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STUDY ON REACTOR BUILDING STRUCTURE USING ULTRAHIGH STRENGTH MATERIALS - PART 7: OUTLINE OF MIXED STRUCTURE TESTS

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ABSTRACT

The objective of this study is to comprehend the basic structural characteristics of box shaped mixed structures proposed for a future nuclear reactor building structure. Specimens of reinforced concrete precast panel walls of the mixed structures were prepared using ultrahigh strength materials. Two bending shear tests were conducted with a parameter of the quantity of reinforcement bars. The results include: (1) Relationship of shear stress and the angle of the structure, and (2) Failure mode.

1. INTRODUCTION

The box shaped mixed structure proposed consist of PCa-panel walls (reinforced concrete precast panels) with SC-columns (concrete filled steel tube columns) and S-beams (steel beams) jointed by high tension bolts (Fig.1).

This paper, Part 7, describes the outline of the test procedure and some results. More detailed discussion will be given in the subsequent paper, Part 8.

2. EXPERIMENTS

2.1 Specimens

The specimen was constructed on the basis of the fundamental premises (1) to (5) mentioned below:

(1) Structural members of the proposed nuclear reactor building such as SC-columns, S-beams, PCa-panels, and their joints are modeled.

(2) The ratio of Qm (shear force at bending yield)/Qs (shear strength) of the specimen is adjusted that of the box shaped mixed structures proposed. (i.e. the ratios in the specimen and in the box shaped mixed structure were 4.22 and 3.56, respectively.)

(3) The specimen's ratio of As/Ac (where As is defined as the effective sectional area against the horizontal shear forces, and Ac is concrete sectional area) is similar to that of the actual building. (i.e. the ratios in the specimen and in the box shaped mixed structures were 0.082 and 0.074, respectively.)

(4) The shear span ratio is 0.8, in accordance with reference 2.

(5) The parameter of the specimen is "the quantity of reinforcement bars in PCa-panels" $P_S \cdot {}_S\sigma_y$, the total strength of the rebars (calculated from P_S, the ratio of the rebars in concrete and ${}_S\sigma_y$, the strength of the rebars).

The shape of the specimen is shown in Fig. 2. Two specimens, one is F64M (P_S = 0.8%, $P_S \cdot {}_S\sigma_y$ = 6.28 MPa [64.0 kgf/cm^2]) and the other is F38M (P_S = 0.48%, $P_S \cdot {}_S\sigma_y$ = 3.78 MPa [38.0 kgf/cm^2]) were prepared. The details of the joints were designed similar to those of the specimen with anchor reinforcement described in the previous paper, Part 6.

2.2 Material

The physical properties of concrete, reinforcement bars, steel materials, and high tension bolts are shown in Tables 1 and 2.

2.3 Loading and measurements

Cyclic horizontal load was applied with continuously increasing displacement amplitude as shown in Fig.3. The magnitude of the vertical load was kept constant at an average stress $\sigma_0 = 1.96$ MPa in the PCa panel.

The detail of this loading was given in references 1 and 2.

The measurements were conducted for:

(1) Displacement of each part
(2) Strains of the reinforcement bars
(3) Strains of the steel materials (SC-columns and joints)
(4) Crack widths of the concrete

3. RESULTS AND DISCUSSION

3.1 Hysteresis loop of shear stress τ - shear deflection angle R relationship

The relationship between τ and R is shown in Figures 4 and 5. The shear stress τ was calculated by dividing the shear force Q by the equivalent shear sectional area A_w. Numerical notation in Figures 4 and 5 shows events in failure mode. The interpretation of the relationship between τ and R is as follows:

(1) After shear cracks (specimens of PCa-panel walls of the mixed structures were prepared using ultrahigh strength materials. Two bending shear tests were conducted with a parameter of the quantity of reinforcement bars.) were generated in PCa-panels, both specimens showed almost no change in their rigidities.
(2) When initial slippage occurred at the joints, the member angle increased suddenly for F64M, while it showed only a minor increase for F38M. With further loading repetition, hard slippage was observed several times, and an increase of the member angle was observed for each slippage. Furthermore, by increasing the loading repetition frequency, a tendency of slipping stress increase was observed. This slippage increased the loop area of the τ-R relationship.
(3) The slippage, as can be seen in a change of the loading direction for the τ-R relationship of an ordinary shear wall, was not observed.
(4) In the case of F38M specimens with a lower quantity of reinforcement bars, although no splice plate yield was observed, a longitudinal reinforcement yield was observed.

3.2 Stress and shear deflection angles in various states

Table 3 shows the stresses and the shear deflection angles in various states. The interpretation of that table is as follows:

(1) The stress of the slippage at the joint's friction surface exceeded the value of the reinforcement bar quantity $P_s \cdot {}_s\sigma_y$.
(2) The maximum shear stress τ_u exceeded the value of the reinforcement bar quantity $P_s \cdot {}_s\sigma_y$ in both specimens. Furthermore, the difference of the maximum shear stress τ_u between two specimens was not so evident in comparison to that of the reinforcement bar quantity.
(3) The member angle R_u at the maximum stress was 9 ~ 10 x 10^{-3} rad., which was nearly the same value as that of the test results in reference 2.

3.3 Crack condition and type of collapse

Figures 6 and 7 show the crack conditions of both specimens.

Interpretations are as follows:

(1) The cracks at final stage were uniformly generated with almost regular intervals and obliquely in a 45-degree direction, similar to the results obtained of reference 2.
(2) The type of collapse were a shear slippage collapse in the case of F64M and a shear compression collapse in the case of F38M which contains a lower reinforcement bar quantity.

4. CONCLUSION

Experimental results elucidated the basic structural characteristics of the box shaped mixed structure, loaded by cyclic horizontal forces.

References

1. Usami S., et al.(1989) . Application of High Strength Rebar for RC Shear Wall (Part 1~7), Pro. of the Annual Congress of AIJ, pp. 567-580.
2. Uchiyama T., et al. (1991) . Study on Reactor Building Structure Using Ultrahigh Strength Materials (Part 4) Bending Shear Tests of RC Shear Walls, Pro. of SMiRT 11 Vol.H, pp.377-382.

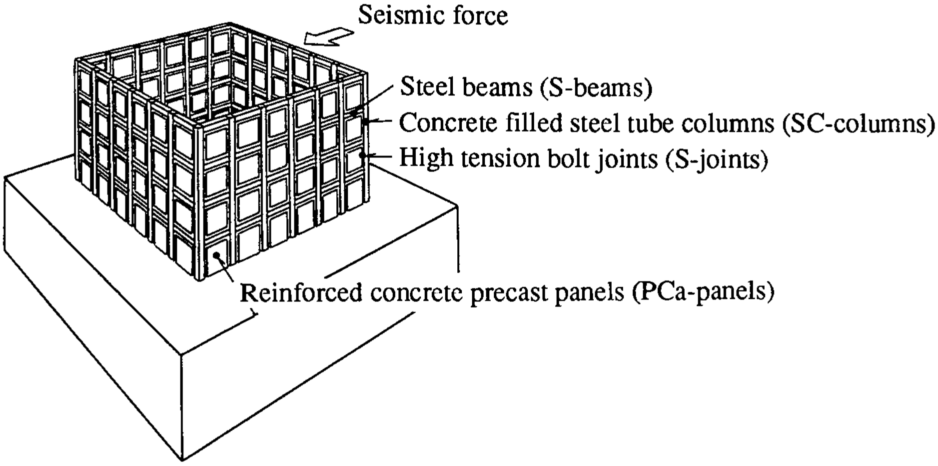

Fig. 1 A box shaped mixed structure for a future reactor building

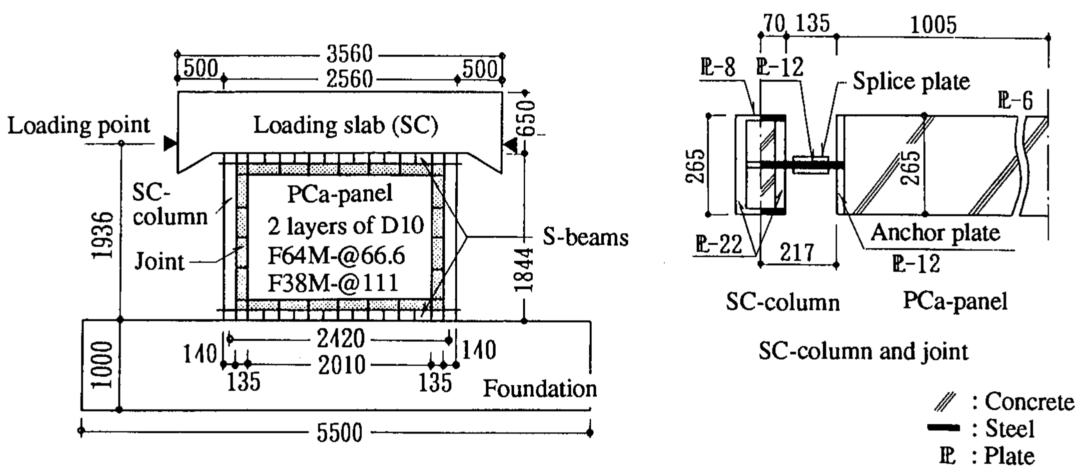

Fig. 2 Specimen of bending shear test (unit : mm)

Table 1 Physical properties of concrete

Specemen name	Member	Compression strength σ_c (MPa)	Young's modulous E_c ($\times 10^4$MPa)	Poisson ratio ν	Tensile strength σ_t (MPa)
F64M	PCa-panel	77.7	4.08	0.236	3.95
	SC-column	77.8	3.79	0.230	4.16
F38M	PCa-panel	73.2	3.94	0.239	3.99
	SC-column	70.8	3.57	0.219	3.83

Table 2 Physical properties of rebars, steel material, and high-tension bolts

Material	Thickness or diameter (mm)	Young's modulous Ec ($\times 10^5$MPa)	Yield strength (YP) ${}_s\sigma_y$ (MPa)	Strain of yielding ε_y ($\times 10^{-6}$)	Tensile strength σ_t (MPa)	Extension at breaking (%)
Rebar	D10	1.96	766	4410	803	11.9
Steel	6	2.09	986	5230	1013	23.9
	8	2.09	977	5225	1006	26.6
	12	2.09	973	5090	1011	28.1
	22	2.09	985	5175	1044	32.4
Bolt	M12	—	1457	—	1614	—

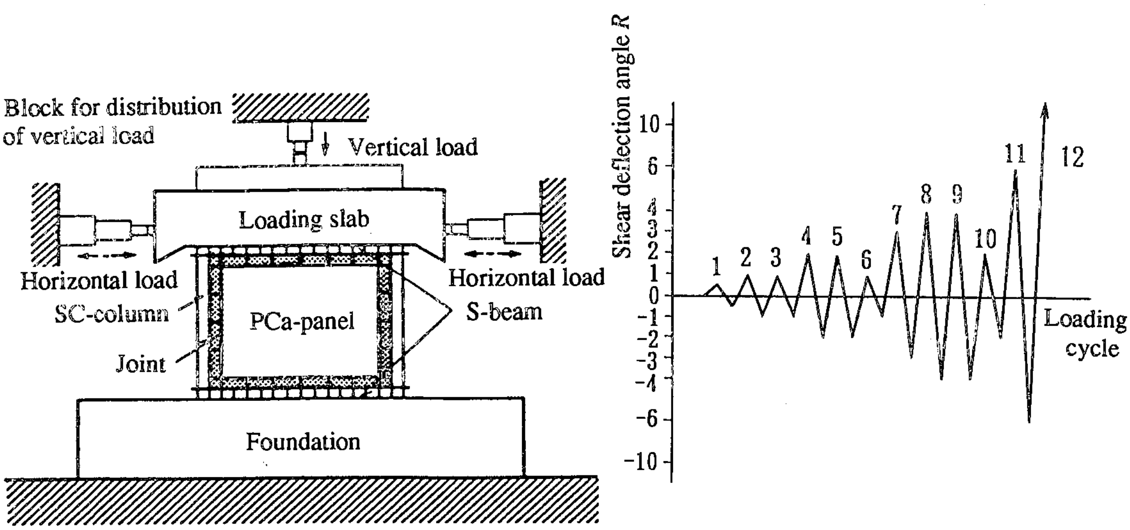

Fig. 3 Loading method

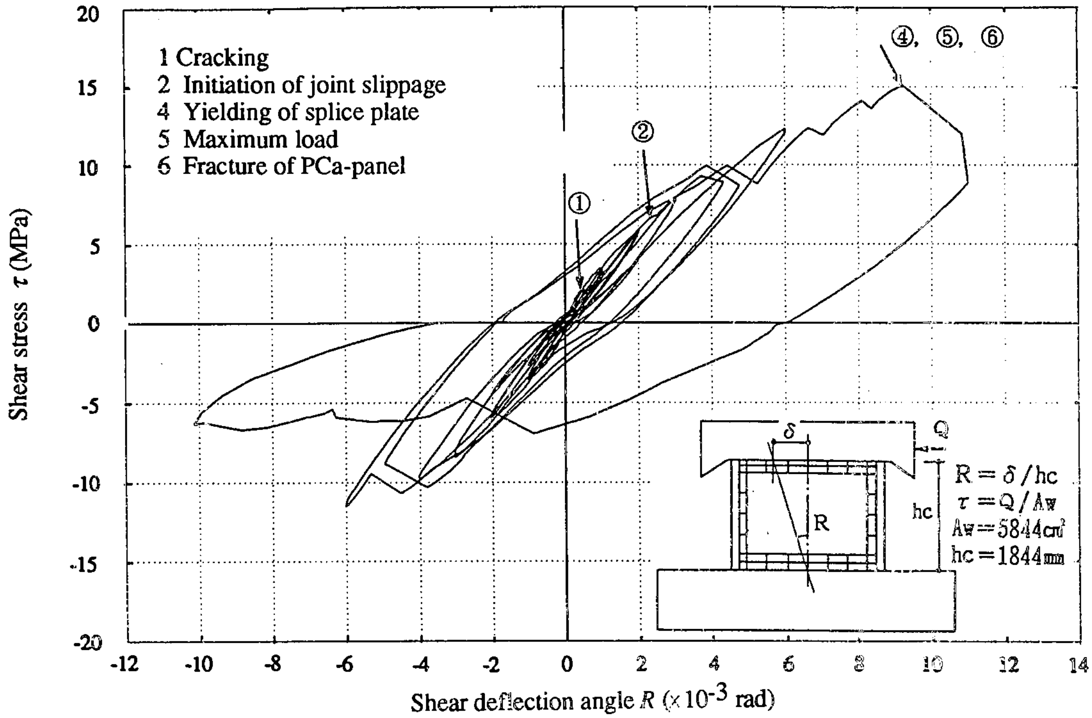

Fig. 4 Relationship between Shear Stress and deflection angle (F64M)

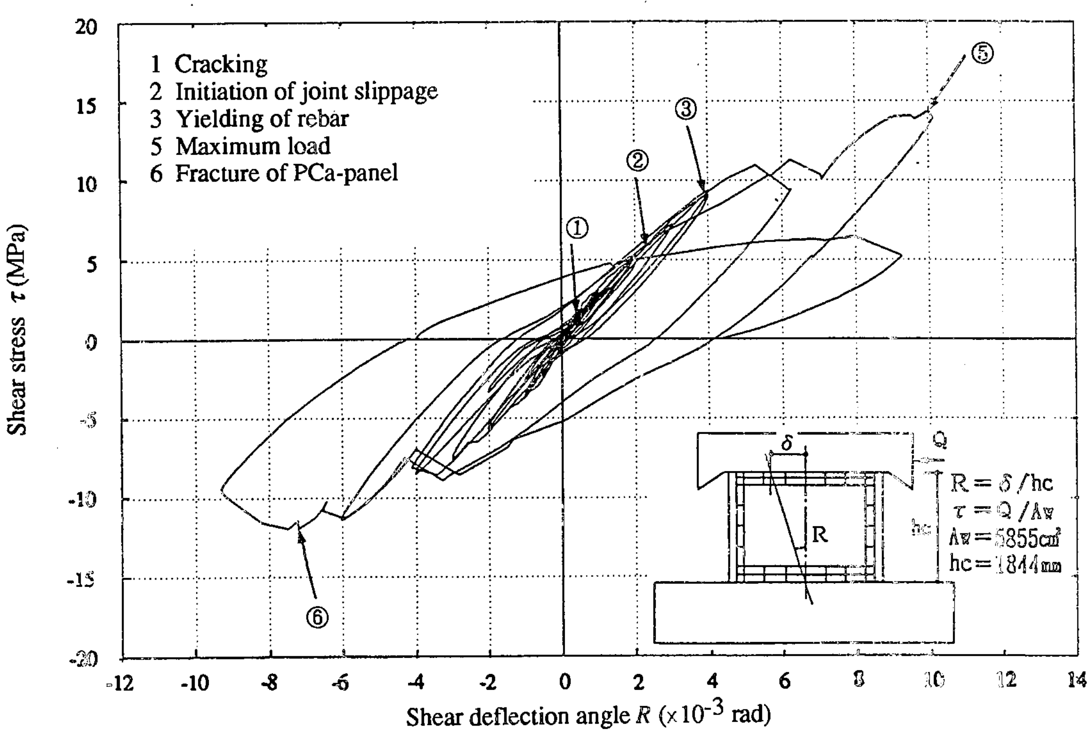

Fig. 5 Relationship between Shear Stress and deflection angle (F38M)

Table 3 List of the test results

Item	F64M	F38M
Quantity of reinforced bars (MPa) [kgf/cm^2]	6.28 [64]	3.73 [38]
Shear sterss at the initiation of crack τ_{cr} (MPa) [kgf/cm^2]	2.10 [21.4]	1.81 [18.5]
Shear stress at the initiation of joint slippage τ (MPa) [kgf/cm^2]	6.63 [67.6]	5.83 [59.4]
Shear stress at the yielding of vertical rebar τ_y (MPa) [kgf/cm^2]	–	8.97 [91.4]
Shear stress at the yielding of splice plate τ_y (MPa) [kgf/cm^2]	14.82 [151.1]	–
Shear stress at the maximum load τ_u (MPa) [kgf/cm^2]	14.82 [151.1]	14.16 [144.3]
Joint translation angle R_u ($\times 10^{-3}$rad)	9.21	10.13
Fracture mode	Shear slippage	Shear compression

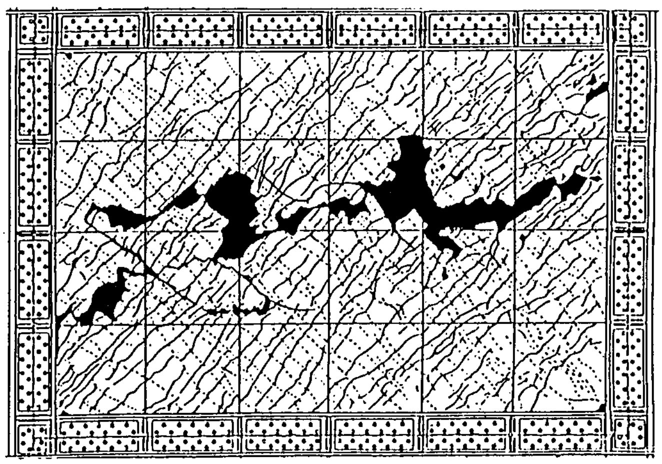

Fig. 6 Crack condition at final stage (F64M)

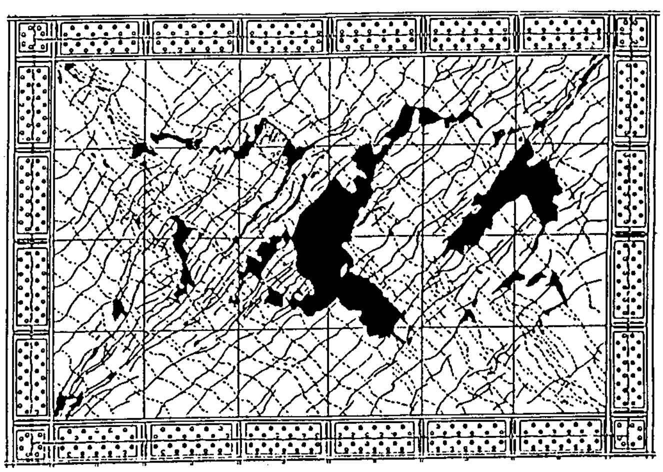

Fig. 7 Crack condition at final stage (F38M)