Chapter 16

Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

16.1 Introduction:

In this study the behavior of reinforced rat-trap bond masonry infilled RC frames with stilt floor provided with vertical reinforcement in the infill (SGRTIV) is studied. The behavior is compared with bare RC frame, plain masonry infilled RC frame, SGRTI and SGRTIH. The table 16.1 shows the nomenclature of the models studied. The figure.16.1 shows the typical descrtized model.

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Model No</th>
<th>Aspect Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SGRTIV4023</td>
<td>1.23</td>
</tr>
<tr>
<td>2</td>
<td>SGRTIV4523</td>
<td>1.41</td>
</tr>
<tr>
<td>3</td>
<td>SGRTIV5023</td>
<td>1.60</td>
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</table>

Fig.16.1 : Typical Descrtized Model

16.2 Natural frequency:

Ten modal frequencies are captured. It is observed that the natural frequency has increased as the aspect ration increases. The variation in the natural frequency with the aspect ratio is shown in the fig.16.2 and the typical mode shapes are shown in fig.16.3.
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

Mode 1

Mode 2

Mode 3

Mode 4

Mode 5

Mode 6

Aspect Ratio 1.60, masonry with vertical reinforcement

Fig. 16.3: Mode shapes of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor.
16.3 Stiffness:

The typical deflection contours are presented in fig. 16.4. The variation of components of deflection for different aspect ratio is presented in Fig. 16.5.

16.3.1 Deflection:

**Load case 1:** The X-component of deflection reduces as aspect ratio increases and reduction varies from 18.28% to 31.90%. In case of Y-component the reduction varies from 9.88% to 17.55%. Z-component of deflection is almost negligible.

When compared with bare RC frame the deflection has reduced in all the components. The reduction varies from 22.99% to 31.29% in the X component.

When compared with plain masonry infilled RC frame the reduction in deflection is observed in all the components. The percentage reduction in the X-component varies from 9.94% to 11.24%.

When compared with SGRTI the deflection has reduced in all the components and the reduction in the X-component varies from 2.23% to 3.98%.

When compared with SGRTIH the deflection has reduced marginally in all the components. The reduction in deflection varies from 0.62% to 0.82% in the X-component.

**Load case 2:** In this case the X-component of deflection reduces and the reduction varies from 18.28% to 31.89%. Reduction is also noticed in the Y-component. The Z-component of deflection is almost negligible.

When compared with bare RC frame, the deflection has reduced in the X-component and it varies from 22.93% to 31.26%.

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 10.03% to 11.31%.

When compared with SGRTI, the reduction in stresses is observed in all the components, and the reduction in the X-component varies from 2.22% to 4.04%.

When compared with SGRTIH, minimum reduction in deflection is observed in all the components.
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

Zone 4

Zone 5

Kobe

MX : Maximum deflection; MN = Minimum deflection

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

Aspect Ratio: 1.23, Masonry with Vertical Reinforcement

Fig. 16.4: Deflection Contours of Reinforced rat-trap Bond Masonry infilled RC frames
with stilt floor.
Load case 3: In this case the maximum deflection is noticed in the X-component. The deflection varies from 31.22 to 32.477 mm. In case of Y-component the deflections are less than 3 mm and the deflection in Z-component is almost negligible. The deflection has increased when compared to load case 1 and load case 2 to a larger extent.

When compared with bare RC frame, the deflections have reduced in the X and Z-component whereas they have increase in the Y-component. The reduction in Y-component varies from 24.02% to 32.93%.

When compared with plain masonry infilled RC frame, the deflection has reduced in all the components and the reduction in the X-component varies from 10.87% to 12.26%.

When compared with SGRTI, in this case also the reduction is observed in all the components. The reduction in X-component varies from 2.46% to 4.46%.

When compared with SGRTIH, the reduction in the X-component varies from 0.69% to 0.89%.

The maximum deflection is located at the top right corner in the X-component, whereas the maximum deflection in the Y-component is located at the ground floor left column.

Fig. 16.5
Maximum Deflection
16.4 Stresses

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

16.4.1 Normal stresses:

The typical contours and the variation of stresses is shown in figure 16.6, 16.7 & 16.8.

Load case 1:

a) RC frame: The stresses in the frame varied from 1.970 to 16.80 N/mm². In case of X-component the stresses decrease and decrease varies from 5.88% to 27.73%. 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 2.5 N/mm².

b) Masonry: Masonry stresses varied from 0.080 to 0.794 N/mm². The stresses are higher in the Y-component. The stresses are almost negligible in the Z-component.

When compared with bare RC frame, the stresses in the frame have increased and the increase in X-component varies from 26.86% to 63.98%.

When compared with plain masonry infilled RC frame, the stresses have reduced predominantly in the frame with aspect ratio 1.23 in all the components. The masonry stresses have increased in all the components. The percentage increase in the X and Y-component varies from 45% to 98.78%.

When compared with SGRTI, the stresses have reduced in the frame with aspect ratio 1.23, whereas in the other frame the stresses have increased. The masonry stresses also have decreased marginally in the frame with aspect ratio 1.23 in the X-component.

When compared with SGRTIH, it is observed that there is no variation in the stresses of the frame. Masonry stresses have marginally varied.

Load case 2:

a) RC frame: In this case the stresses vary from 2.99 to 23.90 N/mm². In this case also the stresses in the Y-component are higher. The stresses reduce as the aspect ratio increases.

b) Masonry: The stresses vary from 0.121 to 1.20 N/mm². The stresses are higher in case of Y-component.
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor (with vertical reinforcement)

Zone 4

Zone 5

Kobe

MX : Maximum stress; MN = Minimum stress

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

Aspect Ratio: 1.23, Masonry with Vertical Reinforcement

Fig. 16.6: Normal Stress Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor. (X-Component)
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

Zone 4

Zone 5

Kobe

MX : Maximum stress; MN = Minimum stress

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

Aspect Ratio: 1.23, Masonry with Vertical Reinforcement

Fig. 16.7: Normal Stress Contours of Stilt Reinforced rat-trap Bond Masonry infilled RC frames
(Y-Component)
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

When compared with bare RC frame, the stresses in the frame have increased and the increase in the X-component varies from 27.48% to 62.5%.

When compared with plain masonry infilled RC frame the stresses in the frame have reduced for the frame with aspect ratio for all the components. The masonry stresses have increased in all the components. The increase in the Y direction varies from 83.48% to 98.59%. In case of X-component the increase varies from 56.94% to 70.14%.

When compared with SGRTI, the stresses in the frame with aspect ratio 1.23 have reduced in all the components, whereas marginal increase is noticed in the frames with aspect ratio 1.41 and 1.60. The masonry stresses have increased in the Y-component and it is observed that the masonry stresses have reduced for the frame with aspect ratio 1.23 in the X and Z plane.

When compared with SGRTI, it is observed that, there is no difference in stresses in the frame. In case of masonry stresses the stress has reduced for the frame with aspect ratio 1.23 in the Y-component. It is seen that the frame with aspect ratio 1.23 has offered better resistance.

Load case 3:

a) RC frame: In this case stresses vary from 9.060 to 75.30 N/mm². In this case also Y-component stresses are higher. In all the three components the stresses reduce as the aspect ratio increases.

b) Masonry: The stresses are predominant in the Y-component and they vary from 3.010 to 3.790 N/mm².

When compared with bare RC frame the stresses in the frame have increased in all the components and the increase varies from 25.33% to 174.56%.

When compared with plain masonry infilled RC frame it is observed that the stresses have reduced predominantly in the frame with aspect ratio 1.23 in all the components. Masonry stresses have increased in all the components and the increase in the Y-component varies from 82.21% to 97.11%.

When compared with SGRTI, it is observed that the stresses in the frame with aspect ratio 1.23 have reduced in all the components. The masonry stresses have increased in all the components but it is observed that the stresses have reduced in the X and Z-component for the frames with aspect ratio 1.23.
When compared with SGRTIH it is observed that, stresses have not varied predominantly. It is observed that the masonry stresses have increased in all the components.

The maximum X-component normal stresses are located in the ground floor left bottom corner, whereas the maximum masonry stresses are located in the first floor infilled panel at the left corner in all the load cases.

16.4.2 Principal stresses:

The typical contours and the variation of stresses is shown in figure 16.9, 16.10 & 16.11.

Load case 1:

a) RC frame: The stresses vary from 1.310 to 15.800 N/mm². The maximum stresses are noticed in the 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.
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

b) Masonry: The stresses vary from 0.079 to 0.851 N/mm². The third principal stresses in the masonry are almost negligible. The masonry stresses are higher in case of the first principal stresses.

When compared with bare RC frame, the stresses have increased in all the planes and the increase in the XY plane varies from 65.79% to 98.54%.

When compared with plain masonry infilled RC frame, the principal stresses in the frame with aspect ratio 1.23 have reduced considerably in all the planes. The reduction is observed in the second principal stress for the frames with all the aspect ratio. The stresses in the masonry have increased considerably and the increase varies from 69.56% to 172.72% in the second principal plane.

When compared with SGRTI, the stresses in the frame with aspect ratio 1.23 have reduced predominantly in all the planes. The masonry stresses also have reduced in the frame with aspect ratio 1.23 in the second and third principal plane.

When compared to SGRTIH, the stresses in the frame with aspect ratio 1.23 have reduced predominantly in all the planes, whereas they have increased in the frames with aspect ratio 1.41 and 1.60. The masonry stresses have also increased in the second principal plane. It is observed that the stresses in the frame with aspect ratio 1.23 have reduced in the first principal plane and second principal plane.

Load case 2:

a) RC frame: The stresses in the frame vary from 1.990 to 23.900 N/mm². Higher stresses in the frame are observed in the first principal plane.

b) Masonry: The masonry stresses are higher in the first principal plane.

When compared with bare RC frame, the stresses have increased in all the planes and the increase in XY plane varies from 65.97% to 98.07%.

When compared with plain masonry infilled RC frame, the stresses in the frame with aspect ratio 1.23 have reduced in all the planes. Reduction is observed in the second principal plane and the reduction varies from 9.282 to 43.07%. The masonry stresses have increase in all the components and the increase in the Y-component varies from 76.43% to 189.26%.
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

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MX : Maximum stress; MN = Minimum stress

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

Aspect Ratio: 1.23, Masonry with Vertical Reinforcement

Fig. 16.9: Principal Stress Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor. (1st Principal Stress)
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

Fig. 16.10: Principal Stress Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor. (2nd Principal Stress)
When compared with SGRTI, the stresses in the frame have reduced for the frame with aspect ratio 1.23 in all the planes. The stresses have reduced in the second principal plane. The masonry stresses have reduced in the first principal plane and the reduction varies from 7.50% to 18.03%. It is observed that the stresses in the frame with aspect ratio 1.23 have reduced in the second and third principal plane.

When compared with SGRTI'H there is no predominant variation observed in case of stresses in the frame. The stresses in the masonry have increased in the first principal plane and second principal plane.

Load case 3:

a) RC frame: The principal stresses in the frame vary from 6.040 to 75.400 N/mm². The stresses have increased when compared to load case 1 and load case 2.

b) Masonry: The masonry stresses vary from 0.367 to 4.070 N/mm². Higher stresses are observed in the first principal plane. The stresses reduce as the aspect ratio increases.

When compared with bare RC frame the stresses in the frame have increased in all the planes and the increase varies from 10.14% to 138.23%.

When compared with plain masonry infilled RC frame the stresses in the second principal plane have reduced and the reduction varies from 10.22% to 43.56%. It is observed that the stresses in the frame for aspect ratio 1.23 have reduced in all the planes. The masonry stresses have increased in all the planes and the increase varies from 26.95% to 185.40%. The increase is higher in the second principal plane.

When compared with SGRTI the stresses in the frame with aspect ratio 1.23 have reduced considerably in all the planes. The masonry stresses have increased in the first principal plane and the increase varies from 7.38% to 17.94%. The masonry stresses with aspect ratio 1.23 have reduced in the second and third principal plane.

When compared with SGRTI'H predominant variation is not noticed in the stresses of the frame, whereas the masonry stresses are increased in the first and second principal plane. Marginal decrease in stresses is observed in third principal plane.

In all the load cases the maximum principal stress in the first plane are located in the ground floor at top left corner, whereas the maximum stress in the masonry is located in the first floor infilled panel at the right corner.
16.4.3 Shear stresses:

The typical contours and the variation of stresses is shown in figure 16.12, 16.13 & 16.14.

**Load case 1:**

*a) RC frame:* The stresses vary from \(0.189\) to \(2.720\) N/mm\(^2\). Higher stresses were observed in the XY plane. The stresses reduce as the aspect ratio increase 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 \(0.328\) to \(0.373\) N/mm\(^2\).

When compared with bare RC frame the stresses have increased in all the planes and the increase varies upto 98% in the XY plane.

When compared with plain masonry infilled RC frame the stresses in the frame have increased in the YZ plane. The stresses in the frame with aspect ratio 1.23 have
Reduced in the XY plane and XZ plane. The masonry stresses have increased in the XY plane and YZ plane. Predominant increase is noticed in the YZ plane.

When compared with SGRTI the stresses in the frame have increased, but stresses in the frame with aspect ratio 1.23 have reduced in the XY plane and YZ plane. The masonry stresses have increased but it is observed that masonry stresses have reduced for the frame with aspect ratio 1.23 in the YZ plane.

When compared with SGRTI it is observed that the stresses in the frame have not altered in the YZ plane, whereas in the XY and XZ plane the reduction in stresses is observed. The increase in masonry stresses is noticed in case of XY plane and the increase varies from 1.73\% to 2.19\%.

**Load case 2:**

*a) RC frame:* The shear stresses vary from 0.287 to 4.130 N/mm^2. The stresses have increased when compared to load case 1.

*b) Masonry:* The stresses in the XY plane vary from 0.006 to 0.566 N/mm^2. The stresses in the other two planes are almost negligible.

When compared with bare RC frame the stresses in the XY plane have increased and the increase varies upto 1.28 times.

When compared with plain masonry infilled RC frame the stresses in the frame have increased in the YZ plane and the increase varies from 8.74\% to 46.66\%. The stresses in the frame with aspect ratio 1.23 have reduced in the XY and XZ plane. The masonry stresses have reduced and the reduction in the XY plane varies from 30.41\% to 33.66\%.

When compared with SGRTI it is observed that the stresses have decreased. The stresses in the frame with aspect ratio 1.23 have reduced in the XY and XZ plane. The masonry stresses have shown mixed response in the XY plane. The stresses in the frame with aspect ratio 1.23 have reduced by 1.9\%, whereas the stresses in the frame with aspect ratio 1.41 and 1.60 have increased by 8.5\%.

When compared with SGRTI it is observed that the stresses have decreased. The stresses in the frame with aspect ratio 1.23 have reduced in the XY and XZ plane. The masonry stresses have shown mixed response in the XY plane. The stresses in the frame with aspect ratio 1.23 have reduced by 1.9\%, whereas the stresses in the frame with aspect ratio 1.41 and 1.60 have increased by 8.5\%.

When compared with SGRTI it is observed that the stresses have decreased. The stresses in the frame with aspect ratio 1.23 have reduced in the XY and XZ plane. The masonry stresses have shown mixed response in the XY plane. The stresses in the frame with aspect ratio 1.23 have reduced by 1.9\%, whereas the stresses in the frame with aspect ratio 1.41 and 1.60 have increased by 8.5\%.

When compared with SGRTI it is observed that the stresses have decreased. The stresses in the frame with aspect ratio 1.23 have reduced in the XY and XZ plane. The masonry stresses have shown mixed response in the XY plane. The stresses in the frame with aspect ratio 1.23 have reduced by 1.9\%, whereas the stresses in the frame with aspect ratio 1.41 and 1.60 have increased by 8.5\%.
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

Zone 4

Zone 5

Kobe

MX : Maximum stress;  MN = Minimum stress
(a) infilled RC frame (IFF)  (b) Masonry (MS)

Aspect Ratio: 1.23, Masonry with Vertical Reinforcement

Fig. 16.12: Shear Stress Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor. (XY-Plane)
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

Zone 4

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MX : Maximum stress; MN = Minimum stress

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

Aspect Ratio: 1.23, Masonry with Vertical Reinforcement

Fig. 16.13: Shear Stress Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor. (YZ-Plane)
Load case 3:

a) **RC frame**: The stresses vary from 0.872 to 13.00 N/mm$^2$ 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 0.017 to 1.780 N/mm$^2$. The stresses are higher in XY plane. The stresses are almost negligible in XZ and YZ planes.

![Graphs showing stress variations](image)

**Fig. 16.14**

**Maximum shear Stress**

When compared with bare RC frame the stresses in the frame have increased in all the components and the increase varies from 33.48% to 215.63%.

When compared with plain masonry infilled RC frame the stresses in the frame have increased whereas in the frame with aspect ratio 1.23, the stresses have decreased in the XY and XZ plane. The masonry stresses have increased and the increase varies from 28.98% to 33.05% in the XY plane.

When compared with SGRTI it is observed that the stresses are increased except for the frame with aspect ratio 1.23 where the stresses have decreased in the XY and XZ
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor (with vertical reinforcement)

plane. The masonry stresses have increased in the XY plane and the increase varies from 1.13% to 8.63%.

When compared with SGRTIH the predominant variation is not noticed in the stresses of the frame, whereas the stresses in the masonry have increased and the increase varies from 1.71% to 2.02%.

The maximum shear stress in the XY panel is located at the ground floor top left corner, whereas the maximum masonry stresses is located at the first floor infilled panel in all the load cases.

16.5 Acceleration:

The acceleration contours are shown in fig 16.15. The variation of acceleration is shown in Fig. 16.16.

Load case 1: The acceleration varies from 0.010 to 6.793 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 Y and Z-components, whereas, it reduces in case of the X-component. The acceleration in the Z-component is almost negligible.

When compared with bare RC frames the acceleration decreases and the decrease varies from 10.80% to 11.77% in the X-component. When compared with SEBI it is observed that the acceleration has decreased in the X-component and the acceleration has increased in the Y and Z-component. When compared with SGRTI and SGRTIH it is observed that the acceleration have not varied predominantly.

Load case 2: The acceleration varies from 0.014 to 10.294 m/sec$^2$. In this case also the acceleration in Y and Z-component has increased as the aspect ratio increases. But again the reduction is observed in case of X-component, where the acceleration is higher.

When compared with bare RC frames the acceleration have decreased in all the components decrease varies from 11.71% to 11.90%. When compared with SEBI the reduction in acceleration is observed in Y-component. When compared with SGRTI and SGRTIH it is observed that the acceleration has reduced for the frame with aspect ratio 1.23 in the Y-component, whereas it has increased in the frames with other aspect ratios. Predominant variation is not noticed in the X-component.

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Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

Zone 4

Zone 5

Kobe

MX : Maximum acceleration; MN = Minimum acceleration
(a) X-Component  (b) Y- Component

Aspect Ratio: 1.23, Masonry with Vertical Reinforcement

Fig. 16.15: Acceleration Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor.
Load case 3: The acceleration varies from 0.043 to 32.432 m/sec$^2$. These values are higher when compared with load case 1 and load case 2. In case of the X-component the acceleration reduces as the aspect ratio increases, whereas in case of Y and Z-component it is vice versa.

When compared with bare RC frames the acceleration has reduced in the X-component whereas acceleration is increased in the Y and Z-component. When compared with SEBI the acceleration has reduced in the X-component and the acceleration has increased in the Y-component. Similar variation is noticed when compared with SGRTI. Predominant variation is not noticed when compare with SGRTIH.

16.6 Summary:

- Because of the addition of stiffness, lateral deflections have reduced further in comparison with reinforced rat-trap bond masonry infilled RC frames with horizontal reinforcements.
Reinforced Rat-trap Bond Masonry infilled RC frames with stilt floor
(with vertical reinforcement)

- When compared with reinforced rat-trap masonry infilled RC frames with horizontal reinforcement, no significant change is observed in the RC frame.

- Masonry stresses have not varied significantly in comparison with grouted rat-trap bond masonry. The arrangement of reinforcement has minimal influence on the stress variation.

- The infilled RC frames have offered better resistance when compared with plain masonry infilled RC frames and grouted rat-trap bond masonry infilled RC frames.

- The variation in acceleration components is insignificant when compared with reinforced masonry infilled RC frames with horizontal reinforcements.