*The 2016 World Congress on*
***The 2016 Structures Congress (Structures16)***
*Jeju Island, Korea, August 28-September 1, 2016*

# Prefabricated cast-in-place shear wall level node stress finite element analysis

*Chunyi Xu[1)], Yuanqing Wang[2)], Yingying Ma[3)] and Jiabao Ma[4)]

[1), 3), 4)]*Department of Civil Engineering, Shenyang Jianzhu University, Shenyang,110168*
[2)] *Department of Civil Engineering, Tsinghua University,Beijing, 100084*

## ABSTRACT

This paper focuses on the regular pattern of level of cast-in-place node connection assembled concrete shear wall stress,bearing capacity, and deformation properties.By using ABAQUS finite element analysis software through displacement control mode,we try to get the stress performance analysis by loading on 14 different axial compression ratio, reinforcement ratio of concrete shear wall and stirrup ratio of monotone horizontal loading. In the common role of horizontal displacement and vertical load, the maximum stress peak value appears on the left edge in the beam and wall limb junction.Shear walls yield before wall, which is good for to the formation of the beam hinge mechanism.It can make the shear wall has the large capacity of ductility and energy dissipation before it yields to wall;two pieces of wall cast-in-place without obvious stress concentration phenomenon,junction structure cracks occurred mainly between the shear walls and coupling beams,which is the position the maximum tensile stress occurs.The cast-in-place belt between the prefabricated wall are without first cracks.Bearing performance of Cast-in-place joints is good, to make the shear wall has good bearing ability and deformation ability.

## 0 SUMMARY

The assembly structure is a kind of structural system that prefabricating the components in the factory,then transport them to the scene and conduct the assembly. It has the ability to reduce the amount of wet operation, shorten the construction period, low labor intensity, high production efficiency, protect the environment, reduce cost and other advantages which meet the requirements of China's construction industry because that its production process is completed in the factory[1-4].Horizontal cast-in-place nodes reserve post-cast joints at the connection point of the transverse

---

[1)] Doctor
[2)] Professor
[3)] Graduate Student
[4)] Graduate Student

precast shear wall and deploy transverse reinforcement at the connection point of the transverse precast shear wall that anchored mutually at post-cast joints.The number, spacing and diameter of reinforcement are as same as the original section precast shear wall reinforcement .And binding stirrups to form a connection node after cast in place. The utility model has the advantages of safety,reliability, convenient operation, low cost and low effect of environment. A great number of experimental researches on precast concrete shear wall have been done in foreign countries[5] and the relevant design codes,calculation rules and construction procedures have been put forward.How ever,there are few researches on the connection of the concrete shear wall with the level of the cast in place joints in domestic.In China, Jiaru Qian [6-7], Zhangfeng Zhu [8] had done experimental researches on the level of the cast node connection,but the Finite Element Analysis is oppositely less.In this paper, the finite element method is used to simulate the stress analysis of the concrete wall with 14 horizontal joints. The development law of the stress, bearing capacity and deformation property of the research is studied in order to provide a basis for further research on the mechanical behavior of precast concrete shear wall with horizontal joints.

## 1 THE ESTABLISHMENT AND VERIFICATION OF FINITE ELEMENT MODEL

### 1.1 finite element model

In order to verify the rationality of the finite element model, the model can be divided into two parts, which are cast in place and prefabricated. Considering the calculation speed, the mesh size of concrete, steel bar and sleeve are 200mm, 200mm and 100mm, respectively, and the sleeve length is 400mm. The structure form of the connection of the post cast in the middle of the two precast shear wall is selected to conduct the finite element model.Precast shear wall connection in practical engineering application of the post cast width to take 70mm and the strength of concrete is the same as the precast wall panels.Insert longitudinal reinforcement after the wall lateral anchor ring go deep into cast-in-place strip,and then bind stirrup in construction structure. Take measures of reinforced steel bar at the zone of cast-in-place.Binding bound together with tie binding between the precast wall and the ground beam as well as between the wall and the strip cast-in-place to ensure that the two part will not be separated during the analysis and to guarantee that the bottom of the wall constraint three translational degrees of freedom [1].

### 1.2 The selection of material constitutive behavior

The constitutive relation of concrete chose uniaxial stress-strain relationship curve in the literature [9]. Constitutive relation of steel bar select bilinear elastic-hardening model and the stress-strain curve of the strengthened section is simplified to be a straight line in order to ensure the convergence of computing structure.In the meanwhile, the elastic modulus of elastic segment is 2.06×105MPa.The elastic modulus of the strengthened section is 2.06×103MPa, and the Poisson's ratio is 0.3.

### 1.3 Determination of boundary conditions

Ignoring the slip effect between steel bars and concrete, the reinforcement is embedded in the concrete units through the region Embedded technology provided by

ABAQUS. The embedded node degrees of freedom are determined by the concrete unit embedded in reinforced unit and sleeve unit instead of being independent, which means that the translational degrees of freedom of the embedded steel sleeve unit node are consistent with the nodes of concrete unit.In order to avoid that the the calculation result do not convergent because of local stress concentration happening in some elements near the horizontal loading point ,an independent additional node (RP-1) is established at the end of the end.For the realization of the rigid surface loading,all the nodes of the additional node and the loading surface are connected by Coupling ,thus realizing constraints of three translational degrees of freedom of the bottom surface of the beam .

1.4 Determination of loading mode

The shear wall is divided into two analysis steps to load,displacement control mode is used to load the horizontal monotonic load in horizontal direction Displacement control is 50mm while the vertical direction adopt equivalent uniform loading and the axial force is 1000KN.

1.5 Verification of finite element model

To compare the load displacement curve obtained in the literature [10] with finite element analysis and the loading-displacement curves of both are almost coincident (see Figure 1). The ultimate bearing capacity of the shear wall in the finite element analysis and experiment are 373KN and 346KN respectively. relative to the experimental results，the error of finite element analysis is 7.8%,which shows that the finite element analysis results are very close to the test results.So the extended parameters of the finite element model is used to carry out the finite element analysis of 14 shear walls.

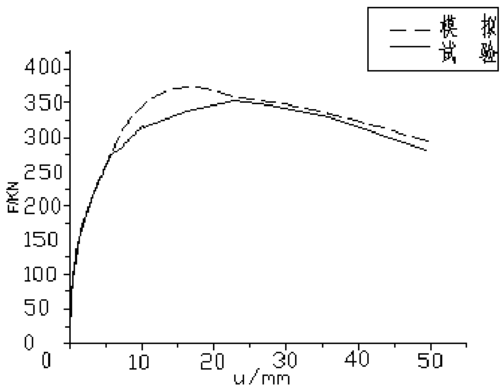


Fig.1 Comparison of capacity-displacement curves between the finite element analysis and the experiment

**2.The finite element analysis results of the horizontal cast-in-place nodes of concrete shear wall**

Based on the finite element model established by the author was carried out on 14 concrete shear walls connected with the horizontal of the cast-in-place nodes which have different axial compression ratio, reinforcement ratio and hoop ratio.The section size and reinforcement are shown in Figure 2 and the main parameters and groups are shown in Table 1.

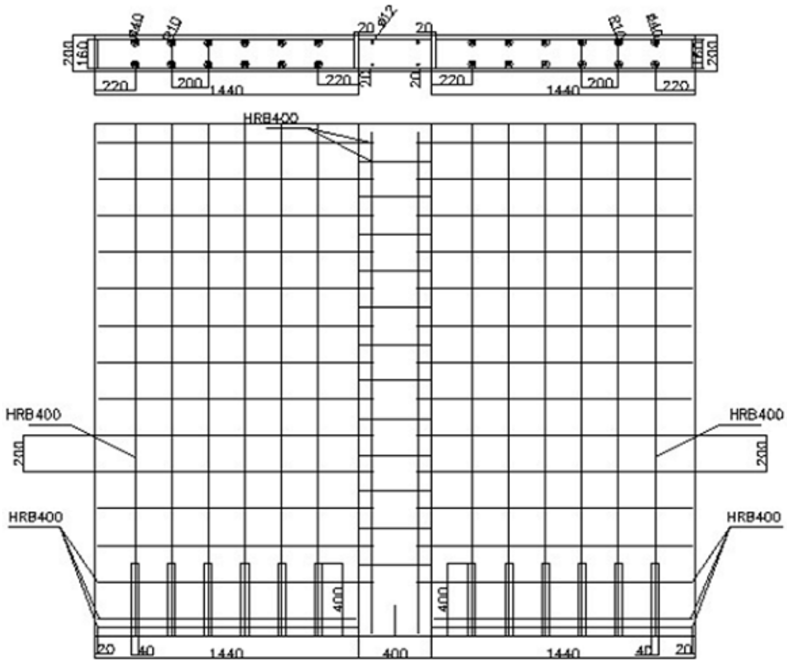


Fig.2 Precast shear wall and cast-in-place node dimension reinforcement graph

Table 1 main parameters and grouping of shear wall

| Shear wall number | axial compression ratio | Reinforcement ratio (/%) | Stirrup ratio (/%) |
|---|---|---|---|
| 1 | 0.12 | 0.39 | 0.31 |
| 2 | 0.24 | 0.39 | 0.31 |
| 3 | 0.36 | 0.39 | 0.31 |
| 4 | 0.48 | 0.39 | 0.31 |
| 5 | 0.12 | 0.39 | 0.41 |
| 6 | 0.24 | 0.39 | 0.41 |
| 7 | 0.36 | 0.39 | 0.41 |
| 8 | 0.48 | 0.39 | 0.41 |
| 9 | 0.12 | 0.39 | 0.48 |
| 10 | 0.24 | 0.39 | 0.48 |
| 11 | 0.36 | 0.39 | 0.48 |
| 12 | 0.48 | 0.39 | 0.48 |
| 13 | 0.12 | 0.57 | 0.48 |
| 14 | 0.12 | 0.77 | 0.48 |

2.1 stress analysis

In this paper, the finite element analysis is carried out for each number of shear walls. Figure 3 is the concrete stress-clouds-figure in typical shear wall named number 9 from which we can see that the maximum stress peak appeared at the left edge of the junction between the shear wall and wall limb. Figure 4 is the steel bars stress-clouds-figure in typical shear wall named number 9 from which we can see that the boundary longitudinal reinforcements at the same side of the horizontal loading point yield firstly. And then,with the increase of the loading force, the yield region is gradually enlarged. The coupling beam of shear wall yield before the wall limb which is conducive to the formation of beam hinge mechanism. So that the shear wall has a greater ductility and energy dissipation capacity. There is no obvious stress concentration phenomenon in the cast-in-place zone between two walls, which shows that the cast in place node has better bearing capacity and is suitable for application in practical engineering.

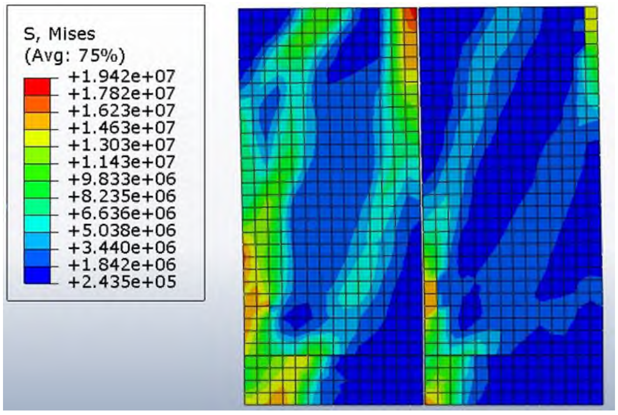


Fig.3 The stress cloud pattern of concrete in the shear wall 9

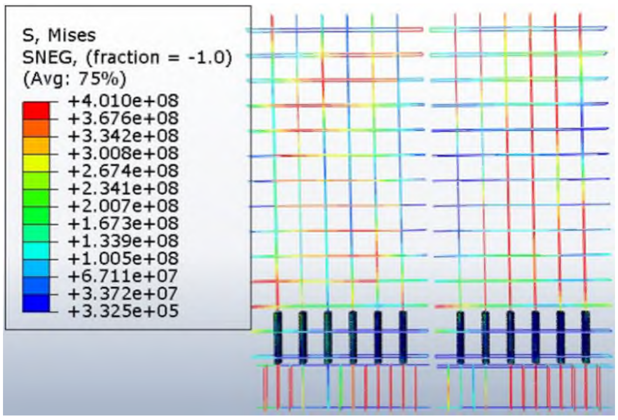


Fig.4 The stress cloud pattern of the steel bar in the shear wall 9

2.2 crack analysis

Structural cracks occurred mainly at the junction of shear wall and coupling beam under the combined action of horizontal and vertical load,which indicate that it is the very position of maximum tensile stress.Mechanical behaviors of shear wall under vertical load are basically consistent with the principal stress cloud image.And there is no cracks between the cast-in-site band and the precast wall.

2.3 bearing capacity analysis

2.3.1 Influence of reinforcement ratio on mechanical behavior

Fig 5 shows the load-displacement curves of shear walls 14, 13, and 9 with different reinforcement ratios and we analyze how the reinforced ratio of post cast strip of precast shear wall affect the bearing capacity of precast shear wall.Under the reinforcement ratio of 0.39%, 0.57%, 0.77%,reinforcement ratio of post cast strip influence the bearing capacity of shear wall so tiny that the impact is much smaller than the effect of shear wall reinforcement ratio on the bearing capacity of the wall.Therefore,we can place steel bar according to the structural requirements .

Table 2 The ultimate bearing capacity and the maximum displacement of the shear wall under the influence of the reinforcement ratio

| Reinforcement ratio | Ultimate bearing capacity (KN) | maximum displacement (mm) |
|---|---|---|
| 0.39% | 1585 | 5.57 |
| 0.57% | 1583.6 | 5.67 |
| 0.77% | 1582.58 | 5.31 |

2.3.2Effect of the stirrup ratio on the mechanical behaviors

Shear wall 1, 5, 9 have different stirrup ratio.Fig 6 shows load-displacement curve of precast shear wall when the post-pouring belt under different stirrup ratio.Stirrup ratio are 0.31%，0.41%，0.48% and it can be seen that there is very tiny alternation along with the changes of stirrup ratio for shear wall with the same reinforcement ratio of the post cast strip.And increasing the stirrup ratio of the post cast band has little effect on improving the bearing capacity of the shear wall, thus we can place steel bar according to the structural requirements.

Table3The load-displacement curve of the shear wall  under the stirrup ratio's influence

| Reinforcement ratio | Ultimate bearing capacity (KN) | maximum displacement (mm) |
|---|---|---|

| | | |
|---|---|---|
| 0.31% | 1583.8 | 5.79 |
| 0.41% | 1583.9 | 5.67 |
| 0.48% | 1585 | 5.57 |

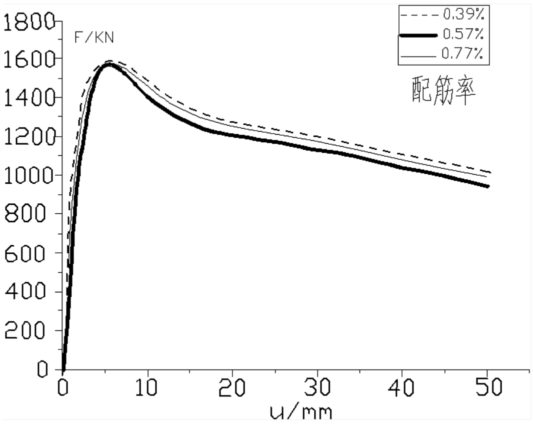


Fig.5 Influence of reinforcement ratio on load-displacement curve

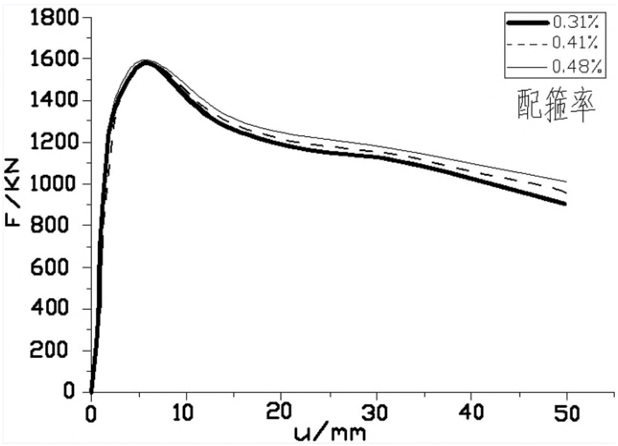


Fig. 6 Effect of reinforcement ratio on load displacement curve

2.3.3Effect of axial compression ratio on the mechanical properties

The load-displacement curve of the cast-in-place node of transverse shear walls with different axial compression ratio is shown in fig 7 . At the time of initial loading , we can see that all zones of load-displacement curve of the cast-in-place node coincide,indicating that axial compression ratio has less influence on this stage . But the load-displacement curve of all the cast-in-place node is gradually separated with increase of the load. And there's a greater bearing-capacity for the cast-in-place nodes with larger axial compression ratio of transverse shear wall .

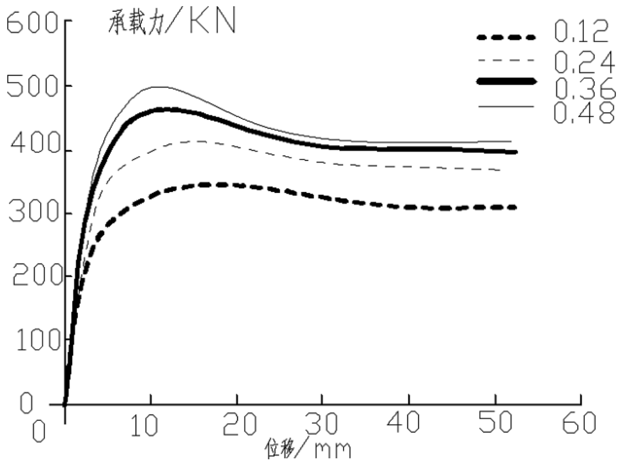


Fig. 7 load displacement curve

## 3 CONCLUSIONS

Under the action of horizontal-displacement loading and vertical load loading,the maximum stress appeared at the junction of wall and bottom-beam and the first crack showed up. At the same time, there is no phenomenon of stress concentration in the cast in place joint, which can make the part of the transverse shear wall carry load together. Therefore, the cast in place node has good bearing performance and is suitable for practical engineering .

When the reinforcement ratio of post-cast strip and prefabricated post cast strip various is different,increasing reinforcement ratio has little impact on bearing-capacity and the deformation of the shear wall.So we can place steel bars at the cast-in-place node according to structure.

In a certain range,the bearing capacity of the joint increases with the increase of the axial compression ratio. After reaching the ultimate bearing capacity,all bearing capacity-displacement curves have different degrees of decline.And along with the increase of the axial compression ratio, the bearing capacity decreases gradually.It is not feasible to increase the ultimate bearing capacity of the joints only by increasing the axial compression ratio.

## REFERENCES

[1] Yuanqing Wang, and Jiabao Ma,et al." Finite element analysis of concrete shear wall with sleeve connection[J]". Journal of Shenyang Jianzhu University,2014,(4):577-584.(in Chinese)

[2] Yuxing Huang,zhu Lei,et al. Summary of precast concrete structural connection[J]. Concrete,2013(1):120-126.(in Chinese)

[3] Blandon J J,and Roeriguez M E.Behavior of connections and floor diaphragms in seismic-resisting precast concrete buildings[J].
PCI Journal,2005,50(2):56-75.

[4] Jianwei Chen,Youpo Su. Prefabricated concrete shear wall structure and its connectingtechnology[J]. World Earthquake,Engineering,2013,29(1):38-48.(in Chinese)

[5] Smith B J,Kumam Y C, Mcginnis M J. Design and measured behavior of a hybrid precast concrete wall specimen for seismic regions[J].Journal of Structural Engineering,2010,137(10):1052-1062.

[6] Jiaru Qian,Xinke Yang,Heng Qian,et al. Test on seismic behavior of precast shear walls with various methods of vertical reinforcement splicing[J]. Journal of Building Structures,2011,32(6):51-59.(in Chinese)

[7]Jiaru Qian,Jingmng Zhang,et al.Tests on seismic behavior of precast shear walls with vertical reinforcements spliced by grout sleeves[J].Building Structure2011，41(2):1-6.(in Chinese)

[8] Zhangfeng Zhu,Zhengxing Guo. Seismic test and analysis of joints of new precast concrete shear wall structures[J].China Civil Engineering Journal,2012,45(1):69-76.(in Chinese)

[9] The Ministry of Construction of the People’s Republic of China.GB 50010-2010 Code for design of concrete structures[S].Beijing:China Architecture & Building Press，2010.(in Chinese)

[10] Yuanyuan Peng . Experimental study on seismic behavior of precast reinforced concrete shear walls[D].Beijing: Tsinghua University,2010.(in Chinese))