# Study on Reactor Building Structure Using Ultrahigh Strength Materials
## Part 1 Summary of Research


Kikuo ISHIMURA
*Tokyo Electric Power Company, Tokyo, Japan*

Masashiro ODAJIMA
*Kajima Corporation, Tokyo, Japan*

Kazuo IRINO
*Simizu Corporation, Tokyo, Japan*

Toshio HASHIBA
*Takenaka Corporation, Tokyo, Japan*



ABSTRACT

This study was promoted to be aimed at realization of the optimal nuclear reactor building structure of the future. As the first step, the study regarding ultrahigh strength reinforced concrete (abbr. RC) shear wall was selected.

As the result of various tests, the application of ultrahigh strength RC shear walls was verified. The tests conducted were relevant to; ultrahigh strength concrete material tests; pure shear tests of RC flat panels; and bending shear tests and its simulation analysis of RC shear walls.


## 1. INTRODUCTION

Up to the present, various studies and research have been conducted regarding RC structure which is the main structural element of nuclear reactor buildings. And yet, it cannot be said that other types of structures besides ordinary RC structure has necesarily been given sufficient study.

Social demands now call for factory prefabrication of building units and machine utilization for construction projects, in addition to up grading the standard of building quality. Also, the needs to nuclear reactor building, are the further compliance with such as; safety, readiness of construction, longevity, and measures for wastes disposals.

The objective of this research is in studying for the realization of the optimum nuclear reactor building structure of the future. First of all the composite structures consisting of steel concrete (abbr. SC) frames and precast RC panels (abbr. PCa) as shown in Fig. 1 are proposed. In the structures, ultrahigh strength materials and prefabrication system are used.

For the study aimed at realization of composite structures, this report selected 2 items as follows:

1) Research regarding ultrahigh strength RC shear wall
2) Research appertained to PCa

The general flow of the research is shown in Fig. 2. Reported matters herein as the first step, are the results of study conducted for ultra-high strength RC shear wall.

## 2. OBJECTIVE

This study was conducted with the objective of comprehending the structural characteristics of RC shear wall using ultrahigh strength materials. Contents of research included, material tests, pure shear tests of the RC panel, and bending shear tests and its simulation analysis of the RC shear wall. The materials considered were concrete of grade Fc = 400kgf/cm² (39.2MPa) to 1000kgf/cm² (98.1MPa) and reinforcing bars (abbr. rebars) grade of SD60 and SD80. The strength of concrete and rebers used in this study is shown in Fig. 3, compared with that of conventional one.

## 3. TEST PLAN AND OUTLINE OF RESULTS

### 3.1 Material tests

Concrete mixing tests were conducted in the laboratory and at the mixing plant for ultra high strength concrete by adding admixture (silicafume). The targets of concrete strength were of grade Fc = 400kgf/cm² (39.2MPa) to 1000kgf/cm² (98.1MPa) and rebars of SD60 to SD80. In the test, the reviews were conducted regarding that the silicafume blending percentage, water binding admixture ratio, and the mixing quantity of high performance air entraining (abbr. AE) water reducing agent affect on the strength and workability of concrete. As the results, it was found that for concrete with silica fume of water-cement ratio=25%, appropriate workability was obtained, confirmation was made that the compressive strength at age of 91 days was over 1300kgf/cm² (127.4MPa) and that ultrahigh strength concrete with design basis strength of about 1000kgf/cm² (98.1MPa) could be produced.

### 3.2 Cyclic pure shear test of RC panels

The specimen is a flat panel that has no restraining member such as flange walls as shown in Fig. 4. The parameters of the specimen are as shown in Table 1 with, rebars strength (SD6O and SD80), concrete compression strength (Fc = 400, 700 and 1000kgf/cm² [39.2, 68.6 and 98.1MPa]) and rebars quantity (product of rebar ratio Ps and yielding point $_s\sigma_y$, $Ps \cdot {}_s\sigma_y$ = 48, 72 and 96kgf/cm² [4.71, 7.06 and 9.41MPa]) Totally, five specimens were tested.

From the cyclic pure shear test results, it was found that for designing RC shear walls the conventional design formula in Japan was applicable even when ultrahigh strength materials are used.

### 3.3 Bending shear test of RC shear walls

The bending shear tests was conducted with the objective of grasping the fundamental structural characteristics of shear walls using ultra high strength concrete and rebers. The specimen is an H-shape cross section as shown in Fig.5. The parameters of the specimens are as shown in Table 2 with, rebars strength (SD40, SD60 and SD80), concrete compression strength (Fc = 400, 700 and 1000kgf/cm² [39.2, 68.6 and 98.1MPa]) and rebars quantity ($Ps \cdot {}_s\sigma_y$ = 48, 72 and 96kgf/cm² [4.71, 7.06 and 9.41MPa]). Totally, nine specimens were tested.

From the bending shear test results it was found that for designing RC shear walls the conventional design formula in Japan regarding ultimate strength and restoring force characteristics were applicable even when ultrahigh strength materials were used.

### 3.4 Nonlinear analysis of RC shear walls

The simulation analyses of bending shear tests were performed using non-linear Finite Element Method (abbr. FEM), with the objective of comprehending analytically the mechanical characteristics of the shear wall. Four specimens were selected to the simulation analysis, which are W48L6, W48M6, W72M8 and W72M8. For the analytical model, only 1/2 of the specimen as shown in Fig.6 was considered in view of the symmetrical condition, and was modelized by laminated layered shell elements. The RC wall was divided in the width direction and the rebars were modelized by plate elements in equivalent layer thickness. Moreover, the relationship of concrete compression stress and strain were used the material test results that had been apprehended even after the maximum strength.

From this analytical result, it was found that even when ultrahigh strength materials are used for RC shear wall could be comprehended analytically very precisely, by appropriate modeling of the material characteristics.

## 4. CONCLUSIONS

The outline of research results till now have been described here (Part - 1). The particulars will be reported in (Part - 2) and following. The fruits of research herein is that the prospect of applying ultra high strength materials for RC shear walls have been confirmed.

From now on the plan of studies is to conduct the experiments of PCa joints and steel concrete frames with the PCa, and to review the applicability of the large scale prefabrication method using ultrahigh strength materials for nuclear reactor buildings.

This study was conducted as a joint study under, "Research in Optimization of Nuclear Reactor Building Structure", by The Tokyo Electric Power Co.,Inc., Kajima Corporation, Shimizu Corporation and Takenaka Corporation. Also, appreciation is expressed to Sumitomo Metal Industries, Ltd. who offered sincere cooperation in the experiments.

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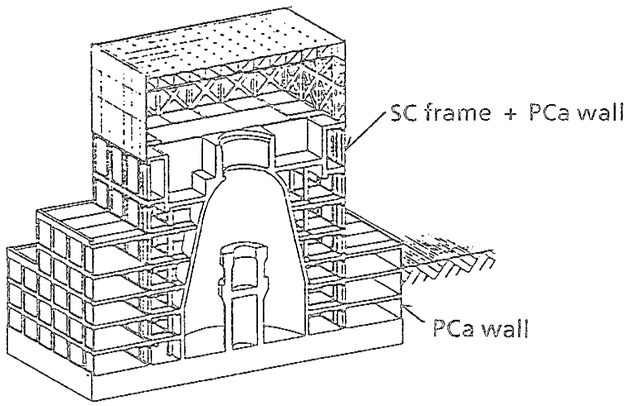


Fig . 1 New structure system of reactor building toward the future

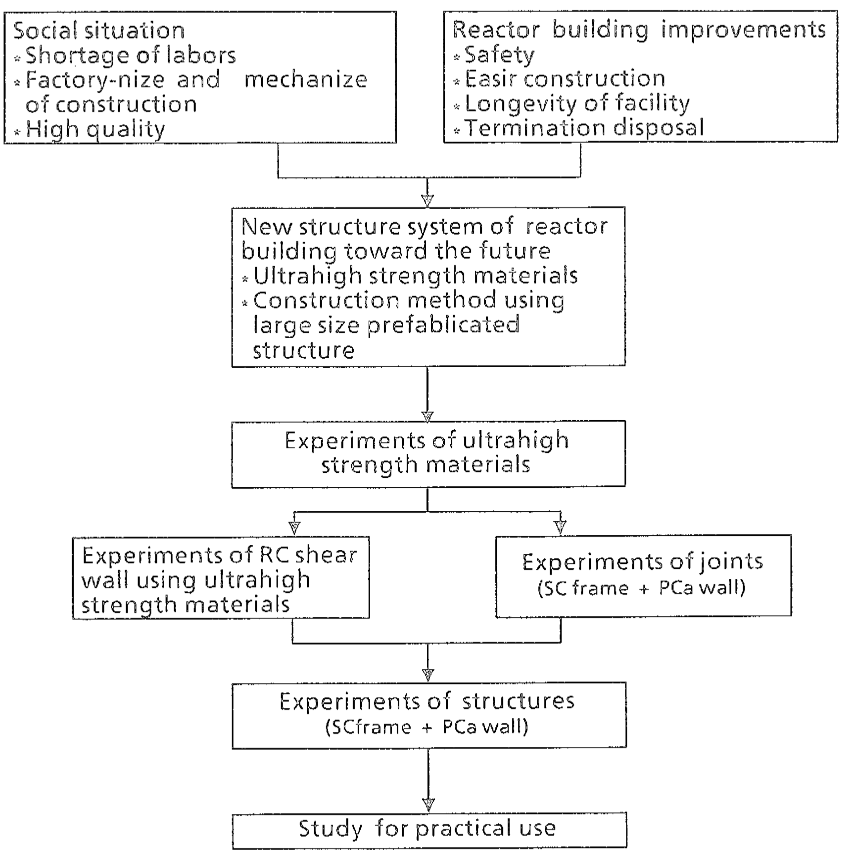


Fig . 2 Flow chart of study

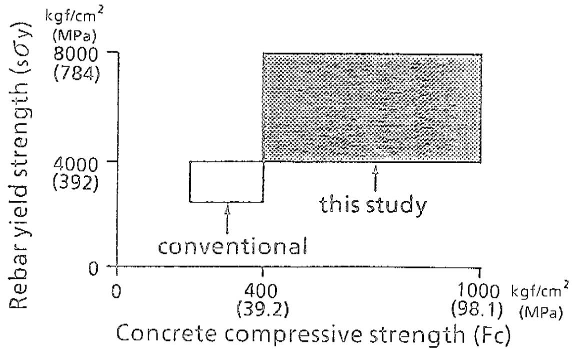


Fig . 3 Range of materials strength used in this study

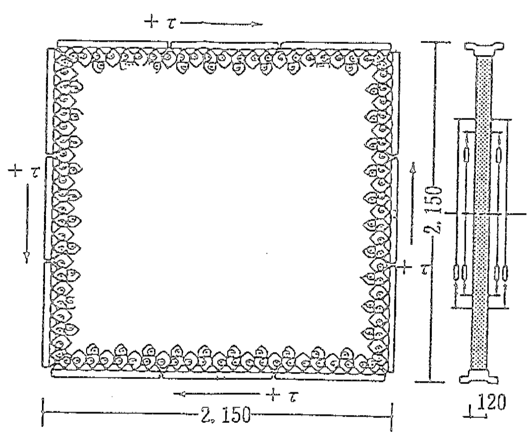


Fig . 4 Spacimen of pure shear test (unit : mm)

Table 1 List of spacimens for pure shear test

| Rebar quantity (Ps · sσy) | | Concrete compressive strength (Fc) | | Rebar yield strength (sσy) | | |
|---|---|---|---|---|---|---|
| kgf/cm² | (MPa) | kgf/cm² | (MPa) | SD40 (4000kgf/cm²) [392 MPa] | SD60 (6000kgf/cm²) [588 MPa] | SD80 (8000kgf/cm²) [785 MPa] |
| 48 | (4.71) | 400 | (39.2) | — | P48L6 | — |
| | | 700 | (68.6) | — | P48M6 | — |
| 72 | (7.06) | 400 | (39.2) | — | — | — |
| | | 700 | (68.6) | — | — | P72M8 |
| | | 1000 | (98.1) | — | — | P72H8 |
| 96 | (9.41) | 1000 | (98.1) | — | — | P96H8 |

Name of Spacimen : P ① 72 ② M ③ 8 ④

① : Pure Shear Test P, Bending Shear Test W

② : Ps · sσy = 72kgf/cm² (48, 72, 96)

③ : Fc = 700kgf/cm² → M (400→L, 1000→H)

④ : Name of rebar SD80 (4, 6, 8)

Ps : Rebar ratio

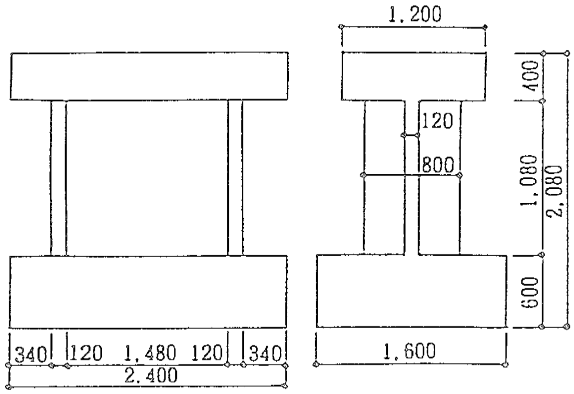


Fig . 5 Spacimen of bending shear test (unit : mm)

Table 2 List of spacimens for bending shear test

| Rebar quantity ($Ps \cdot s\sigma y$) | | Concrete compressive strength (Fc) | | Rebar yield strength ($s\sigma y$) | | |
|---|---|---|---|---|---|---|
| kgf/cm² | (MPa) | kgf/cm² | (MPa) | SD40 (4000kgf/cm²) [392 MPa] | SD60 (6000kgf/cm²) [588 MPa] | SD80 (8000kgf/cm²) [785 MPa] |
| 48 | (4.71) | 400 | (39.2) | W48L4 | W48L6 | — |
| | | 700 | (68.6) | W48M4 | W48M6 | — |
| 72 | (7.06) | 400 | (39.2) | — | W72L6 | — |
| | | 700 | (68.6) | — | W72M6 | W72M8 |
| | | 1000 | (98.1) | — | — | W72H8 |
| 96 | (9.41) | 1000 | (98.1) | — | — | W96H8 |

Shear span to length ratio (M/QD) : 0.8
Constant axial stress ($\sigma_0$) : 20kgf/cm² (1.96MPa)

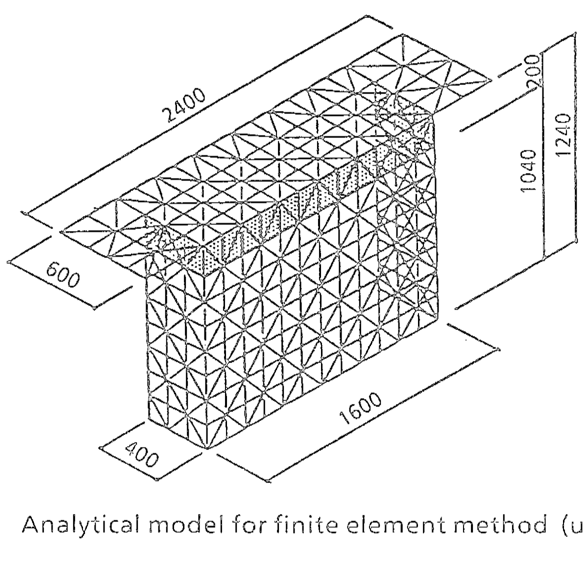


Fig . 6 Analytical model for finite element method (unit : mm)