V－32 鋼板で補強された鉄筋を用いないコンクリート部材の強度試験

TESTS ON REINFORCEMENT-FREE CONCRETE MEMBERS STRENGTHENED BY STEEL STRAPS

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1. INTRODUCTION

Reinforcement-free concrete members rely on the effective use of an internal arch-action which occurs if the member is sufficiently confined. Several tests in Canada(1) and Japan(2) have established the possible application of reinforcement-free slabs for decks of bridges. From these tests, it was proved that providing an external confinement to one-way slab – in order to restrain its transverse movement – would raise its capacity and change the failure mode from a flexural to shear failure. The quantification of the restraining level, however, was not thoroughly studied.

This paper presents experimental tests on small-scale reinforcement-free concrete members restrained by means of external straps. The restraining effect is quantified using the stiffness of these members. By changing the straps and the concrete strength, different levels of stiffness – thus different levels of confinement – was achieved. The effect of this confinement level on the strength and failure mode of the studied members is discussed.

2. EXPERIMENTAL WORK

The shape, dimensions, and details of the specimens are

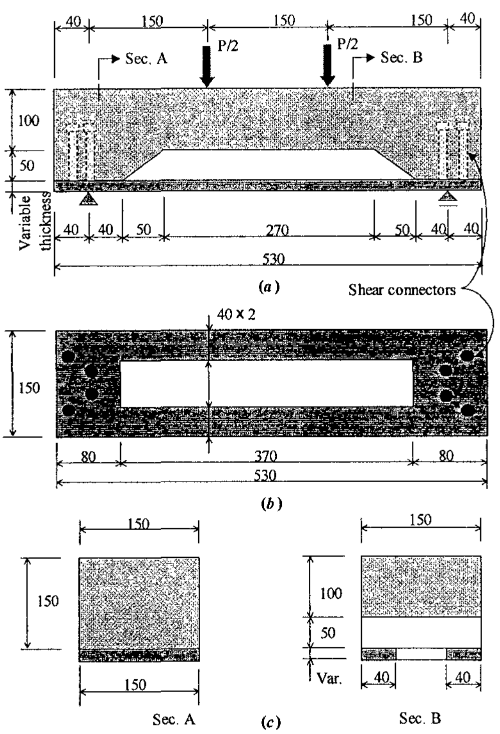

Fig. 1. Details of the specimens: (*a*) front view, (*b*) steel straps (upper view before casting), and (*c*) sections. Units are in mm.

Table 1. Specimens details

Specimen Name	Concrete Strength	Straps	Strap Ratio	Total Stiffness	Perc. of Strap Stiffness
	MPa	mm x mm x No.	%	kN.m / m	%
n-1	46	2.3 x 40 x 2	1.2	2703	81
h-1	71	2.3 x 40 x 2	1.2	2938	76
n-2	47	3.2 x 40 x 2	1.7	3486	84
h-2	72	3.2 x 40 x 2	1.7	3755	80
n-3	47	4.5 x 40 x 2	2.4	4485	87
h-3	72	4.5 x 40 x 2	2.4	4819	83
n-4	46	6.0 x 40 x 2	3.2	5469	88
h-4	55	6.0 x 40 x 2	3.2	5687	87

shown in Figure 1. The concrete of the specimen was void of any reinforcement. The concrete was confined by means of steel straps and made composite with the straps at the ends using shear connectors.

Concrete strength had a wide range between 46~72Mpa. The strap was steel plate with the same width of the member at the support, and had two branches of 40mm along the span. The specimens are arranged in Table 1 according to the strap section ratio at the mid-span of the beam.

Stiffness was calculated for a transformed elastic section (before cracking) around the center of the transformed section. In this way both concrete strength and the confinement action of the strap could be accounted for. The stiffness is expressed per meter width of the member. Although the contribution of the concrete section to the stiffness would be smaller after cracking, the total stiffness is due in the largest part to the straps as shown in the last column of Table 1. Therefore, the order showed in Table 1 would still be valid after cracking even though the value of the stiffness would be slightly smaller.

The static loading was done using two loading points on the simply supported members as shown in Figure 1.

3. RESULTS AND DISCUSSION

Characteristic of reinforcement-free membes is the very limited number of cracks in comparision to reinforced members. The reinforcement bars in RC members distributes – through bond – the stress occuring at the main section due to external forces to different sections of the span. In the case of reinforcement-free members, the first one or two cracks that occure would continue propagating until the specimen fails in bending. Providing a sufficient restraint to the member's supports, however, would initiate an arch-action (compresion membrane) in the concrete. This arch-action will then resist the bending failure and causes the member to fail eventually in shear mode as illustrated in Figure 2.

Figure 3 gives an example on the development of stresses in three specimens with different levels of restraint. It is clear that with low restraint level the specimen acted in pure bending with small value of the stresses in the compression zone. This bending failure is shown in Figure

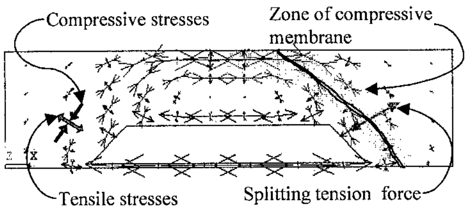

Fig. 2. Illustrative figure from FEM analysis for specimen h-4, showing the arch action

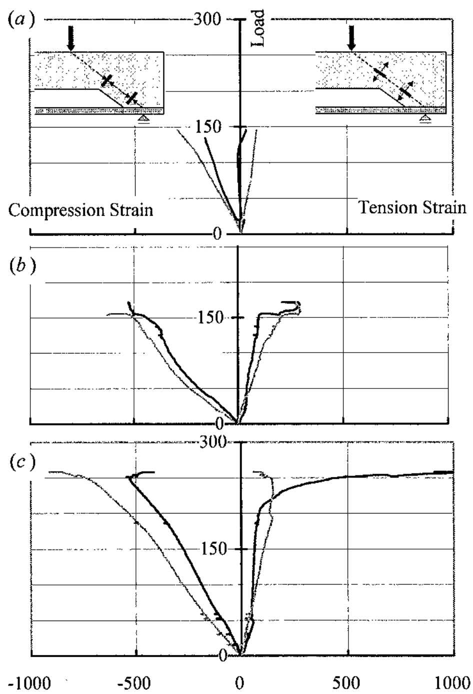

Fig. 3. Strain in the direction and the perpendicular direction of the compressive zone for (*a*) specimen h-1, (*b*) specimen h-2, and (*c*) specimen h-4

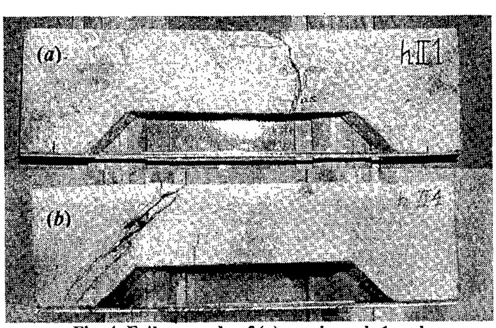

Fig. 4. Failure mode of (*a*) specimen h-1 and (*b*) specimen h-4

4(*a*). The fact that was mentioned earlier about the number of the cracks could be clearly seen in the photo.

The higher restraint to the specimen caused a greater level of stresses in the compression zone. Consequently, the

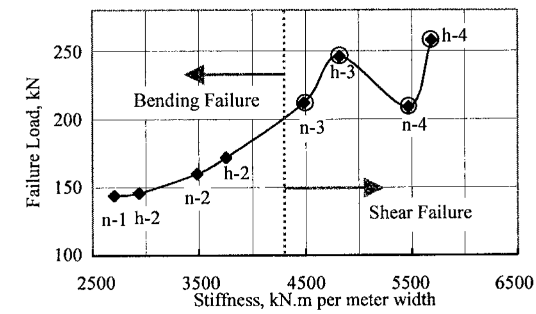

Fig. 5. Changes of failure loads and failure modes with stiffness of the tested members

splitting tension stresses were larger and led to a shear failure as shown in figure 4(*b*).

The cracking strength of the specimens did not increase significantly with the increase of concrete strength or with the increase of the stiffness (restraint level). The reason is that the arch-action does not take place until after cracking. Cracking strength depends on the reinforcement-free concrete tensile strength. Because this tensile strength does not change significantly even for concrete with higher compressive strength, the cracking loads of all the specimens were close and ranged between 19 to 25 kN.

Figure 5 illustrates the tests results at ultimate for all the specimens. The higher restraint level changed the failure mode from bending to shear due to the extra resistance caused by the occurrence of the arch action. The increase in ultimate loads generally corresponded to the increase in the stiffness. This meant that the chosen parameter (stiffness of the transformed non-cracked section) was able to correctly express the restraint level.

4. Conclusions

- The fact that restrained reinforcement-free concrete members have a sufficient strength comparable to that of reinforced members was emphasized in the tests described in this paper. Providing a sufficient confinement increases substantially the ultimate resistance of the members. The failure load is high even though cracks occur in the early stage of loading due to the absence of the reinforcement.
- Expressing the restraint level by means of the stiffness of the transformed non-cracked section proved to be a successful method to quantify the restraint level. Both failure load and failure mode results matched the increase in the stiffness of the reinforcement-free members.
- The stresses measured during the tests verified the occurrence of the arch-action. The changes that took place on the distribution of the stresses in the members with different level of restraint proved the postulated effect of the restraining straps on changing the failure mode of the members.

References

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2. Hassan, A., et al., *An experimental investigation of steel-free deck slabs*, Canadian Journal for Civil Engineering, V.29, N.6, 2002, pp. 831- 841.