EXPERIMENTS ON THE SPATIAL BEHAVIOR OF PLASTIC FRAMES

by
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SYNOPSIS

This paper reports on experimental tests, in the plastic range, of spatial one story mild-steel frames subjected to horizontal static loads and on experimental dynamic response of reinforced concrete plane frames, of a building under demolition, subjected to forced vibrations.

In the tests on spatial frames, asymmetry in the ground plan of the columns involves rotations and displacements normal to the load direction: relationships between these movements, load direction and structural geometry has been studied.

In the dynamic tests it is noticed that also brick panel wall of the frames can collapse without cracks, by separation from the concrete structure.

INTRODUCTION

In the design of earthquake-resistant structures, it is usually allowed that inelastic deformations can arise in the structural members during earthquake motions of exceptional intensity.

In the last years many theoretical studies have been developed about the dynamic response of plastic frames, while the experimental investigations result relatively lacking.

The theoretical results (1) (2) shown that generally only the first column tier yields with plastic hinges at top and at bottom. In plane frames the collapse involves only one degree of freedom (3); in the three-dimensional frames, admitting always that the plastic hinges manifest only in the first column tier, three degrees of freedom are involved.

When the plane of the frame is not symmetrical, the plastic response to a horizontal dynamic load (or ground movement) changes direction in time.

The problem of a mass supported by rigid-plastic columns has been treated by analytic method (4); in order to control theoretical results some static and dynamic tests on model real frames in scale 1:1 and 1:1,5 are being executed.

TESTS ON STATIC COLLAPSE

All tests were conducted on models constituted of two rigid slabs made of welded plates and I-beam and interchangeable tubolar columns Ø 101 mm, 2 m long (Fig. 1). A horizzontal static force of constant direction was applied to the top slab; rota-

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tions and mouvements of slab were measured, while plastic hinges developed in the columns. At the end of each test, a new set of columns, with a different plan, was mounted. The loading jack was mounted in a hinged mechanism (Fig. 2) able to keep its direction constant: the line of action of the force P didn't coincide with the axis of symmetry of the columns. The load was increased in slow increments up to plastic collapse.

The failure of the spatial frames is a rotation of the upper slab about a vertical axis. An approximate value of the collapse load can be found by assuming that the torsional strength of the columns is negligible (5) (6). In this case the axis of the plastic hinges lies in the plane of the vertical slab's rotations axis and of the columns; for a column of lengh h and yield moment M_{o_i}, the shear force in the yielding columns is (4)

$$V_{o_i} = \frac{2\, M_{o_i}}{h}$$

The shear force V_{o_i} is orthogonal to the segment CA (Fig.3) that connect the point C, trace on a horizontal plane of the axis of rotation, and the point A, trace of the axis of the i^{th} column. The vectorial sum of the V_{o_i} gives the collapse force P_o.

Fig. 4 shows the curves loads-displacements for four different column dispositions; curves represent the component displacement d of the force P with its direction. The collapse loads obtained by experiments are superior to those derived from approximate theoretical method which disregars the torsional moments of the columns.

DYNAMIC RESPONSE OF PLANE R.C. FRAMES

Experimental investigations of the dynamic response have been executed on frames of a building under demolition (7): the frames was of reinforced concrete, with and without perforated brick wall.

Fig. 5 shows the shape of the frames and the device which has been employed for to communicate the periodic forced vibrations to the structures. In order to determine theoretically the natural frequencies, the modulus of elasticity of concrete has been measured previously; the stiffness of the frames with panel wall has been calculated as sum of the stiffnesses of the frame without panel and of the shear wall. The theoretical frequencies f_1 obtained give:

8,53 Hz, for the frames without panel wall
13,59 Hz, for the frames with panel wall

while the frequencies measured on the frames during the free vibrations by accelerometers, give:

7,95 Hz, for the frames without panel wall
14,00 Hz, for the frames with panel wall.

Horizontal average amplitudes of displacements η of the frames obtained theorically and experimentally are presented in Fig. 6 and 7 for frames without and with panel respectively.

CONCLUSIONS

On the basis of the experimental observations the following tentative conclusions can be indicated:

- the torsional moment and the bending moment keep constant, when plastic hinges are developing in a column;
- the collapse motion of the frame happens about a vertical axis which is nearly coinciding with that found in elastic range;
- the collapse load decreases with linear law approximately with the eccentricity e of the force in comparison to barycentre of the stiffnesses (Fig. 8). For little value of e, the collapse load keeps nearly invariable.

Further tests are in progress in order to verify and complete these indications.

In dynamic tests, in both frames with and without panel wall it is observed that the experimental average amplitude of the displacements are generally less than those computed analitycally. Also, it is found that the maximum experimental displacements of the frames are in good agreement with the amplitudes computed with analytic method.

- During the vibrations it has been observed that, after about 200 cycles of load, the brick panel walls detach from the framework and can tumble down without cracks.

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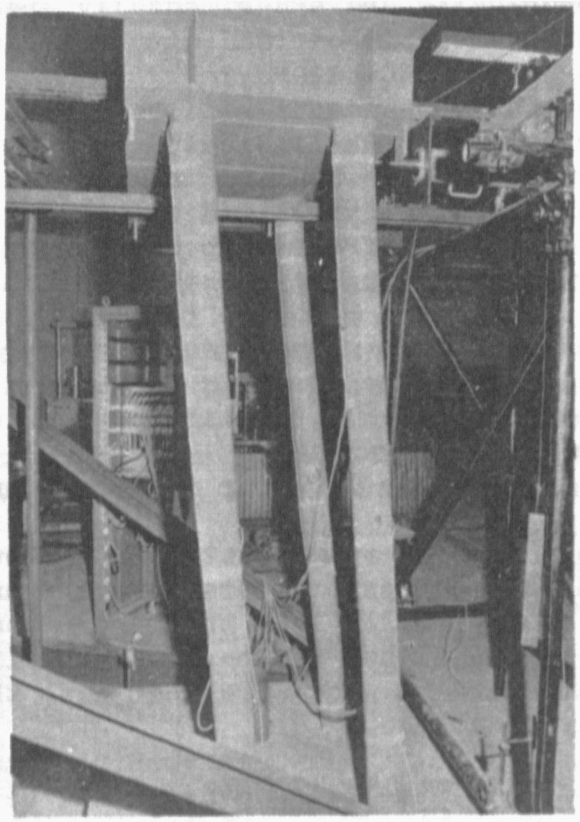

Fig. 1

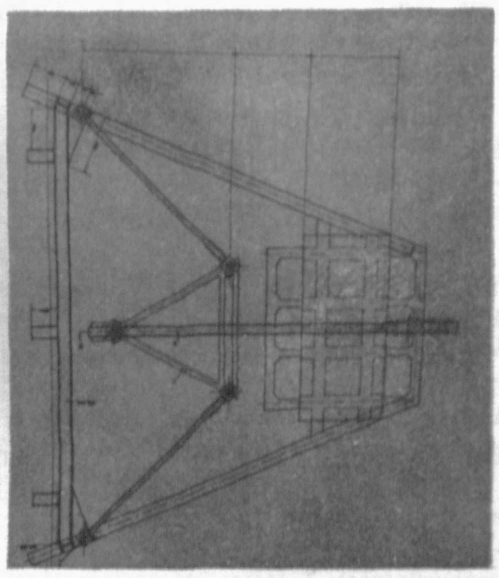

Fig. 2

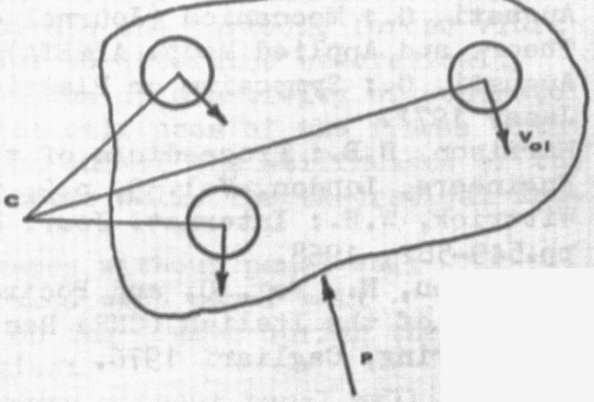

Fig. 3

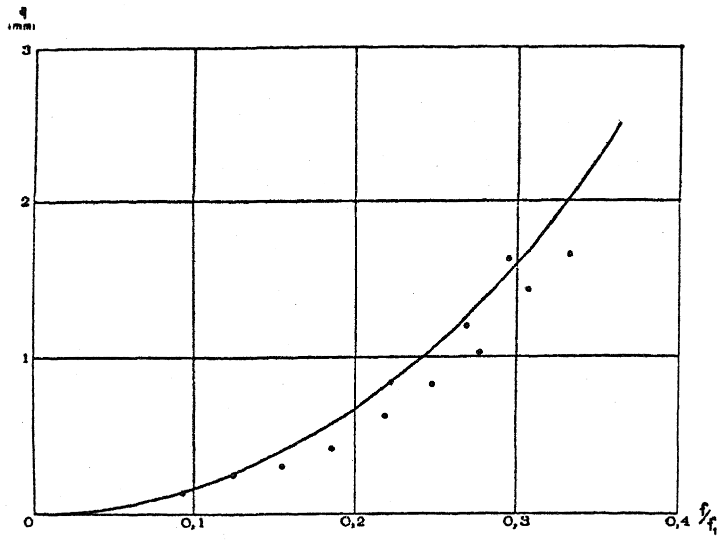

Fig. 6

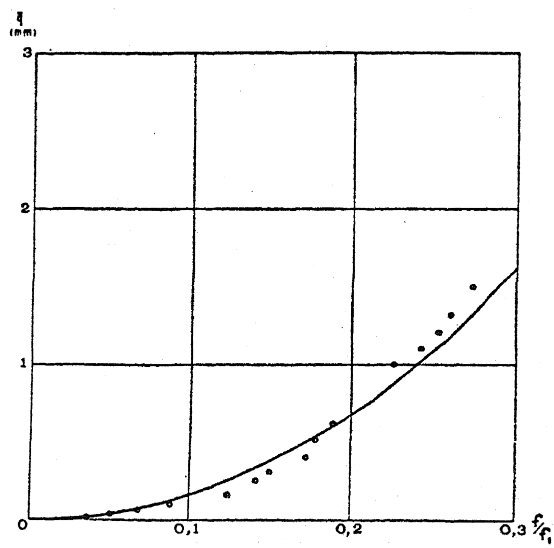

Fig. 7

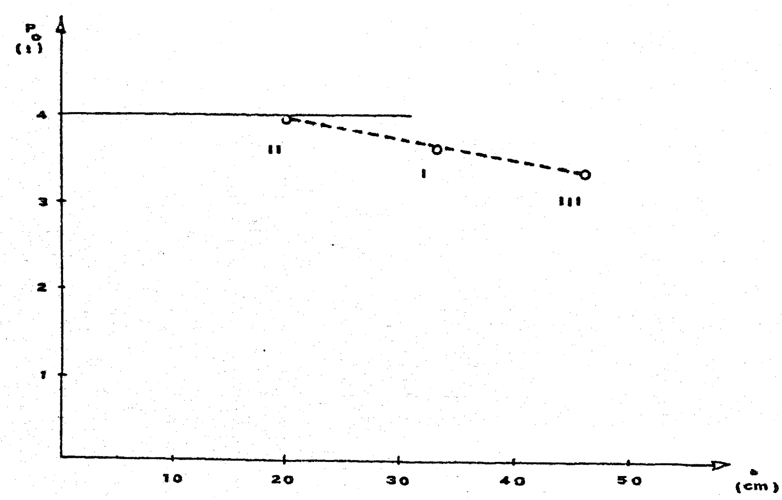

Fig. 8