16. *Vibration Experiments with the Actual Buildings.*

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1. *Vibration experiments with an actual precast reinforced concrete building.*

The building that the writer conducted experiments was a two-storied building of $3m \times 4m$, the column height of $3.41m$ and $3.26m$, and the weight 7250 *kg* in the second floor and 7560 *kg* in the first floor respectively including the live load (1200, 1260 *kg*). The characteristic of the building is that pin joints are fitted to connect the column and beam, and the rigidity of the building is kept with brace-struts. The brace-struts are made of iron and the diameter is 16 *mm* in the first floor and 13 *mm* in the second floor respectively.

The experiments static as well as dynamic were conducted alternately. In the present paper are mentioned only dynamic experiments which were conducted by us.

The vibration of the building was caused by a vibrator utilizing the centrifugal force installed in the central part of the roof. Four revolving discs were used and the eccentric mass was 11.43 *kg*. Two sets, each of which consists of two revolving discs, were revolved inversely with a driving electro-motor. Thus the vertical component being cancelled, the vibrational force of the horizontal component only was generated. By changing the eccentric distance from 0 to 11 *cm* the vibrational force was regulated. The vibration displacements properly magnified was recorded by applying the principle of lever to an arm attached to the pillar. The following four places were selected for the present experiments :—between the ground and the second floor, the second floor, between the second floor and the roof, and the roof.

Keeping the eccentric distance of the vibrator definite and by changing the number of revolution in various ways, the amplitude in each number of revolution was recorded. In such a way the so-called resonance curves were obtained. Such experiments were conducted in succession, and the relation between the vibrational force and the resonance period as well as the resonance amplitude was investigated.

The results obtained are shown in Fig. 1 and Fig. 2. Fig. 1 shows the relation between the vibrational force and the resonance amplitude, and Fig. 2 the relation between the resonance amplitude and the resonance period respectively.

(i) The first experiment (◎); Without the boards.

(ii) The second experiment (○); After hair-cracks were produced in the upper part of column by the static experiment.

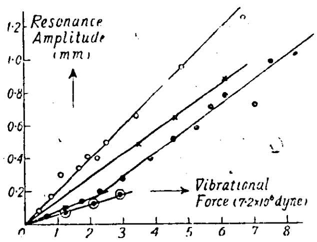

Fig. 1. Relation between the vibrational force and the resonance amplitude.

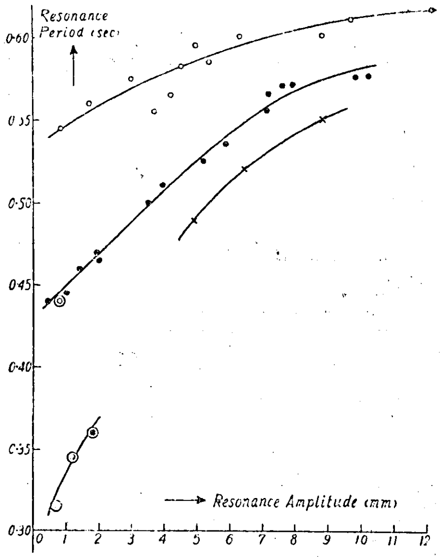

Fig. 2. Relation between the resonance amplitude and the resonance period.

(iii) The third experiment (×); Iron brace-struts covered with concrete.

(iv) The fourth experiment (⊙); With the wall boards.

(v) The fifth experiment (●); After hair cracks were produced by the static experiment in the greater part of morter filled up in the wall board pointing, the capital and the beam.

From Fig. 1 it is known that in the case of (ii), (iii) and (iv) the vibrational force and the resonance amplitude are in the linear relation and apparently the Hook's law holds good of the whole building. In the case of (v) they are arranged on two straight lines, and as long as the vibrational force is small, the same tendency as the case mentioned above is observed, and when the vibrational force reaches to a certain magnitude, the condition changes abruptly. After the condition changed, however, the vibrational force and the resonance amplitude are arranged on a straight line again.

In the case of (ii) the ratio of vibration displacement at the four measuring points takes a almost definite value without any relation with the vibrational force (or the vibration displacement). Namely, even if the vibrational force increases and the vibration displacement becomes large, the mode of vibration of the whole building remains unchanged. The mode of vibration stated above and resonance period correspond with the results of theoretical study upon vibrations of buildings fitted with pin joints and brace-struts. At least in the case of (ii) no change accompanying the increase of the amplitude was found in the elastic constant and the constructive conditions (mainly the connecting conditions of beams, pillars and brace-struts). Nevertheless, it is shown in Fig. 2 that the resonance period becomes larger as the resonance amplitude increases.

It is known from ⊙ and × of Fig. 2 that when the damping of the iron brace-struts covered with concrete increases, the resonance period becomes shorter and resonance amplitude becomes very small at the same time. This nature has already been clarified by theoretical study.[1)]

It is known from Fig. 1 and Fig. 2 that the wall boards strengthen the rigidity of the building as long as no crack is produced in the wall boards, while the wall boards increase the mass more than the rigidity of the building, when crack is produced in the pointings.

2. *Vibration experiments with an actual wooden school building.*

The vibration of a wooden school building built according to the Japanese Government standard was measured by us. The school building is a tile-roofed, two-storied building. The column height is 3.5 *m*, the width is 6 *m* in the class room and 2 *m* in the corridor respectively, and the length is 10 *m*. In both sides of the building there are partitions, and the part between the partitions is assigned to a classroom. Many brace-struts are fitted. The brace-struts of vertical members are 135 × 135 *mm*, and those of horizontal members 105 × 105 *mm* respectively. To connect the vertical members with horizontal ones many partial braces and metal fittings are fitted. Therefore, the school building is a much more rigid construction than those in the past.

The vibration of the building was caused by a vibrator utilizing the centrifugal forces, which was set in the middle part of the second floor, and the vibration was measured with a portable seismograph installed on the beam and on the second floor. The seismograph, the period of which was 4 *sec*, was kept in the critical damping condition, and the geometrical magnitude was arranged so as to be 5.8 times on the beam and 9.6 times on the second floor.

Changing the number of revolution in various ways, the relation between the number of revolution and vibration amplitude was examined.

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1) K. KANAI, *Bull. Earthq. Res. Inst.*, **17** (1939), 695—712.

From the resonance curve the relations between the vibrational forces and resonance amplitude as well as resonance period were read. The results are shown in Table I and Table II.

Table I. Relation between the vibrational forces and resonance amplitude as well as resonance period in the beam direction.

Vibrational force (10^6 dyne)	Resonance period (sec)	Resonance amplitude (mm)		
		On the beam	On the second floor	On the beam / On the second floor
7.4	0.348	0.16	0.10	1.6
27.4	0.362	0.48	0.31	1.6
62.3	0.380	1.00	0.63	1.6
92 4	0.395	1.48	0.93	1.6
113.3	0.418	1.88	0.47	1.3

Table II. Relation between the vibrational forces and resonance amplitude as well as resonance period in the girder direction.

Vibrational force (10^6 dyne)	Resonance period (sec)	Resonance amplitude (mm)		
		On the beam	On the second floor	On the beam / On the second floor
9.7	0.305	0.26	0.24	1.1
35.4	0.319	0.48	0.45	1.1
80.2	0.335	—	0.85	—
129.0	0.334	1.25	1.10	1.1
135.0	0.383	1.43	1.10	1·3

In Table I, the amplitude is almost in proportion to the vibrational force. This shows that the elastic constant does not undergo change by the amplitude of vibration (or the vibrational force). The ratio of displacement 1.6 on the beam and on the second floor of the beam direction corresponds to the case of rigid connections at the floors and the base, and shows that the boundary conditions of the construction does not change by the amplitude of vibration, while the period of rasonance becomes larger as the vibrational force (or the amplitude of resonance) increases.

In the girder direction, from the relation between the vibrational force and the resonance amplitude, the slight vibrational force suffices when the amplitude is small. And in this case the displacement on the beam does not differ much from that on the second floor. These phenomena may probably due to the stiffness of building and the vibrational force consumed to some extent to the bearing power of the ground. Accordingly, in this case the vibration of the building may probably be the resultant vibration of the usual elastic vibration and the rocking vibration with the base as the axis.

The phenomenon that the proper period becomes longer as the vibration amplitude of the building increases is very important regarding the destruction of buildings due to earthquake shocks. If a part of building is destroyed at the time of earthquake, the proper period becomes longer as a matter of course. By the present investigation it has been explained that the proper period may change even if the condition of structure remains unchanged.

In conclusion, we wish to express our thanks to the Ministry of Education, for financial aid (Funds for Scientific Research) granted us for a series of investigations, of which this study is a part.