Chapter 15

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

15.1 Introduction:

In this study the behavior of reinforced rat-trap bond masonry infilled RC frames with stilt floor (SGRTIH) and horizontal reinforcement in the infill is studied. The behavior is compared with bare RC frame, plain masonry infilled RC frame and GRTI. The table 15.1 shows the nomenclature of the models studied. The fig.15.1 shows the discretized model with stilt floor.

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Model No</th>
<th>Aspect Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SGRTIH4023</td>
<td>1.23</td>
</tr>
<tr>
<td>2</td>
<td>SGRTIH4523</td>
<td>1.41</td>
</tr>
<tr>
<td>3</td>
<td>SGRTIH5023</td>
<td>1.60</td>
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</table>

15.2 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.15.2 and the typical mode shapes are shown in fig.15.3.
Reinforced Rat-trap Bond Masonry infilled RC frames with Stilt Floor
(with horizontal reinforcement)

Fig. 15.3: Modal Shapes of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor

Aspect Ratio 1.60, masonry with horizontal reinforcement
15.3 Stiffness:

The typical deflection contours are presented in fig.15.4. The variation of components of deflection for different aspect ratio is presented in Fig. 15.5.

15.3.1 Deflection

Load case 1: The X-component of deflection reduces as the aspect ratio increases and the reduction varies from 18.18% to 31.76%. In case of Y-component the reduction varies from 9.87% to 17.53%. The Z-component of deflection is almost negligible.

When compared with bare RC frame the deflection has reduced in all the components. The reduction in X component from 22.51% to 30.72%.

When compared with plain masonry infilled RC frame in this case also the deflection has reduced in all the components. The reduction in deflection in the X-component varies from 9.27% to 10.51%. Similarly the reduction in deflection in the Y-component varies from 2.66% to 3.6%.

When compared with SGRTI the deflections have reduced in all the components. The reduction in deflection in X-component varies from 1.50% to 3.38%. Similarly the reduction in deflection in Y-component varies from 0.287% to 1.66%.

Load case 2: In this case the X-component of deflection reduces and reduction varies from 18.07% to 31.66%. Similarly 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 all the components. Reduction in the deflection in the X-component varies from 22.56% to 30.70%.

When compared with plain masonry infilled RC frame in this case also the deflection has reduced in all the components the reduction in deflection in X-component varies from 9.37% to 10.58%. Marginal reduction in deflection is observed in the Y-component.

When compared with SGRTI it is observed that the deflection has reduced in all the components. Higher reduction in deflection is noticed in the X-component and it varies from 1.51% to 3.51%.
Reinforced Rat-trap Bond Masonry infilled RC frames with Stilt Floor
(with horizontal reinforcement)

Zone 4

Zone 5

Kobe
MX : Maximum deflection; MN = Minimum deflection

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

Aspect Ratio: 1.23, Masonry with Horizontal Reinforcement

Fig. 15.4: Deflection Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor

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**Load case 3:** In this case maximum deflection is noticed in the X-component. The deflection varies from 31.33 to 47.67 mm. In case of Y-component the deflections are less than 4 mm and the deflection in Z-component is almost negligible. The deflection is higher when compared to load case 1 and load case 2.

When compared with bare RC frame the deflection has reduced in the X and Z-component, whereas, they have increased in the Z-component. The increase in deflection varies from 45.37% to 62.83% in the Y-component.

When compared with plain masonry infilled RC frame in this case also the deflection has reduced in all the three components. The reduction in deflection in the X-component varies from 10.15% to 11.46%.

When compared with SGRTI it is observed that the deflections are reduced in all the components. In the X-component the reduction in deflection varies from 1.67% to 3.79%, which is higher when compared to the reduction in the other two components.

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

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

15.4.1 Normal Stresses:

The typical contours and the variation of stresses is shown in figure 15.6, 15.7 & 15.8.

Load case 1:

1. **RC frame:** The stresses in the frame vary from 1.97 to 15.7 N/mm². In case of the X-component the stress has decreased and decrease varies from 5.88% to 27.64% as the aspect ratio increases. The Y-components of stresses are higher when compared to X-component and the stresses have reduced as the aspect ratio increased. The Z-components of stresses are less than 2.5 N/mm².

2. **Masonry:** In case of the masonry stresses, the stresses are higher in the Y-component and they varied from 0.624 to 0.761 N/mm². The stresses in the Z-component are almost negligible.

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

   When compared with plain masonry infilled RC frame the stresses in the frame have reduced in all the components for the frame with aspect ratio 1.23, whereas, in the frames of other aspect ratio the variation in stress is not predominant. The stresses in the masonry have increased in all the components and the increase varies from 28.37% to 90.16%. Higher increase is observed in the Y-component and it varies from 76.56% to 89.66%.

   When compared with SGRTI the stresses in the frame have increased in all the components for the frames with aspect ratio 1.41 and 1.60. The stresses have reduced in the frames with aspect ratio 1.23. In case of masonry stresses the stresses have increased in the frames with aspect ratio 1.41 and 1.60 and the stresses have reduced in the frame with aspect ratio 1.23.
Reinforced Rat-trap Bond Masonry infilled RC frames with Stilt Floor
(with horizontal 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 Horizontal Reinforcement

Fig. 15.6: Normal Stress Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor (X-Component)

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Reinforced Rat-trap Bond Masonry infilled RC frames with Stilt Floor
(with horizontal 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 Horizontal Reinforcement

Fig. 15.7: Normal Stress Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor (Y-Component)
Load case 2:

*a) RC frame:* In this case the stresses vary from 2.19 to 23.9 N/mm$^2$. In this case also the stresses in the Y-component are higher. The stresses reduce as the aspect ratio increases.

*b) Masonry:* In case of the stresses the stresses vary from 0.122 to 1.15 N/mm$^2$. In this case also the stresses are higher in Y-component.

When compared with bare RC frame the stresses in the frame have increased. The increase in the X-component varies from 27.46% to 62.50%.

In comparison with plain masonry infilled RC frame it is observed that the stresses in the frame have reduced in the X-component and for the frame with aspect ratio 1.23 in the Y and Z-component. Reduction in the stress is also observed in the Z-component for the frame with aspect ratio 1.60. The stresses in the masonry have increased in all the components and the increase varies from up to 1.52 times.

In comparison with SGRT1 the stresses in the frame have reduced for the frames with aspect ratio 1.23. In the other frames marginal increase in the stresses is observed. In the Z-component reduction of the stress in the frame with aspect ratio 1.60 is observed. The stresses in the masonry have increased in most of the frames but in the X and Z-component the stresses in the masonry for aspect ratio 1.23 have reduced.

Load case 3:

*a) RC frame:* In this case the stresses vary from 9.07 to 75.2 N/mm$^2$. In this case also the stresses in the Y-component are higher. In all the three components the stresses reduced as the aspect ratio increases.

*b) Masonry:* The stresses are higher when compared to load case 1 and load case 2 and they vary from 0.37 to 3.64 N/mm$^2$. Higher stresses are observed in the Y-components.

When compared with bare RC frame the stresses in the frame have increased in all the components and the increase varies from up to 1.74 times. Higher increase is noticed in case of Y-component, where the increase varies from 1.66 to 1.74 times.

When compared with plain masonry infilled RC frame the stresses in the frame with aspect ratio 1.23 have reduced in all the components, whereas in the frames with other aspect ratios, the variation is very much minimum. The stresses in the masonry have increased in all the components and the increase in stress varies from 28.29% to 88.43%. Higher increase is noticed in Y-component and it varies from 75% to 88.43%.
When compared with SGRTI the stresses in the frame have reduced for the frame with aspect ratio 1.23 in all the components, whereas the stresses have marginally increased for the frames with aspect ratio 1.41 and 1.60. The stresses in the masonry have increased in all the components for the frames with aspect ratio 1.41 and 1.60, whereas the stresses have reduced in the frames with aspect ratio 1.23.

Maximum X-component of the normal stress is located in the ground floor left corner, whereas the maximum stress in the masonry is located in the first floor infilled panel in all components.

15.4.2 Principal Stresses:

The typical contours and the variation of stresses is shown in figure 15.9, 15.10 & 15.11.

**Load case 1:**

*a) RC frame:* The stresses vary from 1.320 to 15.800 N/mm². 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. In case of second principal and third principal stress, the stresses vary from 3.860 to 15.8 N/mm$^2$. The masonry stresses vary from 0.080 to 0.816 N/mm$^2$. The third principal stress in the masonry is almost negligible.

b) Masonry: The stresses are higher in case of the first principal stress and they vary from 0.681 to 0.816 N/mm$^2$.

When compared with bare RC frame the stresses in the frames have increased in all the planes and the increase varies from 65.79% to 98.4% in the first principal stress.

When compared with plain masonry infilled RC frame the stresses in the frame have reduced predominantly for the frame with aspect ratio 1.23 in all the planes. The stresses have reduced in the second principal plane and the reduction varies from 8.82% to 42.84%. The masonry stresses have increased in all the planes. Higher increase is noticed in the second principal stress and the increase varies up to 1.72 times.

When compared with SGRTI the stresses in the frame have varied marginally in all the planes for the frames with aspect ratio 1.41 and 1.60. Substantial reduction is noticed in the frames with aspect ratio 1.23 in all the planes. The stresses in the masonry have increased in most of the frames, but the masonry stresses have reduced for the frame with aspect ratio 1.23 in the second and third principal plane.

Load case 2:

a) RC frame: The stresses vary from 1.99 to 23.90 N/mm$^2$. Higher stresses in the frame are observed in the first principal plane.

b) Masonry: The stresses are higher in the first principal plane and the stresses vary from 3.140 to 3.90 N/mm$^2$.

When compared with bare RC frame the stresses have increased in all the planes and the increase varies from 65.97% to 98.0% in the first principal stress.

When compared with plain masonry infilled RC frame the stresses have reduced predominantly in the frame with aspect ratio 1.23. Second principal stresses have reduced and the reduction varies from 8.75% to 42.83%. The stresses in the masonry have increased in all the planes. The second principal stresses have increased predominantly and the increase varies up to 1.74 times.

When compared with SGRTI the stresses in the frame have reduced in the frame with aspect ratio 1.23 in all the planes. Marginal variation is noticed in the other frames.
The stresses in the masonry have increased in the frames with aspect ratio 1.41 and 1.60, whereas the stresses have decreased in the frames with aspect ratio 1.23.

Fig. 15.9: 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 horizontal 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 Horizontal Reinforcement

Fig. 15.10: Principal Stress Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor (2nd Principal Stress)
Load case 3:

a) RC frame: The principal stresses vary from 6.05 to 75.40 N/mm². The stresses have increased when compared to load case 1 and load case 2. The stresses have decreased as the aspect ratio increases.

b) Masonry: The stresses vary from 0.369 to 3.9 N/mm². Higher stresses are observed in the first principal plane. The increase in aspect ratio has resulted in the decrease of stresses.

When compared with bare RC frame the stresses in the frame have increased in all the planes and the increase up to 1.24 times. In case of X-component the increase in stresses varies from 63.55% to 95.09%.

When compared with plain masonry infilled RC frame the stresses in the frame have reduced in the second principal plane and the reduction varies from 9.77% to 43.31%. It is observed that the stresses in the frame with aspect ratio 1.23 have reduced in all the planes. The stresses in the masonry have increased in all the planes. The increase in the stresses varies up to 1.61 times in the second principal stress.
Reinforced Rat-trap Bond Masonry infilled RC frames with Stilt Floor
(with horizontal reinforcement)

When compared with SGRTI the stresses in the frame have reduced for the frames
with aspect ratio 1.23 in all the planes. Marginal variation is observed in the frames with
aspect ratio 1.41 and 1.60. The masonry stresses also have increased marginally in all
the planes except in the frame with aspect ratio 1.23.

The maximum first principal stresses are located in the ground floor top left
corner, whereas the maximum masonry stresses are located in the infilled panel of the
first floor at the right corner in all components.

15.4.3 Shear Stress:

The typical contours and the variation of stresses is shown in figure 15.12, 15.13
& 15.14.

Load Case 1:

a) RC frame: The stresses in the frame vary from 0.189 to 2.69 N/mm$^2$. Higher stresses
are observed in the XY plane. In case of XY plane the stresses vary from 1.80 to 2.69
N/mm$^2$.

b) Masonry: The stresses in the XY plane vary from 0.32 to 0.365 N/mm$^2$. The stresses
reduce as the aspect ratio increases from 5.4% to 11.8%.

When compared with bare RC frame the shear stresses have increased in all the
frames and the increase in the XY plane varies from 36.56% to 95.65%.

When compared with plain masonry infilled RC frame the stresses have increased
in the X-component and the increase varies from 8.61% to 46.83%. In the XY and XZ
plane the reduction in stress is observed in case of frames with aspect ratio 1.23. The
masonry stresses also have increased but the stresses are not predominant.

When compared with SGRTI the shear stresses in the frame have increased and
the percentage increase in the YZ plane varies from 0.85% to 47.71%. The shear stresses
have reduced in the frame with aspect ratio 1.23. The masonry stresses have increased in
all the planes.

Load case 2:

a) RC frame: The shear stresses vary from 0.286 to 4.080 N/mm$^2$. The stresses have
increased when compared to load case 1.
Reinforced Rat-trap Bond Masonry infilled RC frames with Stilt Floor
(with horizontal reinforcement)

b) Masonry: The stresses in the XY plane vary from 0.488 to 0.553 N/mm². The stresses in the other two planes are almost negligible.

When compared with bare RC frame the stresses in the frame have increased in all the planes. The percentage increase in the XY plane varies from 33.18% to 96.40%.

When compared with plain masonry infilled RC frame the stresses in the frame have reduced in all the planes but the shear stress in the frame with aspect ratio 1.23 has reduced in the XY plane and XZ plane. The masonry stresses have increased. The percentage increase in the XY plane varies from 26.81% to 30.64%.

When compared with SGRTI in most of the cases the stresses in the frame have increased. The stresses in the frame with aspect ratio 1.23 have reduced in the XY plane and YZ plane. The masonry stresses also have increased in most of the frames except in the frames with aspect ratio 1.23.

Load case 3:

a) RC frame: The stresses vary from 0.871 to 12.900 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 0.019 to 1.750 N/mm². The stresses are higher in XY plane. The stresses are almost negligible in XZ and YZ planes.

When compared with bare RC frame the stresses in the frame have increased and the increase in XY plane varies from 31.13% to 91.66%. The shear stresses have increased predominantly in the frames with aspect ratio 1.60.

When compared with plain masonry infilled RC frame the stresses in the frame have increased in all the planes except in the frame with aspect ratio 1.23, where the reduction is observed. The stresses in the masonry have increased and the percentage increase in the XY plane varies from 26.81% to 30.61%.

When compared with SGRTI the stresses in the frame have increased except in the frame with aspect ratio 1.23 where the stresses have decreased. Similarly the stresses in the masonry have increased. Marginal decrease in masonry stress is observed in case of frame with aspect ratio 1.23.

The shear stresses in the XY plane are located in the ground floor at the top left corner, whereas the maximum shear stress is located in the first floor infilled panel at the right corner in all components.
Reinforced Rat-trap Bond Masonry infilled RC frames with Stilt Floor
(with horizontal reinforcement)

Fig. 15.12: Shear Stress Contours of Reinforced rat-trap Bond Masonry infilled RC frames
with stilt floor (XY-Plane)

Kobe

MX : Maximum stress;  MN = Minimum stress

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

Aspect Ratio: 1.23, Masonry with Horizontal Reinforcement

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Reinforced Rat-trap Bond Masonry infilled RC frames with Stilt Floor (with horizontal 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 Horizontal Reinforcement

Fig. 15.13: Shear Stress Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor (YZ-Plane)
Reinforced Rat-trap Bond Masonry infilled RC frames with Stilt Floor (with horizontal reinforcement)

15.5 Acceleration:

The acceleration contours are shown in fig 15.15. The variation of acceleration is shown in Fig. 15.16.

Load case 1: The accelerations vary from 0.009 to 6.799 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 has decreased in the X-component and it varies from 10.72% to 11.88%.

When compared with SEBI the acceleration is increased in the Y-component and the increase varies from 6.0% to 7.30%. The acceleration is reduced in the X-component and the reduction varies from 0.59% to 1.19%.

In comparison with SGRTI marginal variation is noticed in all the components.
Reinforced Rat-trap Bond Masonry infilled RC frames with Stilt Floor
(with horizontal reinforcement)

Zone 4

Zone 5

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

Aspect Ratio: 1.23, Masonry with Horizontal Reinforcement

Fig. 15.15: Acceleration Contours of Reinforced rat-trap Bond Masonry infilled RC frames with stilt floor

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Load Case 2: The accelerations vary from 0.014 to 10.303 m/sec². 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 has decreased in all the components and the percentage decrease varies from 11.63% to 11.89%. The decrease percentage is higher in the X-component.

When compared with SEBI, the acceleration has increased in the Y-component and it varies from 6.19% to 7.39%. Marginal reduction is observed in the X-component.

When compared with SGRTI it is observed that, minimum variation in the acceleration is observed.

Load case 3: The accelerations vary from 0.043 to 32.477 m/sec². These values are higher when compared to 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 increased in Y and Z-components whereas it has decreased in the X-component and decrease varies from 12.81% to 13.96%.

When compared with SEBI the acceleration has increase in the Y and Z-component, whereas it has marginally reduced in the X-component.

When compared with SGRTI again it is observed that, the acceleration have marginally increased in the Y-component but the difference is very much minimum.

15.6 Summary:

- Deflections in the members of the frame have shown reducing trends due to the increase in stiffness when compared with plain masonry infilled RC frames and grouted rat-trap bond masonry infilled RC frames.

- Stresses in the frame have increased marginally, with an exception in frame with aspect ratio where the stresses have reduced remarkably when compared with plain masonry infilled RC frames and grouted rat-trap masonry infilled RC frames with stilt floor. The frame members in the ground floor are highly stressed but the stresses are local.

- Stresses in the masonry infill have increased but they are found to be concentrated in the first floor panel. The stresses are markedly higher when compared to fully infilled RC frames. Exceptional behavior is observed in frames with aspect ratio 1.23, where the resistance to lateral excitation is remarkable when compared with grouted rat-trap masonry infilled RC frames with stilt floor probably because of its geometry.

- Accelerations have shown decreasing trends in the X-component whereas they are increasing in the Y-component because of increase in stiffness in comparison with grouted rat-trap masonry infilled RC frames with stilt floor.