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Study on the Force Behavior of Parallel Double Precast Coupling Beams with Different Width

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Abstract: Coupling beam is the first line of seismic defense. In order to study on seismic performance of coupling beams between cast-in-situ and prefabricated frame shear wall**,** based on finite element ABAQUS software analysis, the load-bearing process of 11prefabricated coupling beam and 11 cast-in-situ coupling beams under low-cycle repeated load are simulated. The bearing capacity and seismic performance of two types are analyzed from the skeleton curves and ductility coefficient. The simulation results were compared with two types, which results show: two types of coupling beam have good ductility, but the cast-in-situ is better than the prefabricated.

1．Introduction

In reinforced concrete frame-shear wall structure (FSW), coupling beam is the first line of seismic defense and plays a role in connecting wall limbs and transferring loads. Under earthquake action, the plastic hinge is formed on the ends of the beam, which uses the plastic hinge to dissipated the energy of the earthquake[1-3].With coupling beam in FSW, as shown in Fig1, shear coupling beam(SCB) and the corresponding frame beam up to it, briefly called frame coupling beam(FCB),has a stage of cooperative working under horizontal load[4-6].So, the parallel double coupling beams with different width composed of SCB and FCB, briefly called double beams(DB),is taken as a research object. Meanwhile, a new type of assembly method is proposed of coupling beam in FSW. Based on assembly method, the seismic performance of prefabricated is analyzed. In accordance with standards cast-in-situ coupling beam is designed.
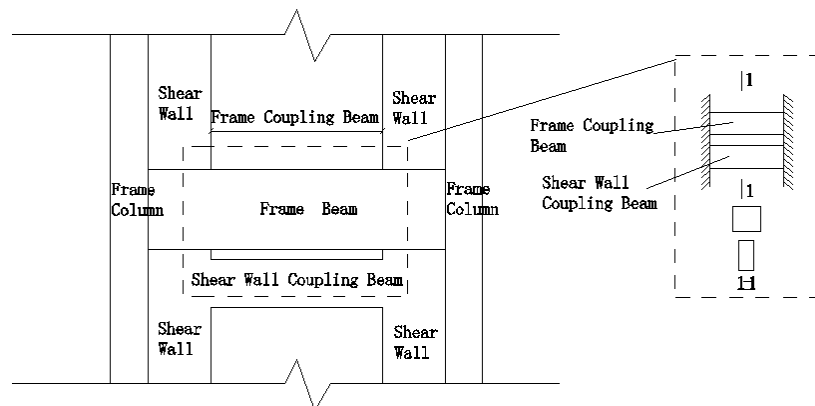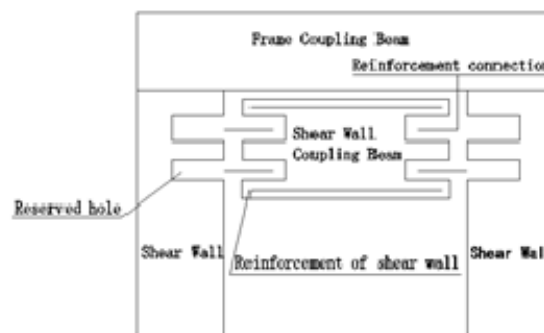
Fig 1. Frame-shear wall structure layout

Fig 2. The assemble model of prefabricated

2. Assembly method of prefabricated coupling beam

At the end of prefabricated coupling beam, the connection position of the wall is divided. Prefabricated coupling beam and two pieces of prefabricated wall are fabricated, respectively. Prefabricated coupling beam and two pieces of prefabricated wall in the reserved hole. The spiral stirrups were set in the hole, and inside the hole equivalent reinforcement is installed. The micro expansion mortar is inserted into the reserved prefabricated coupling beam and two pieces of prefabricated wall with holes. The mortar makes equivalent reinforcing bars and two precast parts together. The assemble model of prefabricated is shown as Fig.2.
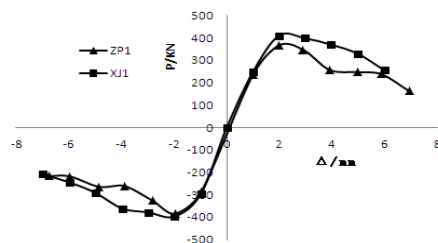
3. The specimen design and analysis

Based on frame beam span ratio、coupling beam span ratio、frame beam thickness etc, the author designed 11cast-in-situ double beams and prefabricated double beams, specimen named ZP and XJ. The detailed parameters of specimens are shown table1. This article simulated the Loading Process by using nonlinear finite element software ABAQUS.In order to analyze the differences of skeleton curves between prefabricated and cast-in-situ double beams, comparing the skeleton curve obtained, the comparison is shown in figure 3.
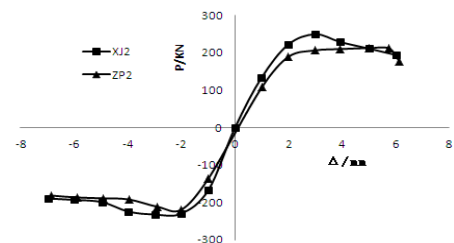
Table1. The list of the specimens

nu m be r	Frame coupling beam				Shear coupling beam					
	span（mm）	height（mm）	thickness（mm）	Span ratio	span（mm）	height（mm）	thickness（mm）	Span ratio	fc (MPa)	Area ratio

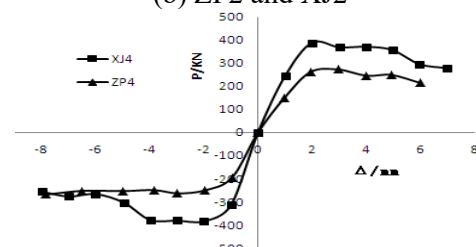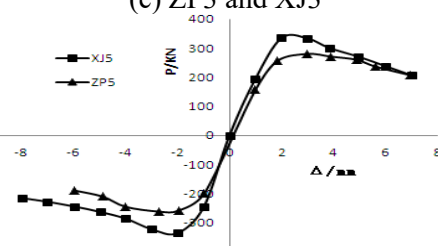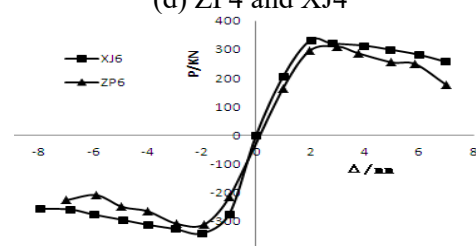| 1	1200	800	300	1.5	1200	400	200	3	14.3	2
2	1200	480	300	2.5	1200	400	200	3	14.3	2
3	1200	600	300	2	1200	400	200	3	14.3	2
4	1200	600	300	2	1200	800	200	1.5	14.3	2
5	1200	600	300	2	1200	550	200	2.2	14.3	2
6	1200	600	400	2	1200	400	200	3	14.3	2
7	1200	600	250	2	1200	400	200	3	14.3	2
8	1200	480	300	2.5	1200	400	200	3	11.9	2
9	1200	480	300	2.5	1200	400	200	3	16.7	2
10	1200	480	300	2.5	1200	400	200	3	14.3	2.5
11	1200	480	300	2.5	1200	400	200	3	14.3	1.5

(a) ZP1and XJ1

(b) ZP2 and XJ2

(c) ZP3 and XJ3

(d) ZP4 and XJ4

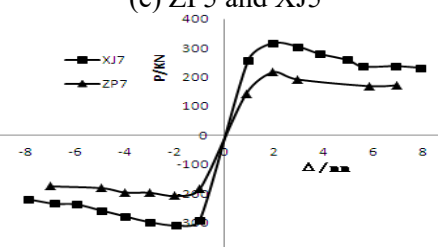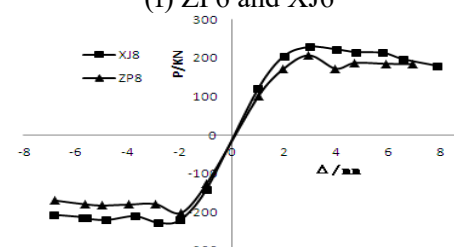(e) ZP5 and XJ5

(f) ZP6 and XJ6

(g) ZP7 and XJ7

(h) ZP8 and XJ8

(i) ZP9 and XJ9

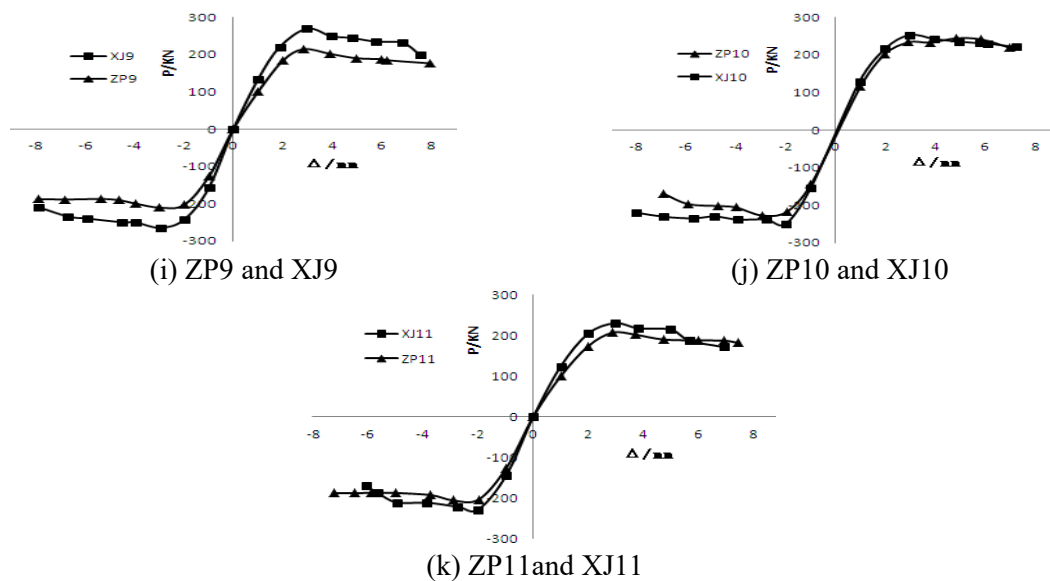(j) ZP10 and XJ10

(k) ZP11and XJ11

Fig 3. Comparation between the skeleton curves of cast-in-place and precast

As can be seen from Fig.3 (a) skeleton curve, both ZP1 and XJ1 were in the elastic stage before yielding, and the load-displacement curve changed linearly. As the displacement increases, the load-displacement gradually becomes nonlinear. XJ1 skeleton curve is always at the outer side of ZP1 skeleton curve, indicating that XJ1 is larger than ZP1 carrying capacity in this case, and their peak load differs by 12%. As can be seen from Fig.3 (b) skeleton curve, the stress of ZP2 is basically consistent with that of XJ2. It is indicated that the size of specimen has little influence on the bearing capacity of cast-in-place double beam and precast double beam. However, the hysteretic curve area of XJ2 is greater than that of ZP1, indicating that XJ2 has superior seismic performance and energy dissipation performance. As can be seen from Fig.3 (c) skeleton curve, the peak load of XJ3 (325.711KN)is 25% higher than that of ZP3 (259.907KN). As can be seen from Fig.3 (d) skeleton curve, the peak load of XJ4 (387.627KN)is 47% higher than that of ZP4 (261.11KN). As can be seen from Fig.3 (e) skeleton curve, the peak load of XJ4 (334.454KN)is 23% higher than that of ZP4 (271.366KN). As can be seen from Fig.3 (f) skeleton curve, the stress of ZP6 and XJ6 is basically the same at the elastic stage. It is indicated that the size of specimen has little influence on the bearing capacity of cast-in-place double beam and precast double beam. After the peak load, the ZP6 capacity decreases faster than the XJ6. As can be seen from Fig.3 (g) skeleton curve, the peak load of XJ7 (317.005KN)is 46% higher than that of ZP7 (216.799KN). As can be seen from Fig.3 (h) skeleton curve, the peak load of XJ4 (229.5KN)is 9.6% higher than that of ZP4 (207.405KN). As can be seen from Fig.3 (i) skeleton curve, the peak load of XJ9 (270KN)is 21% higher than that of ZP4 (214.945KN). As can be seen from the skeleton curve in Fig.3 (j), the elastic phases of XJ10 and ZP10 are in linear change, and the load-displacement curve becomes a straight line. As can be seen from the skeleton curve of Fig (k), the trend of XJ11 and ZP11 are basically the same in each stage, but the XJ11 bearing capacity is larger than that of ZP11.

From the above comparison, it can be seen that the peak load of the precast double coupling beam is lower than that of the cast-in-place double coupling beam, and this peak load is affected differently by the parameters of the coupling beam in the frame and the wall. Among these factors, the most obvious influence is the span height ratio of frame coupling beam, the span height ratio of shear coupling beam, the thickness of frame coupling beam and the concrete strength, the less affected by steel area ratio. However, the ductility coefficient increases with the increase of steel area ratio. Therefore, the above factors should be taken into account comprehensively in the design precast of double coupling beams.

4. Ductility analysis of double coupling beam
The seismic performance of a component or structure depends not only on the bearing capacity of the structure, but also on the ductility of the structure. Ductility is an important characteristic in seismic

performance of structures. In order to analyze the ductility of parallel double coupling beams with different width between precast coupling beam and cast-in-place coupling beam. The yield displacement, limit displacement and ductility coefficients of all specimens are calculated, and the calculated results are compared in table 2. It can be seen from the table that the yield displacement of the precast double coupling beam is between 1.8 and 2.4, and the maximum difference is 14.2% and the minimum difference is 4.3% when comparing with the cast-in-situ double coupling beam; the limit displacement of the precast double coupling beam is between 3.8 and 6, the maximum difference is 27.1% and the minimum difference is 1.63% when comparing with the cast-in-situ double coupling beam; the ductility coefficient of the precast double coupling beam is between 1.79 and 2.7, the maximum difference is 29% and the minimum difference is 2.2% compared with the cast-in-place double coupling beam. It is shown that the ductility of the precast double coupling beam is lower than that of the cast-in-place double coupling beam.

Table 2. Ductility coefficient of specimens

number	Yield displacement	differ	Limit displacement	differ	Ductility coefficient	differ
ZP1/XJ1	2/1.8	11%	4.5/4.3	4.6%	2.25/2.38	2.2%
ZP2/XJ2	2.4/2.2	9%	5.3/5.5	3.6%	2.2/2.5	12%
ZP3/XJ3	1.8/2	10%	3.8/4.9	22.4%	2.1/2.45	14.2%
ZP4/XJ4	1.8/1.7	5.8%	4.2/4.8	12.5%	2.3/2.82	18.4%
ZP5/XJ5	1.9/1.8	5.5%	4.4/3.9	12.8%	2.3/2.2	4.5%
ZP6/XJ6	2/1.9	5.2%	4.3/5.9	27.1%	2.2/3.1	29%
ZP7/XJ7	2/1.8	11%	4.1/3.9	5.1%	2/2.2	9%
ZP8/XJ8	2.4/2.1	14.2%	4.3/5.4	20.3%	1.79/2.52	28.9%
ZP9/XJ9	2.4/2.3	4.3%	5.9/5.7	3.5%	2.45/2.47	8%
ZP10/XJ10	2.2/2.1	4.7%	6/6.1	1.63%	2.7/2.9	6.8%
ZP11/XJ11	2.4/2.1	14.2%	5.2/5.3	1.8%	2.2/2.52	12.6%

5. Conclusion

In this paper, the joint positions of the two ends of the coupling beam and the shear wall are split, and the simulation of double coupling beam in the form of area is equal to the reinforcement is carried out. This article simulated the Loading Process by using nonlinear finite element software ABAQUS. The corresponding skeleton curve and ductility index of the precast double coupling beam are calculated quantitatively. At the same time, some parameters on the skeleton curve are emphatically analyzed. Finally, the comparison between the above results and the cast-in-place double coupling beam can be seen:

（1）In this paper, the skeleton curve of the precast double coupling beams with different sizes are lower than the cast-in-situ double coupling beam. Its displacement ductility coefficient is between 1.79 and 2.7, and compared with cast-in-place double coupling beam, the maximum difference is 29%, and the minimum difference is 2.2%;

（2）By comparing the skeleton curve of the precast double coupling beam and the cast-in-place double coupling beam, the peak load of the precast double coupling beam is lower than that of the cast-in-place double coupling beam, and this peak load is affected differently by the parameters of the coupling beam in the frame and the wall. Among these factors, the most obvious influence is the span height ratio of frame coupling beam, the span height ratio of shear coupling beam, the thickness of frame coupling beam and the concrete strength, the less affected by steel area ratio. However, the ductility coefficient increases with the increase of steel area ratio. Therefore, the above factors should be taken into account comprehensively in the design and precast of double coupling beams.

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