EXPERIMENTAL RESEARCH ON THE SEISMIC BEHAVIOR OF FRAME COLUMN WITH CONSTRUCTION JOINTS

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ABSTRACT :

In order to investigate the effect of construction joints on the seismic behavior of building structures, an experiment for column members with construction joints under low cyclic loading is done. The characteristics of ductility, strength, hysteretic curves, and strains in steel reinforcements of columns are compared with monolithic columns. Experimental results show that the bearing capacity drops 3％～7％, and the maximum decrease of displacement ductility is more than 30％. The slip of steel bars and rheostriction of hysteretic curves is heaver than monolithic concrete columns.

KEYWORDS: construction joints, seismic behavior, frame column

1. INTRODUCTION

Construction joints are stopping places in the process of concrete construction and can't be avoid in cast-in-site concrete structure. A well-treated construction joint should bond new concrete to existing concrete just like monolithic concrete. However, it is a perfect condition that, even with good workmanship, a construction joint zone may be less able to transmit some force (such as shear force and tensile force etc.) than the adjacent solid concrete. Although reinforced concrete cast-in-site frame structures with construction joints have been widely used in seismic zones, earthquake resistant tests of frame columns with construction joints had not been done before. Whether construction joints can influence earthquake resistant behavior of structure or not is unknown. The primary purpose of the study was to determine the earthquake resistant behavior of frame columns with construction joints, and compared difference between columns with construction joints and monolithic columns.

2. TEST GENERALIZATION

All of the test columns were cast by formwork erection. Horizontal construction joints located on the top of beams (see Figure1). The first cast part of the members with construction joints was three days old when the second part was cast. Concrete design strength is C30. Shear span ratio is 2.75. Longitudinal steel ratio is 1.13%. Volumetric stirrup ratio is 1.57%. The variables include in the tests are: (1) type of specimens, i.e., monolithic columns, or columns with construction joints;(2) bond condition of the interface in the construction joint specimens;(3) the axial compression ratio. The survey of specimens is set out in Table1. Mix proportion of bond materials is shown in Table 2. Load mode is force-displacement compound controlling loading.

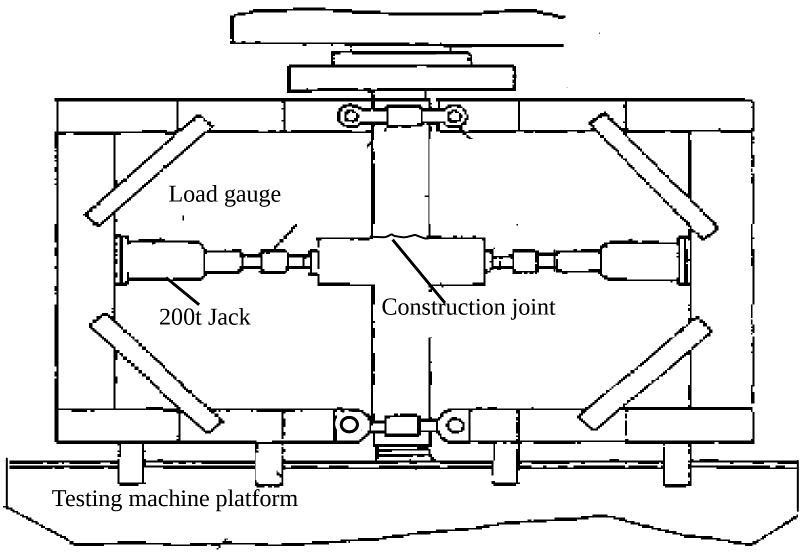

Figure 1 Test setup

Table 1 Survey of specimens

Series	Test axial compression ratio	Surface treatment of construction joints
CMC1 CMC2 CMC3	0.171 0.267 0.457	• Without construction joints
CU1 CU2 CU3	0.171 0.267 0.457	• Removed laitance and loose stone, cleaned, wetted
CM1 CM2 CM3	0.171 0.267 0.457	• Removed laitance and loose stone, cleaned, wetted • Covered with a 10mm layer of cement mortar
CFA1 CFA2	0.171 0.267	• Removed laitance and loose stone, cleaned, wetted • Covered with a 10mm layer of modified fly ash mortar
CS	0.267	• Removed laitance and loose stone, cleaned, wetted • Covered with a 10mm layer of self-stressing cement paste
CJ	0.267	• Removed laitance and loose stone, cleaned, wetted • Covered with a 100mm layer of joint concrete

Table 2 Mix proportion of bond materials

Bonding material	Water cement ratio	Sand aggregate	Coarse aggregate	Flash ash
CM	0.47	1.39	—	—
CFA	0.40	1.00	—	0.10
CS	0.30	—	—	—
CJ	0.47	1.52	2.95	—

2.1. Failure Characteristics Description

Under 0.171 axial compression ratio, the failure mode of all members was bending-compression failure. Main crack of the monolithic column and columns with construction joints occurred in the vicinity of construction joints and the column shaft except CU1. Main crack of the CU1 only occurred along the construction joints. The rate of crack propagation increased rapidly under cyclic loading. An opening crack plane along the construction joints could be seen all through the test. Construction joints had no effect on the location of incipient crack and loading at first crack.

Under 0.267 axial compression ratio, the mass of incipient crack of columns with construction joints occurred on construction joints and the column shaft. While the first crack of monolithic column only occurred on the column shaft. At failure, the main crack of CMC2 and CJ concentrated on the column shaft. The main crack of CS and CU2 was on the construction joints. The main crack of CM2 and CFA2 was adjacent to construction joints and on the column shaft. Compared with other specimens with construction joints, the incipient crack of CJ occurred later. Under low cyclic loading, the cracks of CJ tended to concentrate on the conjoint section between joint concrete and upper young concrete. Also, a lot of cracks extended upwards and downwards at a progressively increasing rate from the conjoint section. While the cracking of the construction joints itself was not obvious. At failure, cracks of CJ focused on the conjoint section and upwards of them.

Under 0.457 axial compression ratio, the failure mode of members was small eccentric compression failure. The failure characteristics of the monolithic column and columns with construction joints have little distinction.

2.2. Bearing Capacity and Displacement Ductility Ratio

Comparison between columns with construction joints and monolithic cast columns on peak strength is shown in Table3. It was noticed that when axial expression ratio was lower, the bearing capacity of columns with construction joints covered by cement mortar was stranger than the construction joints column without mortar covered. While compared with monolithic concrete, the bearing capacity of them was lower than monolithic column and dropped 3％～7％. When axial expression ratio was higher, the bearing capacity of the construction joints column was no less than monolithic cast column.

Table 3 Comparison between monolithic concrete columns and construction joints columns on peak strength

Axial compression ratio/n	CMC/%	CU/%	CM/%	CFA/%	CS/%	CJ/%
0.171	100	93.19	95.27	94.52	—	—
0.267	100	96.95	97.53	96.73	92.96	87.74
0.457	100	111.45	101.34	—	—	—

Axial expression ratio and displacement ductility ratio curves graph is shown in Figure 2. It was seen that ductility of CU and CM was lower than CMC under middle and low axial expression ratio. The displacement ductility of CU1 was only 70% of CMC1, and CM was about 90% of CMC. As the increasing of axial expression ratio, ductility gap between columns with construction joints and monolithic columns dwindled. When axial expression ratio was 0.457, ductility of CU and CM was higher than CMC.

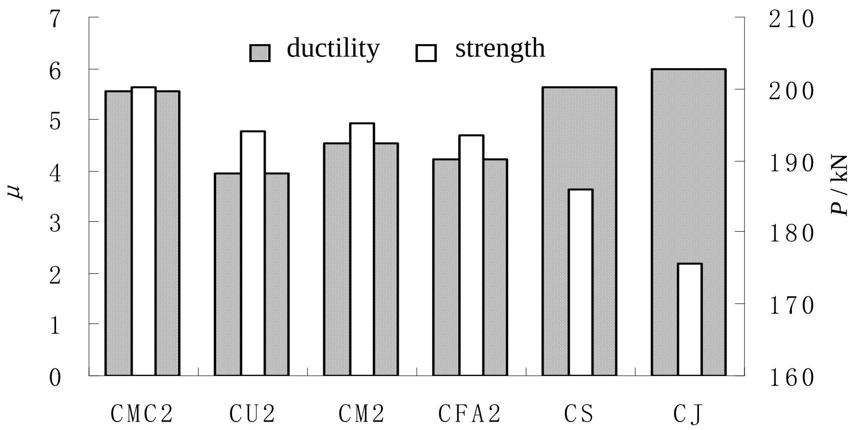

Figure 2 Comparison of ductility and strength

2.3. Hysteretic curves and stiffness degradation

In these tests, the response of the specimens changed as the number of cycles of loading and the level of loading increased. This is illustrated in Figure3~6, which show the hysteretic curves of CMC1, CM1，CFA1

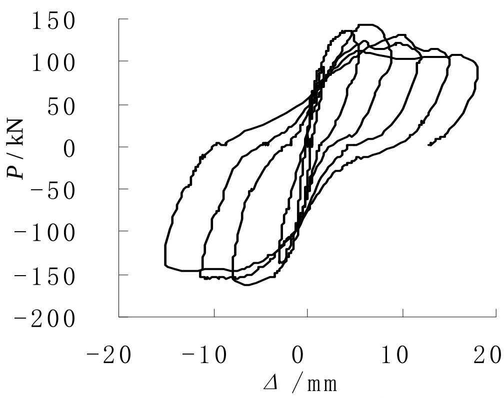

Figure 3 Hysteretic curves of CMC1

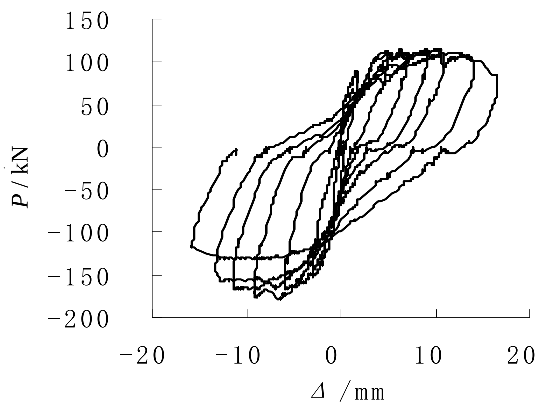

Figure 4 Hysteretic curves of CM1

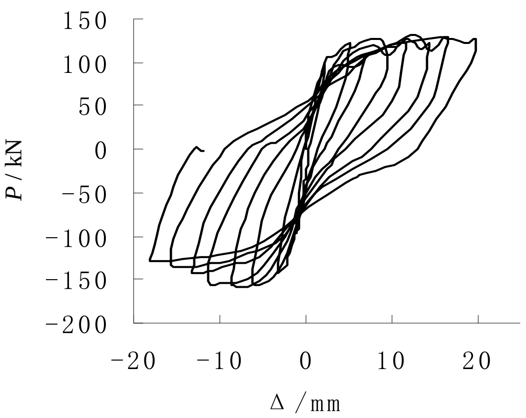

Figure 5 Hysteretic curves of CFA1

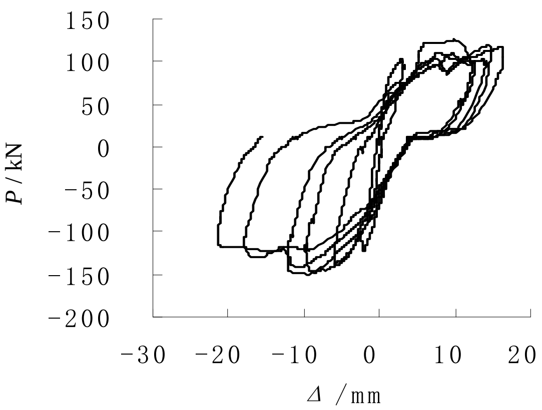

Figure 6 Hysteretic curves of CU1

and CU1 under 0.171 axial compression ratio. Compared with CMC1, the hysteretic curve of CU1 was not smooth, and the rheostriction was visible too. After the crack of construction joints occurred, the stiffness degradation of CU1 was rapidly. In the succeeding cycles of loading, longitudinal rods slipped largely. Tension reinforcements yielded soon and accompanied by a rather large plastic deformation and wider crack. After unloading completely, crack didn't close entirely and strains of longitudinal reinforcements were elongation still. When loaded in opposite direction, tension crack closed and slip platform appeared. But stress didn't increase until extrusion force occurred again between ribs of steels and concrete. This was the reason that slip occurred.

Compared with CU1, the hysteretic curve of CM1 was smooth, and only a small quantity of rheostriction was observed. After the construction joints opened, the stiffness degradation of the specimen was quickly too. Stiffness degradation curves graphs under different axial expression ratio are shown in Figure7 and Figure8.

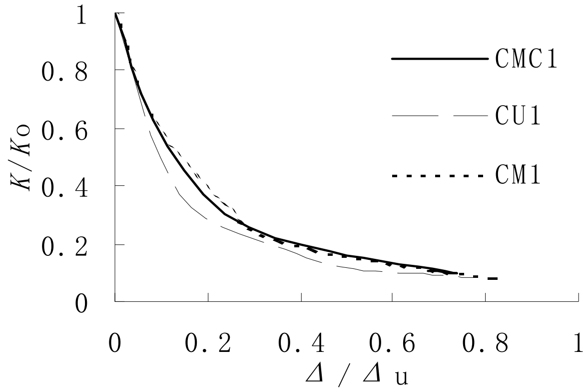

Figure 7 Stiffness degradation curves of 0.171 axial compression ratio

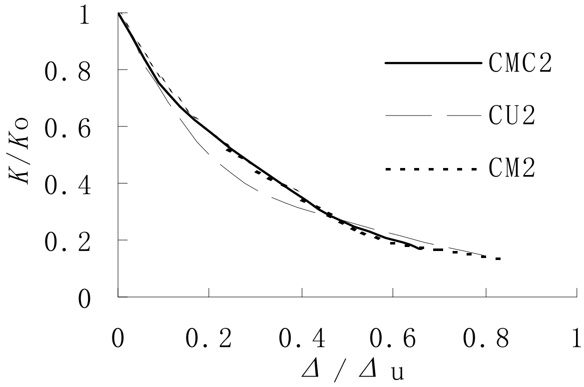

Figure 8 Stiffness degradation curves of 0.267 axial compression ratio

Compared with CU1 and CM1, the hysteretic curve of CFA1 was smooth relatively, and the stiffness degradation of the specimen was not so obvious as them. The stiffness degradation of CFA1 was similar to CMC1.

Under 0.267 axial compression ratio, hysteretic curves of CU2 and CS still had a little of rheostriction compared with CMC2. It could be seen from the unloading curves that certain of slip was still existed in columns，however, the slip was less than CU1. Hysteretic curves of CJ，CM2 and CFA2 were plump and similar to CMC2.

3. Conclusions

The existing of construction joints destroys the random distribution of aggregates, which will reduce both bearing capacity and ductility of columns. Under press-shear cyclically reversing loading, the crack of construction joints will earlier than matrix concrete. Compared with monolithic concrete, the bearing capacity will drop 3％～7％, and the maximum decrease of displacement ductility was more than 30％.

Before continuing placing fresh concrete, covered a layer of bond materials is necessary. It is good for improving the characteristics of construction joints surface. Test results indicated that bond materials could increase displacement ductility more than 10％～30％. And the clamping action provided by bond materials was so good that failure didn't occur at the construction joints itself, but in the concrete adjacent to it.

Both cement mortar bond materials and cement paste bond materials improve strength and ductility of specimens effectively. Under seismic force, the bond effect of the former is better than the latter. It is proposed using cement mortar bond materials. When the design axial compression ratio less than or equal to 0.3, it is proposed using modified fly ash mortar.

Since moment of flexure and shear force of construction joints sections are maximal, and reinforcing bars are close packing and so on, every precaution should be taken to obtain adequate bearing capacity and good bond strength on construction joints to resist seismic loading.

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