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APPLICATION OF NEW FIBER REINFORCED COMPOSITE MATERIAL(NFM) TO SHEAR WALL OF CONCRETE STRUCTURES

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SUMMARY

Newly developed NFM in place of reinforcing steel bars is made of fiber reinforced plastics that is formed in two-dimensional grid shape. NFM, which has a non-corrosive characteristics, is developed for the purpose of improving the durability of reinforced concrete structures. To investigate the applicability of NFM to concrete shear walls, lateral loading test was carried out. As a result , it is cleared that NFM is an applicable material in place of reinforcing steel bars to shear wall of ordinary low/middle-rise concrete buildings.

INTRODUCTION

Recently, some researches have been going on for the utilization of high-performance fibers as concrete reinforcing materials with the purpose of improving the durability of reinforced concrete structures. There are two methods to make good use of high-performance fibers. One is to prevent the concrete from cracking by improving its tensile strength such as a carbon fiber reinforced concrete, and the other is to replace reinforcing steel bars themselves with new material. New Fiber Reinforced Composite Material (NFM) was developed from the viewpoint of the latter (Ref. 1).

NFM has already been used as reinforcing grids for shotcrete at several tunnels and reinforcements for concrete linings at a few tunnels (Ref. 2). However, there is no application of NFM as reinforcements for structural or non-structural members of buildings. So, to investigate the applicability of NFM to them, first of all, lateral loading test was carried out on the concrete shear walls reinforced by NFM. The purpose of this experimental study is to comfirm that the shear wall reinforced by NFM has enough strength and deformation capacity comparing with the shear wall reinforced by deformed steel bars (Ref. 3).

FEATURES OF NFM

NFM is a new composite material for reinforcing concrete, which is made of high-performance continuous glass and/or carbon fibers impregnated with resin, and it is formed in grid shape by the filament winding method as shown in Photo 1. Its features are shown in Table 1. Fig. 1 shows the relationship between tensile force and strain of deformed steel bar D6, NFM G6 and NFM H6. In NFM H6, the tensile force - strain relationship becomes non-linear and shows the similar phenomenon as the yielding of a reinforcing steel bar by combining different kinds of fibers. It is called "Hybrid Effect". Properties of material, properties of anchorage and lapped splice joint, fatigue properties, shearing properties and so on are described in reference 1.

Table 1 Features of NFM

• Non-corrosive	• Improving the durability of concrete structure under severe condition
• Using continuous fibers	• Effective use of fibers
• Enough strength at the cross points	• Sufficient anchorage to concrete • Lapped splice joint
• Light in weight (specific gravity ≒ 2) • Forming in complicated shapes	• Improving work productivity in the field

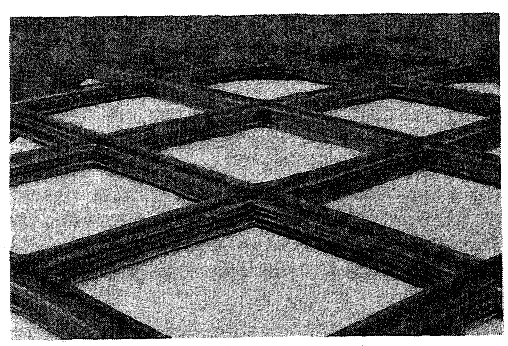

Photo 1 New Developed Material NFM

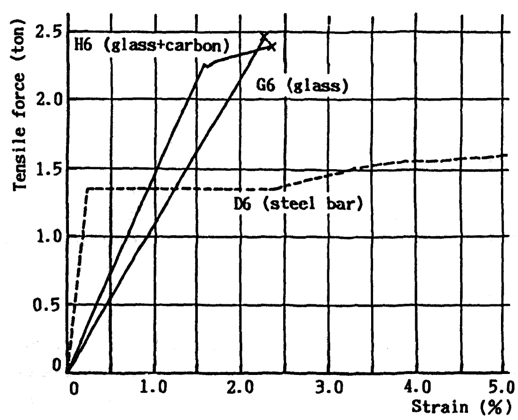

Fig. 1 Load-Strain Relationship

TEST SPECIMEN

Test specimens were provided 3 types as shown in Fig. 2, 3, 4 and 5. Fig. 2 shows the details of the specimen's configuration and reinforcement distribution of columns and beams. The column is 20cm by 20cm in dimensions, the wall-beam 20cm by 82.5cm and the shear wall 87.5cm by 180cm, of which the thickness is 7.5cm.

Columns and beams are reinforced by conventional deformed steel bars D6, D10, D13, D16 and D22. Wall part is reinforced by deformed steel bars or NFM which is made of impregnated glass and carbon fibers with resin. In No.1 *specimen, the wall is reinforced by deformed steel bars D6 arranged 100mm* intervals (Refer to Fig. 3). In No.2 specimen, the wall is reinforced by 100mm grid NFM which has same maximum tensile load as steel bars D6 (Refer to Fig. 4). In No.3 specimen, the wall is reinforced by 50mm grid NFM which has 50% maximum tensile load of steel bars D6 (Refer to Fig. 5).

Fig. 6 shows the relationship between tensile force and strain of reinforcements for walls. In addition, the deformed steel bars D13, which were used as the main reinforcing bars of the columns, had the yield strength of 3,630 kg/cm^2, the deformed steel bars D6, which were used as the hoops, had the yield strength of 4,110kg/cm^2.

The compressive strength of the base concrete was 243kg/cm^2 and that of the other parts (i.e. columns, wall-beam and wall) was 233kg/cm^2 (No.1 and No.2) or 213kg/cm^2 (No.3).

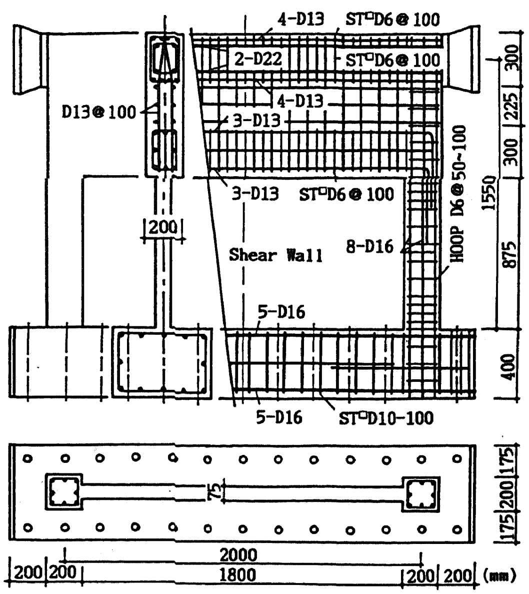

Fig. 2 Specimen

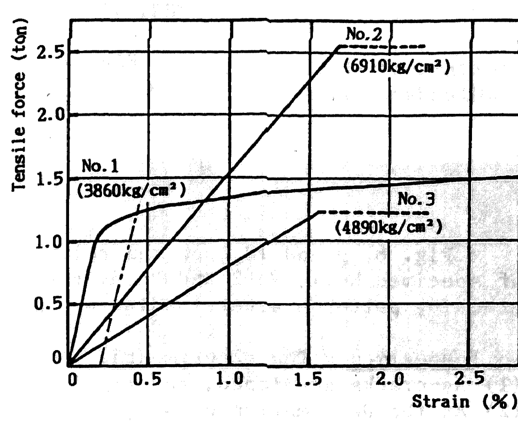

Fig. 6 Load-Strain Relationship of Reinforcements for Wall

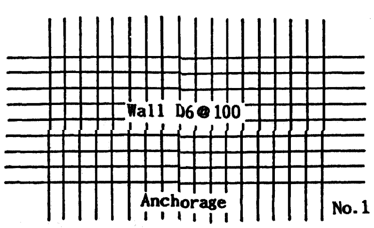

Fig. 3 Reinforcements for Wall(No.1)

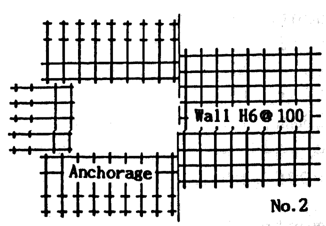

Fig. 4 Reinforcements for Wall(No.2)

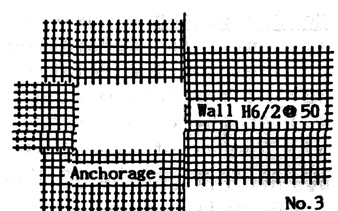

Fig. 5 Reinforcements for Wall(No.3)

TESTING PROCEDURE

Fig. 7 shows the loading system. The specimen was placed virtically in the loading rig. The concrete base of specimen was firmly fastened to the base beam of the loading rig.

Lateral load was applied cyclically at the upper sides of wall-beam by the two jacks to supply the uniform shear stress at the wall. At the same time, axial load was always applied at the top of the columns vertically. The axial load of 16.5ton is nearly equal to one-tenth of the compressive strength of the columns.

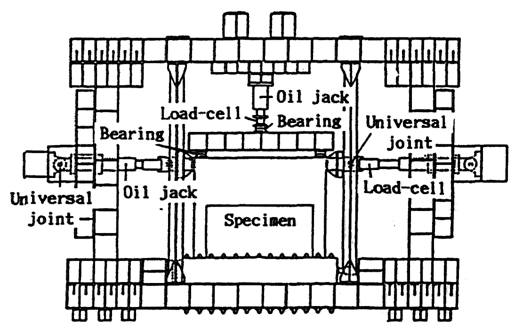

Fig. 7 Loading System

TEST RESULTS

Fig. 8, 9 and 10 show the relationships between lateral load and deformation of specimen No.1, No.2 and No.3, respectively. And Photo 2, 3 and 4 show the cracking patterns after loading of specimen No.1, No.2, No.3,respectively, too.

<u>No.1 specimen</u> The experimental behaviors of No.1 specimen are shown as follows.
(1) As cracks developed, the rigidity decreased.
(2) At the deformation of 4mm, yielding occured in tensile reinforcementsoof column.
(3) At the deformation of 5mm, lateral load reached the maximum.
(4) At larger deformation level, lateral load decreased gradually following the compressive failure of concrete at the base of column and cornerof wall.

<u>No.2 specimen</u> The experimental behaviors of No.2 specimen are shown as follows.
(1) Until the defomation of 12mm, No.2 specimen showed almost same load - deformation relationship as No.1 specimen.
(2) At the deformation of 12mm, breaks of NFM started.
(3) At the deformation of 13mm, the resistance to lateral load failed suddenly.
(4) Number of cracks in the wall of No.2 specimen is less but each cracks is wider than cracks in No.1 specimen.

<u>No.3 specimen</u> The experimental behaviors of No.3 specimen are shown as follows.
(1) Until the deformation of 5mm, No.3 specimen showed almost same load - deformation relationship as No.1 specimen.

(2) At the deformation of 8mm, lateral load reached the maximum, breaks of NFM started and the resistance to lateral load failed suddenly.
(3) Cracks in the wall of No.3 specimen are dispersed rather than those of No.2 specimen.

Specimens reinforced by NFM showed almost same behaviors as the specimen reinforced by steel bars until the translation angle of 1/100.

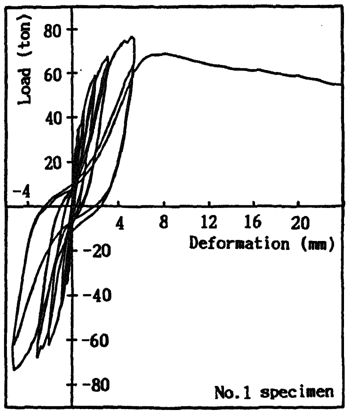

Fig. 8 Load-Deformation Relationship(No.1)

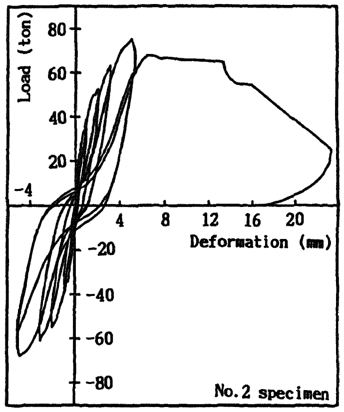

Fig. 9 Load-Deformation Relationship(No.2)

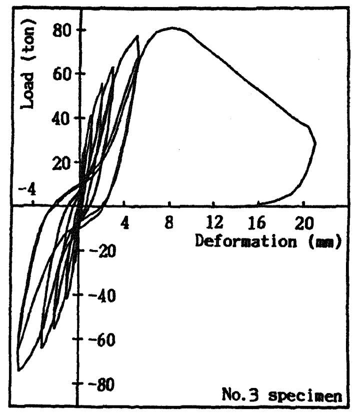

Fig. 10 Load-Deformation Relationship(No.3)

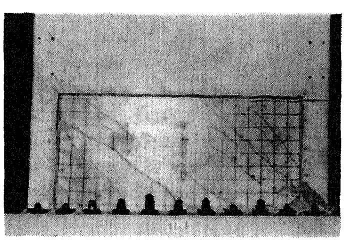

Photo 2 Crack Pattern (No.1)

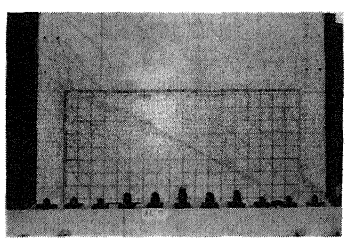

Photo 3 Crack Pattern (No.2)

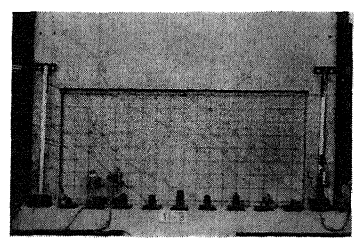

Photo 4 Crack Pattern (No.3)

CONCLUDING REMARKS

NFM is a newly developed composite material for reinforcing concrete. To investigate the applicability of NFM to concrete shear walls, lateral loading test was carried out. As a result, the concrete shear walls reinforced by NFM showed almost same strength and deformation as the concrete shear wall reinforced by steel bars until the translation angle of 1/100. So, it is cleared that NFM is an applicable material in place of reinforcing steel bars to shear wall of ordinary low/middle-rise concrete buildings.

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