Mechanical Analysis and Simplified Models of Concrete Block Infill Wall under Out-of-Plane Action

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Research Background

- In 1994, China Taiwan Strait magnitude 7.3 earthquake
- In 1999, China Taiwan Chi-chi magnitude 7.3 earthquake
- In 1999, Turkey Kocaeli magnitude 7.4 earthquake
- In 2004, Japan Niigata magnitude 6.8 earthquake
- In 2008, China Wenchuan magnitude 8.0 earthquake

Performance of infill wall under earthquake → out-of-plane collapse

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Research Background


Infill wall of frame building collapsed in Whenchuan, China

Damage of infill wall in Mianyang, China

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Research Development and Problems to Solve

- McDowell, theory of arching action, the reason why out-of-plane carrying capacity of infill wall greater.
- Abrams, experimentally & numerically analyzed, unreinforced masonry infill wall, out of plane.
- Tu, mechanics of out-of-plane wall, four full size monolayer structures on the shaking table.
- Robert, the effect of ratio of height to thickness and connection mode on out-of-plane capacity of infill wall.

- **Huang, out-of-plane capacity was related to constraint boundary & the ratio of height to thickness can not be too small.**
- **Li, a better measure was to connect to column, verified by static experiment.**
- **Cheng, connected to beam and column by steel bar, good out-of-plane seismic performance.**
- **Yuan, design and construction method of infill wall separated from beam and column.**

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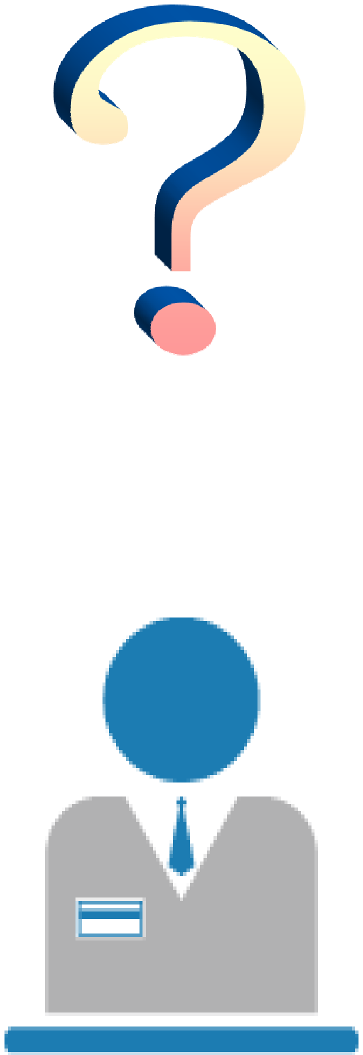

Under Out-of-Plane Action:

- **What about mechanical property of infill wall?**
- **How to calculate the capacity of infill wall?**
- **What about the simplified model of infill wall?**

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Research Content

software

ANSYS

connection type of infill wall

1. Rigidly connected to top beam
2. Connected to beam with steel bar

material

Concrete block

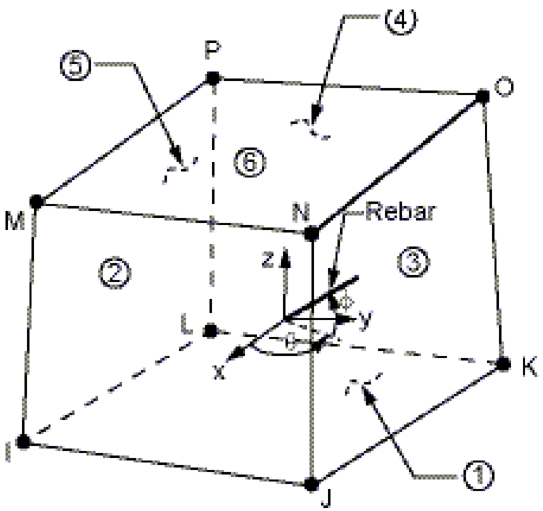
out-of-plane action

1. Uniformly distributed load
2. Horizontal displacement

ANSYS Finite Element Model

➢Choice of element type

SOLID65



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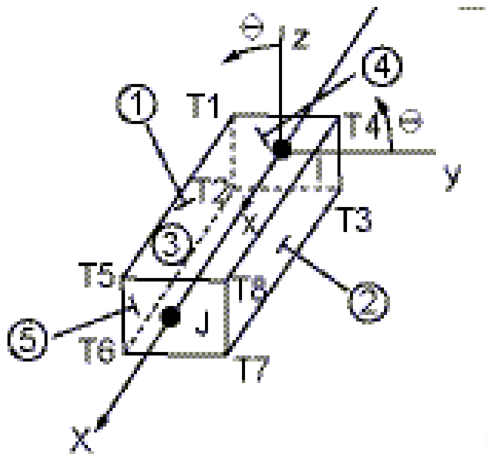
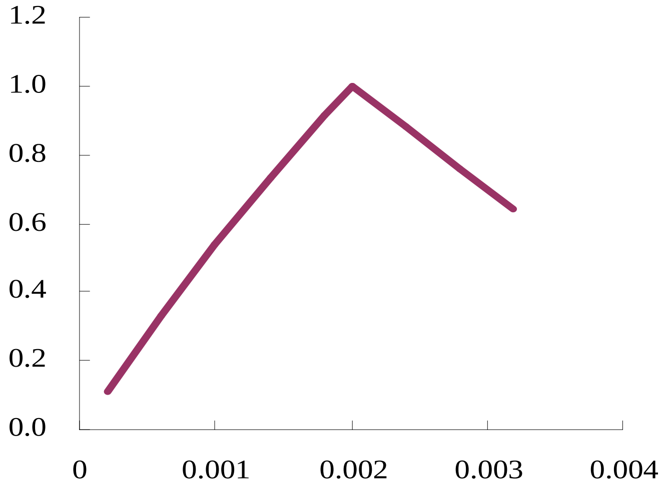


➢Material constitutive relation

concrete block

$$\frac{\sigma}{f_m} = 1.15\left(\frac{\varepsilon}{\varepsilon_0}\right) - 0.15\left(\frac{\varepsilon}{\varepsilon_0}\right), 0 \le \frac{\varepsilon}{\varepsilon_0} \le 1$$

$$\frac{\sigma}{f_m} = 1.6 - 0.6\frac{\varepsilon}{\varepsilon_0}, 1 \le \frac{\varepsilon}{\varepsilon_0} \le 4$$



steel bar

BISO for steel bar in ANSYS, its yield strength f_y =235MPa.

➢Geometric model

rigidly connected

0.4m width, 3m height, 0.3m thickness. The bottom and top were constraint.

connected to beam with steel bar

0.4m width, 3m height, 0.3m thickness. The top gap width: 30mm, two steel bars of ϕ6 whose distance was 240mm.

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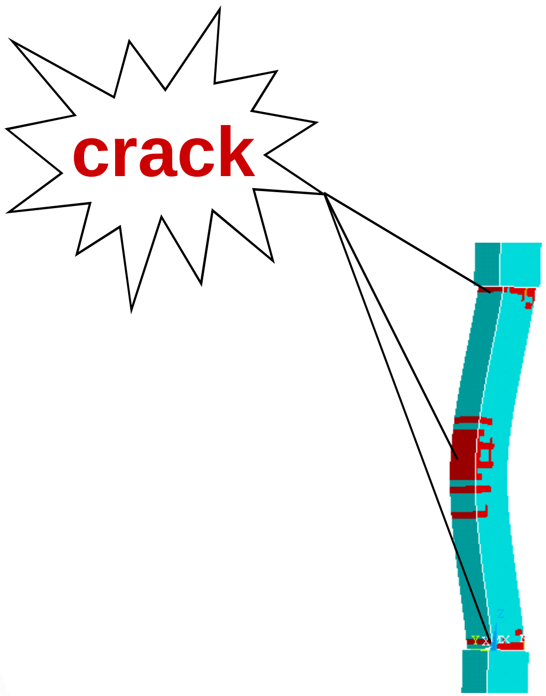
Out-of-Plane Mechanics of Infill Wall under Uniform Load

➢Rigid connection with beam



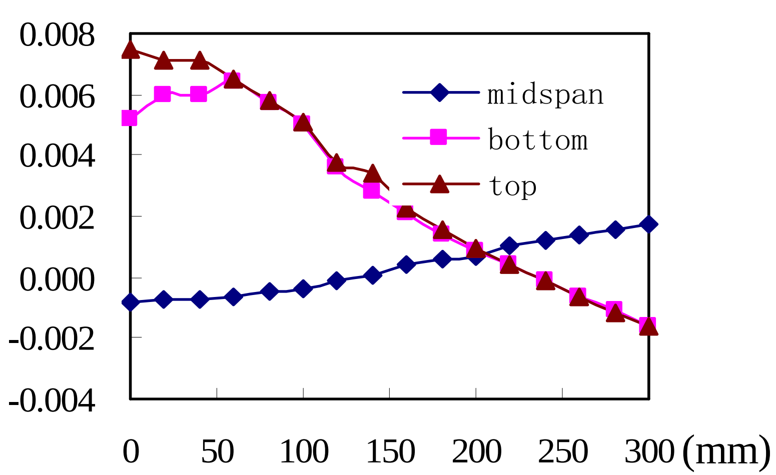
cracking

vertical stress contour

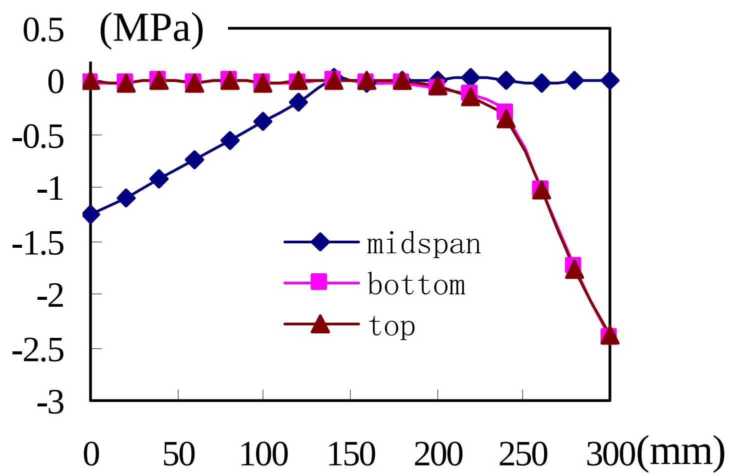
5

Out-of-Plane Mechanics of Infill Wall under Uniform Load

Rigid connection with beam



Vertical strain-thickness of wall



Vertical stress-thickness of wall

strain and stress of different section under the ultimate load

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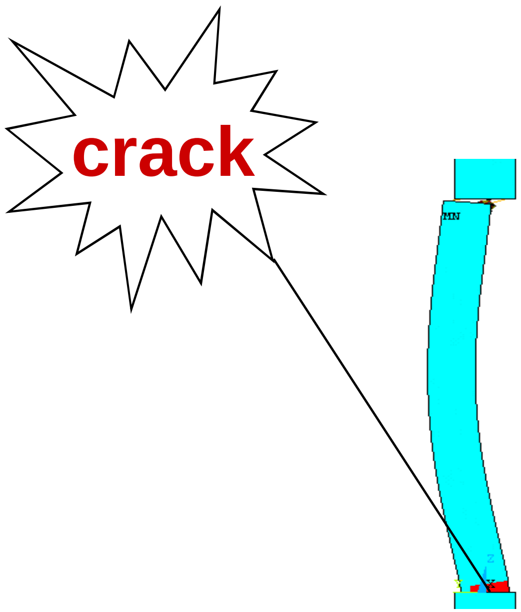
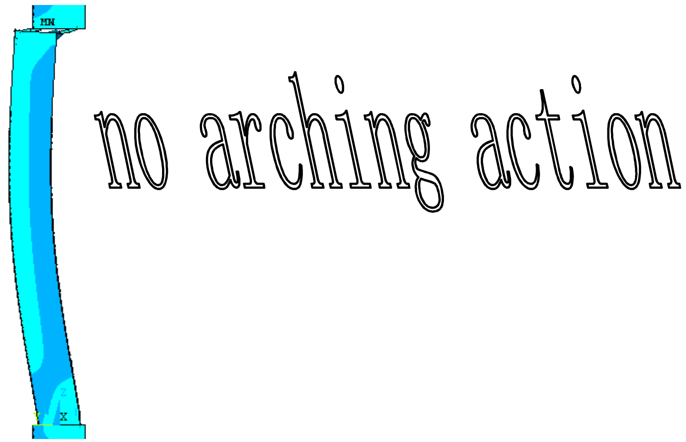
Out-of-Plane Mechanics of Infill Wall under Uniform Load

➤Connection to beam with steel bar



cracking



vertical stress contour

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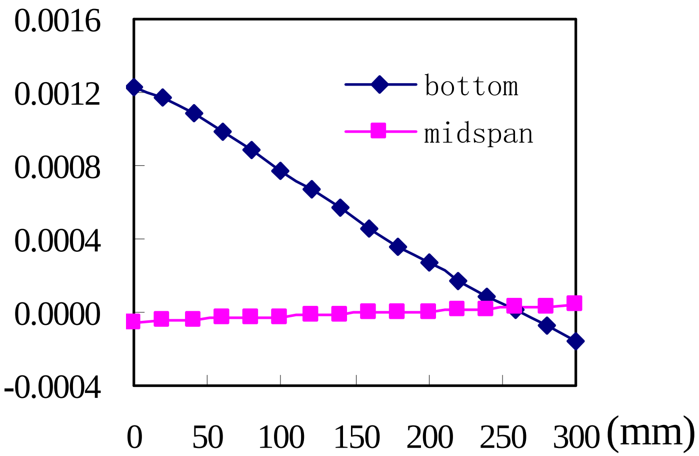
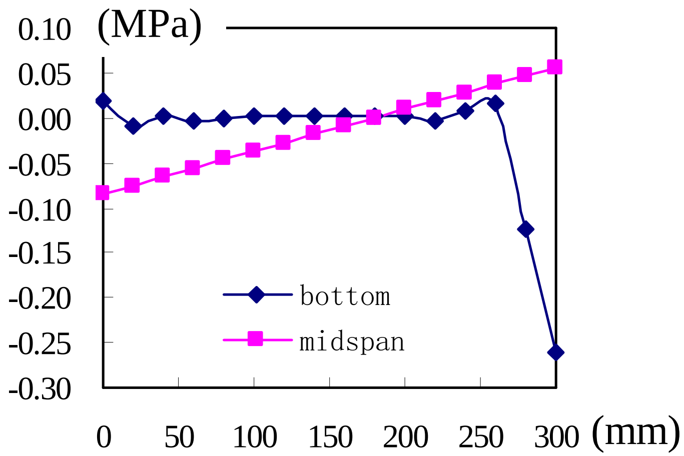
Out-of-Plane Mechanics of Infill Wall under Uniform Load

➢Connection to beam with steel bar



Vertical strain-thickness of wall



Vertical stress-thickness of wall

strain and stress of different section under the ultimate load

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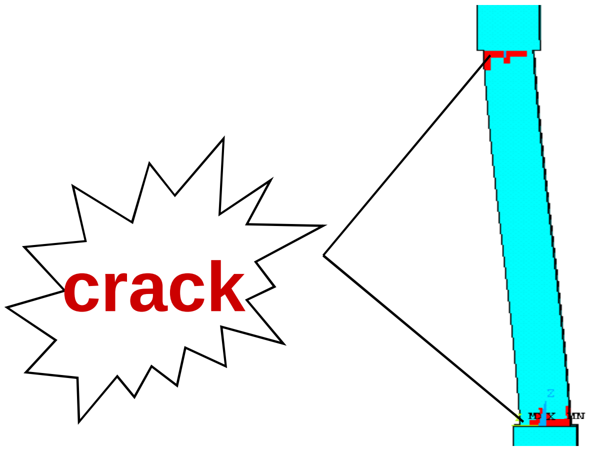
Out-of-Plane Mechanics of Infill Wall under Horizontal Displacement

➢ Rigid connection with beam

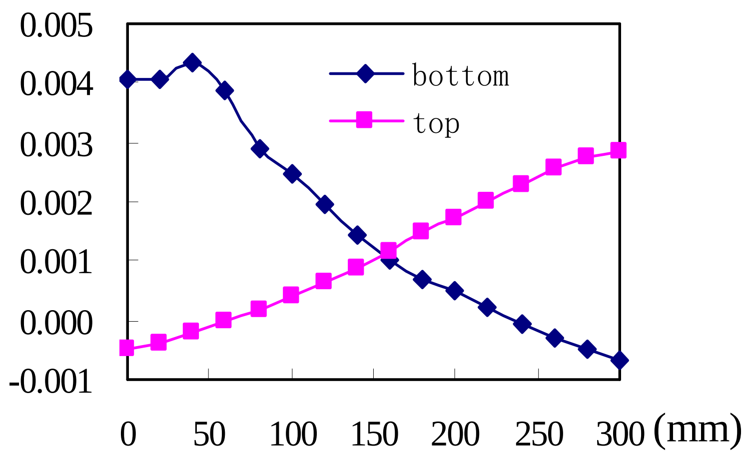


cracking

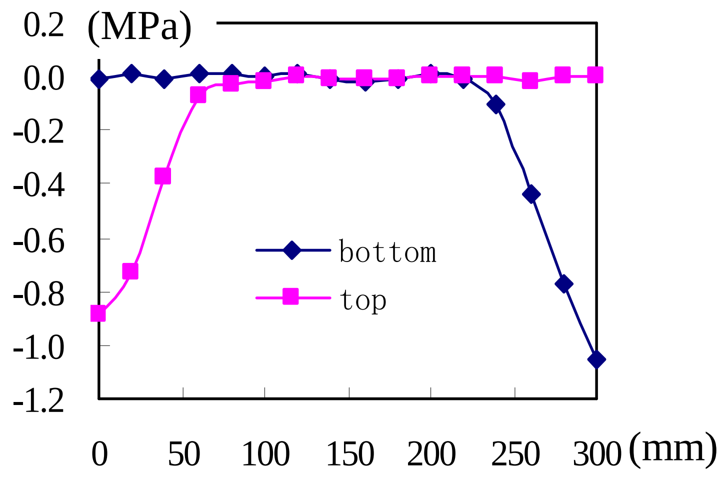
vertical stress contour

Out-of-Plane Mechanics of Infill Wall under Horizontal Displacement

➢Rigid connection with beam



Vertical strain-thickness of wall

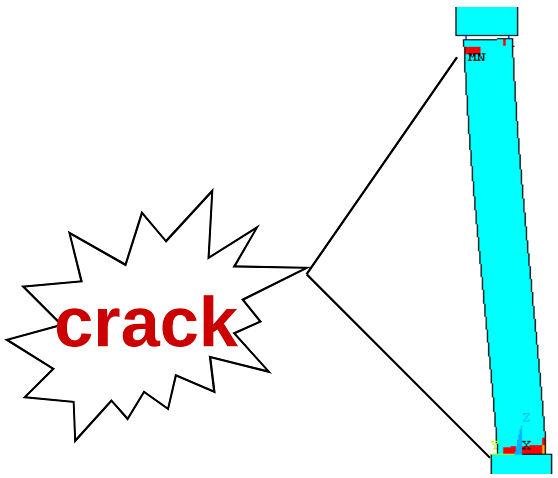


Vertical stress-thickness of wall

strain and stress of different section under the horizontal displacement

6 Out-of-Plane Mechanics of Infill Wall under Horizontal Displacement

➢ Connection to beam with steel bar

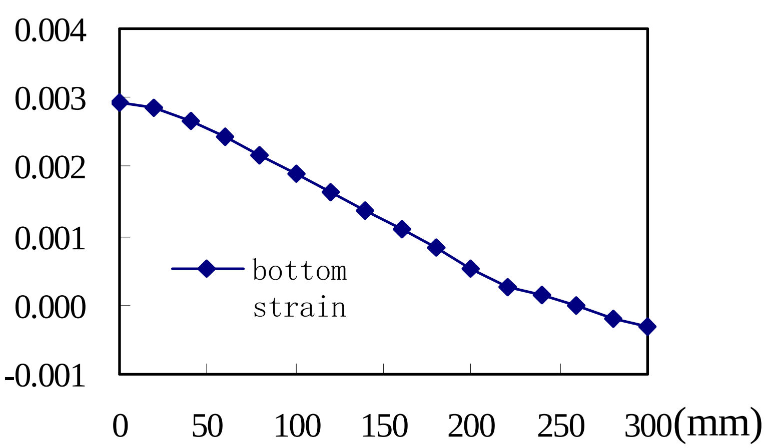


cracking

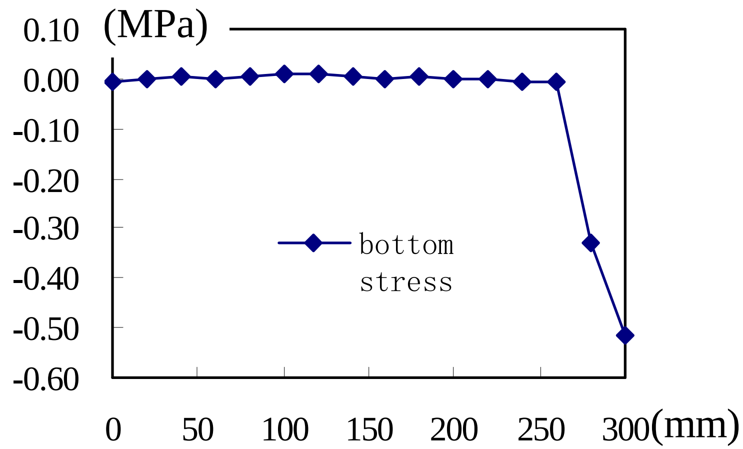
vertical stress contour

6 Out-of-Plane Mechanics of Infill Wall under Horizontal Displacement

➢Connection to beam with steel bar



Vertical strain-thickness of wall



Vertical stress-thickness of wall

strain and stress of different section under the horizontal displacement

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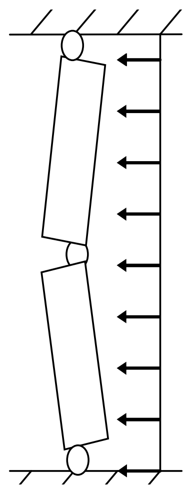
Analysis on Simplified Model of Infill Wall

➢Rigid connection with beam under uniform load

In the light of arching action in the finite element analysis results and stress distribution figure, the wall can be considered as a two link (or three hinged arch), and the compression damage of equivalent members is corresponding to the ultimate state of infill wall.



three hinged arch

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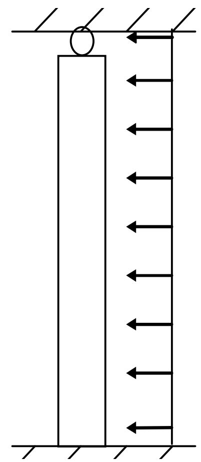
Analysis on Simplified Model of Infill Wall

➢Connection to beam with steel bar under uniform load

Because the damage belonged to brittle damage, the status prior to damage was considered to be the ultimate state, so in the premise of enhancing measure of mesh reinforcement, hinge joint on the top and rigid joint on the bottom can be considered to be the simplified model. At this moment, the status taking combination of gravity and bending into account is ultimate.



hinge joint on top and rigid joint on bottom

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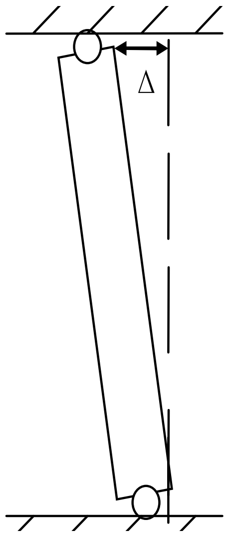
Analysis on Simplified Model of Infill Wall

➢Rigid connection with beam under horizontal displacement

In the entire process, there was no crack at the mid span, the stress distributed in inverse symmetry, that was obvious arching action. The wall can be simplified to be a link (or two hinged arch), and the equivalent's compressive damage is corresponding to the ultimate state of carrying capacity.



two hinged arch

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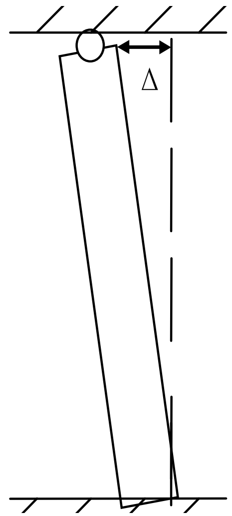
Analysis on Simplified Model of Infill Wall

Connection to beam with steel under horizontal displacemen

The ultimate state was when the plastic hinge formed on the bottom because there was no arching action. In the premise of enhancing measure of mesh reinforcement, **hinge joint on the top and rigid joint on the bottom** can be considered to be the **simplified model**. At this moment, the status taking combination of gravity and bending into account becomes the **ultimate state**.



hinge joint on top and rigid joint on bottom

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Conclusion

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Analysis demonstrates, under the uniform load and horizontal displacement out of plane, there is arching action for the infill wall rigidly connected with top beam, the wall show good carrying capacity in the late period, the arching action influence on the infill wall should be taken into account when choose the simplified model.

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Conclusion

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Different simplified models are for different load and different connection modes. Under uniform load, rigidly connected wall was simplified with three hinged arch, flexibly connected wall can be simplified with hinge joint on the top and rigid joint on the bottom; under the horizontal displacement, rigidly connected wall was simplified with two hinged arch, flexibly connected one can be simplified with hinge joint on the top and rigid joint on the bottom.

Thank you

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