EXPERIMENTAL RESEARCH ON THE ELASTO-PLASTIC BEHAVIOUR IN DYNAMIC OPERATIVE CONDITIONS OF SYSTEMS OF TWO DEGREES OF FREEDOM

by

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SYNOPSIS

A two degree of freedom oscillator has been tested using a series of pseudo-earthquakes, artificially generated by means of a vibrating table. Each earthquake has been applied at the base of the samples being tested, with three different, increasing levels. This has made possible to compare the response of the oscillator in the elastic and in the elasto-plastic range. The comparison has been performed using, as significant parameter, the mean value of the maximum strain measured at each floor.

INTRODUCTION

The possibility of a structure to resist seismic actions is strongly dependent upon its capacity to dissipate energy when it is stressed beyond the elastic limit. A great deal of work in both theory and experiment is available on the behaviour of a one degree of freedom system. When entering a two degree of freedom system, it is necessary to take into account more parameters: the ratios between the values of the natural periods, of the stiffnesses, of the masses and of the yielding forces; this makes the problem extremely more complex. The purpose of this research is to study, through an experimental investigation on numerous samples, the behaviour beyond the elastic range of a two degree of freedom system, subject to seismic actions. The research goes along side the theoretical studies already available on such an argument (1).

CHARACTERISTICS OF THE SAMPLE

A frame of two floors has been chosen having the characteristics indicated in fig. 1. The elastic elements consist, for each floor, of two pairs of flat springs (fig. 1, detail A), in aluminum type UNI 4507 Al 99.5% H 70 having dimensions in such a way that:

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a) the natural frequencies of the sample fall into the frequency range explorable with the vibrating table (10-200 cps);

(b) yielding occurs for an acceleration value at the base of the oscillator, easily reached with the available testing equipment.

Therefore, the static and dynamic characteristics of the samples resulted to be the following:

- natural frequencies: 20 cps (first mode), 58 cps (second mode); the adoption of such values carries a necessary alteration of the time parameter in the scale ratio:

$$\tau = T_{prototype}/T_{model} = 10$$

- equivalent viscous damping coefficient (determined from a dynamic test on a sample):

First mode		Second mode	
$\zeta = 0.62\%$	$(\varepsilon = 860 \times 10^{-6})$	$\zeta = 0.21\%$	$(\varepsilon = 80 \times 10^{-6})$
$\zeta = 0.82\%$	$(\varepsilon = 1,260 \times 10^{-6})$	$\zeta = 0.25\%$	$(\varepsilon = 290 \times 10^{-6})$
$\zeta = 1.28\%$	$(\varepsilon = 1,650 \times 10^{-6})$	$\zeta = 0.37\%$	$(\varepsilon = 385 \times 10^{-6})$

- the force-displacement diagram of fig. 2.

The hysteresis loops inserted there have been obtained by applying reverse static forces to the model's lower floor. At present only the case is examined in which the stiffnesses of the columns, the masses of the floors and the yielding points were equal.

TESTING PROCEDURE

The tests were executed in care of ISMES with a vibrating table moved by two electrodynamic exciters able to generate random motions having predetermined spectral characteristics and length (fig. 3). The adopted excitation is constituted of a series of 20 earthquakes, lasting 3 seconds each, belonging to a random stationary process whose power spectral density (fig. 4) consists of two bands of 15 cps around the two natural frequencies of the oscillator (2). The amplitudes of these two bands have been chosen in a way to make equal the r.m.s. values of the elastic responses measured at the two floors. With this choice, even if such a type of excitation differs from that of seismic motion, the case has been reproduced in which the structure is designed to have uniform strength at each floor. Each earthquake has been applied at the base of the oscillator (which was changed after having reached the yielding point) with three different levels, the first of which stressed the samples within the elastic limit, the second a little outside that limit, the third decisively in the plastic field. An example of such an earthquake with the response of the sample to it is referred to in fig. 5.

CONCLUSIONS

The most significant results are referred to in the following table:

Maximum acceleration (g)		Number of samples	Maximum strain (x 10^6)			
			first floor		second floor	
mean value	standard deviation		mean value	standard deviation	mean value	standard deviation
0.326	0.018	20	438	71.4	490	91.9
0.95	0.05	20	1,128	167	1,200	175.8
3.96	0.15	8	3,397	576,5	3,395	351

These values have given rise to the diagrams of fig. 6, from which the following conclusions can be drawn:
The mean values of the maximum strain obtained at the two floors are practically equal not only in the elastic range (according to the criterion adopted for the sample design) but also in the plastic range up to a ductility factor of 2.5. Moreover, these mean values show, with increasing excitation levels, a much lower increase than that expected according to a proportionality law. This means that the relative displacements of the frame - at least in the case under test - have a tendency to decrease for higher ductility factor values. However, on this result might have had some influence the increase in the viscous damping of the sample when passing from the very low stress values of the first excitation level to the higher ones of the second level. The maximum value of the ductility factor reached during the tests ($\mu = 2.5$) is obviously low as compared with the usually accepted values. It would be therefore of interest to extend the researches to cover higher values. Nevertheless these conclusions are believed to be sufficiently valuable for the common practice.

ACKNOWLEDGMENTS

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CHARACTERISTICS OF THE OSCILLATOR

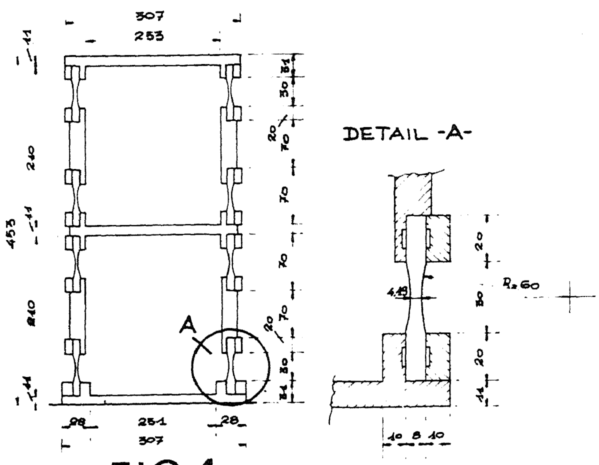

FIG. 1

BEHAVIOR OF THE OSCILLATOR UNDER REVERSE STATIC LOAD

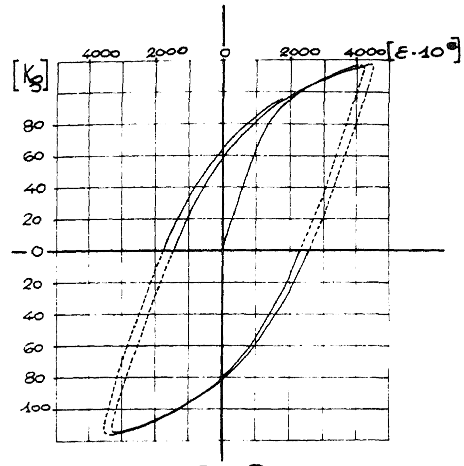

FIG. 2

VIBRATING TABLE

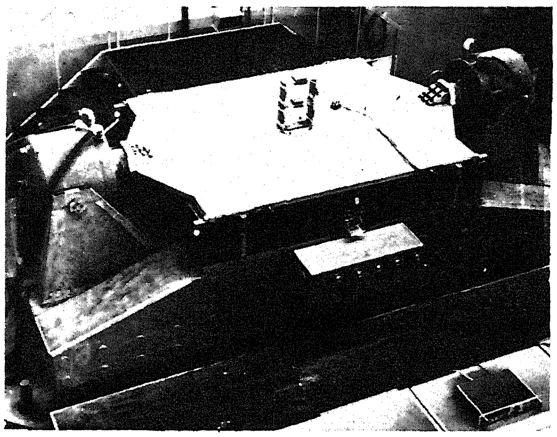

FIG. 3

SPECTRAL DENSITY OF STATIONARY RANDOM PROCESS

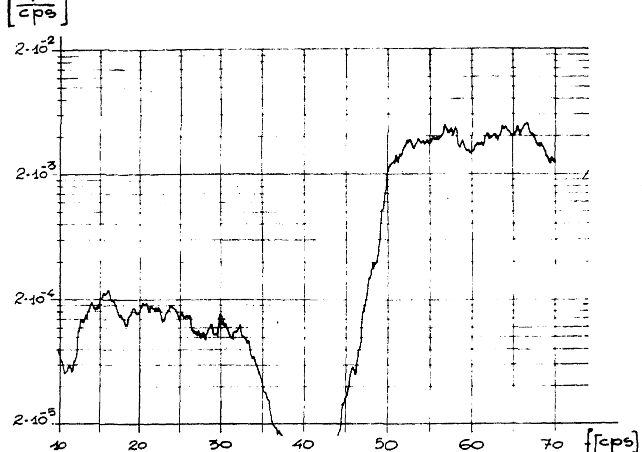

FIG. 4

AN EXAMPLE OF AN ACCELEROGRAM AND THE RELATIVE RESPONSE OF THE OSCILLATOR

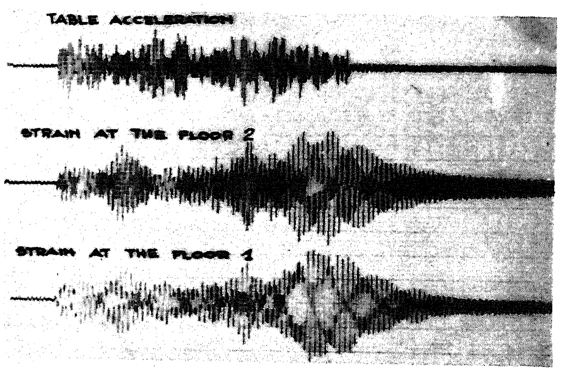

FIG. 5

THE MEAN VALUES OF THE MAXIMUM STRAIN IN RESPECT TO EXCITATION LEVEL

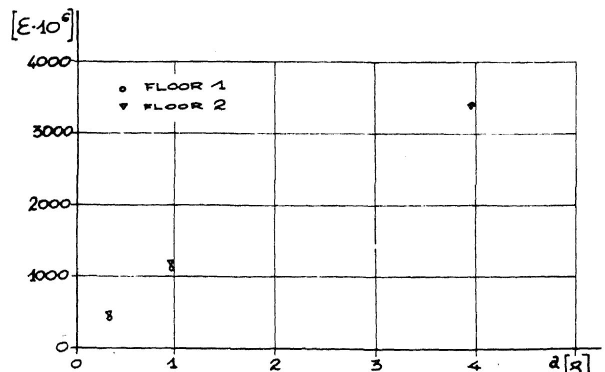

FIG. 6