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BEHAVIOR OF NONSTRUCTURAL ELEMENTS INSTALLED ONTO FULL SCALE STEEL BUILDING

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SUMMARY

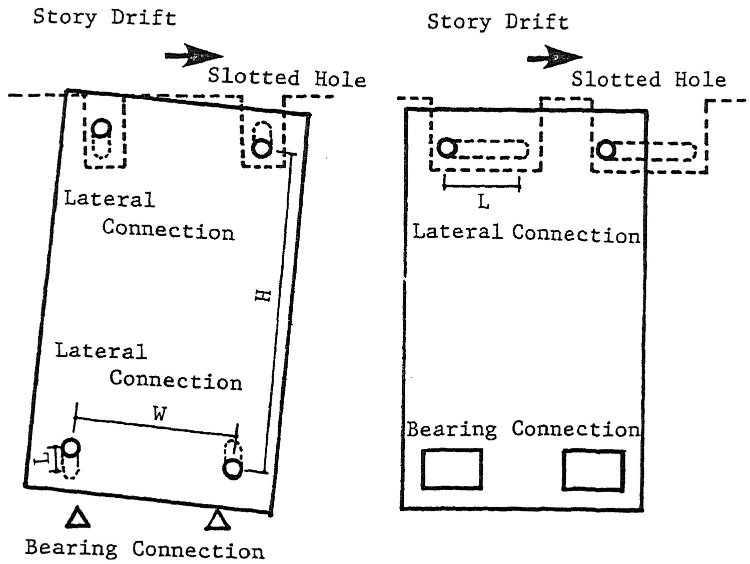
This paper describes the results of aseismic test of nonstructural elements. Movement of rocking type curtain walls at static loading test agreed with the geometrical analysis. In the static loading test one of the GFRC panels was cracked at early stage(story drift 1/125) than design story drift. The force induced by deflection of high modulus sealant prevented a panel from the freely rocking. The force is comparable to 150 percent of panel weight. In the case of light weight cladding, modulus of sealant could affect the free rocking motion of cladding.

INTRODUCTION

The last phase on the full scale steel structure tests in the U.S.-Japan Cooperative Research Program aimed at confirming the seismic behavior of non-structural elements. Before and after the installation of internal partitions and external cladding free and forced vibration tests were carried out to determine the effects of these nonstructural elements on dynamic properties of structure. The main portion of the tests was static loading test. This paper describes the comparison of the seismic motion of nonstructural elements between the assumption in seismic design and the results of static loading test.

TEST METHOD

The Japanese specimens were precast concrete (PC) curtain walls, glass fiber reinforced concrete (GFRC) panels and other kinds of nonstructural elements, which represented the common construction practice in Japan. These elements were installed onto 2nd - 6th story of the moment resistant steel frame. PC curtain walls were installed onto 2nd-4th story on the frame of loading direction. GFRC panels were installed opposite side of PC curtain walls. Loading jacks applied one direction of horizontal displacements on the floor (from $\pm 1/1000$ to $\pm 1/40$) which resulted in approximately the same story drift at each level. But horizontal displacements of 3rd and 6th floor were reduced to $1/\sqrt{2}$ (about 0.7) of other floors displacements. Here after, we would like to use the ratio of story drift and story height as an index of loading progress.



ROCKING TYPE

Movable length of slotted hole (L) is about W/H of story drift.

SWAYING TYPE

Movable length of slotted hole (L) is about twice of story drift.

Fig.1 Mechanisms of Drift Accomodation in Cladding Design

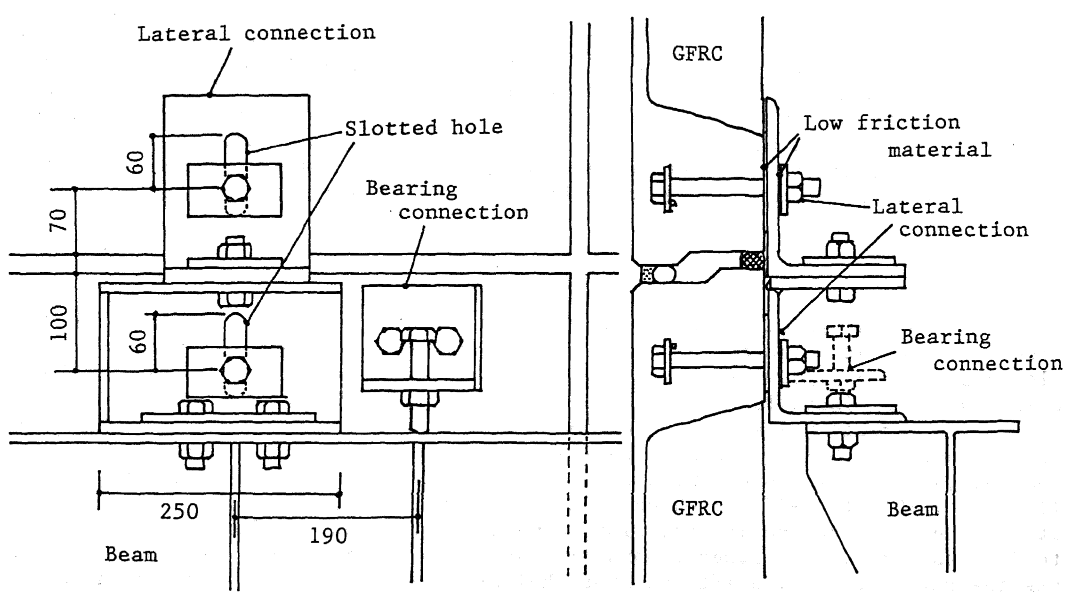


Fig.2 Connection Detail of GFRC Panel on Japanese Side

MECHANISM TO ACCOMMODATE STORY DRIFT

In Japan, two types of mechanisms which enable PC and GFRC panels to accommodate story drift are utilized: swaying type and rocking type(Fig.1). The sway mechanism requires the connections with horizontal slotted holes to isolate the story drift. On the contrary, the rocking mechanism requires the connections with vertical slotted holes to accommodate the panel's rotation. In this test, PC and GFRC panels adopted the rocking mechanism the most common construction practice in Japan. Fig.2 shows the connection detail of GFRC panels on Japanese side. The connection was composed of vertical slotted holes, bolts and low friction materials(stainless steel plate and teflon sheet). The lateral connection can move in a vertical direction and the bearing connection supports panels dead load.

GEOMETRICAL ESTIMATION OF PANELS MOVEMENT

The movement of panels can be derived from the geometrical relation of the panel's rotation. The equations describe the movement of GFRC panel on the assumption that the panel is rotated around point P, the lateral connection moves only in vertical direction and the bearing connection (Q) moves only in a horizontal direction.

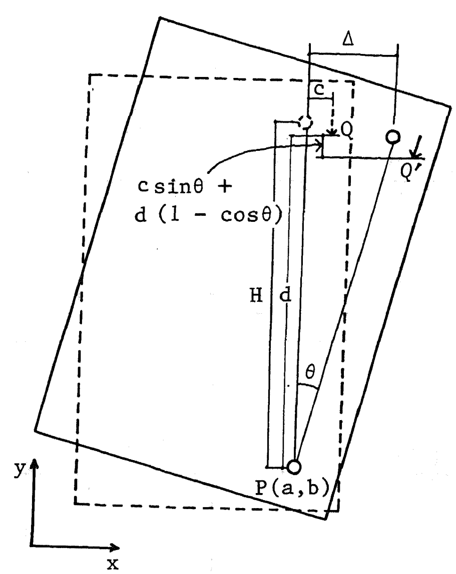
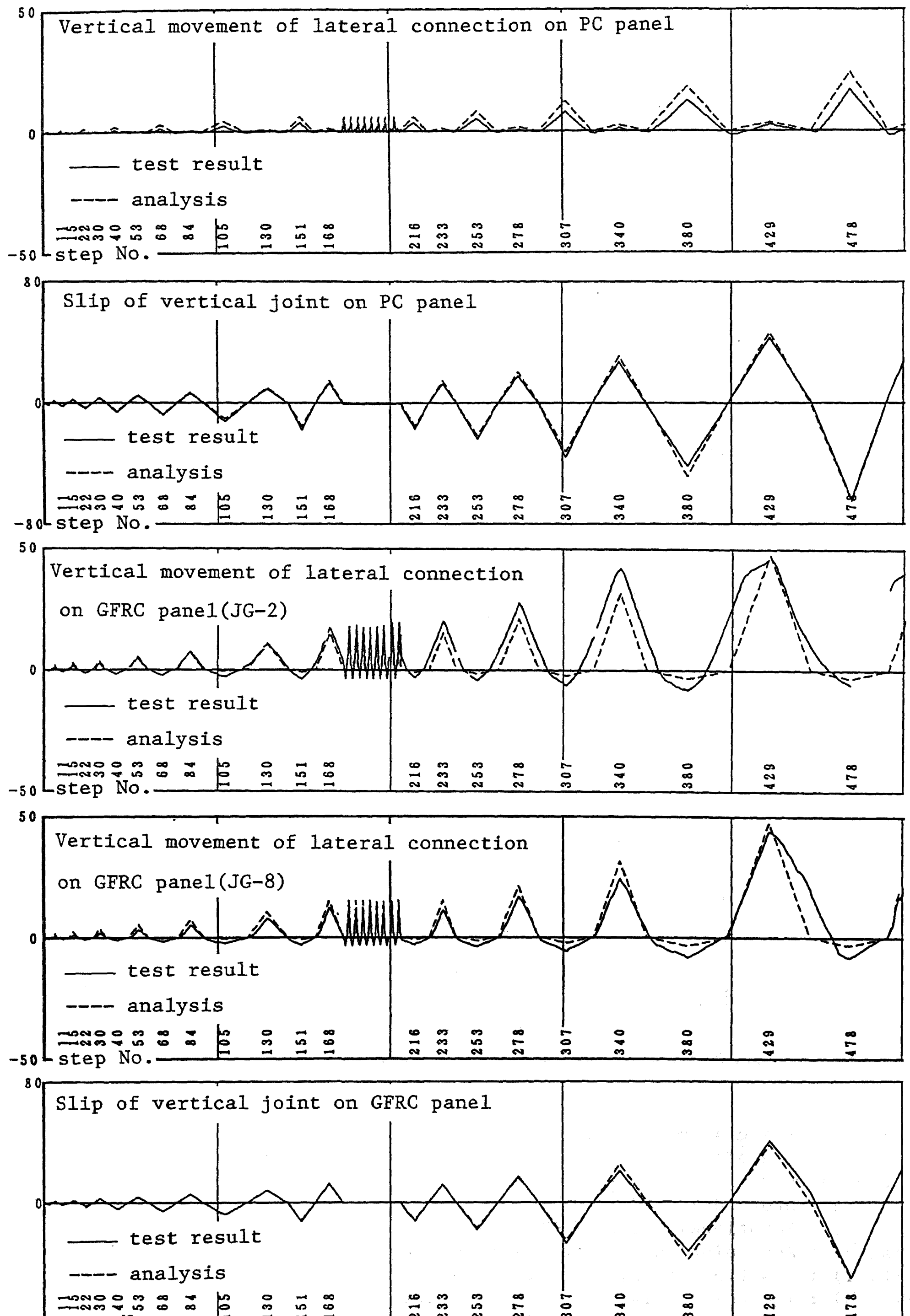


Fig.3 Rocking Motion of GFRC Panel

$$X = (x - a)\cos\theta + (y - b)\sin\theta + a \qquad (1)$$
$$Y = -(X - a)\sin\theta + (y - b)\cos\theta + b + c\sin\theta + d(1 - \cos\theta) \qquad (2)$$
$$\sin\theta = \Delta/H \qquad (3)$$

Δ : Story drift
θ : Rotational Angle of GFRC Panel
(x, y) : Any point on GFRC before movement
(X, Y) : Position of (x, y) after rotation
$P(a, b)$: The point P is the center of rotation
c, d : horizontal and vertical components of the distance among points P and Q.

Fig.4 Comparison of analysis and test results in PC panel and GFRC panel.



In a similar way, required length of slotted hole can be conducted. Required movable length of PC connections is calculated at 32mm on the assumption that design story drift is 1/40. Actual length of a slotted hole was designed at 35mm. As for GFRC panels, required movable length is resulted at 12mm under design story drift 1/120. Actual length was designed at 50mm, adding the enough tolerance.

TEST RESULTS

The fig.4 shows displacement versus loading step No. relation. A solid line indicates test result and a broken line indicates analytical one. The test results on the motion of PC panels fairly agreed with the design assumption. The motion obtained from the test shows rather less than calculated value. On the corbel of a PC panel, the first cracking began at 1/90. The mis-construction that the slotted hole plate was attached upside down caused the early stage failure prior to design story drift 1/40. Failure drift 1/90 agreed with the actual movable length of mis-attached connection. The test results on the motion of GFRC panel(JG-2) did not agree with the design assumption in comparison of case of PC panels. On the motion of panel JG-8 it agree with the design assumption.

On the GFRC panels(JG-8 and JG-9) sealed with silicone sealant, the cracking began at 1/125 as shown in fig.5. As GFRC panels have sufficient movable length, it is considered that the force introduced by deflection of high modulus sealant or friction of a slotted hole prevented from the free rocking motion. The force of 760kg was induced by slip of vertical joint sealant and compression of horizontal joint sealant at 1/125. The force is comparable to 150 percent of GFRC panels weight (500kg).

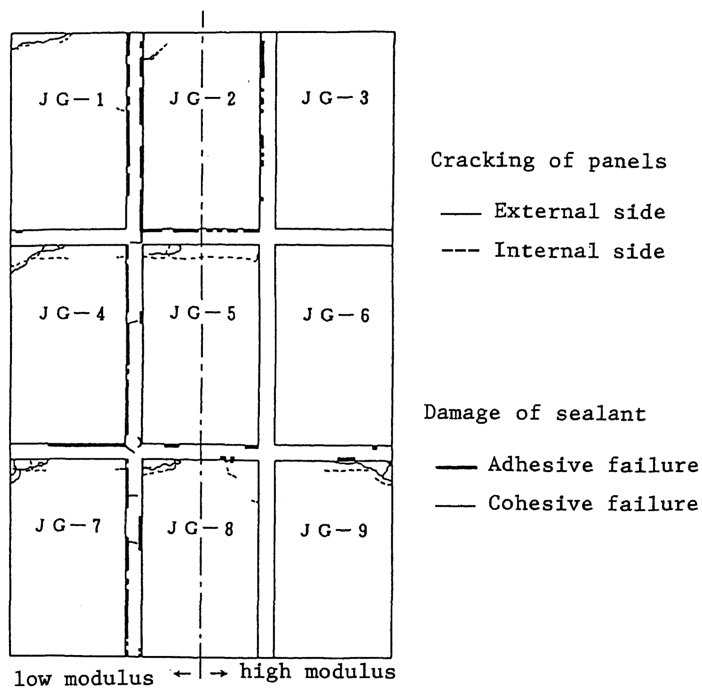


Fig.5 Cracking on GFRC panels

CONCLUSIONS

Concluding remarks are as follows;

1) From the viewpoint of seismic design method of PC and GFRC panels adopting the rocking mechanism, the geometrical estimation could be considered to provide allowable story drift.

2) In the case that the cladding is light, high modulus sealant could affect the free rocking motion of cladding.

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