STATIC AND DYNAMIC RESPONSE ANALYSIS OF A R/C BUILDING DAMAGED BY MIYAGI-KEN-OKI EARTHQUAKE OF JUNE, 1978

by Tomoya NAGASAKA[1]

SUMMARY

A reinforced concrete building with no aseismatic wall or bracing in the 1st story, severely damaged by Miyagi-ken-oki, Japan Earthquake of June, 1978, was statically and dynamically analyzed to seismic forces. From the analytical results the following conclusion was derived: the design of such a building based simply on the static seismic coefficient method might involve the collapse of the structure to strong motions unless sufficient ductility is given to the columns in the 1st story, because they have generally only a little extra bearing capacity for the design shear.

INTRODUCTION

Miyagi-ken-oki, Japan Earthquake of June, 1978 brought about serious damages to many buildings in Sendai and the outskirts of Miyagi prefecture. Particularly it arrested the author's attention that the several R/C buildings with few aseismatic wall in the 1st story had suffered severe damages.

In this paper one of such buildings was statically analyzed to assumed horizontal forces by the author's method1) which was obtained by developing thê conventional beam theory to be able to analyze R/C framed structures to the inelastic range. Then, on the basis of the results it was dynamically analyzed to the accelerograms of the earthquake in another district in Sendai.

ANALYTICAL PROCESS

Static Analysis The building chosen as the object to study was designed following the former "Recommendation and Comments for Structural Calculation of R/C Structures" by A.I.J., Nov., 1962, which was three stories and one bay in either of two directions perpendicular to each other and has earthquake resistant walls in the 2nd and the 3rd story but not any one in the 1st story. Fig. 1 shows the outline of this building. Two parallel frames in the same direction were analyzed as a plane frame to horizontal forces by joining them with rigid bars hinged to two opposite nodes, and the walls were displaced by diagonal bracings equivalent in shear stiffness of story to them as shown in Fig. 2. In order to apply the author's method to the structure, each of the structural members was longitudinally and transversally divided into several elements as shown in Fig. 3 and Table 1, and the inelastic behaviors of concrete, reinforcing steel bar, and interaction between bar and concrete with "composite spring system" used for the elements with bars are shown in Fig. 4. As for loading, the long time vertical loads were applied to simulate the actual condition as well as possible befor horizontal loading, and then horizontal loads were step by step applied to each node except for the supporting points at the increment of 1.5t in terms of base shear.

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[1] Assoc. Professor, Faculty of Engineering, Tokai University, Tokyo

Dynamic Analysis For the vibration model, one mass system was adopted, because in the N-S direction, where the building was severely damaged, the rigidities of the 2nd and the 3rd story were extremely large owing to earthquake resistant walls, in comparison with that of the 1st story, as it was shown by the static analysis. The elastic-plastic behaviors of the spring were idealized by "degrading tri-linear model"[2], as the basic skeleton curve is shown in Fig. 5. Two sets of spring system were used herein; one was obtained from base shear(Q_B)-1st story displacement(δ_1) relation, named "case 1" and the other was obtained from base shear(Q_B)-2nd story displacement(D_2) relation, named "case 2"; and the characteristics values are given in Table 2, which were determined from the results of the static analysis. The total weight of the building was about 461t. T in Table 2 is the natural period of each system. For the viscous damping coefficient of the systems the value of o.o2 was given. The accelerograms, N-S component and E-W component, recorded at the 1st floor of Tohoku University[3] during the earthquake were used scaling as the input waves for the response analysis, in which "Runge-Kutta method with the fifth order truncation error was adopted with the incremental computation time of 0.005 sec..

Although the author carried out the analysis of this building for both of N-S and E-W direction, only the results of N-S direction are discussed in this paper out of space consideration.

RESULTS AND CONSIDERATION

Fig. 6 to 8 show the results obtained by the static analysis, where in Fig. 6 the numerals attached to the symbols indicate the incremental step no. of horizontal loads at which some yielding or failure occurred. From these figures the following observations were found: in N to S loading and S to N loading, there is not a significant difference in both of shear displacement relation and failure process; the shear displacement relations can be idealized by degrading tri-linear model; failure or yielding concentrated at the 1st story, while in the 2nd and the 3rd story no significant damages occurred; the maximum bearing capacity of the building was determined by the flexural failure at the top of the columns in A frame; and the maximum base shear coefficient was 0.208, only a little larger than the design one presumed to be the value of 0.018. Further, the maximum response displacement remarkably exceeded the one at which the flexural failure was supposed to occur by the static analysis.(see Table 3 by dynamic analysis) The above observations are fairly correspondent with the actual damage conditions.

REFERENCES

1) T. Nagasaka, "A Theoretical Study on Restoring Force Characteristics of Reinforced Concrete Framed Structures", Proc. of the Faculty of Engineering, Tokai University, Vol. 5, 1978, pp. 1-27.
2) Y. Fukada, "Study on Restoring Force Characteristics of Reinforced Concrete Buildings (Part 1)", Proc. of Kanto Branch of A.I.J., Nov., 1969, pp. 121-124 (in Japanese).
3) Building Research Institute, Ministry of Construction, Government of Japan, "Accelerograms of Strong Motion Earthquake, 12 June, 1978.

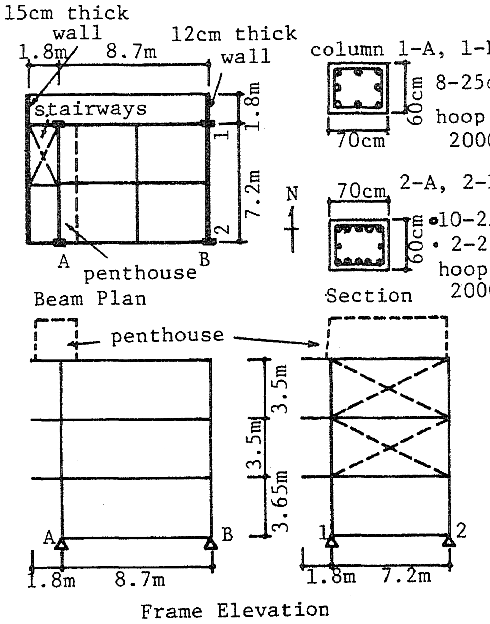

Fig. 1. Outline of Analyzed Building

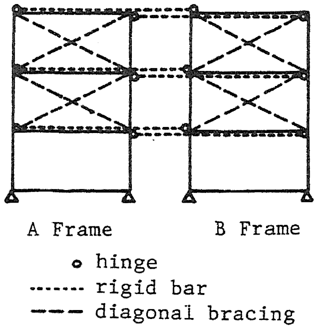

Fig. 2. Analytical Idealization

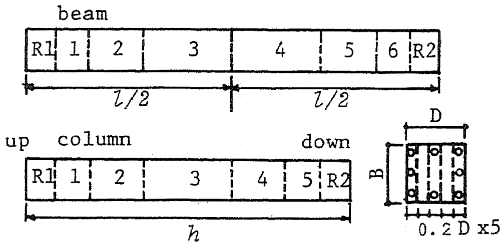

Fig. 3. Division of Members

Table 1. Longitudinal Division Ratio, γ, of Members

Floor Level	Beam R1, R2	Beam 1, 6	Beam 2, 5	Beam 3, 4	Story	Column R1	Column 1, 5	Column 2, 4	Column 3	Column R2
R	0.0104	0.0486	0.1910	0.25	3	0.0643	0.0714	0.2	0.3286	0.0643
3	0.0139	0.0486	0.1875	0.25	2	0.0607	0.0786	0.2	0.3143	0.0678
2	0.0069	0.0694	0.0167	0.25	1	0.0620	0.0380	0.2	0.2480	0.1240
F	0.0	0.0830	0.1670	0.25						

$\Sigma\gamma = 1.0$

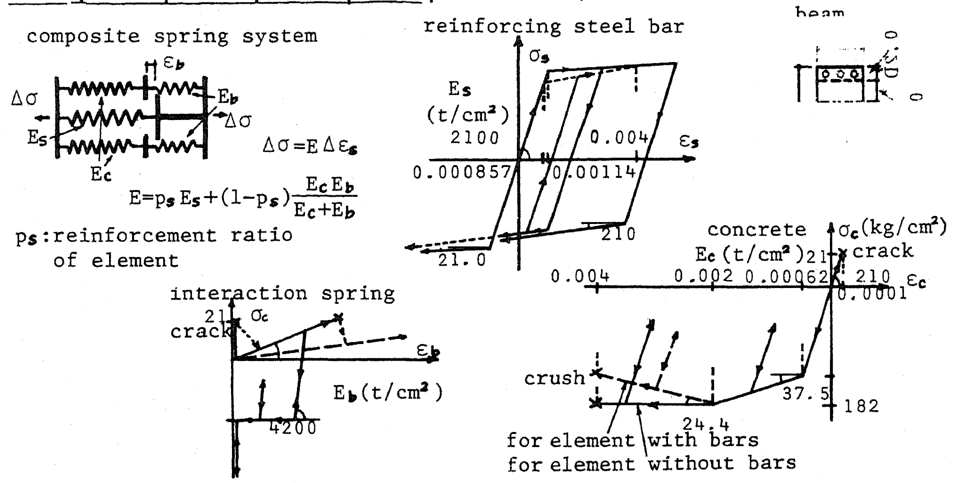

Fig. 4. Idealization of Material Properties

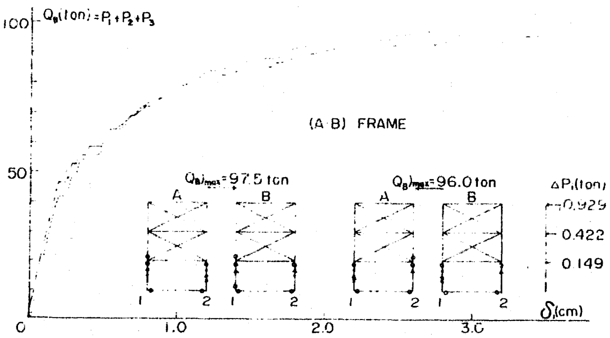

Fig. 6. Base Shear-1st Story Displacement Relation

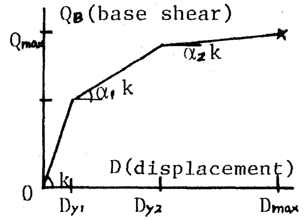

Fig. 5. Basic Skeleton Curve of Degrading Tri-linear Model

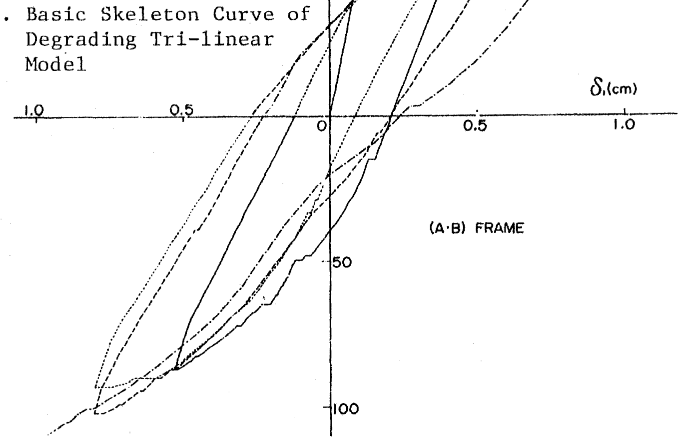

Fig. 8. Base Shear-1st Story Displacement Relation

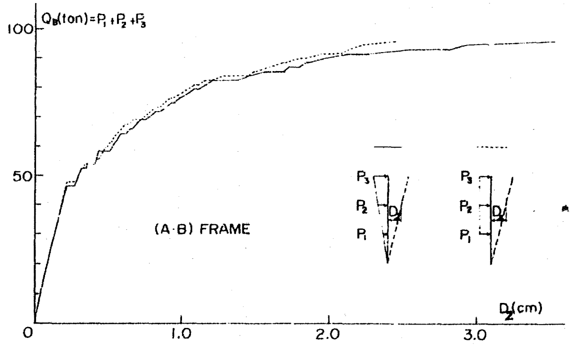

Fig. 7. Base Shear-2nd Story Displacement Relation

Table 2. Characteristics Values of Degrading Tri-linear Model

Case No.	k (ton/cm)	α_1	α_2	D_{y1} (cm)	D_{y2} (cm)	D_{max} (cm)	T_0 (sec)
1	258	0.160	0.013	0.18	1.20	3.44	0.268
2	211	0.183	0.015	0.22	1.32	3.53	0.297

Table 3. Maximum Response Displacement by Dynamic Analysis (cm)

input wave (gal)	N-S		E-W	
max. acc.	250	350	250	350
case 1	8.27	15.7	6.68	12.2
case 2	9.04	16.3	7.03	13.0