V-320 EFFECT OF STEEL PLATE STRENGTHENING ON DUCTILITY OF RC MEMBERS

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1. INTRODUCTION

In order to improve the ductile behavior, many methods have been proposed and some of them have actually been applied in the site. Regarding to the ductility , the minimum requirement is to confine the cracked concrete. Wrapping the member by steel plates with anchor bolts is a method which has been reported effective. Considering the basic concept of confining the cracked concrete, the strengthening method adopted in this paper is steel plate wrapping without anchor bolts. The objectives are as follows:

1) To study mechanism how ductility is improved
2) To develop a model to evaluate the effect of steel plate wrapping.

2. TEST PROGRAM

In the experimental program reinforced concrete columns were tested where the parameter was the type of reinforcement in the critical zone defined by 1.5d from the fixed end section of the specimen. Four specimens were tested. The design compressive strength of concrete was 300 kg/cm². Dimensions and the arrangement of reinforcement are shown in Fig.1, and the detail of the specimens is summarized in Table 1.

The specimens were loaded cyclically by deformation control taking the yield displacement as a reference value. The load was increased incrementally with three cycles of application at each stage.

3. TEST RESULTS AND DISCUSSION

3.1 CRACK PATTERN

Fig.2 shows the crack patterns of the four specimens. The effect of steel plate can be seen in No.1 (Fig.2-a) and No.2 (Fig.2-b) specimens which presented approximately the identical properties of two main cracks inclined 45 degree for both directions, creating a plastic hinge near the fixed end. Few cracks were produced. The failure was accelerated when the plate was fractured at the corner, letting concrete spall off followed by buckling of longitudinal bars. The presence of stirrups and plate in No. 2 (Fig.2-b) specimen collaborated to confine the cracked concrete, permitting good distribution of cracks. On the contrary, No. 3(Fig.2-c) specimen showed no crack distribution and no stepped concrete crushing occurred, consequently failed soon by shear. Stirrups of No.4 specimen (Fig.2-d) produced a good distribution of cracks but the concrete loosen causing buckling of longitudinal bars due to not adequate confinement.

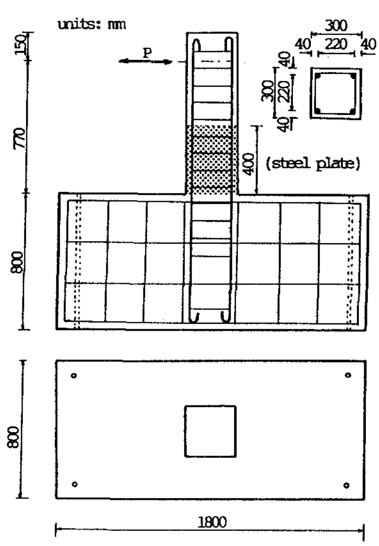

Fig. 1 Test specimen

Table 1. Detail of specimens

Specimen	bxh cmxcm	a cm	a/d	Longitudinal Reinf. Grade	As cm²	ρ %	Transverse Reinf. Grade	s cm	An cm²	ρn %	Reinforcement in critical zone 1.5d
1	30x30	10	3	SD35	5.73	0.735	SD35	10	0.633	0.211	steel plate
2	30x30	10	3	SD35	5.73	0.735	SD35	10	0.633	0.211	stirrups+steel plate
3	30x30	10	3	SD35	5.73	0.735	SD35	10	0.633	0.211	nothing
4	30x30	10	3	SD35	5.73	0.735	SD35	10	0.633	0.211	stirrups

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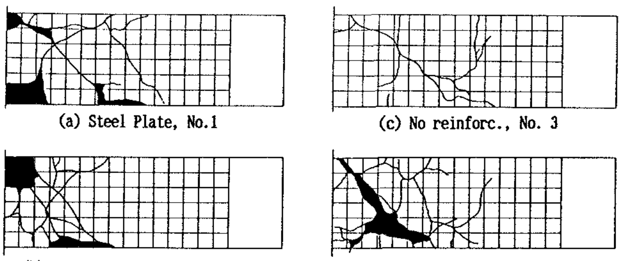

(a) Steel Plate, No.1 (c) No reinforc., No. 3

(b) Stirr. + Steel plate, No. 2 (d) Stirrups, No. 4

Fig. 2 Crack pattern

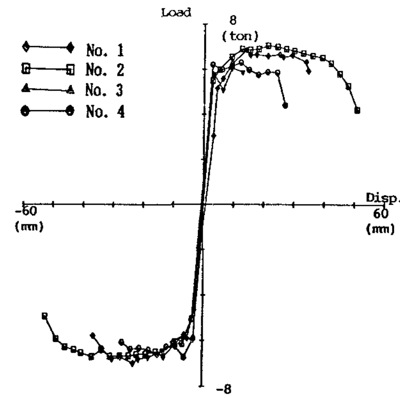

Fig. 3 Load deflection envelopes

3.2 LOAD DEFLECTION CURVE

Fig.3 shows the envelope curves of load-deflection relationships of four specimens. The steel plate increased the load carrying capacity (No. 1 and, No. 2), compared with the standard specimen (No. 4). Steel plate had some contribution to increase the load carrying capacity. However, its role was remarkable for prevention against the drastic reduction of the capacity at large deflection levels . The combination of stirrups and plate (No. 2 specimen) presented this characteristics very notable.

Table 2. Ductility ratio

spec.	δy, mm	δu, mm	μ
1	2.849	36.582	12.8
2	3.603	52.635	14.6
3	3.091	9.242	3.0
4	3.030	26.938	8.9

3.3 DUCTILITY

The critical deformation for ductility evaluation was taken when the peak capacity at any cycle of load decreases below the first yield capacity. The ductility was then calculated as the ratio of the critical deflection to the first yield deflection (Ref.1). The ductility values of the specimens are shown in Table 2.

Table 3. Comparison of calculated load carring capacity

spec.	Py, exp.	Py, cal.	Exp/Cal	Pu, exp.	Pu, cal.	Exp/Cal
1	4.671	5.776	0.808	6.987	7.197	0.970
2	5.496	5.776	0.951	6.705	7.292	0.919
3	5.961	5.776	1.031	5.973	6.733	0.887
4	5.910	5.776	1.023	6.735	7.197	0.930

4. MECHANISM FOR STEEL PLATE STRENGTHENING

Based on the discussion of crack patterns, and since main diagonal cracks were similars, the steel plate effect was modeled as an element which purely provided the additional confinement of concrete. This confinement produced a variation of the stress-strain curve of concrete. To consider this phenomenon the plate was modeled as an equivalent very closed stirrups as indicated in Fig. 4. The equivalent spacing (s_{eq}) and transverse reinforcement (Av_{eq}) are given by

$s_{eq} < s$ (in this analysis, $s_{eq}=1$ cm)

$$Av_{eq}=2\cdot t\cdot s_{eq} + Av/s\cdot s_{eq} \qquad \text{.................(1)}$$

Where, s= spacing of stirrup, Av= area of stirrup and, t= thickness of steel plate.

The equivalent quantity of stirrup was considered in the classical evaluation of Py and Pu by considering the stress-stain curve for confined concrete and stress strain curve for the steel including the strain hardening effect. Table 3 shows the comparison of the calculated results with test results.

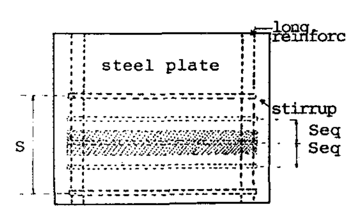

Fig. 4 Plate modeling

5. CONCLUSIONS

(1) Steel plate had little contribution to the load carrying capacity. However, its role was remarkable for prevention against the drastic reduction of the capacity at large deflection levels.

(2) The contribution of steel plate to the confinement effect can be evaluated by treating the plates as an equivalent very closed additional stirrups.

REFERENCES

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