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EXPERIMENTAL STUDY OF AXIAL STABILITY OF RC RECTANGULAR COLUMN UNDER HIGH AXIAL FORCE WITH HORIZONTAL LOAD

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SUMMARY

To find causes of serious damage of reinforced concrete buildings in the Republic of Turkey, we investigated in regions where it had suffered heavy damage as it was attacked by recent large earthquakes.
A lot of RC multiple dwelling house were lost, and the layer or the whole collapsed, and, as a result, extremely a lot of lives were lost.
As a result of investigation in Turkey, we guessed the main cause of the collapse of buildings might be induced by axial destruction of columns by the large compression load, not the one depending in the P-δ effect generally thought.
However, it was difficult to find a lot of negligible damages which became the sign or the evidences so that buildings may destroy it extremely and completely in the quake-stricken area.
Then, we tried to reproduce this phenomenon with the column specimens of the specification generally used in these buildings, and to find the condition that the phenomenon occurs.
The result of this experiment showed that the axial deformation of the column became unstable within 1cm, and the sudden debacle was shown in the case with a high axial force ratio according to the number of very few, horizontal cyclic deformations.

INTRODUCTION

We investigated damage in buildings in detail in the stricken area in the Dinar earthquake in 1995, the Adana-Ceyhan earthquake in 1998, and the Izmit earthquake in 1999. In these earthquakes, a great number of reinforced concrete construction multiple dwelling houses had received serious damage.
About several caused the layer collapse by a lot of buildings it was not possible to know, became so-called pancake destruction the most important example, and was lost a lot of lives here. A main purpose of this investigation of us is to ascertain the cause of such a collapse, and, in addition, to propose the method of preventing this phenomenon. However, it was difficult to find evidences to show the causes directly in the stricken area.
Because, the damage of the structural member was severe, and we found few clues which showed the cause in the building the layer collapse had been caused. In general, in the quake-stricken area, we can find evidences to show the cause from buildings where damage at various levels were received.

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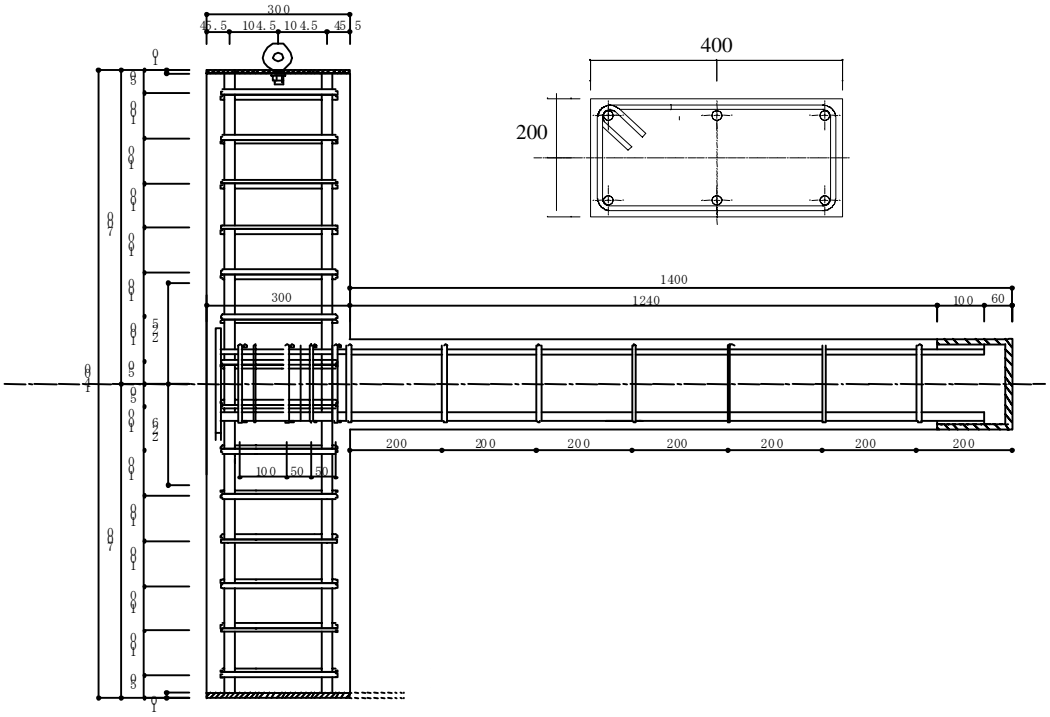
However, the damage of the structure part was divided to a negligible example and collapsing what in the example in Turkey, and it was difficult to find evidence to presume the cause.
But, we were able to find some interesting phenomena to very few, light damage examples at the Adana-Ceyhan earthquake in 1998.It was a phenomenon of main reinforcement's the cover concrete's peeling off, and showing the buckling in the capital of a rectangular section column. This seemed a caused plastic hinge by the bending stress of the repetition in the weak direction of the column.
We were able hardly to find damage on structural members other than this column in any building where this phenomenon had appeared. However, faint peculiar cracks which appear to the compression side concrete surface of the column are excluded.
Moreover, we were able to confirm most buildings where the layer collapsed had fallen vertically in the stricken area of the Izmit earthquake in 1999.
We came to believe that it was the main cause that columns had lost the axial bearing capacity in the building which collapsed the layer or collapsed completely from the above-mentioned result.
Then, to confirm this judgment, we experimentally reproduced this phenomenon, and examined the condition that the phenomenon occurs. We report on the content as follows.

EXPERIMENTS

Specimens

We selected shape and the reinforcing bar arrangement of the specimen referring to columns used in buildings which existed in Turkey.



In the ruined area of two earthquakes, we have tried to collect the drawings of the building as much as possible. To our regret, we could not obtain the drawing of the collapsing building.
However, we could understand a structural feature in the multiple dwelling house buildings by collecting a lot of drawings. The characteristic concerning the structure of a general multiple dwelling house building is as follows.
The design plan is given priority from the beginning, and the column is arranged along this result.
It has the same directionality as the wall, and as for most columns, it is a flat section configuration, and the example which uses a square section is few for the above-mentioned reasons.
There are few vertical slabs except the elevator shaft, most of the wall is made from the midair brick, and they are not anchored in the structure at all.
The column of the housing complex of five stories on an Asian side of Istanbul has been extracted based on the above-mentioned examination result. However, the vicinity of length was adjusted to 2/3 of things for the reason for the capacity of the loading frame.
The section configuration and the appearance of the bar arrangement are shown in Figure.1. This experiment was executed for two years. It is the same and the bar arrangement of main reinforcement is also same as the shape of all of the 14 specimens. Both of longitudinal and lateral reinforcements are round shape steel bar. Concrete strength aimed at 10N/cm^2 based on the result of the investigation. The characteristic of the material actually used was a mean value, concrete compressive strength became 12-17MPa, and the yield strength of reinforcing bars was 300MPa.
The specifications of specimen are shown in Table.1. Name of specimen are distinguished one digit as 1st series, and two digits as 2nd year. The concrete strength of the latter was higher than that of the former. However, strength of the reinforcing bar did not have the remarkable difference between the two.

Table.1 Specification of Column

Name	Longitudinal Bar	Hoops	Hoop space(mm)	Share-reinforcement Ratio (%)
100-1	6-16(mm)	9(mm)	100	0.318
100-2	6-16	9	100	0.318
100-3	6-16	9	100	0.318
200-1	6-16	9	200	0.159
200-2	6-16	9	200	0.159
200-3	6-16	9	200	0.159
100-11	6-16	9	100	0.318
100-12	6-16	9	100	0.318
100-13	6-16	9	100	0.318
100-14	6-16	9	100	0.318
200-11	6-16	9	200	0.159
200-12	6-16	9	200	0.159
200-13	6-16	9	200	0.159
200-14	6-16	9	200	0.159

Table.2 Loading Data

Name	Axial Force(kN)	Axial Force Ratio	Rotating Angle (Max)	Number of Loading
100-1	274□¨431	0.26□¨0.41	1/49	94
100-2	353	0.41	1/49	20
100-3	392	0.45	1/58	33
200-1	235 to 353	0.27 to 0.41	1/35	61
200-2	510	0.49	1/78	46
200-3	588	0.56	1/86	36
100-11(40C+)	441	0.37	1/45(C)	29
100-12(45C)	539	0.44	1/50(C)	14
100-13(45E)	539	0.44	1/50	33
100-14(40N+)	441	0.38	1/45	21
200-11(45E)	539	0.43	1/50	17
200-12(40C+)	441	0.36	1/45(C)	20
200-13(35C)	441	0.38	1/50(C)	56
200-14(40C)	441	0.38	1/50(C)	31

The axial force ratio, the loading schedule and Final Loading cycle number of each specimen are shown in Table.2. In this table, the character in parentheses after the name of the specimen means a constant, by "C" horizontal amplitude, and "E" means various amplitudes were given. Moreover, "N" means there was poor anchorage in the capital of longitudinal bar. This specimen was made to simulate actual columns that could find easily in disastrous area.

Testing

We added the cyclic flexure moment to the capital controlling angle of rotation of member with constant axial compression in the column specimens. The axial force ratio of the column was a ratio of axial compression to the maximum strength requested from concrete strength. This ratio was adjusted to 034-0.56 in this experiment and axial force was decided. Because many were 20cm intervals in the site investigation, two kinds of hoop intervals were tried in this experiment though the horizontal reinforcing bar was 10cm interval in the drawing and specification. The experiment was executed by using the specimen of 14 in total for two years.

The cyclic flexure force was controlled by the angle of rotation of column member θ. It is a ratio to length h of the column of the horizontal deformation δ (floor height), and it corresponds to the distortion angle between floors.

We chose two different repetition methods. One is a method of an increase gradually, and other one is a method of mixing big and small amplitude (E in table 2). In addition, two different methods are included in the former. One is a method of gradually increasing angle of rotation of member from 1/400, and another is a method to reach maximum value 1/50 at an early stage then to repeat with constant amplitude (C in table 2). In each method, the value of the maximum angle of rotation of member θ was 1/50 or more.

RESULTS

The relation between bending moment M and the angle of rotation of member θ is shown in Figure.2 about the experiment result of each specimen. Moreover, the relation between axial deformation Δ and the bending moment of the column are shown in Figure.3 and Figure 4.

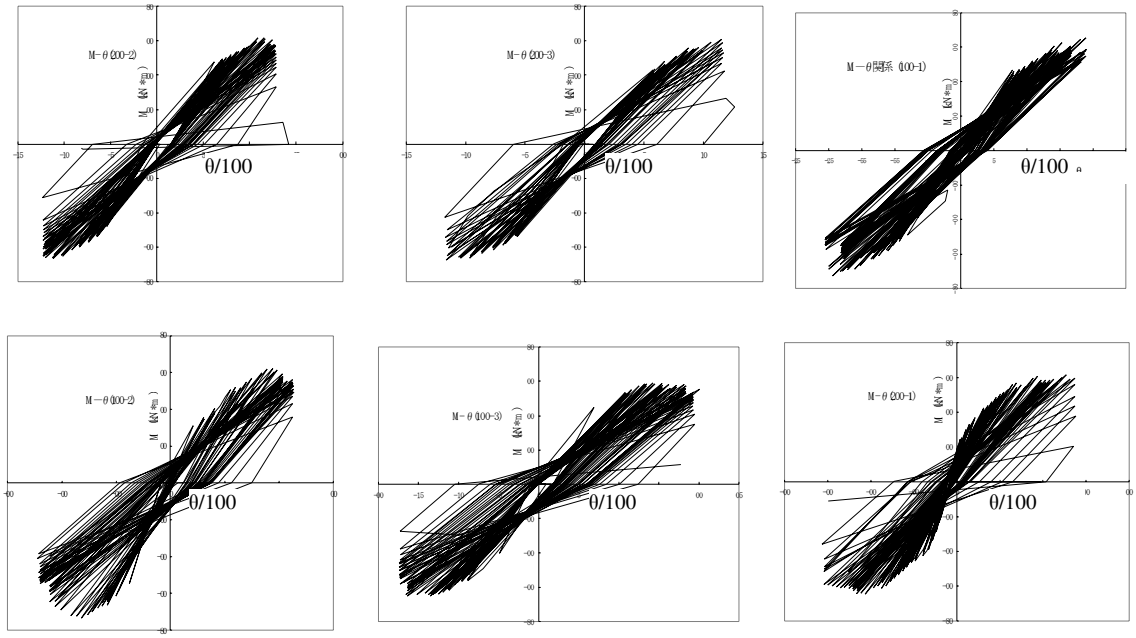


Fig. 2 M-θ Relationship

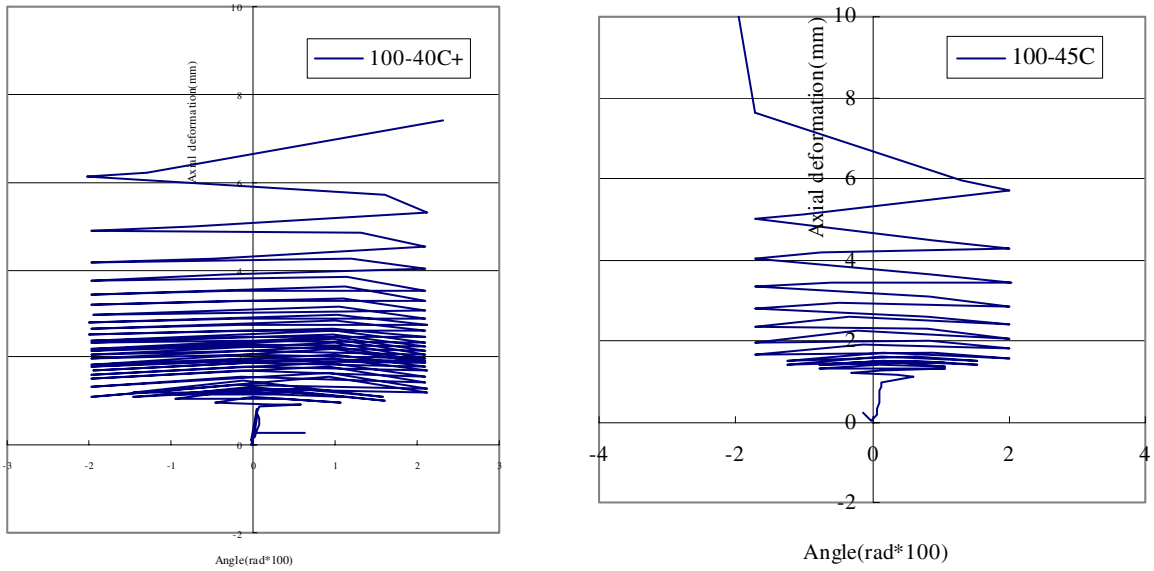


Fig.3 Axial deformation - Rotation θ Relationship

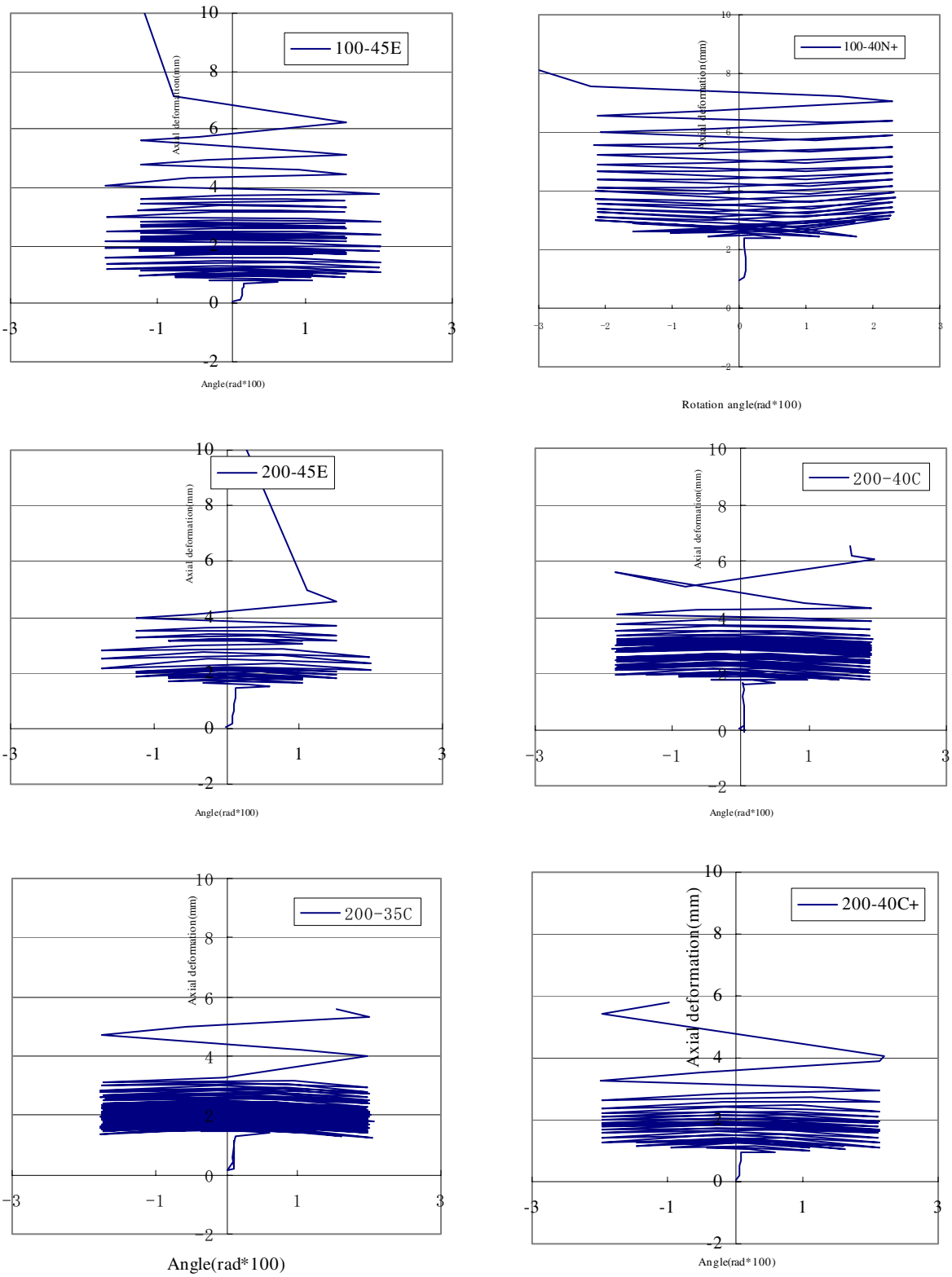


Fig.4 Axial deformation - Rotation θ Relationship

It is understood to grow more rapidly, and to become unstable though the shrinkage of the column advances slowly first than these results. In addition, to clarify the progress of axial deformation (shrinkage)Δ of columns, the relation between Δ and cycle number when the bending load at each loading cycle is 0 is shown in Figure 5.

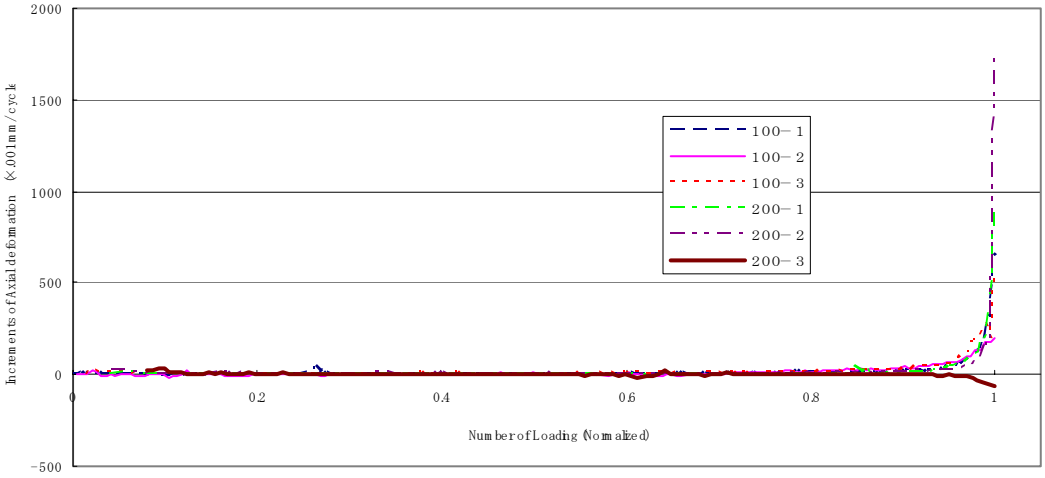


Fig. 5 Relationship between Increment of axial deformation and Number of bending

When the axial force ratio is large, it is clear that comparatively small horizontal transformation frequency makes the column unstable from this figure. The tendency that the repetition by a big, horizontal deformation also brings the collapse forward is seen. The amount of shrinkage became unstable about half compared with the specimen of 10cm as for the one of 20cm in the interval of the hoop, and the size was 5mm or less at the critical point. If increments dΔ of shrinkage amount Δ of the column at the one cycle were compared by each specimen, all specimens became unstable soon when both of the 1mm/a cycle was exceeded. In addition, it was able to be forecast that destruction would be caused soon if 0.2mm/cycle/cycle was exceeded if it's increment was seen. Destruction started suddenly at the close in dramatic form. However, the crack in the capital did not stand out immediately before the phenomenon's occurring, and it was difficult in watching to forecast destruction. Finally, we could observe the same phenomenon as the content witnessed in the quake-stricken area such as buckling of main reinforcement and flaking off of concrete.

CONCLUTIONS

The collapse process which had been guessed from the site investigation of the RC column of a flat section configuration by this experiment was able to be reproduced. Seemingly negligible damage of shrinkage of the column of only about 5mm or less could confirm the possibility of leading sudden destruction soon existed.

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There are a lot of parameters of concrete strength, the axial force ratio and the reinforcing bar, the cyclic flexure frequency, and the amplitude, etc. to explain this phenomenon, and it is necessary to examine these all and elucidate it.