8.1 Introduction:

The most commonly used plain masonry type is English bond. It is a widely used as an un-reinforced masonry. In this chapter the behavior of the plain masonry infilled RC frames under lateral excitation is studied. The behavior is compared with the bare RC frames. These frames are subjected to lateral excitations and the response is studied with respect to deflections, stresses and accelerations. Nomenclature of the models is shown in table no.8.1. Fig.8.1 shows the typical descritized model.

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Model No</th>
<th>Aspect Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EBI4023</td>
<td>1.23</td>
</tr>
<tr>
<td>2</td>
<td>EBI4523</td>
<td>1.41</td>
</tr>
<tr>
<td>3</td>
<td>EBI5023</td>
<td>1.60</td>
</tr>
</tbody>
</table>

Fig.8.1 : Typical Descritized Model

8.2 Natural frequency:

Ten modal frequencies have been captured. It is observed that the natural frequency increase from 6.78 to 7.84 as the aspect ratio increases. When compared with bare RC frames the natural frequency has increased by about 75%. The variation in the natural frequency is shown in the fig.8.2 and the typical mode shapes are shown in fig.8.3.
Fig. 8.3: Mode shapes of RC Frames fully infilled with plain masonry.

Aspect Ratio 1.60
8.3 Stiffness:

The typical deflection contours are presented in fig.8.4. The variation of components of deflection for different aspect ratios is presented fig 8.5.

8.3.1 Deflection:

**Load case 1:** X-component of deflection reduces as the aspect ratio increases and the reduction varies from 15.13% to 25.74%. Similarly the Y-component of deflection reduces and it varies from 10.52% to 18.75% as the aspect ratio increases. The Z-component of deflection is almost insignificant.

When compared to bare RC frames reduction is X-component of deflection varies from 63.50% to 64.49% as the aspect ratio increases. In case of the Y-component the increase in deflection varies from 14.88% to 29.36% as the aspect ratio decreases.

**Load case 2:** Reduction in X-component of deflection varies from 15.40% to 26.34% with increase in aspect ratio. In comparison with load case 1 the increase in deflection varies from 51.4% to 51.66%. Y-component of deflection decreases and the decrease varies from 10.42% to 18.57% as the aspect ratio increases. The increase in deflection component in comparison with load case 1 is noticed in all the three aspect ratios. The Z-component deflection is almost negligible but in this case also the deflection goes on reducing as the aspect ratio increases.

When compared to bare RC frames the X-component of deflection has reduced and the reduction varies from 63.44% to 64.74% as the aspect ratio increases. The Y-component of deflection has increased and it varies from 15.38% to 29.71% as the aspect ratio decreases.

**Load case 3:** The lateral deflection increases considerably in comparison with load case 1 and load case 2 and the increase in deflection when compared with load case 1 vary from 3.0 to 3.33 times and it varies from 1.77 to 2.0 times when compared to load case 2. The variation is noticed in accordance with the aspect ratio. The reduction in the X-component varies from 16.54% to 25.36% as the aspect ratio goes on increasing. In case of Y-component also the reduction varies from 11.98% to 21.01%. The reduction is higher for larger aspect ratio and for stiffer frames.

When compared to bare RC frames the reduction in the X-component varies from 67.30% to 68.48% as the aspect ratio increases. Increase in deflection is noticed in case of
Y-component of deflection and it varies from 3.58% to 16.63% as the aspect ratio decreases.

In all load cases maximum deflection is found to be at top right hand corner of the frame in the X-component, whereas the maximum deflection is located on the top floor left column in the Y-component of deflection.

**Fig. 8.4: Deflection Contours of RC Frames Fully Infilled With Plain Masonry.**
8.4 Stresses:

The variation of the stresses for different aspect ratios and load cases is studied.

8.4.1 Normal Stresses:

The typical contours and the variation of stresses is shown in figure 8.6, 8.7 and 8.8.

Load Case 1:

a) RC frame: The stresses in the frame vary from 1.24 to 8.07 N/mm². In case of X-component the stress decrease and the reduction varies from 4.62% to 13% as the aspect ratio increases. Similarly the Y-component of stress also decreases and it varies from 11.64% to 21.43%. The Z-component of stresses increases from 1.240 to 1.560 N/mm² as the aspect ratio decreases. The Y-component stresses are higher when compared the corresponding X and Z-component stresses. The Y-component stresses increases from 6.34 to 8.07 N/mm² as the aspect ratio decreases.

b) Masonry stresses: In case of masonry stresses the stresses increases from 0.031 to 0.230 N/mm². The masonry stresses are higher in the Y-component. Increase of stresses
is noticed in case of the X-component for aspect ratio 1.41 but the same variation is not noticed in the case of Y and Z-component of stresses.

When compared to bare RC frames the stresses in the frame decrease in the X-component and the decrease varies from 51.68% to 63.11% whereas the stresses increase in the Y and Z-components and the increase varies from 38.42% to 50%.

Fig. 8.6: Normal Stress Contours of RC Frames Fully Infilled With Plain Masonry (X-Component)

Kobe
MX = Maximum stress; MN = Minimum stress
(a) infilled RC frame (IFF) (b) Masonry (MS)
Aspect Ratio 1.23
RC frames fully infilled with plain masonry

Fig. 8.7: Normal Stress Contours of RC Frames Fully Infilled With Plain Masonry. (Y-Component)

(a) Infilled RC frame (IFF)  (b) Masonry (MS)

Aspect Ratio 1.23

MX : Maximum stress;  MN = Minimum stress

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Load Case 2:

*a) RC frame*: The stresses vary from 0.87 to 12.20 N/mm$^2$. In all the three components the reduction of stresses is noticed. In case of X-component the stresses reduce and the reduction varies from 4.58% to 12.98% as the aspect ratio increases. The stresses are higher in the Y-component and they vary from 9.61 to 12.20 N/mm$^2$ as the aspect ratio decreases. Z-component of stresses is negligible. When compared to load case 1 stresses have increased and the percentage increase varies from 33.69% to 34.17%.

*b) Masonry*: The stresses vary from 0.047 to 0.349 N/mm$^2$. Higher stresses are noticed in case of the Y-component. They increase from 0.272 to 0.349 N/mm$^2$ as the aspect ratio decreases. In case of aspect ratio 1.41 the X-component of stress increases when compared to the corresponding stress for aspect ratio 1.23, but the stress decreases when compared to the stress of frame with aspect ratio 1.61. In case of Y and Z-component the stresses decrease as the aspect ratio increases. The Z-component of stresses is almost insignificant. When compared to load case 1 the masonry stresses increase and the increase varies from 51.25% to 53.84%.

When compared with the stresses in bare RC frame, the stresses decrease in the X-component and the decrease varies from 51.92% to 63.09%. In the other two components it is observed that the stresses have increased from 38.0% to 50.36%.

Load Case 3:

*a) RC frame*: The stresses vary from 5.21 to 35.0 N/mm$^2$. The reduction in the X-component of stresses varies from 6.0% to 15.3% as the aspect ratio increases. The Y-component stresses increases from 26.7 to 35 N/mm$^2$. These stresses are higher when compared to the other two stress components and they reduce as the aspect ratio increases and it varies from 13.14% to 23.71%. The stresses in the frame have increased considerably in the Z-component and the stress increases from 5.21 to 6.77 N/mm$^2$ as the aspect ratio decreases. When compared with load case 1 and load case 2, it is observed that all the three components of stresses have increased.

*b) Masonry*: The stresses vary from 0.130 to 0.998 N/mm$^2$. The Y and Z-components of stresses reduce as the aspect ratio increases. The reduction in the Y-component varies from 12.52% to 24.14% whereas the reduction varies from 8.82% to 23.52% in the Z-component as the aspect ratio increases. Lower stresses are observed in the Z-component.
RC frames fully infilled with plain masonry

When compared to bare RC frames the stresses in the infilled RC frame reduce considerably in the X-component and the reduction varies from 56.61% to 66.90%, whereas stresses increase in the other two components and the increase varies from 23.61% to 35.09%.

The maximum normal stresses in the frame is located at the bottom right corner, whereas the maximum stress in the masonry is located at bottom right corner in the infilled panel of the ground floor in all the load cases.

![Stress Contours and Variation](image)

(a) X Component  
(b) Y Component  
(c) Z Component

**Fig. 8.8**
Maximum Normal Stress

8.4.2 Principal Stresses:

The typical contours and the variation of stresses is shown in figure 8.9, 8.10 and 8.11.

**Load Case 1:**

a) *RC frame*: The stresses vary from 0.822 to 8.14 N/mm². The reduction in first principal stress varies from 11.54% to 21.00% as the aspect ratio increases. Similarly the
second and third principal stresses reduce and the reduction varies from 11.65% to 23.00% as the aspect ratio increases.

b) Masonry: The stresses increase from 0.003 to 0.29 N/mm². The third principal stresses are almost negligible. The maximum stresses are noticed only in case of first principal stress and the reduction in the stress varies from 6.87% to 15.46% as the aspect ratio increases.

When compared to the bare RC frames the decrease in principal stresses is noticed in the second principal plane and the decrease varies from 19.44% to 47.19%. In case of aspect ratio 1.23 the decrease in first principal stress is observed but the stress has increased in the other two aspect ratios. The principal stresses in the third principal plane have increased considerably when compared to the corresponding stresses of bare RC frame and the increase varies from 40.90% to 50.00%.

Load Case 2:

a) RC frame: The stresses vary from 1.25 to 12.30 N/mm². The first principal stresses decrease and the decrease varies from 11.38% to 20.73% as the aspect ratio increases. The decrease in stress varies from 12.17% to 22.80% in second and third principal stress as the aspect ratio increases. When compared to load case 1 the stresses increase and the increase varies from 33.57% to 34.24%.

b) Masonry: The stresses vary from 0.005 to 0.44 N/mm². Stresses are significant in the first principal plane. The first principal stresses decrease and the decrease varies from 7.24% to 15.61% as the aspect ratio increases. When compared to load case 1 the principal stresses have increased by about 50%. The third principal stresses are almost negligible.

When compared to the bare RC frames the decrease in principal stresses is noticed in the second principal plane and the decrease varies from 19.26% to 47.38%. In case of frames with aspect ratio 1.23 a decrease of 14% in stress is observed in the second principal plane and stress have increased in the other two aspect ratios marginally by about 2%. The principal stresses in the third principal plane have increased considerably when compared to the corresponding stresses of bare RC frames and the increase varies from 23.81% to 58.19%.
RC frames fully infilled with plain masonry

Kobe

MX : Maximum stress; MN = Minimum stress

Aspect Ratio 1.23

(a) infilled RC frame (IFF)  (b) Masonry (MS)

Fig. 8.9: Principal Stress Contours of RC Frames Fully Infilled With Plain Masonry. (1st Principal stress)
RC frames fully infilled with plain masonry

Fig. 8.10: Principal Stress Contours of RC Frames Fully Infilled With Plain Masonry.

(a) infilled RC frame (IFF)  (b) Masonry (MS)

Aspect Ratio 1.23

MX : Maximum stress;  MN = Minimum stress

Kobe

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Load Case 3:

a) RC frame: The stresses vary from 3.47 to 35.30 N/mm². As the aspect ratio increases stresses have decreased in all the planes. It is observed that the stresses in the frame with aspect ratio 1.23 have reduced in the second principal plane by 23.4% and by 52.65% in the third principal plane.

b) Masonry: The stresses vary from 0.015 to 1.26 N/mm². The third principal stresses is negligible. The stresses reduce as the aspect ratio increases and the decrease varies from 7.93% to 17.46% in case of the first principal stress.

When compared with the bare RC frames the decrease in principal stresses is noticed in the first and second principal plane and the decrease varies from 5.52% to 52.65%. The principal stresses in the third principal plane have increased considerably when compared to the corresponding stresses of bare RC frames and the increase varies from 11.19% to 42.27%.

For all load cases the location of the maximum first principal stress is at the right bottom corner at support, whereas the maximum stress in the masonry is at the left corner of the ground floor infilled panel.

![Maximum Principal Stresses](Fig. 8.11)
8.4.3 Shear Stresses:

The typical contours and the variation of stresses is shown in figure 8.12, 8.13 and 8.14.

Load Case 1:

a) RC frame: The shear stresses vary from 0.074 to 1.21 N/mm² as the aspect ratio decreases. Higher shear stresses are noticed in case of XY plane, they increase from 0.916 to 1.21 N/mm².

b) Masonry: The stresses vary from 0.002 to 0.177 N/mm². The shear stresses are almost negligible in the YZ and XZ planes. The shear stresses in the XY plane increase from 0.164 to 0.177 N/mm². The stresses have reduced as the aspect ratio increases in all the components and the reduction varies from 22.31% to 24.29% in the first principal plane and 24.42% to 43.5% in the second principal plane.

When compared with bare RC frames, the stresses in the frame have reduced considerably for all aspect ratios and the reduction varies from 53.3% to 75.33%.

Load Case 2:

a) RC frame: The stresses vary from 0.11 to 1.41 N/mm². It is observed that with the variation in aspect ratio there is no significant variation in shear stresses.

b) Masonry: The stresses vary from 0.003 to 0.26 N/mm². The stresses in the YZ and XZ plane are almost negligible. The stresses in the XY plane increase from 0.249 to 0.269 N/mm² as the aspect ratio decreases. When compared to load case 1 the stresses have increased and the increase varies from 33.33% to 51.97%.

When compared to bare RC frame stresses in the frame have reduced considerably. The reduction is not significant in case of the frames with aspect ratio 1.61. Maximum reduction is noticed in the XY plane and the reduction varies from 34.56% to 48.35% as the aspect ratio decreases.

Load case 3:

a) RC frame: The stresses vary from 0.314 to 4.03 N/mm². There is a substantial increase in stress in all the planes. The stresses reduce as the aspect ratio increases. The stresses are higher in the XY plane and they increase from 3.860 to 4.030 N/mm² as the aspect ratio decreases.
Fig. 8.12: Shear Stress Contours of RC Frames Fully Infilled With Plain Masonry. (XY-Plane)

Kobe
MX : Maximum stress; MN = Minimum stress

(a) infilled RC frame (IFF) (b) Masonry (MS)

Aspect Ratio 1.23
Fig. 8.13: Shear Stress Contours of RC Frames Fully Infilled With Plain Masonry. (YZ-Plane)

(a) Infilled RC frame (IFF)  (b) Masonry (MS)

Kobe

MX : Maximum stress;  MN = Minimum stress

Aspect Ratio 1.23
b) Masonry: The stresses vary from 0.007 to 0.771 N/mm². Even in this case the shear stresses in the YZ and XZ plane are almost negligible. The stresses decrease as the aspect ratio increases. The stresses in the XY plane increase from 0.694 to 0.771 N/mm² as the aspect ratio decreases. When compared to load case 1 the stresses have increased by about 3.0 times and stresses have increased by about 2.0 times when compared with load case 2.

When compared with bare RC frames the shear stresses decrease from 7.91% to 53.83% as the aspect ratio decreases. The maximum reduction of 53.83% is noticed in the XY plane for infilled RC frame with aspect ratio 1.23.

The maximum shear stress in all load cases in the XY plane is located in the left bottom corner of the ground floor, whereas the maximum shear stress in the brick masonry is located in the bottom panel.

Fig. 8.14
Maximum Shear Stresses
8.5 Acceleration:

The variation of acceleration is shown in Fig. 8.15 and the acceleration contours are shown in fig 8.16.

**Load Case 1:** The accelerations vary from 0.014 to 8.55 m/sec\(^2\). The acceleration in the Z component is almost negligible. The acceleration has increased in the Y-component as the aspect ratio increases and it varies from 4.6% to 8.22% and X-component of acceleration decreases and it varies from 0.9% to 1.82% as the aspect ratio increases.

When compared with bare RC frames the acceleration has increased for all the aspect ratios and in all the components. The increase in the X-component of acceleration varies from 9.0% to 11.40%. Substantial increase in acceleration is noticed in the Y and Z- components and it varies from 1.6 to 2.9 times.

**Load Case 2:** Accelerations vary from 0.020 to 12.95m/sec\(^2\) in this load case. The acceleration in the Z component is almost negligible. The acceleration has increased in the Y-component as the aspect ratio increases by 4.16% to 8.0% while it has decreased in the X-component from 0.92% to 1.77% as the aspect ratio increases.

When compared with bare RC frames the acceleration has increased for all the aspect ratios and in all the components. The increase in the X-component of acceleration varies from 8.99% to 11.06%.

**Load Case 3:** Accelerations vary from 0.058 to 37.06 m/sec\(^2\). The acceleration in the Z component is almost negligible. The acceleration has increased in the Y-component by 2.9% to 5.1% while it has reduced by 2.45% to 4.5% as the aspect ratio increases.

When compared with bare RC frames the acceleration has increased in the Y and Z components, whereas it has reduced in the X-component. The percentage of reduction varies from 0.51% to 2.48% in the X-component, where the accelerations are predominant.
RC frames fully infilled with plain masonry

Zone 4

Zone 5

Kobe

MX : Maximum acceleration;  MN = Minimum acceleration

(a) X-Component  (b) Y-Component

Aspect Ratio 1.23

Fig. 8.15: Acceleration Contours of RC Frames Fully Infilled With Plain Masonry.
8.6 Summary

- Deflections in RC frames with plain masonry infill have reduced substantially in comparison to those of bare RC frames. More reduction occurs with increase in aspect ratio. Reduction occurs only in X-component while Y-component shows increasing trend, because of the increase in the stiffness.

- Stresses in the overall masonry infill have increased with increase in ground acceleration, indicating active participation of masonry infill due to the composite action of frame and masonry, which is more evident as the aspect ratio decreases.

- Stresses in RC frames with plain masonry infill have considerably reduced in comparison with bare RC frames thereby the reserve strength in the frame elements has increased.

- Critical masonry stresses are observed only in the periphery of the ground floor panel and are local in nature.

- Critical stresses in the frame are observed in the frame elements of the ground floor and are concentrated at the joints.

- Accelerations have increased in plain masonry infilled RC frames in comparison to that of bare RC frames in load case 1 and 2, while they have decreased in the X-component for load case 3.