Experiments on the Vibration of Brick Columns.

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With Pls. XLIX-LII.

1. ***Columns.*** The present note gives an account of the experiments on the vibrations of five rectangular brick columns, whose dimensions were exactly alike, each being composed of 69 layers of 4 bricks. (See Fig. 1.) The height was 15 *shaku* (=495 cm), and the sectional area was 45.5×22.5 cm. The columns, composed of bricks of superior quality of one and the same kind (日本煉瓦會社製造燒過ぎ), and fixed to a single large solid foundation of concrete specially made for the purpose, had mortars of different compositions, as follows :—

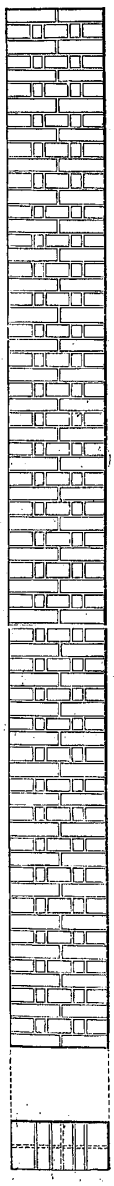
Column No. I..... Pure cement.
„ No. II .... 1 part of cement, 1 part of sand.
„ No. III.... 1 „ , 2 „
„ No. IV .... 1 „ , 3 „
„ No. V .... 4 parts of lime, 6 „

The columns, arranged in series as shown in Fig. 2, with a mutual distance of 50 cm were constructed between Nov. 25 and Dec. 18, in 1901.

2. ***Experiments.*** The object of the experiments carried on three months later, at the end of March 1902, was the determina-

tion of the periods of natural vibration of the different columns. For this purpose each of the latter was caused to move by being pushed or struck with hand once or several times at the top in direction normal to the broad side, being then left to vibrate freely and to gradually come to rest. The record of motion was obtained by means of a stiff pointer, which was attached to the top of the column, and to whose end was hinged a pen tracing in ink the vibrations on a record-receiver mounted on an independent staging of timbers. The diagrams obtained in this manner are reproduced in Plates XLIX to LII. The column No. V, of lime mortar, was very easily thrown into movements of a considerable amount; while the column No. I, of pure cement mortar, could be made to vibrate only slightly. Again, it happened almost always that, when one of the columns was vibrating, the neighbouring ones were also thrown into a state of motion to an appreciable degree. The following table gives for the different columns, the maximum or initial range (double amplitude$=2a$) of motion and the period of vibration during the earlier and end portions.

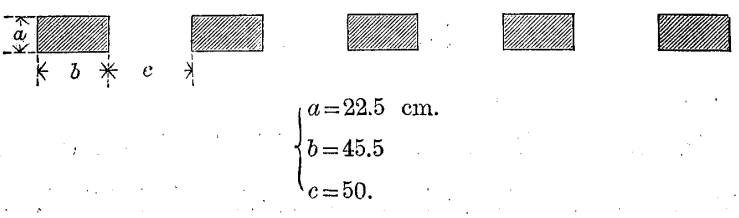
Fig. 1.



Brick Column. (Elevation and Section.)

Fig. 2.

Plan showing the arrangement of tho columns in series.



$a = 22.5$ cm.
$b = 45.5$
$c = 50.$

No. of Column.	No. of Experiment.	Initial or Max. $2a$.	Average Period in the	
			Earlier part.	End part.
		mm	sec.	sec.
I	1	0.8	———	0.23
	2	1.8	———	0.23
	3	4.3	0.24	0.24
	4	4.6	———	0.23
	5	7.0	0.25	0.25
	6	6.7	0.26	0.25
	7	6.3	0.26	0.25
	8	4.9	0.25	0.24
	9	8.0	0.27	0.24
	10	8.0	0.27	0.24
	11	6.9	0.26	0.25
	12	7.8	0.27	0.24
	13	5.9	0.27	0.25
	Mean.	**6.5** (1 and 2 excepted)	**0.26**	**0.24**
II	1	4.6	0.22	0·22
	2	4.7	0.24	0.23
	3	5.7	0.23	0.23
	4	5.3	———	———
	5	4.5	———	———
	6	6.7	0.24	0.23
	7	5.3	0.23	0.23
	Mean.	**5.3**	**0.23**	**0.23**
III	1	7.1	0.25	0.24
	2	6.8	0.25	0.23
	3	7.5	———	———
	4	9.5	0.27	0.24
	5	8.2	0.26	0.25
	Mean.	**7.8**	**0.26**	**0.24**

No. of Column.	No. of Experiment.	Initial or Max. $2a$.	Average Period in the	
			Earlier part.	End part.
		mm.	sec.	sec.
IV	1	5.5	0.24	0.24
	2	8.5 (Column broken)	0.31	0.25
	3	13.0	0.50	0.27
	4	16.5	0.54	0.25
	5	19.0	0.62	0.26
	Mean.	8.5—19.0	0.31—0.62	———
V	1	6.7	0.42	0.33
	2	9.4	0.45	0.35
	3	7.6	0.48	0.36
	4	17.1	0.62	0.37
	5	18.7	———	0.38
	6	21.5	0.67	0.41
	7	24.0	0.77	0.40
	8	3.9	———	0.40
	Mean.	3.9—24.0	0.42—0.77	0.33—0.41

The column No. I seemed to indicate a slight lengthening of period with the repetition of the vibration experiments. Thus, in the experiments Nos.3–8, the period in the earlier part of motion varied between 0.24 and 0.26 sec., with the average of 0.25 sec.; while in the experiments Nos.9–13, the corresponding period varied between 0.26 and 0.27 sec., with the average of 0.27 sec. The period in the later part of motion seems to show also a similar, though very slight, tendency.

The same phenomenon is more markedly shown by the lime-mortar column No. V. Thus, during the eight experiments, Nos. 1–8, the period in the earlier part of motion successively

increased from 0.42 up to 0.77 sec., while the period in the later part of motion increased from 0.33 up to 0.41 sec.

The lengthening of the vibration periods of the columns with the repetition of experiments is probably due to the formation of microscopically fine cracks at the joints and through bricks, which is equivalent to diminishing the elastic moduli of the columns without changing the mass.

3. ***Vibration of columns Nos. I-IV.*** From the above given table, it will be seen that the ranges (double amplitudes) of vibration of the different columns, although not caused by exactly one and the same amount of force, were nearly alike, the mean values varying between 5.3 and 8.5 mm. Half of the last-named limit of range of motion, which fractured the column No. IV, is to be taken as being the displacement at the top of the columns, which may break the latter at the base.

Again, the periods of vibration of the four columns under consideration were practically identical with one another, varying in the earlier, or large amplitude, part of motion only between 0.23 and 0.26 sec., and being in the later or end part between 0.23 and 0.24 sec. This uniformity of motion is quite contrary to what we should be led to expect; as the columns Nos. I, II, III, and IV, whose mortar composition varied from pure cement to 1 part of cement and 3 parts of sand, might be supposed to execute vibrations, of which both amplitude and period increase in proportion to the quantity of the sand mixed in the mortar. The apparent paradox can only be explained on the assumption that in each of the four columns, the mortar was much stronger than the bricks themselves and behaved as if it were practically incompressible, the result being that we got, in these experiments, only the vibrations due to the bricks, and not to the joints. It thus

seems that in brick works a mortar of 1 part of cement and 1 to 3 parts of sand is as good as that of pure cement.

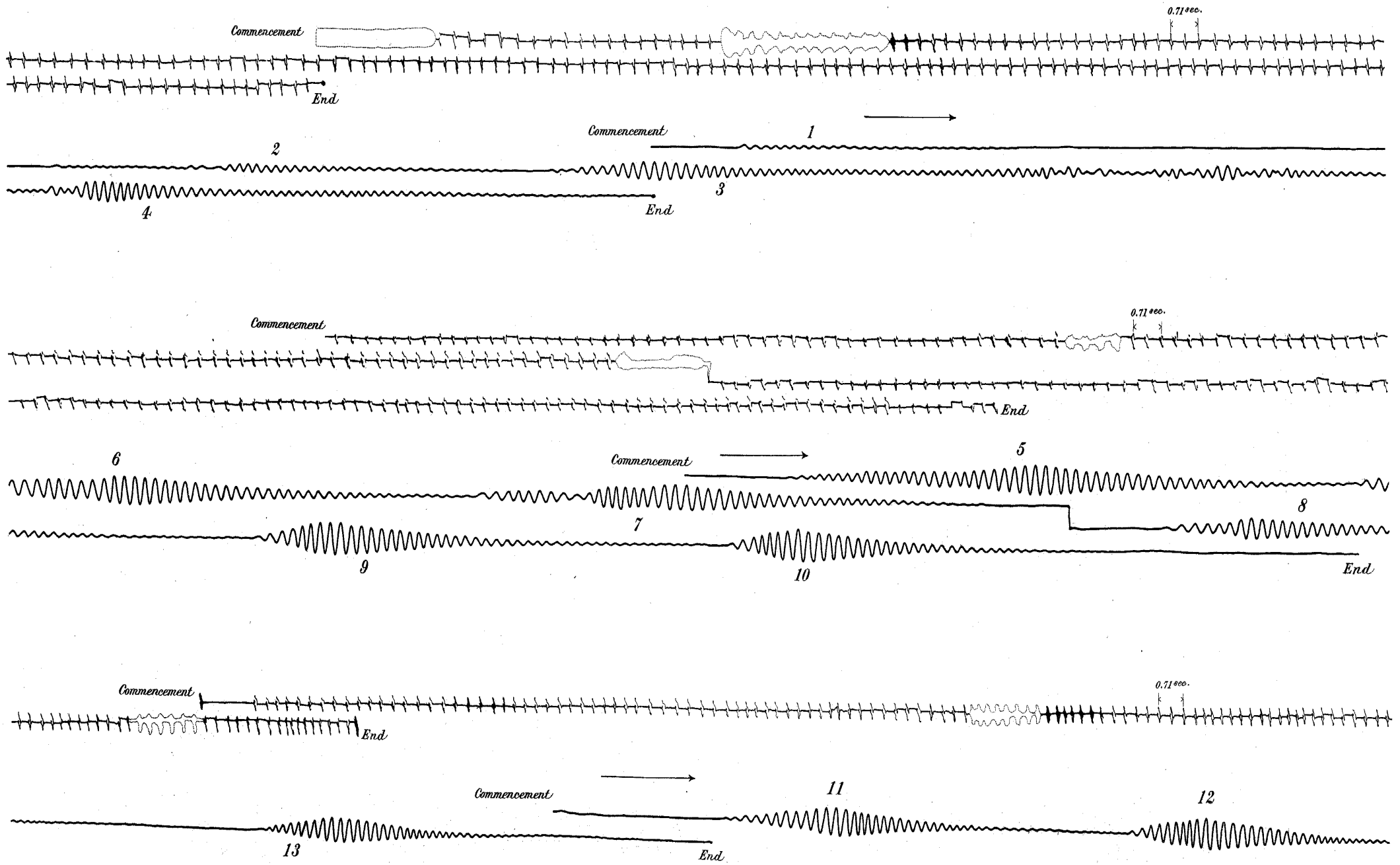
4. ***Vibration of column No. V.*** The column No. V of lime mortar, was thrown, without being broken, up to a vibration of 24 mm, which is nearly three times the maximum motion in the cases of the other columns. This was evidently on account of the inferior quality of the mortar, in consequence of which the elasticity of the bricks themselves did not, in the vibration of the column, at all come into play. Another remarkable feature in the motion of the column No. V was the great length of the vibration period, whose maximum value was 0.77 sec. The difference of the period of vibration for larger amplitude from that for smaller one ranged in the seven experiments, Nos.1–7, from 0.09 sec. to 0.37 sec. From experiments like these we can readily imagine how a tall brick chimney with bad mortar will be thrown, on the occasion of a violent earthquake, into slow oscillations of considerable amplitude.

Vibration of Brick Column No. I. Natural Size. Mortar: pure cement.

Successive experiments are marked 1, 2, 3.....13.

Time: 2 tick intervals = 0.71 sec.

Pl. XLIX.

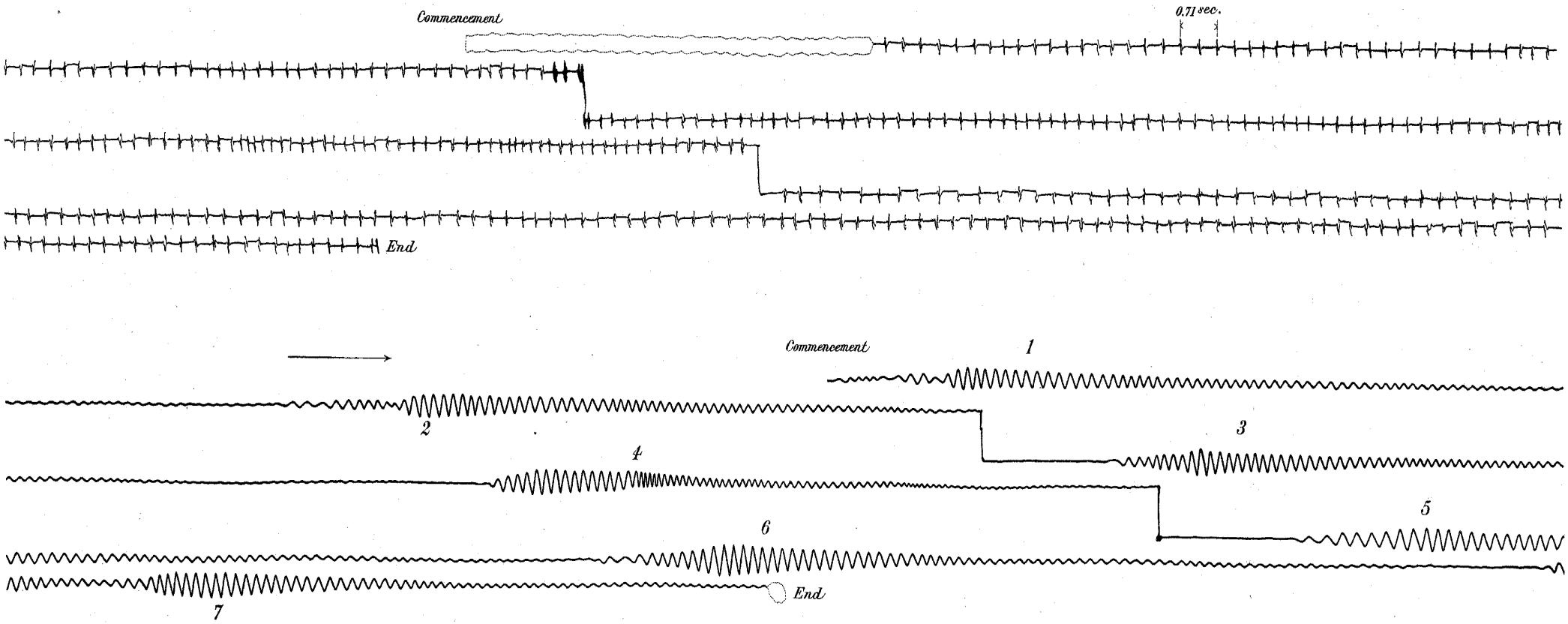


Vibration of Brick Column No. II. Natural size.

Mortar: 1 part of cement and 1 part of sand.

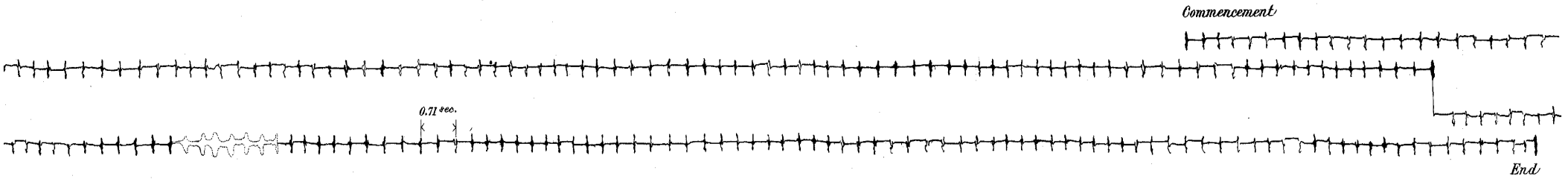
Successive experiments are marked 1, 2,....7.

Time: 2 tick intervals = 0.71 sec.

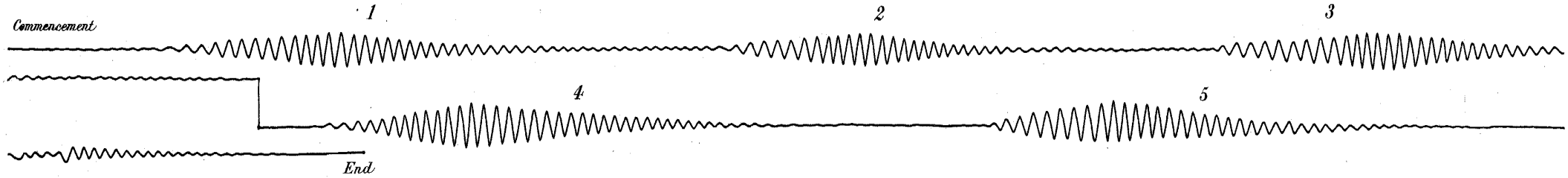


Vibration of Brick Columns Nos. III and IV. Natural size.

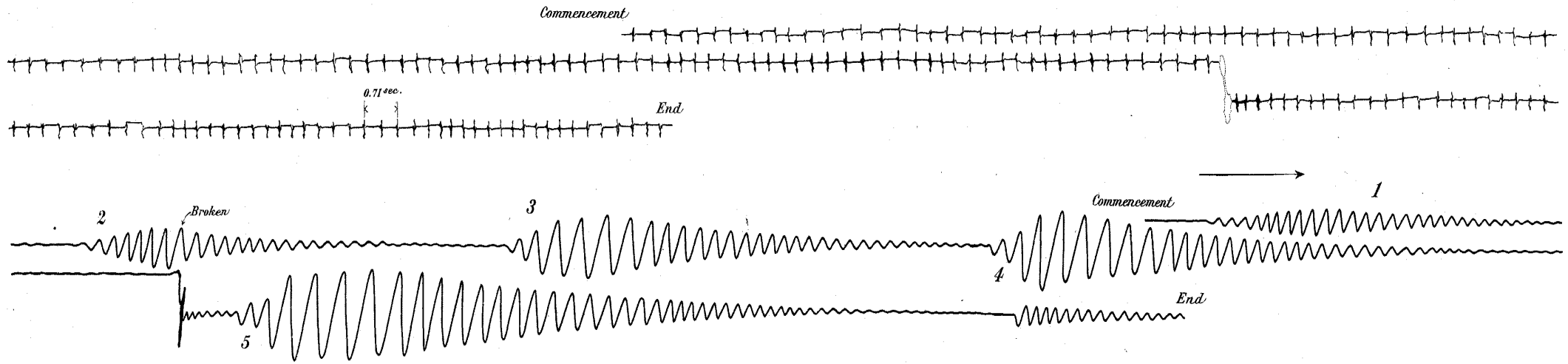
Time: 2 tick intervals = 0.71 sec.
Successive experiments are marked 1, 2, ... 5, for each of the columns.



Column No. III. Mortar: 1 part of cement and 2 parts of sand.



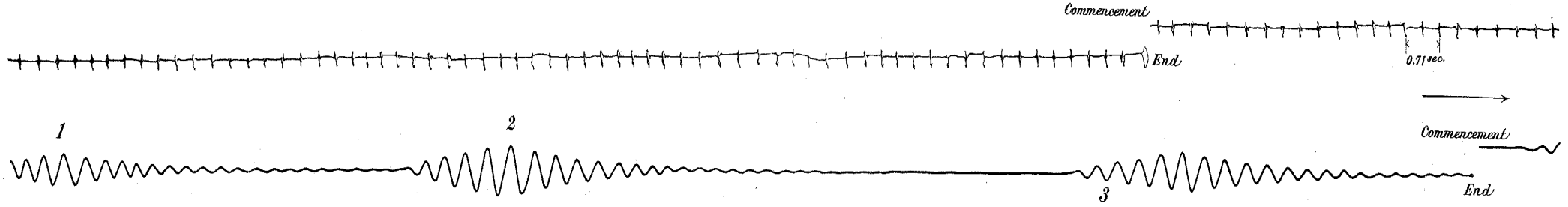
Column No. IV. Mortar: 1 part of cement and 3 parts of sand.



Vibration of Brick Column No. V. Natural size.

Mortar: 4 parts of lime and 6 parts of sand.

Time: 2 tick intervals = 0.71 sec.



Successive experiments are marked 1, 2, 3.....8.