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Objekttyp: **Article**

Zeitschrift: **IABSE reports of the working commissions = Rapports des commissions de travail AIPC = IVBH Berichte der Arbeitskommissionen**

Band (Jahr): **30 (1978)**

PDF erstellt am: **13.05.2024**

Persistenter Link: https://doi.org/10.5169/seals-24160

EFFECT OF CONSTRUCTION JOINTS ON VIBRATIONS OF STRUCTURES

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SUMMARY

In this paper two examples are presented with regard to the vibrational behavior of structures with construction joints. A vibration generator system is used to determine experimentally the vibrational characteristics of the structures. First example is a R.C. 14 story building with 3 wings that are located around a core and separated by construction joints. Second is a 6 story high bare R.C. frame structure separated by a construction joint from another building complex. The actual behavior of the structures studied was quite different than expected by assuming functional construction joints. The construction joints constrained the independent vibration of each separate unit.

1. INTRODUCTION

Construction joints have long been used for reasons other than seismic performance considerations. However recent vibration tests of some multistory buildings brought to open the importance of looking into actual behavior of construction joints as against those functions or behavior assumed or predicted from their ideal and theoretical design considerations.

Vibration tests of several structures have been accomplished by various investigators. They studied the dynamic characterists of structures such as multistory building {1}, dams {2}, and nuclear reactors {3}. As one expects these experimental studies were performed to verify the mathematical model of the structures being tested.

These purpose of the presentation made herein is to put actual observed behavior of two multistory building vibration test results and discuss the implications of the construction joints to the seismic performance of these buildings.

2. OBSERVED BEHAVIOR OF STRUCTURES WITH CONSTRUCTION JOINTS

In this section the description and the test results of two structures within the framwork of research project is presented. The results will be further elaborated to bring forth the method of analysis and testing and to help draw conclusions.

2.1. Building A

The geometrical description of Building A is given in Table I and the plan of the building is given in Fig.I.

TABLE I. DESCRIPTION OF BUILDING A

HEIGHT OF THE STRUCTURE (m)	44.1
TYPE OF THE STRUCTURE	Reinforced Concrete Shear Wall
FLOOR SYSTEM	Slab Plate
FOUNDATION SYSTEM	Continous Ribbed Slab
CONCRETE USED	B225 Assumed $E = 2.1\mathrm{x}10^5$ kg/cm^2

This particular structure was constructed as a reinforced concrete shearwall structure by using prismoidal tunnel forms originally developed in France {4}. Doors, windows and other functional openings were realized by use of standardized frame forms embedded into the wall, and the floor thickness were defined by the adjacent tunnel forms. The face panels and the stairways of the building were precast independently and later attached to the main body of the structure by means of the existing dowels. At the time of vibration tests the present face panels were not attached to the structure yet.

According to the test results obtained, it has been found out that the building vibrated as a monolithic unit as opposed to the ideal design considerations that considers four independent sections. As seen in Fig. I the building is designed in separate units with 3 identical wings located around a central core unit. Each wing is separated from the core by a construction joint.

It should be noted that, the performance of the structure vibrating as a whole unit would not have been noticed without such a test.

- Analytical Results

After the test, to provide correlation with the experimental values, the structural characteristics are based on the following assumptions :

In the computation of the lateral stiffness, only the contribution of the panels denoted by thick lines in Fig.I are considered.

Door and window openings are neglected in the computation of the equivalent areas.

In each wing, the corridor slab is considered to be a slab with hinges at the ends, connecting the two units on both sides.

Reinforcement is neglected in the computation of the sectional properties.

The structure is modelled as a continuous cantilever beam. The rigidities computed at the center of rigidity are :

$k_x = 105797$ t/m, $k_y = 100440$ t/m, $k_\theta = 4.66\text{x}10^7$ t/m.

the uncoupled natural frequencies are then :

$f_{x1} = 2.50$ cps.

$f_{\theta 1} = 2.04$ cps.

The coupled frequencies are computed from the following equation :

$$\left(\frac{f_n}{f_x}\right)^4 \{1 - \left(\frac{e_y}{r_{CR}}\right)^2\} - \left(\frac{f_n}{f_x}\right)^2 \{1 + \left(\frac{f_\theta}{f_x}\right)^2\} + \left(\frac{f_\theta}{f_x}\right)^2 = 0 \qquad \text{Eq. EI.20 \{5\}}$$

using $\frac{f_\theta}{f_x} = 0.82$ and $\frac{e_y}{r_{CR}} = 0.21$,

$f_1 = 1.98$ Hz. and $f_2 = 2.63$ Hz. are found.

- Experimental Results

The locations of the vibration generator and the accelerometers A1 and A2 on the 14th floor (floor below the roof) are shown in Fig.I and the frequency response curves corresponding to the above mentioned accelerometers A1 and A2 are given in Figs. II and III. The resonant frequency obtained from the tests is 1.525 Hz and percentage of critical is $\xi = 1.47\%$.

- Design Period

During the design of the structure the following period formula was used {4} :

$$T = \frac{0.06H}{\sqrt{L_x}} \sqrt{\frac{H}{2L_x + H}},$$

with H = 44.1 m and $L_x = 19.08$ m, the first natural period corresponding to one wing is computed as $T_1 = 0.4435$ sec (or $f_1 = 2.25$ Hz).

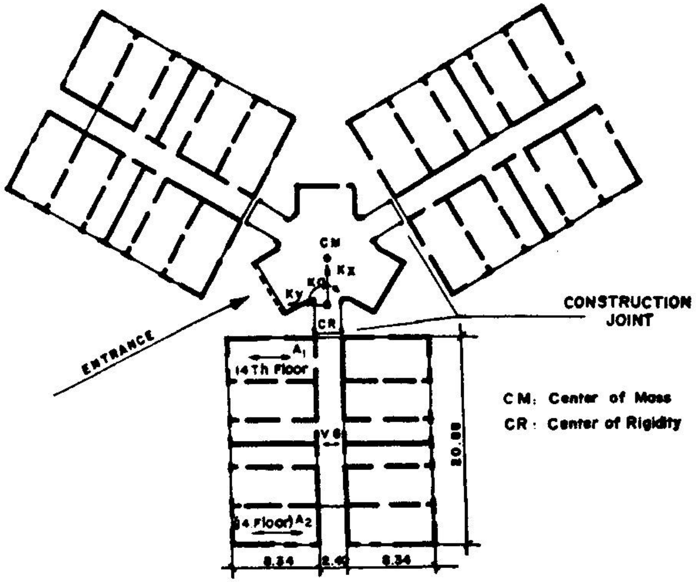
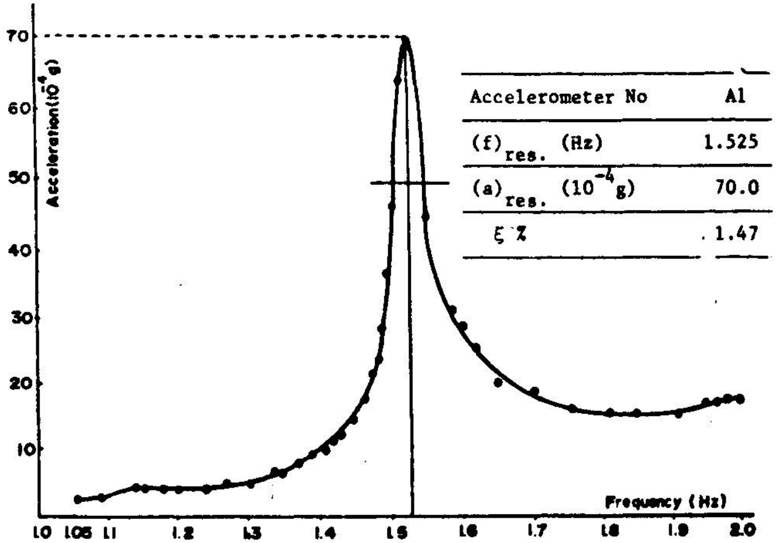


FIG. I PLAN OF BUILDING A



Accelerometer No	A1
$(f)_{res.}$ (Hz)	1.525
$(a)_{res.}$ (10^{-4}g)	70.0
ξ %	1.47

FIG. II FREQUENCY-ACCELERATION CURVE

Accelerometer No	A2
$(f)_{res.}$ (Hz)	1.525
$(a)_{res.}$ (10^{-4}g)	181.44
ξ %	1.47

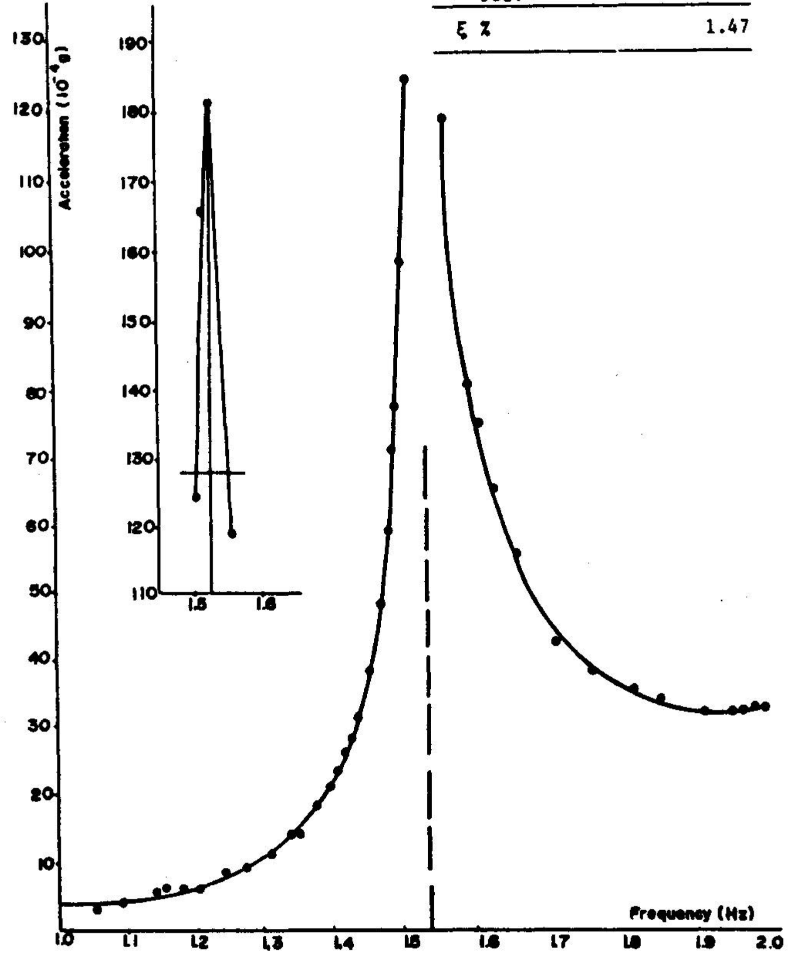


FIG. III FREQUENCY-ACCELERATION CURVE

- Comparison of the Results

Using a procedure developed by WHITMAN {6} it is possible to include the effect of soil-structure interaction on the frequency of vibration. After such a computation analytically obtained first coupled frequency f_1 reduces from 1.98 to 1.72 Hz. This is a 13% reduction, and it is a better result when compared with the experimentally obtained value of 1.525 Hz. It should be noted that the design frequency f_1 = 2.25 Hz obtained for one wing is two much in error when compared with the experimentally obtained value 1.525 Hz, indicating the effect of non-performance of the construction joints.

2.2. Building B

Building B is a six-story reinforced concrete goverment building as described in Table II.

TABLE II. DESCRIPTION OF BUILDING B

HEIGHT OF THE STRUCTURE (m)	H = 20.40
PLAN DIMENSIONS (m)	D = 15.26 B = 48.30
TYPE OF THE STRUCTURE	R.C. Frame
FLOOR SYSTEM	Two-way R.C. Plates
FOUNDATION SYSTEM	Combined column and wall Footings, tied together
CONCRETE USED	B225

As of the day of testing the 7th story of the structure and all outer and partition walls had not been completed. The block was separated from the complex by an expansion joint at the western side. Fig. IV is the N-S section and Fig. V is a typical story plan of the structure. The location of the vibration generator accelerometers, center of mass and center of rigidity are indicated on the typical story plan.

A theoretical dynamic analysis of the structure is carried out through the use of the approximate method developed in {7}. Assuming a rigid foundation, theoretically, first and second coupled natural frequencies are computed to be f_1=3.21 Hz and f_2 = 4.0 Hz respectively. Using WHITMAN's {6} procedure for the soil-structure interaction again, the above frequencies are reduced to the following values :

f_1 = 3.21 Hz and f_2 = 2.69 Hz,

indicating a reduction of 16% in the first lateral frequency of vibration and are very close to the experimentally obtained values which are 2.60 Hz for the first mode and 3.03 Hz for the second mode.

Fig. VI is a comparison of the theoretical and experimental centers of rotation. As one should notice, due to the constraining effect of the construction joint, the experimental centers of rotation are nearer to the construction joint than the theoretical centers.

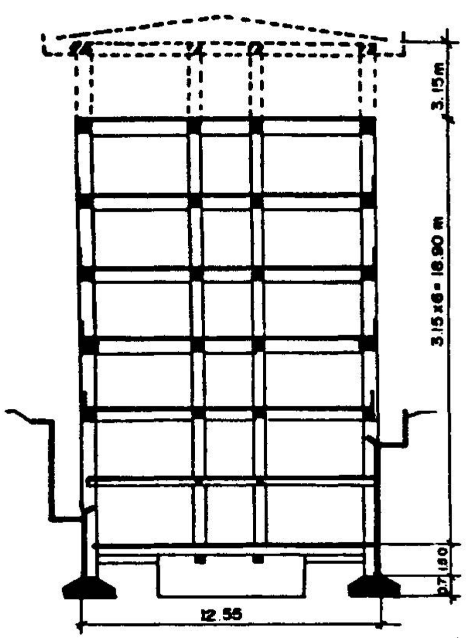


FIG. IV ELEVATION OF BUILDING B

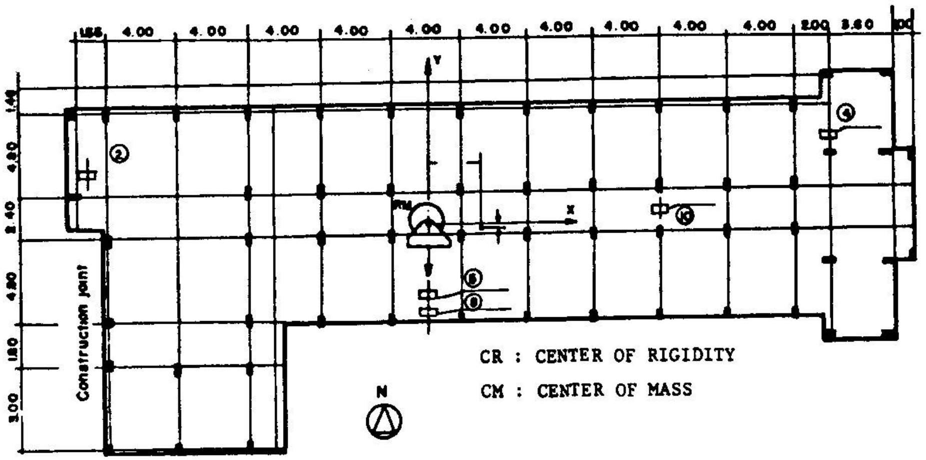
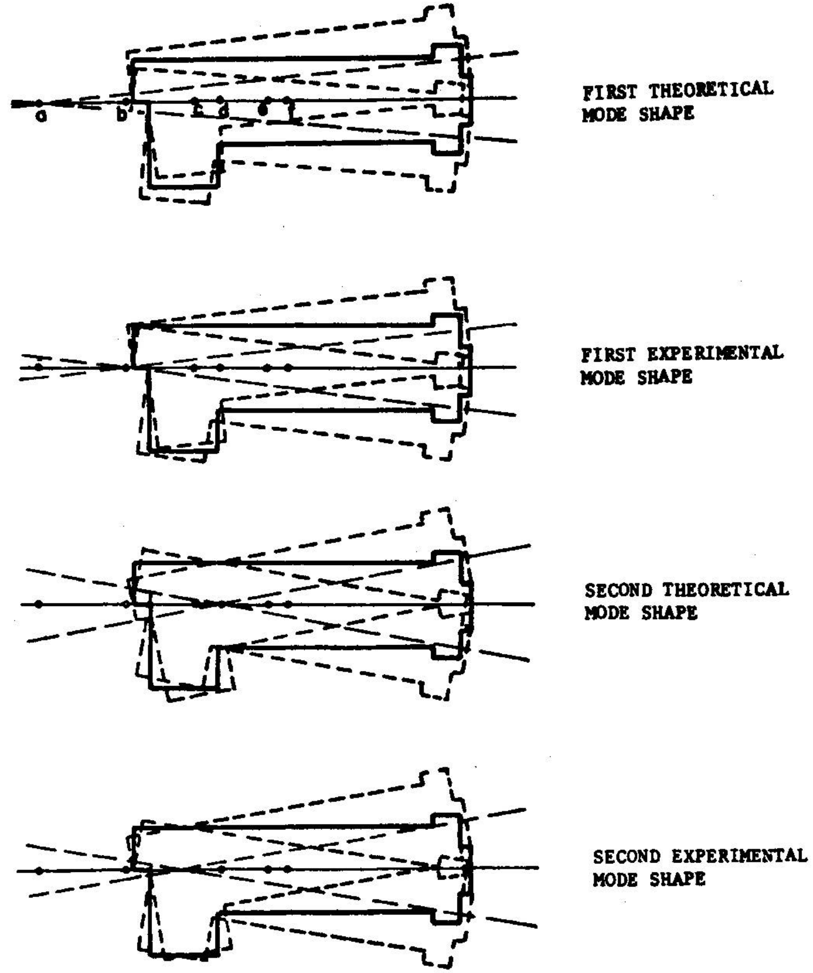


FIG V PLAN OF BUILDING B



a = THEORETICAL CENTER OF ROTATION IN THE FIRST MODE
b = EXPERIMENTAL CENTER OF ROTATION IN THE FIRST MODE
c = EXPERIMENTAL CENTER OF ROTATION IN THE SECOND MODE
d = THEORETICAL CENTER OF ROTATION IN THE SECOND MODE
e = CENTER OF RIGIDITY
f = CENTER OF MASS

FIG. VI FIRST TWO MODAL SHAPES OF BUILDING B

3. CONCLUSIONS

In the light of the two example structures investigated in this paper and also of someother tests that have been carried out the following practical implications and conclusions can be drawn.

- The effects and the function of the construction joints on the vibrational characteristics of the buildings should be kept in mind during the planning phase and design of the structure.

- Two avoid seismic interaction between parts of the building and to secure the fundamental design considerations on the seismic performance of structure proper care and attention should be paid to the actual construction of the construction joints.

- In both of the structures presented herein, torsional modes have been excited because of the inoperative construction joints. This way totally unexpected and not foreseen in actual design considerations.

- Since the forces that will be emposed on the structure during a seismic exposure will be for above those imposed by vibration generator system the re-operation or (forced operation) of the construction joints may be speculated. However, it can be shown that, especially for building parts with similar dynamic properties, the shearing forces that develop on both sides of the construction joint will most likely be in phase and thus the differential shear may not exceed the value required to rupture and re-operate the construction joint.

NOTATIONS

$f_n = (f_1, f_2)$	coupled frequencies
f_x	uncoupled frequency in x-direction
f_θ	uncoupled frequency in θ-direction
e_y	eccentiricity in y-direction
r_{RC}	radius of gyration with respect to the center of rigidity.

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