Torsional Resistance of Slab-Column Connections of Flat Plate under Seismic Force

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Summary

In this paper, an experimental investigation was carried out on a total of two specimens representing interior slab-column connections of flat plate in order to verify the effects of torsional resistance of slab-column connections of flat plate under seismic force. The test parameter was the existence of slits in front and back critical sections in order to transfer moment only by torsion. Punching shear failure occurred in the benchmark specimen without slits whereas torsional failure occurred in the specimen with slits. Furthermore, the deformation shapes of the specimens were different. Based on the test results, an equation to calculate punching shear strength is proposed.

Keywords: flat plate; torsional resistance; slabs; seismic force.

1. Introduction

Many studies of punching shear behaviour involving flexure, shear and torsion in critical section have been done in various countries. As a result, the different methods are used to estimate the strength of punching shear failure. Moreover, the formula of AIJ code is the sum of bending moment, shear force and torsional moment around the column. However, flexural and shear strength are not usually exerted at the same time. In this paper, punching shear behaviour under seismic force is reconsidered, the effects of torsional resistance of slab-column connections of flat plate under seismic force are studied and the following evaluation formula is proposed.

$$M_0 = \min(M_f, M_s) + M_t \tag{1}$$

Where M_f = moment transferred by flexure (Fig. 1a)

M_s = moment transferred by shear (Fig. 1b)

M_t = moment transferred by torsion (Fig.1c)

2. Experiment Outline

To investigate punching shear resistance of interior column-slab connection, two type of 1/2.5 scaled specimens are constructed. The test specimens are shown in Fig.2. The test parameter was the existence of slits in front and back critical sections in order to remove the effects of M_f and M_s. Crack patterns in a surface of the slabs are shown in Fig.3. Thick lines are a lift of the specimen by failure. Punching shear failure occurred in the benchmark specimen without slits. Torsional failure occurred in the specimen with slits. Fig.4 shows the deformation shape of the slabs based on the measurements. The whole slab deforms in the case of the specimen without slit, whereas the slab in the vicinity of the column deforms in the specimen with slit. Shear strain-drift relationship is shown in Fig. 5. Shear strain is calculated by vertical displacement of slabs.

3. Torsional Shear Stress Estimated from the Specimen with Slits

According to the observed cracks and deformation shape, the specimen with slit resisted to the load by the torsional resistance. Consequently, shear stress-strain relationship associated with torsion is estimated from the result of the specimen with slit. In the AIJ code, torsional resistance by the sides of column is calculated from the following equation (Fig.1c).

$$M_t = \tau_{tu}\frac{d^2}{2}\left\{(c+d)-\frac{d}{3}\right\}\times 2 \tag{2}$$

Figure 5 shows the computed stress-strain relationship of the sections B, C, F and G. The broken line in Fig. 5 represents the ultimate shear stress according to the AIJ code. The estimated maximum stress agrees with that in the AIJ code.

4. A Study of a Critical Section

The torsional shear resistance of the critical sections (sides of the column) is directly computed from Fig.5. The torsional resistance of test result of the benchmark specimen without slits is larger than that of the critical sections. In this research, the critical section shown in Fig. 6 is proposed to compute punching shear strength by Eq. (1). To evaluate the area of the additional section, direct shear stress of concrete is assumed. Based on these assumptions, torsional resistance of critical section including the additional section is computed by the following equation (Fig.6).

$$M_{to} = \tau_u \alpha d^2\left(c_1 + d + \alpha d\right)\times 2 \tag{3}$$

At the maximum strength, α is 2.2. The crack shown in Fig. 7 is obtained. The estimated value of α (=2.2) and the location of the crack on the top of the slab (440 mm from the face of the column) agree with the figure.

5. Conclusions

To investigate punching shear strength of interior column-slab connection, an experiment is conducted to the specimens with/without slit on the critical section. The specimen with slit transfers the moment only by torsion, and its deformation is localized around the column. On the other hand, the specimen without slit deforms in the wide range of the slab. Based on the results, a method to calculate the strength which is more rational than the AIJ code is proposed. In this method, the critical section of a slab is larger than that in the AIJ code.

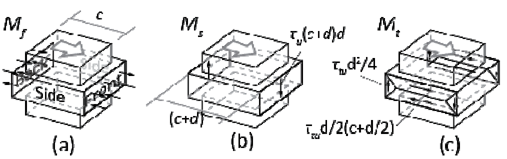

Fig. 1: Transfer of moments in slab-column

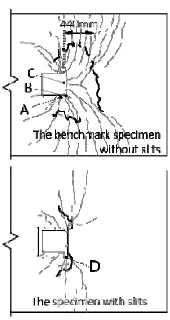

Fig.3: Crack patterns

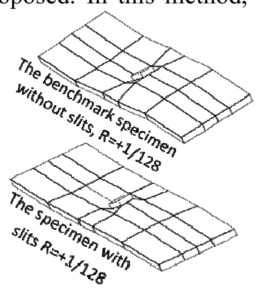

Fig. 4: The deformation shape of the slabs

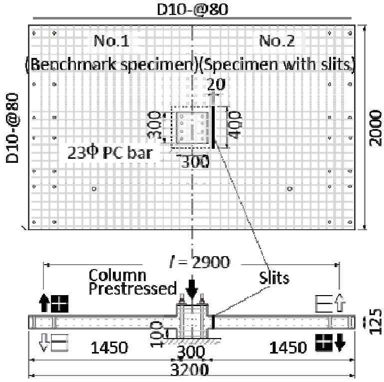

Fig.2: The test specimens

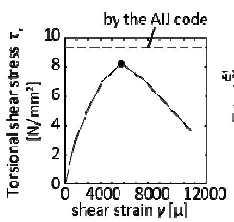

Fig. 5: the computed stress-strain relationship

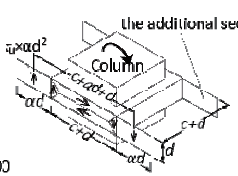

Fig. 6: the critical section

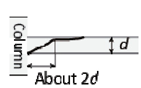

Fig. 7: The crack