5.5)

Here, the value of Mp depends on yield stress of steel $\sigma_y$.

5.3.2. Method 3: Proposed method for full corner braced frames (B4)

While applying the load, particularly on the frames with the bracing, it was observed that though failure mechanism is predominantly the sway mechanism but plastic hinges are formed at base of column and at junction of beam and the bracing. To develop a mathematical model, following assumptions were made:
1. Plastic hinges are formed at column base and beam – bracing junction.
2. The mode of collapse is sway mechanism for all frames.
3. For braced frames, perfect initial fit exists.
4. Small deformation theory is applicable.

The idealization of the proposed method is illustrated in Figure 5.3.

Figure 5.3 Idealization for proposed method 3 and 6(B4)
As per the assumptions, the failure mode is sway mechanism with plastic hinges at P, Q, R and S. For computing the internal work done, the concept of instantaneous centre of rotation is used. So the line RS is extended and from Q a line is drawn parallel to P1 to get the point of intersection ‘C’. ‘C’ is instantaneous centre of rotation. From triangle R2S,

\[ \text{RS} = \sqrt{(0.25H)^2 + (H)^2} = 1.03H \text{ and } \theta = \Delta / \text{RS}, \text{ So, } \Delta = 1.03H\theta \]

If the member PQ is given a virtual rotation \( \theta \) about the point P, point Q moves to the left by a virtual displacement of ‘\((1.03)H\theta\)’. Distance from Q to C when measured was found to be 2.57\( H \), the rotation of member Q1R about the point C will be equal to,

\[ (1.03)H\theta/2.57H = \theta/2.5 \]  \hspace{1cm} (5.6)

Hinge R then, rotates through an angle equal to \( \theta \) due to rotation of R2S about S, plus \( \theta/2.5 \) due to rotation of Q1R about the point C. Hinge Q rotates through \( \theta/2.5 \) due to rotation of Q1R about the point C, plus \( \theta \) due to rotation of PQ about the point P. As the maximum rotation is considered, so same rotation is taken for hinge P and S.

External work done due to ultimate load,

\[ W_u \text{, } U = W_u \text{, } H\theta \]  \hspace{1cm} (5.7)

Internal work done due to hinge rotation,

\[ W_i H = 4Mp[\theta + (\theta/2.5)] \]  \hspace{1cm} (5.8)

External work done = Internal work done,

\[ W_u = \left[5.6 \frac{Mp}{H}\right] \]  \hspace{1cm} (5.9)

**5.3.3. Method 4: Proposed method for horizontal braced and partial infilled steel frames (B5, B6a, B6b, B6c)**

The proposed analytical model to calculate theoretical ultimate lateral load capacity is on the basis of the experimental observations of crack patterns and formation of plastic hinges for various partially infilled frames. To develop a mathematical model certain assumptions were made:

1. The crack in partial infill was taken as observed during experimental work and the propagation of crack was assumed to be straight line.
2. Plastic hinges are formed at column base and column-bracing junction, and mode of collapse is sway mechanism.
3. For partial infilled frames, perfect initial fit exists.
4. Small deformation and short column theory is applicable.

The idealization of the proposed method is illustrated in Figure 5.4.

**Figure 5.4 Proposed method 4 (B5, B6_A, B6_B, B6_C)**
The crushing strength of partial infill was taken as 0.4 times the experimental compressive strength of brick masonry, concrete and cements mortar. As per the assumptions, the failure mode is sway mechanism with plastic hinges at P, Q, R and S. For partial infill, strength is considered along diagonal only.

Let virtual displacement, corresponding to sway mode be represented by $\Delta$ at q and r and hinge rotation $\theta$ at P, Q, R and S.

External work done due to ultimate load,
\[
W_{E}U = W_{u} \Delta = W_{u} \left\{ \frac{3}{4} \theta H \right\}
\]  
\[
(5.10)
\]

Internal work done due to hinge rotation,
\[
W_{I}H = 4 M_{P} \theta
\]

Internal work done due to partial infill,
\[
W_{I}P = F_{c} \left( \Delta_{1} - \frac{C_{y}}{2} \theta \cos \alpha \right)
\]  
\[
(5.11)
\]

\[
W_{E}U = W_{I}H + W_{I}P
\]

\[
W_{u} \left\{ \frac{3}{4} \theta H \right\} = 4 M_{P} \theta + \left[ F_{c} \left( \frac{3}{4} \theta H \right) \cdot \cos \alpha - \left( \frac{C_{y}}{2} \theta \cos \alpha \right) \right]
\]  
\[
(5.12)
\]

\[
W_{u} = \left[ 5.3 \frac{M_{P}}{H} \right] + F_{c} \left[ \left\{ 1 - \left( \frac{2}{3} \frac{C_{y}}{H} \right) \right\} \right] \cdot \cos \alpha
\]  
\[
(5.13)
\]

Where, the values of $F_{c}$ for various partial infills are-

For brick masonry, $F_{c} = 0.4 \cdot \sigma_{bm} \cdot t_{w} \cdot W_{c}$

For Concrete, $F_{c} = 0.4\sigma_{c} \cdot t_{w} \cdot W_{c}$

For Cement Mortar, $F_{c} = 0.4\sigma_{cm} \cdot t_{w} \cdot W_{c}$

The value of $W_{c} = 2 \cdot c_{x} \cdot \sin \alpha$
The effective thickness $t_e$ should be taken as half the thickness of partial infill.

The value of $C_y = C_x \cdot \tan \alpha$ and the value of $C_x$ has been taken as $3.5 \frac{H}{b}$, $5.5 \frac{H}{b}$ and $7.5 \frac{H}{b}$ for brick masonry, concrete, and cement mortar partial infill.

5.3.4. Method 5: Proposed method for corner and central braced partial infilled steel frames (B7, B8, B10 and B11)

While applying the load particularly on the frames with the bracing it was observed that though failure mechanism predominantly the sway mechanism but plastic hinges are formed at base of column and at junction of beam and the bracing. The crushing strength of partial infill was taken as 0.4 times the experimental compressive strength of brick masonry, concrete and cements mortar infill. The idealization of the proposed method is illustrated as per Figure 5.5. As per assumption the failure mode is sway mechanism with plastic hinges at p, q, r and s. For partial infill, strength is considered along diagonal only.

![Figure 5.5 Idealization for proposed method 5(B7, B8, B9 and B11)](image-url)
Let virtual displacement, corresponding to sway mode be represented by $\Delta$ at Q and R and hinge rotation $\theta$ at P, Q, R and S.

External work done due to ultimate load,

$$W_{EU} = W_u \Delta = W_u \left\{ \frac{3}{4} \theta H \right\} \quad (5.14)$$

Internal work done due to hinge rotation,

$$W_i H = 4 M_p \theta$$

Internal work done due to partial infill,

$$W_i P = F_c (\Delta_1) = F_c (\Delta \cos \alpha) \quad (5.15)$$

$$W_{EU} = W_i H + W_i P$$

$$W_u \left\{ \frac{3}{4} \theta H \right\} = 4 M_p \theta + \left[ F_c \left\{ \left( \frac{3}{4} \theta H \right) \cos \alpha \right\} \right] \quad (5.16)$$

$$W_u = \left[ 5.33 \frac{M_p}{H} \right] + F_c \cos \alpha \quad (5.17)$$

Where, the values 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, $F_c = 0.4 \sigma_c \cdot t_w \cdot W_c$

The value of $W_c = 2 \cdot C_x \cdot \sin \alpha$

The effective thickness $t_w$ should be taken as half the thickness of partial infill.

The value of $C_y = C_x \cdot \tan \alpha$ and the value of $C_x$ has been taken as $1.2 \frac{H}{B}$, $2.5 \frac{H}{B}$ for cement mortar (B7, B8) and $1.0 \frac{H}{B}$, $1.5 \frac{H}{B}$ for concrete (B10, B11) partial infill frames analogously. The theoretical ultimate load calculation as illustrated in Appendix D for bare and partially infilled braced steel frames are shown in Table 12.
Table 12: Theoretical ultimate loads for braced and partial infilled steel frames

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Frame</th>
<th>Type of steel bracing</th>
<th>Type of partial Infill</th>
<th>Theoretical ultimate load kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B1</td>
<td>-</td>
<td>-</td>
<td>1.52</td>
</tr>
<tr>
<td>2</td>
<td>B2</td>
<td>Top Corner</td>
<td>-</td>
<td>2.03</td>
</tr>
<tr>
<td>3</td>
<td>B3</td>
<td>Top Central</td>
<td>-</td>
<td>2.03</td>
</tr>
<tr>
<td>4</td>
<td>B4</td>
<td>Full Corner</td>
<td>-</td>
<td>2.13</td>
</tr>
<tr>
<td>5</td>
<td>B5</td>
<td>Braced at ¼ from top in horizontal</td>
<td>-</td>
<td>2.03</td>
</tr>
<tr>
<td>6</td>
<td>B6A</td>
<td>Braced at ¼ from top in horizontal</td>
<td>Brick Masonry</td>
<td>2.06</td>
</tr>
<tr>
<td>7</td>
<td>B6B</td>
<td>Braced at ¼ from top in horizontal</td>
<td>Concrete</td>
<td>2.39</td>
</tr>
<tr>
<td>8</td>
<td>B6C</td>
<td>Braced at ¼ from top in horizontal</td>
<td>Cement Mortar</td>
<td>2.48</td>
</tr>
<tr>
<td>9</td>
<td>B7</td>
<td>Top Corner</td>
<td>Cement Mortar</td>
<td>2.16</td>
</tr>
<tr>
<td>10</td>
<td>B8</td>
<td>Top Central</td>
<td>Cement Mortar</td>
<td>2.3</td>
</tr>
<tr>
<td>11</td>
<td>B9</td>
<td>Full Corner</td>
<td>Cement Mortar</td>
<td>2.46</td>
</tr>
<tr>
<td>12</td>
<td>B10</td>
<td>Top Corner</td>
<td>Concrete</td>
<td>2.14</td>
</tr>
<tr>
<td>13</td>
<td>B11</td>
<td>Top Central</td>
<td>Concrete</td>
<td>2.2</td>
</tr>
<tr>
<td>14</td>
<td>B12</td>
<td>Full Corner</td>
<td>Concrete</td>
<td>2.31</td>
</tr>
</tbody>
</table>
5.3.5. Method 6: Proposed method for top corner braced and partial infilled steel frames (B9, B12)

While applying the load particularly on the frames with the bracing it was observed that though failure mechanism predominantly the sway mechanism but plastic hinges are formed at base of column and at junction of beam and the bracing as per Figure 5.3.

External work done due to ultimate load,

\[ W_{EU} = W_u \Delta = W_u (1.03H\theta) \]  \hspace{1cm} (5.18)

Internal work done due to hinge rotation,

\[ W_IH = 4Mp[\theta + (\theta/2.5)] \]  \hspace{1cm} (5.19)

Internal work done due to partial infill,

\[ W_{IP} = F_c (\Delta_{1}) = F_c (\Delta \cos\alpha) \]  \hspace{1cm} (5.20)

External work done = Internal work done,

\[ W_u = 5.6Mp/H + F_c \cos\alpha \]  \hspace{1cm} (5.21)

The value of \( C_y = C_x \cdot \tan\alpha \) and the value of \( C_x \) has been taken as \( 3 \frac{H}{B} \) and \( 1.5 \frac{H}{B} \) for cement mortar (B9) and concrete (B12) partial infill frames respectively.

5.4 Method 7: Proposed method for braced and R.C.C infilled steel frames (S1, S2, S3, S4)

The proposed analytical model to calculate theoretical ultimate lateral load capacity is on the basis of the experimental observations of crack patterns and formation of plastic hinges for various reinforced concrete and BRC infilled frames. It is observed that due compressive force from diagonal compression band, tensile cracks are developed along tension column for all BRC infilled frames. To develop a mathematical model certain assumptions were made:

1. The cracks in infill were taken as observed during experimental work and the propagation of crack was assumed to be straight line.
2. Plastic hinges are formed at column base and column beam junction, and mode of collapse is sway mechanism.
3. For infilled frames, perfect initial fit exists.
4. Small deformation theory is applicable.

The crushing strength of concrete infill was taken as 0.67 times the experimental compressive strength as mentioned in IS 456:2000 Code of Reinforced Concrete, given under 38.1(c). The idealization of the proposed method is illustrated in Figure 5.6. As per the assumptions, the failure mode is sway mechanism with plastic hinges at p, q, r and s. For all infills, strength is considered along compression diagonal only.

\[ \Delta = \frac{m + M_z}{2} \theta \approx \frac{(m + M_z)^2}{2} \theta \approx \frac{m^2 + M_z^2}{2} \theta \approx \frac{m^2}{2} \theta \approx \frac{M_z^2}{2} \theta \]

Figure 5.6 Idealization for proposed method 7(S1, S2, S3, S4)
Let virtual displacement, corresponding to sway mode be represented by ‘Δ’ at q and r and hinge rotation ‘θ’ at p, q, r and s.

External work done due to ultimate load,

\[ W_EU = W_uΔ = W_u \theta \]

Internal work done due to hinge rotation,

\[ W_iH = 4M_p\theta \]

Internal work done due to infill,

\[ W_iI = F_C \{Δ_1 - [(C_Y/2)\theta \cos α]\} \quad (5.22) \]

External work done = Internal work done,

\[ W_u = 4M_p/H + F_C \left[ (H - C_x \tan α) \right] \cos α /H \quad (5.23) \]

Where the value of ‘Fc’ for various infills are,

(i) For reinforced concrete,

\[ F_C = 0 \cdot 67σ_c t_w W_C + σ_{dwy}A_s N \cos α \quad (5.22) \]

(ii) For BRC infill,

\[ F_C = 0 \cdot 67σ_c t_w W_C + σ_{dwy}A_s N \cos α + σ_{bt}A_{sb} N_1 \quad (5.23) \]

The values of N and N1 are shown in Fig. 5.7 and are obtained from number of reinforcing bars and bracing present in compression diagonal strut. The value of \( W_C = 2C_x \sin α \).
The values of $N$ and $N_1$ for braced R.C.C. infilled frames (a) S1 (b) S2(c) S3 (d) S4

The value of $C_v = C_x \tan a$, where the value of $C_x$ has been taken as 35 H/B, 37.5 H/B, 45 H/B and 50 H/B for S1, S2, S3 and S4, correspondingly.

The theoretical ultimate load calculation as illustrated in Appendix D for R.C.C infilled braced steel frames are shown in Table 13.

**Table 13: Theoretical ultimate loads for R.C.C infilled braced steel frames**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Frame</th>
<th>Type of steel bracing</th>
<th>Type of Infill</th>
<th>Theoretical ultimate load kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>-</td>
<td>R.C.C.</td>
<td>18.2</td>
</tr>
<tr>
<td>2</td>
<td>S2</td>
<td>Corner</td>
<td>R.C.C.</td>
<td>22.3</td>
</tr>
<tr>
<td>3</td>
<td>S3</td>
<td>Top Corner</td>
<td>R.C.C.</td>
<td>28.5</td>
</tr>
<tr>
<td>4</td>
<td>S4</td>
<td>Diagonal</td>
<td>R.C.C.</td>
<td>37.0</td>
</tr>
</tbody>
</table>
5.5 Proposed analytical method for R.C. frames - The analytical methods for bare, braced and infilled R.C. frames are described as follows.

5.5.1 Method 8: Proposed methods for bare R.C. frame (R1)
While applying the load particularly on the bare frames, it was observed that though failure mechanism was predominantly the sway mechanism but plastic hinges are formed at base of column and at junction of column and the beam as illustrated in Figure 5.8.

![Figure 5.8 Idealization for proposed method 8(R1)](image)

To develop a mathematical model, following assumptions were made.

1. The concrete material is homogenous and isotropic.
2. The mode of collapse is sway mechanism for frames.
3. For frames, at joints initial fixity exists perfect.
4. Small deformation theory is applicable.

Let virtual displacement, corresponding to sway mode be represented by ‘\(\Delta\)’ at q and r and hinge rotation ‘\(\theta\)’ at p, q, r, and s.

External work done due to ultimate load,
\[ W_E U = W_u \Delta = W_u (H\theta) \]  \hspace{1cm} (5.24)

Internal work done due to hinge rotation,
\[ W_i H = 4M_p \theta \]  \hspace{1cm} (5.25)

External work done = Internal work done,
\[ W_u = 4M_p / H \]  \hspace{1cm} (5.26)

Here \( M_p \) depends on \( \sigma_c \). The value of \( M_p = [(0.67) \star \sigma_c \star \gamma_c \star Z_{p}] \).

**5.5.2 Method 9: Proposed methods for braced and partial infilled R.C. frames (R2, R3, R5, R6)**

The proposed analytical model to calculate theoretical ultimate lateral load capacity is on the basis of the experimental observations of crack patterns and formation of plastic hinges for various braced and partial concrete filled R.C. frames. It is observed that due to compressive force from diagonal compression band, tensile cracks are developed along tension column for all R.C. infilled frames. To develop a mathematical model certain assumptions were made:

1. Plastic hinges are formed at column base and column beam junction, and mode of collapse is sway mechanism.
2. For partial infilled frames, perfect initial fit exists.
3. Small deformation theory is applicable.

The crushing strength of concrete infill was taken as 0.67 times the experimental compressive strength. The idealization of the proposed method is illustrated in Figure 5.9.

As per assumption, the failure mode is sway mechanism with plastic hinges at p, q, r and s. For all infills, strength is considered along compression diagonal only.

Let virtual displacement, corresponding to sway mode be represented by ‘\( \Delta \)’ at q and r and hinge rotation ‘\( \theta \)’ at p, q, r and s.

External work done due to ultimate load,
\[ W_E U = W_u \Delta = W_u (H\theta) \]

Internal work done due to hinge rotation,
\[ W_i H = 4M_p \theta \]
Figure 5.9 Idealization for proposed method 9(R2, R3, R5, R6)
Internal work done due to infill,

\[ W_I = F_C \left\{ \left( \frac{H + H_2}{2} \right) \right\} \cos \alpha \quad (5.27) \]

External work done = Internal work done

\[ W_d = 4M_p/H + F_C \left\{ \left( \frac{H + H_2}{2} \right) \right\} \cos \alpha /H \quad (5.28) \]

Where the value of 'Fc' for various frames are,

1. For braced R.C. frames,
   \[ F_C = \sigma_{bt} A_{sb} N_1 \quad (5.29) \]
2. For concrete partial infill,
   \[ F_C = 0.67 \sigma_c t_w W_c + \sigma_{bt} A_{sb} N_1 \quad (5.30) \]

The values of N1 are shown in Plate 5.1 and are obtained from bracing present in compression diagonal strut. The value of \( W_c \) has been taken as 15 \( H/B \), 20 \( H/B \) for R5 and R6, respectively.

Plate 5.1(a) \hspace{1cm} N_1 = 0.7
Plate 5.1(b) \hspace{1cm} N_1 = 0.9
Plate 5.1(c) \hspace{1cm} N_1 = 1.2

Plate 5.1 The values of \( N_1 \) for R.C. frames (a) R2, R5 (b) R3, R6 (c) R4, R7
5.5.3 Method 10: Proposed methods for diagonal braced and infilled R.C. frames (R4, R7)

On the basis of the experimental observations of crack patterns and formation of plastic hinges for diagonal bracing and concrete filled R. C. frames. Plastic hinges are formed at column base and column beam junction, and mode of collapse is sway mechanism. To develop a mathematical model, following assumptions were made:

1. The crushing strength of concrete infill was taken as 0.67 times the experimental compressive strength.
2. For infilled frames, perfect initial fit exists.
3. Small deformation theory is applicable.

The idealization of the proposed method is illustrated in Figure 5.10. As per assumption the failure mode is sway mechanism with plastic hinges at p, q, r, and s. For all infills, strength is considered along compression diagonal only.

Let virtual displacement, corresponding to sway mode be represented by ‘Δ’ at q and r and hinge rotation ‘θ’ at p, q, r, and s.

External work done due to ultimate load,

\[ W_{E}U = W_{u}Δ = W_{u} (H0) \]

Internal work done due to hinge rotation,

\[ W_{I}H = 4M_{P}\theta \]

Internal work done due to infill,

\[ W_{I} I = F_{C}\{\Delta_{1} - [(C_{Y}/2)\theta] \} \]  \hspace{1cm} (5.31)

External work done = Internal work done,

\[ W_{u} = 4M_{P}/H + F_{C} [(H- C_{X}\tan \alpha)] \cos \alpha /H \]  \hspace{1cm} (5.32)

Where, the values of ‘Fc’ for various diagonal braced frames are,

1. For braced R.C. frames,

\[ F_{C} = \sigma_{bt}A_{sb} N_{1} \]  \hspace{1cm} (5.33)

2. For concrete infill,

\[ F_{C} = 0 \cdot 67\sigma_{c} t_{w} W_{C} + \sigma_{bt}A_{sb} N_{1} \]  \hspace{1cm} (5.34)
The values of $N_1$ are shown in Plate 5.1 and are obtained from bracing present in compression diagonal strut. The value of $W_C = 2C_X \sin \alpha$.

The value of $C_Y = C_X \tan \alpha$ and where the value of $C_X$ has been taken as zero for R4 and 50B/H for R7, respectively.

The theoretical ultimate load calculation as illustrated in Appendix E for partial and concrete infilled braced R.C. frames are shown in Table 14.
Table 14: Theoretical ultimate loads for concrete infilled braced R.C.C. frames

<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>
</tr>
<tr>
<td>3</td>
<td>R3</td>
<td>Central</td>
<td>-</td>
<td>30.38</td>
</tr>
<tr>
<td>4</td>
<td>R4</td>
<td>Diagonal</td>
<td>-</td>
<td>39.36</td>
</tr>
<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>
</tr>
</tbody>
</table>

5.6 Concluding remarks

By observing the crack pattern for different infilled frames and making certain assumptions, mathematical models are established to obtain the ultimate loads by using plastic analysis. The theoretical ultimate loads are tabulated. In the following chapter the results and formation of crack pattern are discussed and analyzed. Also, the ultimate loads from the numerical results are compared with calculated results from simplified equations for all infilled frames.