

TWO DIMENSIONAL VIBRATION TEST FOR A VERTICAL SLICE MODEL OF HTGR CORE

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SYNOPSIS

The High Temperature Gas-Cooled Reactor (HTGR) is considered a nuclear reactor with higher performance compared to conventional nuclear reactors, and will be constructed in Japan in the near future. Selecting a vertical slice (25 block columns x 12 or 13 layers, and 2 reflector columns) across the core, a forced vibration test of a 1/5 scale model was performed by using a shaking table to obtain dynamic behaviors of the core. In addition to the test, a computer code was developed and its application was successful in simulating the test results.

I. Introduction

The High Temperature Gas-Cooled Reactor (HTGR, Fig.1) developed by the General Atomic Company of U.S.A. is considered a nuclear reactor with high performance. The core in case of large HTGR (1100 MWe) is contained in a thick reinforced concrete pressure vessel called PCRV. The core is made up of 577 hexagonal graphite columns (about 8,000 blocks) and the circumference of the core consists of 36 irregularly-shaped graphite reflectors (about 450 blocks). All blocks are arrayed horizontally with a 4 millimeter clearance between each block and are stacked vertically in 12 or 13 layers. Therefore it can be predicted that seismic behaviors of the core turn out extremely complicated due to inter-block collisions. Although the authors are continuously conducting their research and development¹⁾ of seismic safeness of the core, reported herewith is vibration test of the two dimensional vertical slice which was conducted in 1975 (Photo.1). Namely, selecting a vertical slice (25 block columns and 2 reflector columns) across the center of the core, the forced vibration test of a 1/5 scale model was performed by using a shaking table to obtain such dynamic properties as resonant characteristics and vibration modes of the core, lumping of blocks, collision patterns of blocks and the response distribution of reflector reactions. Together with the test, a computer code called COLLAN2-V was developed to simulate the test results. Consequently, it was clarified that the collision behaviors of the core could be analyzed by the computer.

II. Test Model

Photo.1 indicates the outline of the test model. The support frame is a steel structure which is sufficiently rigid to represent the PCRV, and is fastened firmly to the shaking table. A clearance of 0.8mm (4mm x 1/5) exists between each column. Six graphite reflectors are set on each side. Two steel bars called SPIGOT (the spring constant of 4000 kg/cm) representing the side support spring supports each reflector and measures reflector reactions.

III. Execution of Test

Fig.2 shows the flow diagram of the test.

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Shaking table: The shaking table of the Kajima Institute of Construction Technology was used. Built by MTS Company, U.S.A., it is an electric-hydraulic system in which both the horizontal and vertical inputs are simultaneously available. The size of table is 4m by 4m and maximum loading capacity is 20 ton. The resultant maximum horizontal displacement is $\pm 150\text{mm}$; the maximum horizontal acceleration is $\pm 1.2g$.

Input waves: As stationary inputs, sinusoidal waves (0.1 - 0.5g level, 1 - 10 Hz) were used. As random inputs, EL Centro (1940, NS), Taft (1952, EW) and an artificial wave with their intensity of 0.1 - 0.5g were used. Regarding the latter, the time scale was reduced by $\sqrt{1/5}=0.46$, pursuant to the law of similarity.

Measuring method: The reflector reactions (at L6-L1, R6-R1) and the block displacements relative to the support frame (at D1-D6) were measured with the acceleration, velocity and displacement of the shaking table. The reflector reaction was measured by a strain gauge attached to the central part of the SPIGOT, while block displacement was measured by a displacement meter (Photo.1) of the transformer type (Fig.2). All data were recorded on data recorders and their results can be seen in oscillographs (Fig.4).

IV. Summary of Test Results

Stationary wave: Outstanding resonant phenomena were observed by continuously exciting sinusoidal motions. Fig.3 indicates the resonant curves with parameters of input g-levels. As is clear from the figure, the resonant frequencies increase with the increase of g-level, and its resonant peaks become extremely large at more than 0.2g.

Random wave: As shown in case of the EL Centro wave of 0.5g in Fig.4, collision between the end block and the reflector occurs 5 or 6 times during 3 seconds (actually $3 \times \sqrt{5} = \text{about } 7$) of the main shock. Fig.5 indicates the vibration mode and the distribution of maximum reflector reactions. The upper parts of blocks vibrate in lumping, and the reflector reaction is small at the bottom and greatest at the top.

V. Computer Analysis

A computer code called COLLAN2-V was developed to theoretically simulate the test results. In addition, the computer results were successfully applied to an animated film produced by means of a COM (Computer Output Microfilming) system in order to catch visually the intricate block behaviors and reflector reactions. Phto.2 indicates the case of the EL Centro wave of 0.5g.

VI. Conclusion

The following dynamic characteristics for an HTGR core were obtained from this forced vibration test. (1) Resonant characteristics, (2) Vibration mode, (3) Lumping, (4) Reflector reaction, (5) Impulse.

Safety of HTGR core will be assured by studies which will be rapidly accumulated in the world.

[REFERENCES]

- 1) K. Muto et al. "One Dimensional Vibration Test and Simulation Analysis for HTGR core", a paper at the Third International Conference on Structural Mechanics in Reactor Technology, London, 1-5, September 1975

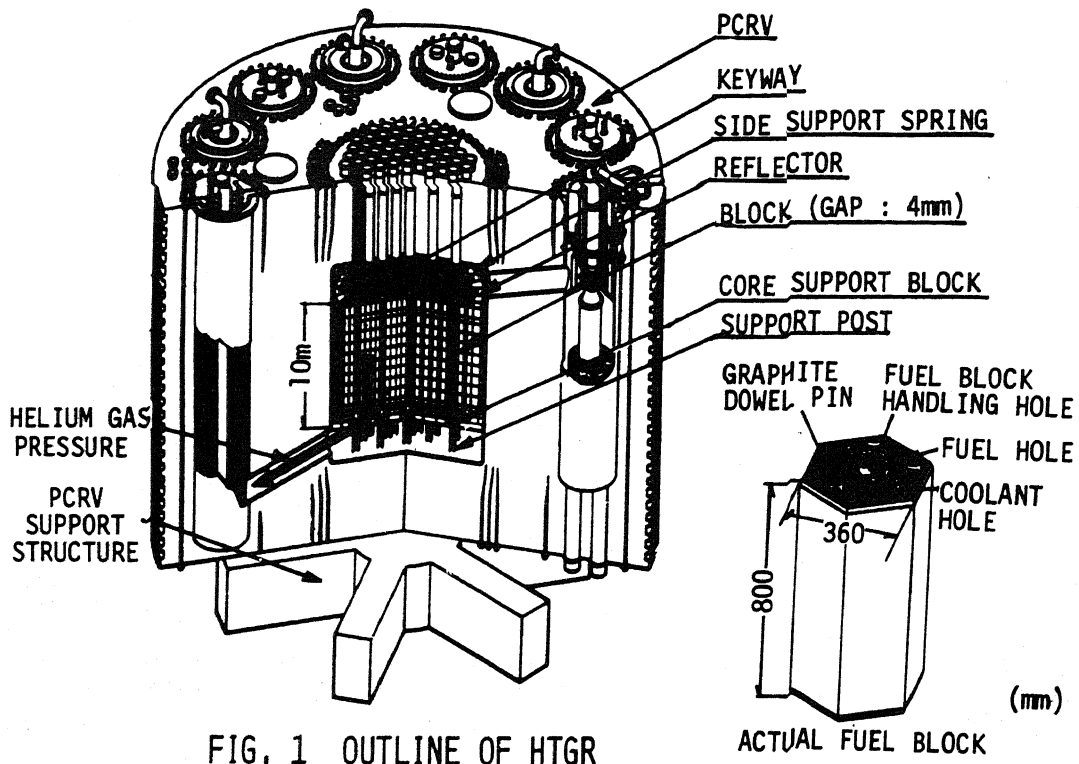


FIG. 1 OUTLINE OF HTGR

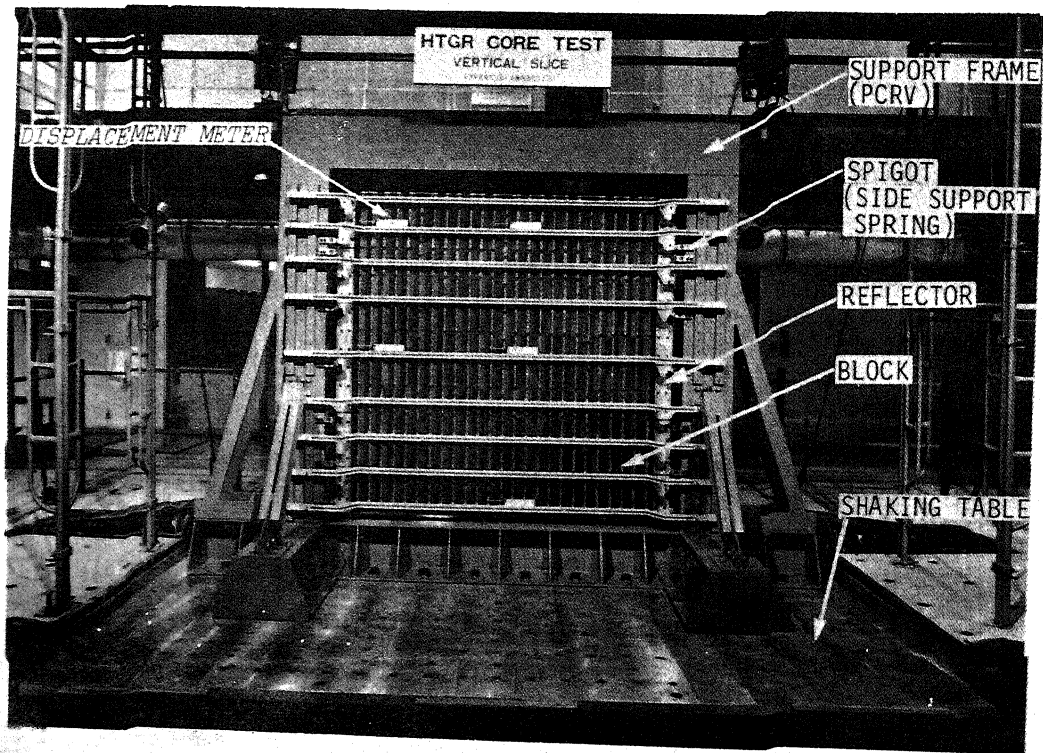


PHOTO. 1 1/5 SCALE VERTICAL SLICE MODEL () : NAME OF PROTOTYPE

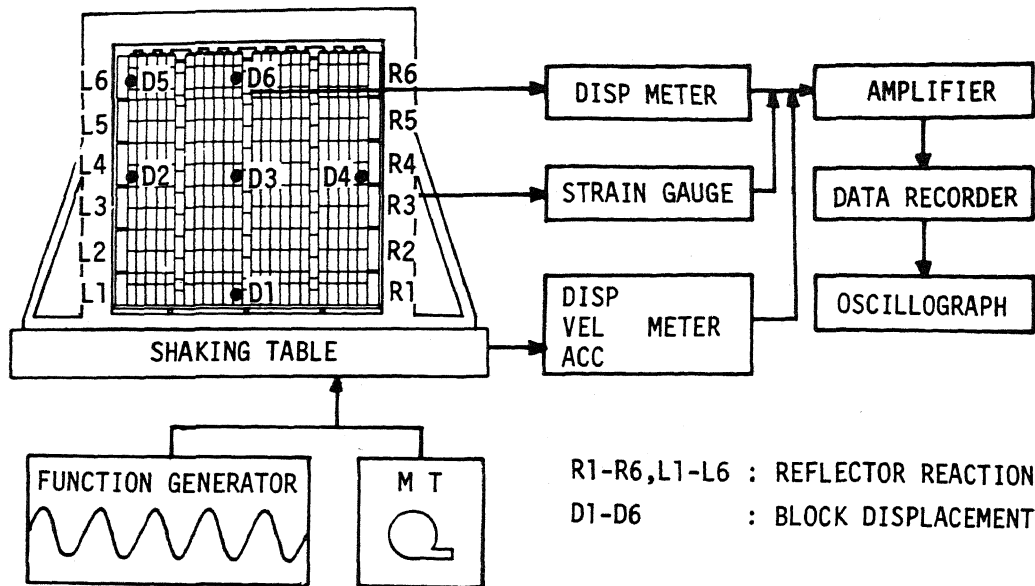


FIG. 2 FLOW DIAGRAM OF MEASURING SYSTEM

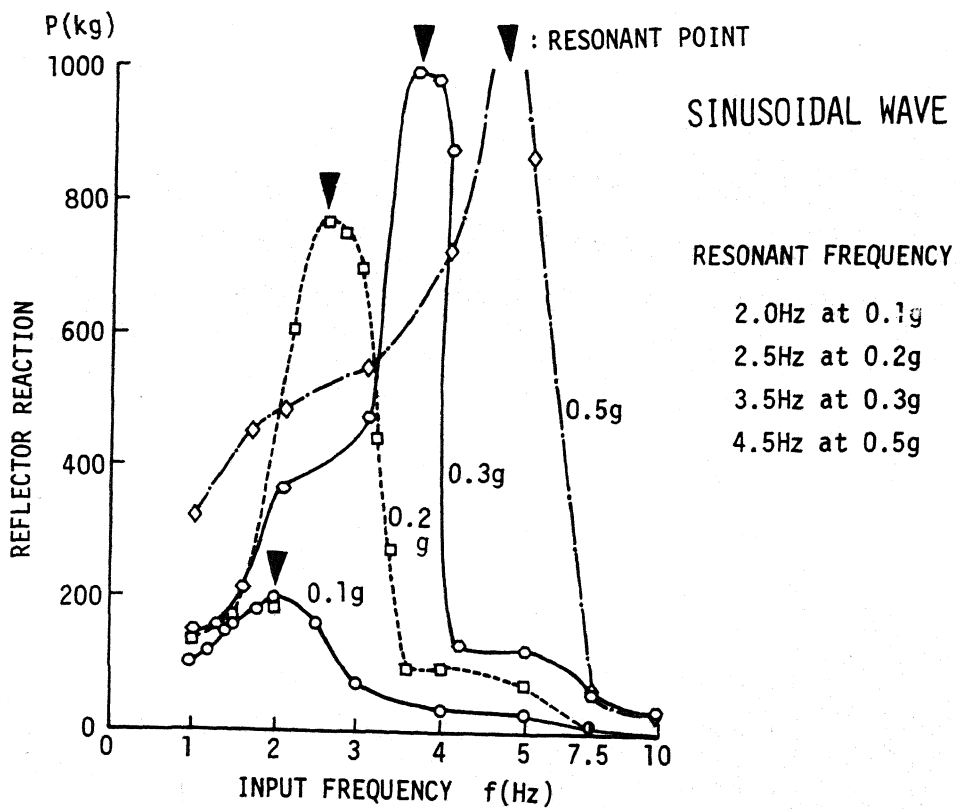


FIG. 3 REFLECTOR REACTION (L6) VERSUS INPUT FREQUENCY

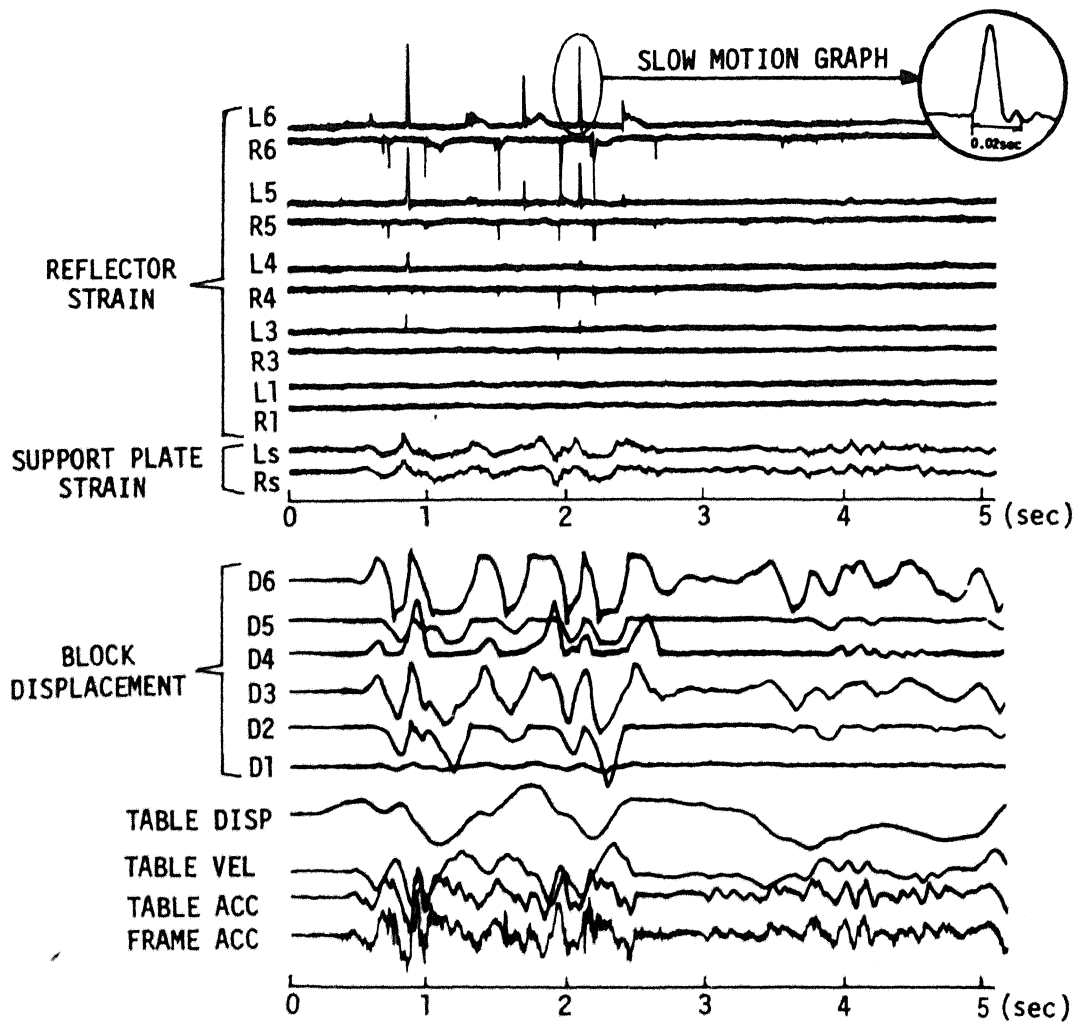


FIG. 4 EXAMPLE OF OSCILLOGRAPH RECORD (EL CENTRO : 0.5G)

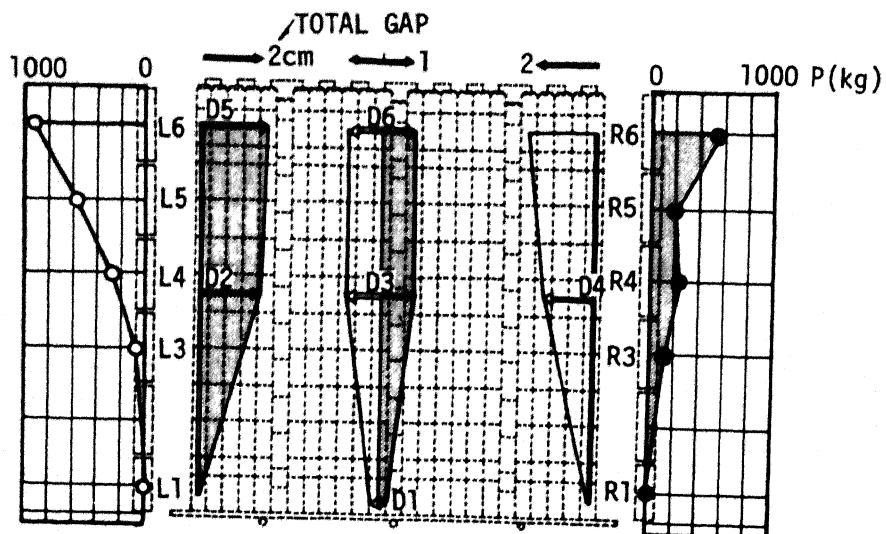
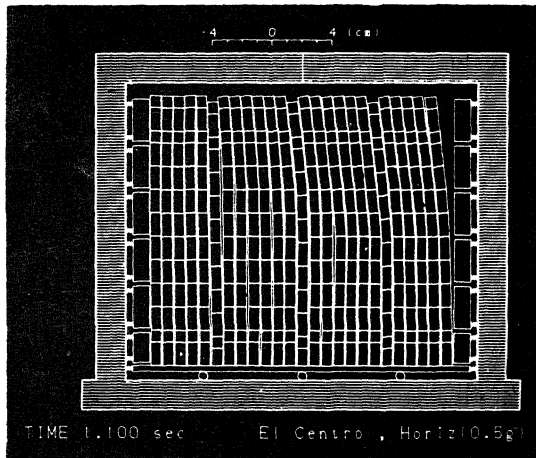
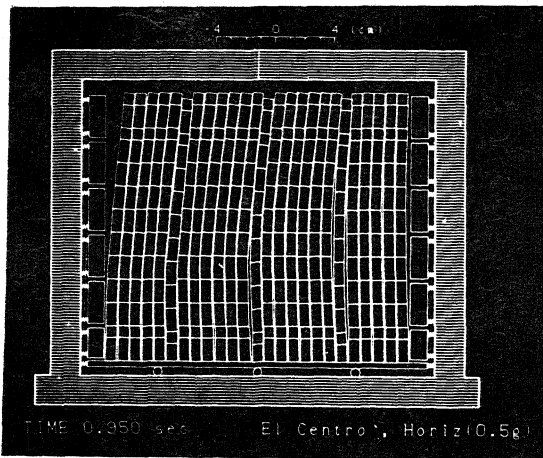
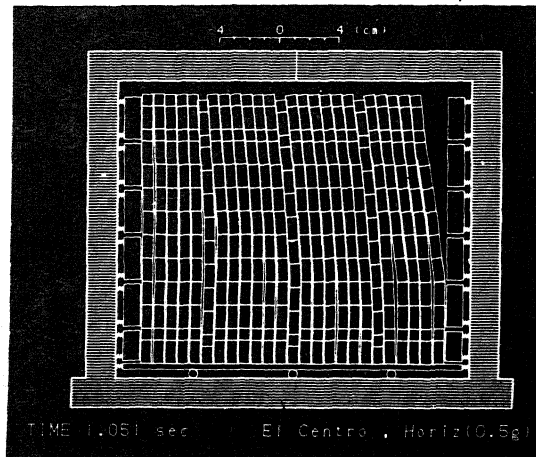
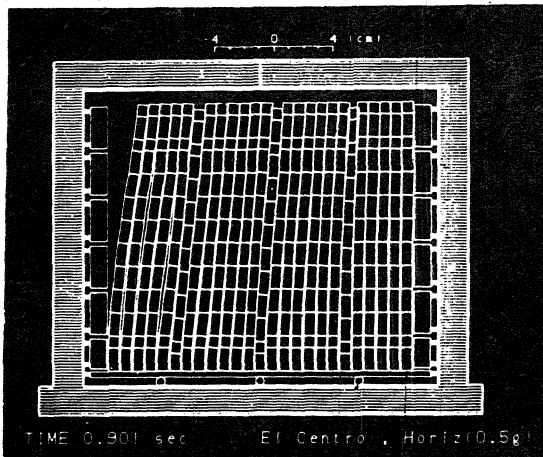
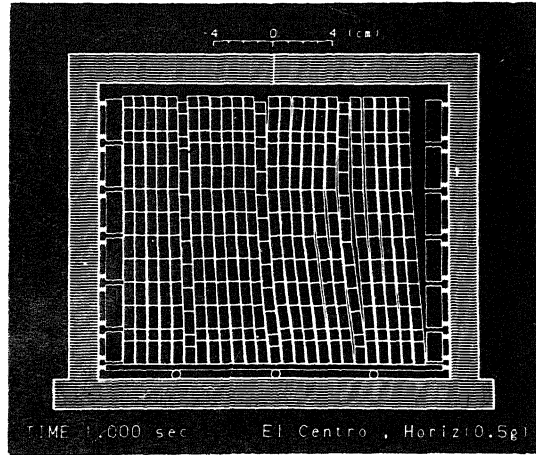
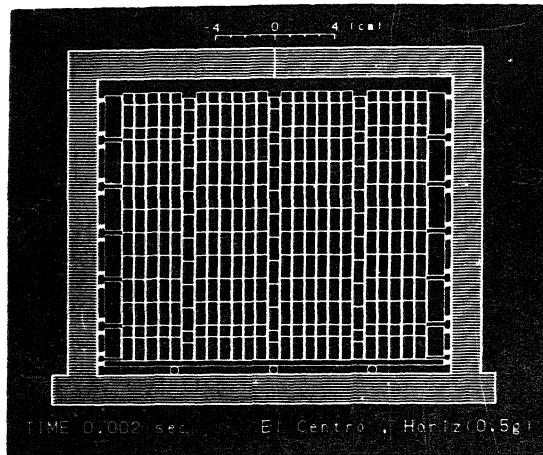


FIG. 5 VIBRATION MODE AND DISTRIBUTION OF MAXIMUM REFLECTOR REACTION (FI CENTRO : 0.5G)

EL CENTRO 0.5g



Block displacement is enlarged by 12.5 times.

PHOTO. 2 BLOCK MOTION BY COM INPUT