Chapter 14

Grouted Rat-trap Bond Masonry infilled RC frames with stilt floor (SGRTI)

14.1 Introduction:

In this study the behavior of grouted rat-trap bond masonry as an infill is studied in the frames with stilt floor. The behavior is compared with bare RC frame and plain masonry infilled RC frame with stilt floor. The table 14.1 shows the nomenclature of the models studied. The figure 14.1 shows the discretized model.

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Model No</th>
<th>Aspect Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SGRTI 4023</td>
<td>1.23</td>
</tr>
<tr>
<td>2</td>
<td>SGRTI 4523</td>
<td>1.41</td>
</tr>
<tr>
<td>3</td>
<td>SGRTI 5023</td>
<td>1.60</td>
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</tbody>
</table>

Fig.14.1: Typical Discretized Model

14.2 Natural frequency:

Ten modal frequencies are captured. It is observed that the natural frequency has increased as the aspect ratio increases. The variation in the natural frequency with the aspect ratio is shown in the fig.14.2 and the typical mode shapes are shown in fig.14.3.

Fig.14.2: Natural frequency
Grouted Rat-trap Bond Masonry infilled RC frames with Stilt floor

Mode 1

Mode 2

Mode 3

Mode 4

Mode 5

Mode 6

Aspect Ratio 1.60

Fig. 14.3: Mode Shapes of Grouted Rat-Trap Bond Masonry infilled RC frames With Stilt Floor
14.3 Stiffness

The typical deflection contours are presented in fig.14.4. The variation of components of deflection for different aspect ratio is presented in Fig. 14.5.

14.3.1 Deflection:

Load Case 1: Still Grouted rat-trap bond masonry infilled RC frames have shown resistance towards the lateral sway. The X-component of deflection reduces as aspect ratio increases and the reduction varies from 19.74% to 32.91%. In case of Y-component the reduction varies from 11.11% to 18.64%. The Z-component of deflection is almost negligible.

When compared with bare RC frame the X-component of deflection reduces and the reduction varies from 19.79% to 29.50%. In case of Y-component increase in deflection is noticed and the increase varies from 48.14% to 66.59%.

When compared with plain masonry infilled RC frame the deflection reduces and the reduction varies from 2.00% to 8.93% in the X and Y-component. The reduction varies in accordance with the increase in aspect ratio.

Load Case 2: In this case the X-component of deflection reduces and the reduction varies from 19.79% to 32.95%. Similarly reduction is also noticed in the Y-component. The Z-component of deflection is almost negligible. Deflections in the X-component are higher when compared to other two components and they vary from 10.50 to 15.6 mm.

When compared with bare RC frame the deflection has reduced in all the components. The reduction in deflection in the X-component varies from 19.69% to 29.48%.

When compared with plain masonry infilled RC frame the deflection has reduced in all the components. The reduction in deflection in the X-component varies from 6.78% to 9.01%. Marginal reduction is noticed in case of the Y-component.

Load Case 3: In this case maximum deflection is noticed in the X-component. The deflection decreases from 31.90 mm to 49.55 mm and the decrease vary from 21.51% to 35.62% as the aspect ratio increases. In case of Y-component the deflections are less than 4 mm and the deflection in Z-component is almost insignificant. When compared with load case 1 the increase in deflection is around 360% and when compared with load case 2 the deflection increases and it is around 210%.

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Grouted Rat-trap Bond Masonry infilled RC frames with Stilt floor

Zone 4

Figure 14.4: Deflection Contours of Grouted Rat-Trap Bond Masonry infilled RC frames with Stilt Floor

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MX : Maximum deflection; MN = Minimum deflection

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

Aspect Ratio 1.23

Fig. 14.4: Deflection Contours of Grouted Rat-Trap Bond Masonry infilled RC frames with Stilt Floor

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When compared with bare RC frame the deflection has reduced in the X and Z-component whereas they have increased in the Y-component. The increase in deflection in the Y-component varies from 46.29% to 66.15%. In the X-component the reduction in deflection varies from 20.47% to 31.10%.

When compared with plain masonry infilled RC frame the deflection has reduced in all the three components. The reduction in deflection is higher in case of X-component and it varies from 7.40% to 9.86%. The reduction in deflection in the Y-component varies from 2.64% to 3.16%.

The maximum deflection is located at the top right hand corner in the X-component, whereas in the Y-component it is located on ground floor right corner in all the load cases.

14.4 Stresses:

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

14.4.1 Normal stresses:

The typical contours and the variation of stresses is shown in figure 14.6, 14.7 & 14.8.
Load Case 1:

a) **RC frame**: The stresses vary from 1.97 to 18.40 N/mm\(^2\). In case of X-component the stresses decrease and the decrease varies from 24.65% to 41.71%. The Y-components of stresses are higher when compared to X-component and the stresses reduce as the aspect ratio increases. The Z-components of stresses are less than 3 N/mm\(^2\).

b) **Masonry**: The stresses vary from 0.079 to 0.759 N/mm\(^2\). The stresses are higher in the Y-component.

When compared with bare RC frame the stresses increase in all the components. The increase in X-component varies from 34.76% to 57.78%.

When compared with plain masonry infilled RC frame the stresses in the frame have reduced in the X and Z-component whereas they have marginally increased in the Y-component. The increase in masonry stress is noticed in all the three components. In case of Y-component the increase in the stress varies from 66.26% to 76.10% which is higher when compared to the other two components.

Load Case 2:

a) **RC frame**: In this case the stresses vary from 2.98 to 27.90 N/mm\(^2\). In this case also the stresses in Y-component are higher. The stresses reduce as the aspect ratio increases.

b) **Masonry**: The stresses vary from 0.11 to 1.11 N/mm\(^2\). In this case also the stresses are higher in the Y-component.

When compared with bare RC frame the stresses in the frame have increased in all the components. The increase in the X-component of stresses varies from 34.79% to 60.57%.

When compared with plain masonry infilled RC frame the stresses in the frame have decreased in the X and Z-components whereas they have increased in the Y-component. The increase in the Y-component varies from 1.82% to 2.33%. The stresses in the masonry have increased in all the components, higher increase is observed in case of Y-component and it varies from 66.30% to 70.48%.
Grouted Rat-trap Bond Masonry infilled RC frames with Stilt floor

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

Kobe

MX : Maximum stress; MN = Minimum stress

Aspect Ratio 1.23

Fig. 14.6: Normal Stress Contours of Grouted Rat-Trap Bond Masonry infilled RC frames with Stilt Floor (X- Component)

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Grouted Rat-trap Bond Masonry infilled RC frames with Stilt floor

Fig. 14.7: Normal Stress Contours of Grouted Rat-Trap Bond Masonry infilled RC frames with Stilt Floor (Y-Component)

MX : Maximum stress; MN = Minimum stress

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

Aspect Ratio 1.23

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Load Case 3:

a) **RC frame:** In this case the stresses in the frame vary from 9.06 to 88.30 N/mm$^2$. In this case also the Y-components of stresses are higher. In all the three components the stresses reduce as the aspect ratio increases.

b) **Masonry:** When compared with bare RC frame the stresses in the frame have increased in all the components and the increase varies from 31.98% to 2.13 times. Higher increase is noticed in case of Y-component.

When compared with plain masonry infilled RC frame the stresses in the frame have reduced in X and Z-component whereas they have increased in Y-component. The stresses in the masonry have increased in all the components. Masonry stresses have increased considerably in the Y-component and the increase varies from 64.70% to 75%.

The maximum normal stress in the X-component is located at the bottom right corner, whereas the maximum shear stresses are located in the first floor infilled panel at the right bottom corner in all the load cases.

![Graphs showing normal stress distribution](image)

**Fig. 14.8**

Maximum Normal Stress
14.4.2 Principal Stresses:

The typical contours and the variation of stresses is shown in figure 14.9, 14.10 & 14.11.

Load case 1:

a) RC frame: The stresses vary from 1.27 to 19.10 N/mm$^2$. The maximum stresses are noticed in first principal stress. The reduction in the first principal stress is noticed as the aspect ratio increases. The similar reduction is also noticed in the second principal and the third principal stress. The stress reduction in the frame with aspect ratio 1.41 is higher when compared to the frames with other aspect ratio.

b) Masonry: The stresses vary from 0.079 to 0.790 N/mm$^2$. The third principal stresses in the masonry are almost negligible. Masonry stresses are higher in the first principal stress.

When compared to bare RC frame the stresses have increased in all the components and the increase in first principal stress varies from 81.67 to 91.27%. Higher reduction is noticed in case of second principal stress.

When compared with plain masonry infilled RC frame the stresses in the frame have decreased in the second and third principal plane, but stresses have increased in the first principal plane. The reduction in the first principal stress varies from 1.31% to 8.13%. The masonry stresses have increased in all the planes and the increase in the second principal plane varies up to 1.33 times.

Load case 2:

a) RC frame: The stresses vary from 1.93 to 28.9 N/mm$^2$.

b) Masonry: The stresses are higher in the first principal plane and they vary from 0.915 to 1.20 N/mm$^2$ in that plane.

When compared to bare RC frame the stresses in the frame have increased in all the planes and the increase in first principal stress varies from 81.43% to 97.91%. The decrease is higher in case of the second principal plane.

When compared with plain masonry infilled RC frames the stresses in the second and third principal planes have reduced whereas the stresses in the first principal plane have increased. Marginal variation is noticed in all the three planes. The masonry stresses have reduced in all the three planes, maximum increase in stress is noticed in the second principal plane and the increase varies up to 1.34 times.
Grouted Rat-trap Bond Masonry infilled RC frames with Stilt floor

Zone 4

Zone 5

Kobe

MX : Maximum stress; MN = Minimum stress

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

Aspect Ratio 1.23

Fig. 14.9: Principal Stress Contours of Grouted Rat-Trap Bond Masonry infilled RC frames with Stilt Floor (1st Principal Stress)
Grouted Rat-trap Bond Masonry infilled RC frames with Stilt floor

Zone 4

Zone 5

Kobe

MX : Maximum stress; MN = Minimum stress

(a) infilled RC frame (IFF)  

(b) Masonry (MS)

Aspect Ratio 1.23

Fig. 14.10 Principal Stress Contours of Grouted Rat-Trap Bond Masonry infilled RC frames with Stilt Floor (2nd Principal Stress)
Load Case 3:

a) RC frame: The principal stresses vary from 5.87 to 91.5 N/mm². The stresses have increased when compared to load case 1 and load case 2.

b) Masonry: The stresses vary from 0.36 to 3.79 N/mm². Higher stresses are observed in the first principal plane.

When compared with bare RC frame the stresses have increased in all the three planes and the increase varies up to 1.5 times. Higher increase is noticed in case of third principal stress.

When compared with plain masonry infilled RC frame the stresses in the frame have reduced in the second and third principal planes whereas the stresses are increased in the first principal plane. The reduction in the second principal stress varies from 1.73% to 8.86%.

The maximum first principal stress in the frame is located in the ground floor right top corner, whereas the maximum masonry stress is located in the first floor infilled panel at the left corner in all the planes in all the load cases.

![Diagram](image-url)
14.4.3 Shear Stresses

The typical contours and the variation of stresses is shown in figure 14.12, 14.13 & 14.14.

**Load case 1:**

a) *RC frame:* The stresses vary from 0.158 to 3.60 N/mm². Higher stresses were observed in the XY plane. The stresses reduce as the aspect ratio increases in all the three planes.

b) *Masonry:* The stresses are almost negligible in YZ and XZ planes. In case of XY plane the stresses vary from 0.302 to 0.367 N/mm².

When compared with bare RC frame the stresses in all the three planes have increased. The increase in XY plane varies from 17.46% to 90.60%.

When compared with plain masonry infilled RC frame the stresses in the frame have increased in the XY plane and the mixed response is observed in case of YZ plane, where the stresses have increased in the frame with aspect ratio 1.23. Marginal reduction is noticed in the other frames. The increase in stresses in the XY plane varies from 4.34% to 10.11%. The masonry stresses have increased in all the three planes. The increase in the XY and YZ plane varies from 21.7% to 71.42%. Higher increase is noticed in the YZ plane.

**Load case 2:**

a) *RC frame:* The shear stresses vary from 0.24 to 5.46 N/mm². The stresses are higher in case of frames with aspect ratio 1.41 in the XY plane. The stresses have increased when compared to load case 1.

b) *Masonry:* The stresses in the XY plane vary from 0.45 to 0.57 N/mm². The stresses in the other two planes are almost negligible.

When compared to bare RC frame the stresses in the frame reduce in all the planes and the reduction varies from 28.82% to 58.88%. The reduction in the XY plane varies from 37.45% to 58.88%.

When compared with the plain masonry infilled RC frame the stresses in the frame increase in the XY plane and for the frame with the aspect ratio 1.23 in the YZ plane. Marginal decrease in stresses is observed in the XZ plane. The masonry stresses have increased in all the planes and the increase varies from 20.00% to 63.63%.
Grouted Rat-trap Bond Masonry infilled RC frames with Stilt floor

Zone 4

Zone 5

Kobe

MX : Maximum stress; MN = Minimum stress

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

Aspect Ratio 1.23

Fig. 14.12: Shear Stress Contours of Grouted Rat-Trap Bond Masonry infilled RC frames with Stilt Floor (XY-Plane)
Grouted Rat-trap Bond Masonry infilled RC frames with Stilt floor

Zone 4

Zone 5

Kobe

MX : Maximum stress; MN = Minimum stress

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

Aspect Ratio 1.23

Fig. 14.13: Shear Stress Contours of Grouted Rat-Trap Bond Masonry infilled RC frames with Stilt Floor (YZ-Plane)
Load case 3:

a) RC frame: The stresses vary from 0.730 to 17.300 N/mm², which are higher when compared to the other two load cases. Higher stresses are observed in the XY plane. The stresses decrease as the aspect ratio increases.

b) Masonry: The stresses vary from 0.016 to 1.760 N/mm². The stresses are higher in XY plane. The stresses are almost negligible and XZ and YZ planes.

When compared to bare RC frame the shear stresses increase in all the planes and the increase in the XY plane vary from 27.31% to 98.16%.

When compared with plain masonry infilled RC frame the stresses in the masonry have increased in the XY plane and the reduction varies from 3.59% to 9.36%. Reduction of shear stresses is observed in the other two planes except for the frame with aspect ratio 1.23 in YZ plane. The stresses in the masonry have reduced in all the components and the reduction in the XY plane varies from 20.87% to 27.53%.

Fig. 14.14
Maximum shear Stress
14.5 Acceleration:

The acceleration contours are shown in Fig. 14.15. The variation of acceleration is shown in Fig. 14.16.

**Load Case 1:** The accelerations vary from 0.008 to 6.790 m/sec$^2$. In all the three planes the acceleration varies in accordance with the aspect ratios. As the aspect ratio increases the acceleration increases in X and Y-components. The acceleration in the Z-component is almost negligible.

When compared with bare RC frames the acceleration has reduced in the X-component and it varies in X-component from 9.73% to 11.16%.

When compared to SEBI the acceleration has increased in the Y and Z-component whereas it reduces in the X-component. Marginal variation is noticed in all the three components.

**Load Case 2:** The accelerations vary from 0.013 to 10.290 m/sec$^2$. In this case also the acceleration in X and Y-components increase as the aspect ratio increases. The acceleration in the Z-component is negligible.

When compared with bare RC frames the acceleration has reduced in all the components and the reduction varies from 16.66% to 72.37%. The reduction in the X-component varies from 71.59% to 72.37%.

When compared with the SEBI the acceleration reduces in the X-component whereas acceleration increases in the other two components. Marginal variation is noticed in all the components.

**Load Case 3:** The accelerations vary from 0.041 to 32.55 m/sec$^2$. The Z-component of acceleration is negligible. The acceleration has decreased in the X-component as the aspect ratio decreases, whereas the acceleration increases in the Y-component as the aspect ratio increases.

When compared with bare RC frames the acceleration decreases in the X-component whereas they acceleration increases in the Y and Z-component. The reduction in the X-component varies from 12.59% to 13.62%, whereas the increase in acceleration varies from 81.5% to 82.47% in the Y-component.
When compared with SEBI the acceleration increases in the Y and Z-component and the acceleration reduces in the X-component. Marginal variation is noticed in all the three components.

Fig. 14.15: Acceleration Contours of Grouted Rat-Trap Bond Masonry infilled RC frames with Stilt Floor
Considerable amount of stiffness is observed in the frame, even in absence of infill in ground floor panel. The deflections have reduced, considerably when compared with plain masonry infilled RC frames, with stilt floor.

It is observed that critical stresses are concentrated in the ground floor frame members and are localized, the stresses diminish as we move to the upper floors.

In the RC frame members normal stresses have shown reducing trends in the lateral direction while the principal stresses have increasing trends in the first principal plane when the stresses are compared with the plain masonry infilled RC frames.

Although the increase in masonry stresses is quite alarming the magnitude of stresses presented in the discussion are localized and are concentrated in the first floor panel, and reduce towards upper floors. The stresses reduce in comparison to corresponding stresses in the masonry infilled RC frames with stilt floors.

Because of the soft storey mechanism and increase in stiffness accelerations have decreased in the X-component while it has increased in the Y-component when compared with bare RC frames.