DYNAMIC RESPONSE STUDY OF THE PALACE CORVIN BUILDING IN CARACAS, VENEZUELA

by

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SYNOPSIS

The Palace Corvin Building suffered high damage due to the Caracas earthquake of July 29, 1967. A 10 story H-shaped building formed by two rectangular units and a circulation body in between, structurally separated by expansion joints. The structure of each main unit has lateral force bracing system of reinforced concrete frames and is on a reinforced concrete spread footing with tie beams between columns for a foundation. The east unit of the H-shaped structure collapsed during the earthquake and the west side stood but was heavily damaged. Four short-period portable direct recording instruments were located at the 1st, 5th, and 9th floors in order to measure the dynamic response of the west unit to three input forcing functions of 5, 10, and 15 tons. The analysis consisted of four stages. Stage No 1: the structure with all partitions on all floors and recordings were obtained at the above floors, for the above forcing functions. The second Stage: a similar procedure as Stage No. 1: however, the partitions were removed from the first floor. Stage No. 3: partitions removed for the first three floors, and Stage No. 4: partitions removed from all the floors. Recordings were Fourier analyzed and the dominant period for each stage was obtained; a marked variation was observed. The recordings also show a higher mode of excitation and the experimental damping coefficient for the west side was determined from the recordings for different input functions.

INTRODUCTION

The Earth Sciences Laboratories (formerly the Division of Seismology of the Coast and Geodetic Survey (1)) of NOAA introduced a procedure to measure the natural period of structures. This technique has been used extensively in California, and it has been extended in the last decade to extract and measure the higher overtones (higher harmonics, modes) of the structure under consideration (2,3,4,5,6). A similar technique was used in Caracas (8,9) to determine the natural free period of vibration of buildings. The procedure used in determining the parameters of a structure, assuming a linear system approach, are (a) free and (b) forced vibration tests. The major parameters of the structure are first of all, the fundamental natural period and the overtones of the structures and secondly, the energy decay of the fundamental and its overtones, separately.

The method of structural dynamic testing used in the present study consisted of the pull-back and instantaneous release type. This type of testing is an equivalent to a displacement deformation, which causes the structure to freely vibrate about its equilibrium position (10). There are a number of complications and difficulties in using this testing technique (3), especially when the structure does not vibrate in one plane only. Any torsional vibration induced in the structure after being

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released gives rise to a superposition of vibrations of different types. Also, there will be a superposition of overtones which will hamper the determination of the damping coefficient for the fundamental mode.

The free vibration test was performed as follows. A gradual pull was applied to the structure at the first floor level. A pre-set fuse was installed between the tractor pulling on the structure. The setting on the fuse was 5 tons, then the procedure was repeated with a 10 ton fuse, and finally with a 15 ton fuse.

The dynamic analysis consisted of four stages: In the first stage, the west unit of the Palace Corvin Building, as shown in Fig 1 and identified as I, consisted of the rectangular cross-section with all of its panels. In the second stage, shown in Fig 1 as II, the panels of the 1st or ground level were removed. The third stage consisted of removing all the panels up to the 4th level, shown as III in Fig 1. Finally, the fourth stage, identified as IV, was stripped of all panels.

The instruments were located at the 1st, 5th and 9th levels. The type of recordings were performed on a direct 321-Hewlett Packard recorder, the sensing element was a transducer (recording displacement). The other three systems were a VS1100 and two VS4002 recording at a preset gain. The transducer with a variable gain was used most of the time at the 1st and 9th level.

BUILDING DESCRIPTION

The Palace Corvin Building in the city of Caracas is located east of the Avenida del Avila in the suburb Sur de Altamira. This structure rises to a height of 100.7' to the roof. The Palace Corvin had ten levels. The average height of each story was of 12.2'. A typical floor plan of this building is shown in Fig 1.

The H-shaped structure consisted of three units, two rectangular cross-section; the east and the west towers, and a circulation body in between the towers, containing the stairwell and elevators. Each rectangular section was 36.41' x 82.06', the longest side of the structure being in a north-south direction. The floor system consisted of joist with tile fillers at 11.6' (longitudinal axis of the structure) with three columns (shown as dark rectangles in Fig 1) on the transverse direction.

The foundation consisted of reinforced concrete spread footings with the tie beams between columns. Ties were located at the floor line (Appendix A in 8, and 11).

The main frame of the two towers spanned in an east-west direction, and the beams cantilevered about 6' at the ends. The structural system was in accordance to the building codes as described elsewhere (12,13). Some of the more technical discussion on a general basis regarding the four collapsed buildings in Caracas are discussed in a report of the Venezuelan Official Seismic Commission (12). The lateral force bracing system consisted of reinforced concrete beams acting as bending.

The east tower of the Palace Corvin failed and collapsed, while the circulation unit and west tower were left standing. The west unit, however, was badly damaged to the extent that it was condemned.

The present study deals only with the west unit, and a qualification is put forward at this point. All the results herewith presented apertain to the west-tower of the Palace Corvin and is a post-earthquake study. Pre-earthquake conditions of the structure are not taken into consideration.

General Statement of the Problem

There are three basic aspects which must be considered in the process of decision making when erecting a structure and these are: 1. the phenomenology, 2. the structural behaviour, and 3. the microzonation and general risk of the area. Briefly, the first point implies a knowledge of the earthquake phenomena per se, and its effects to a given area. The approach here has been to study with mathematical models the behaviour due to a given earthquake (14), considering a given source-time-function for the earthquake, as well as the layering and physical parameters of the media where the structure will be erected, and the attenuation of the seismic signal from source to the structure. The simulation of realistic earth-models then is interpreted to develop engineering concepts which are applied to seismic coefficients to the structural design stage of a building.

The second point implies mathematical modeling (finite element techniques, etc.) as well as laboratory modeling of structures which should be subjected to different loading factors. And the last point implies studies of seismic risk (15) for a given region or detailed studies (16) in which damage can be assessed prior to construction.

The first two basic aspects are of a deterministic nature, while the last is probabilistic. Quantitative results are obtained from field observations, due to ground amplification effects (8) or to special damage studies (16) after a destructive earthquake has taken place. After these special studies have been performed, their results can be used for seismic zoning or code implementation, taking into account, then a seismic coefficient in structural design.

The transfer function was computed using the physical parameters determined by refraction work (17) for a site close to the Palace Corvin Building. These results are shown in Fig 2 (a) for the S-wave (SV horizontal, SV vertical, SH, as identified on the ordinate). The abscissa gamma is a dimentionless quantity proportional to frequency in this figure (Figure 2a: GAMMA = hf/β, where h = layer thickness, f frequency Hz, β = shear wave velocity (m/sec)). the maximum amplification for the S wave (SV type) is in the domain of the very high frequencies ($1.00 \leq \gamma \leq 3.0$), also in the range of 0.1 to 1.00

the amplification for discrete frequencies is as high as 10. In the frequency range corresponding to the reported natural period of the Palace Corvin (9) of 0.71 sec and 1.0 sec for the transverse and longitudinal, respectively, the amplification is of 4 to 5 times (see Fig 2a).

The theoretical seismogram calculated for this site, provided the free-field amplification is the same as the one observed at the basement or first level of the structure, is shown in Fig 2b. This record shows a large amplification effect on the SV horizontal component. By the amplification effects is meant the amount of enhancement of the signal recorded on an alluvial site as compared with the signal recorded on crystalline rock.

A first order approximation computation of the site period is $T=4h/\beta$. Using the average values given in Table I, the quarter wave-length approximation yields a period of 0.77 sec. So far, we have shown that the amplification effects for a discrete frequency is in some cases very large, as well as their corresponding time domain signature (Fig 2b). Also, we have seen that the reported period of the Palace Corvin (9) of 0.7 and 1.0 sec falls within the frequency-octave in Fig 2a, which is amplified by a factor of 4 to 5 times. These theoretical amplifications are in accord with the theoretical amplification factors found in La Floresta (8).

Results and Discussion

The consideration of the masonry and panels, from the structural engineering point of view, have been taken into account for the Palace Corvin Building (18) and also the experimentally determined quality of the material used (9). Taking into consideration previous work (8 Appendix A, 9,11,18) on the Palace Corvin and in particular the work (18) which has assessed the theoretical dynamical computations with the observed recordings, we now, then, proceed to discuss some observations which are and some which are not in agreement with theoretical computations.

In Fig 3 are shown a sample recording for Stage IV at the 1st, 5th and 9th levels. The recording, after release, shown in the upper trace is characteristic of a sinuosoidal motion with a superposed overtone. The sample records at the 5th and 9th levels show three traces: L=longitudinal, V=vertical, and T=transverse components. The vertical component of motion is small, while the transverse is large and its time duration is very long. The forcing function was of 10 Tons. The results of measuring the period visually for fourteen recordings in Stage I, five recordings in Stage II, nine recordings in Stage III and thirty-seven recordings in Stage IV, are shown in Table II. The dominant period for each Stage is shown underlined. Other spectral components which appear more than once and could be identified visually are also given in this table. However, not all the periods are listed in this table.

In Fig 4 some sample recordings for Stages I, II, III, and IV recorded with a transducer located at the 9th level for a forcing function of 10 Tons are shown. These recordings show the increase of period of the structure as the building was stripped of its panels (see Fig 2 b). The amplitude variations have been adjusted by means of a variable gain in Stage IV. The decay of the amplitude with time is well portrayed on these recordings. This information has been used to compute the damping, discussed later on.

From table II, it is evident that some of the spectral components are a higher mode of excitation, but it is not entirely clear how other present spectral components relate to the natural period and the overtones of the structure. A further complication is pointed out. For Stage I, an spectral transverse component of 1.35 sec was recorded on several occasions.

However, this period was not observed in all the recordings.

A digitization of similar recordings, as those shown in Fig 4, was done at a sample interval of 0.0125 sec for a total duration time of 9.43 sec. Then the digitized time signal was Fourier Analysed and a number of salient peaks were identified. In Table III, the dominant spectral component obtained with a Fourier Transform Algorithm is listed for each of the stages, and is compared with the dominant visual spectral components. The agreement between the two methods is evident. The Fourier Analysis yields, of course, more information than the visual analysis. For example, when the signal recorded at the 9th level, with a forcing function of 5 Tons for Stage IV, has been digitized at a 0.005 sec sampling interval for a time duration of 15.125 seconds, then one can distinguish the following spectral components: 1.79, 1.32, 1.02, 0.48, 0.42, 0.38, 0.28 seconds. The dominant spectral component is 1.32 sec, and in amplitude is 4 dB higher than the other highest spectral components. The amount of damping with respect to critical damping for each of the modes is computed by using a mode separation technique from the Fourier Analysis of the recorded time signal.

In Table IV, a sample of the separated spectral components for a given stage and for a forcing function are listed with their corresponding damping. There is a decrease of the damping as the elements on the structure are removed. However, there are some discrepancies, as in Stage IV the dominant spectral component has similar energy decay as the dominant spectral component in Stage I (see Table IV). The differences existing due to different forcing functions on the dominant periods can be seen on the recordings, but is not evident when modal separation by the Inverse Fourier Transform is applied.

The present study brings into focus the phenomenology of the earthquake, the dominant period of vibration of the structure under different destructive stages, the modal separation as a technique to compute the damping of the structure, and the varied changes of the dominant period of the structure for different stages.

The variations of the dominant period, as the various elements are removed from the structure, have been determined, and shown in Table III. From Stage I, II, III to Stage IV, the dominant period varied by 47%, 43%, and 28%, respectively. No consideration has been taken of the soil structure interaction effects (19,20,21,22). However, from the soil amplification studies for that region (8), an amplification of 4 or 5 times for a selective period of 0.7 sec will, as a conjecture, excite the structure in resonance which could have detrimental effects of failure.

In this generalized discussion, no direct consideration has been given to the immediate soil-structure interaction (20,21,22). It has been found in other research work (19,23) that the natural period of vibration of a building changes with time. Also, it was found that in the stage of construction of a building where the slabs and columns are without masonry (19), the natural period of the building changes by 70%. This effect has been attributed solely to the influence of the soil.

The results obtained from the recordings of the dynamical test of the Palace Corvin Bldg. (listed in Tables II through IV) also have shown a definite change in the dominant period (dynamic parameter) for the different stages. A more comprehensive study integrating the present findings and those of other investigators is under way. A theoretical building model (19), which yields the dynamic parameters of the Palace Corvin Building is being programmed in the CDC 6400. The theoretical results will be compared with the observed data.

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TABLE I

α(m/sec)	β(m/sec)	ρ(gm/cc)	h(m)
650	375	1.7	15
1775	1025	1.8	120
2400	1386	2.0	50
4000	2309	2.2	00

TABLE II

STAGE	P E R I O D (SEC)	
	TRANSVERSE	LONGITUDINAL
I	1.35 0.71 0.67 0.28	1.13 0.72
II	0.76 0.22 0.07	0.28
III	0.97 0.26	0.92 0.58 0.26
IV	1.34 0.48 0.2	1.84 0.50 0.24

TABLE III

	P E R I O D (SEC)	
STAGE	VISUAL	FOURIER TRANSFORM
I	0.71	0.73
II	0.76	0.81
III	0.97	1.02
IV	1.34	1.32

TABLE IV

STAGE	FORCING FUNCTION (Tons)	PERIOD (sec)	DAMPING
I	15	1.28	3.5
		0.92	2.4
		0.72	3.1
II	10	1.21	2.4
		0.93	0.8
		0.72	0.5
III	5	1.30	1.4
		1.02	1.5
IV	5	1.32	3.5
		1.02	0.7
		0.42	0.7
		0.28	0.3

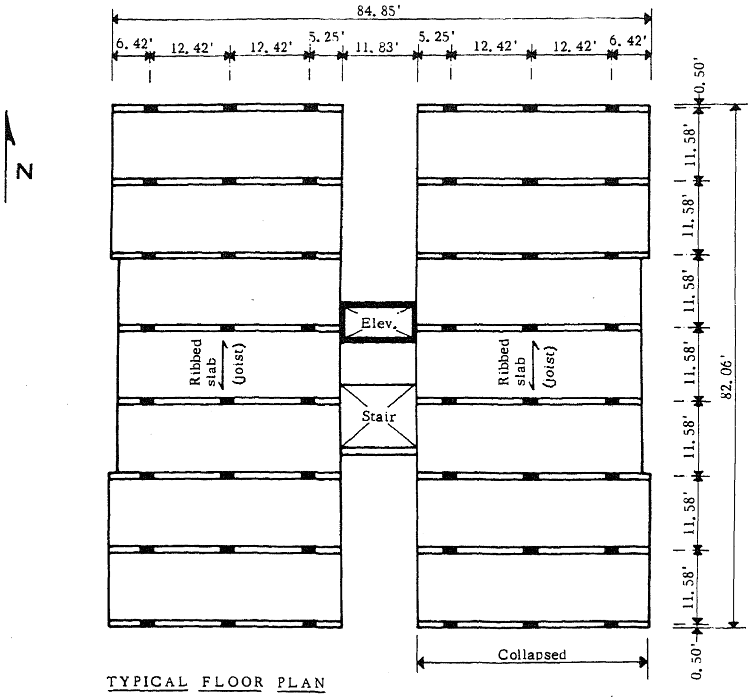

Figure 1(a). Palace Corvin Building Typical Floor Plan.

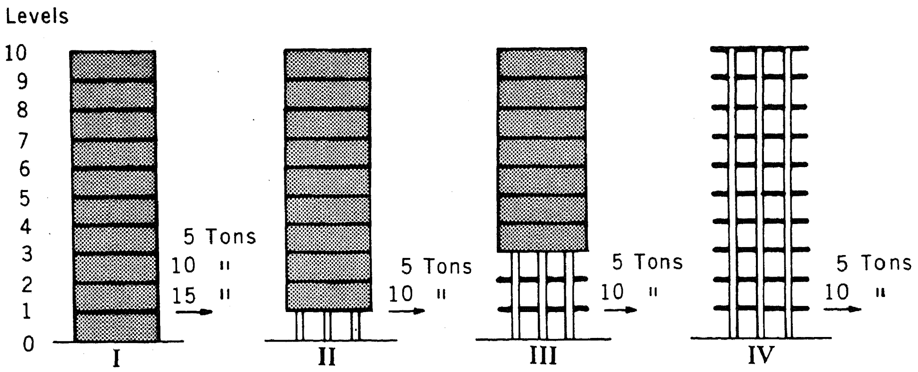

Figure 1(b). Schematic diagram of the dynamical testing of the west-unit, and the four stages of analysis.

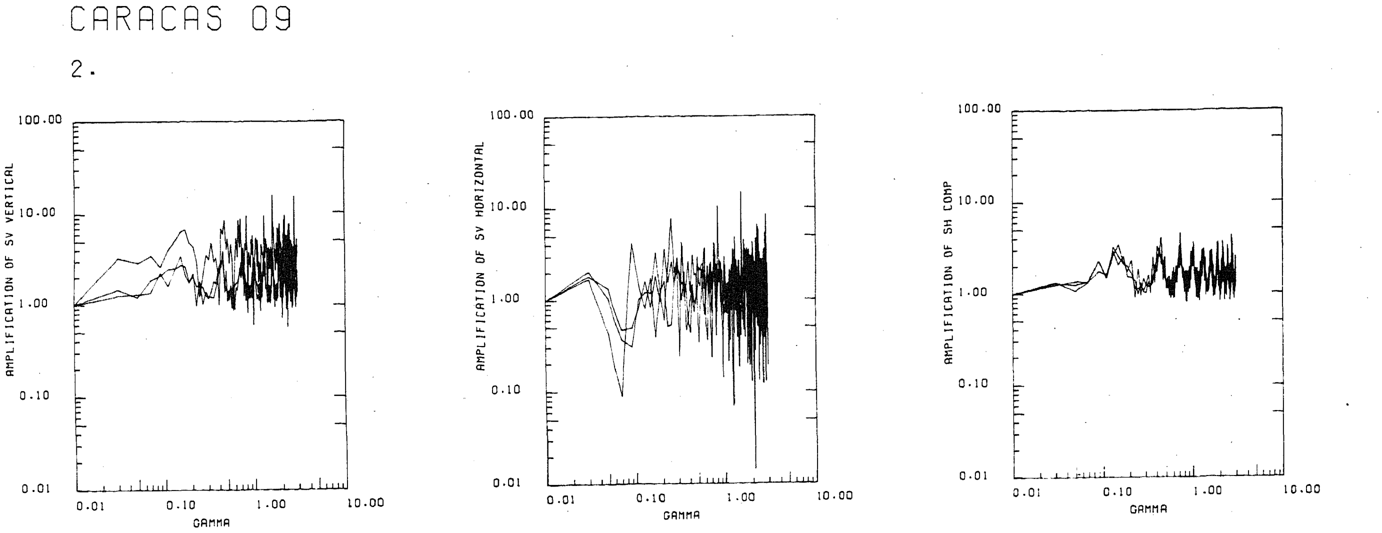

Figure 2(a). Theoretical Amplification of SV horizontal, SV vertical, and SH components for a theoretical model near the Palace Corving Bldg. The abscissa is a dimentionless quantity proportional to frequency.

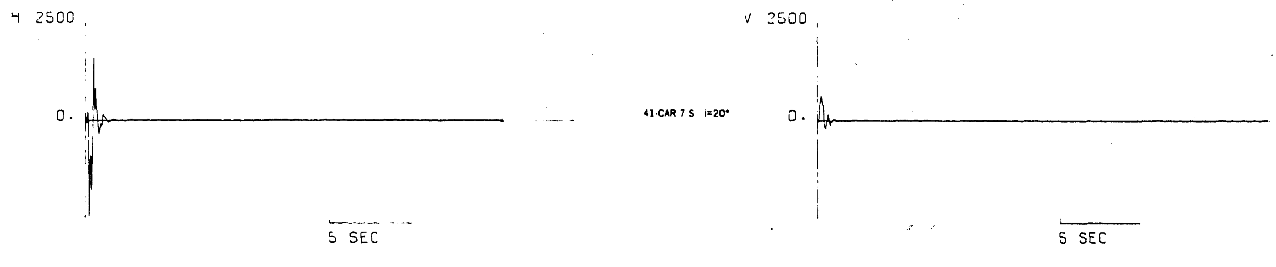

Figure 2(b). Synthetic theoretical seismogram for the S wave using the refraction physical parameters listed in Table I.

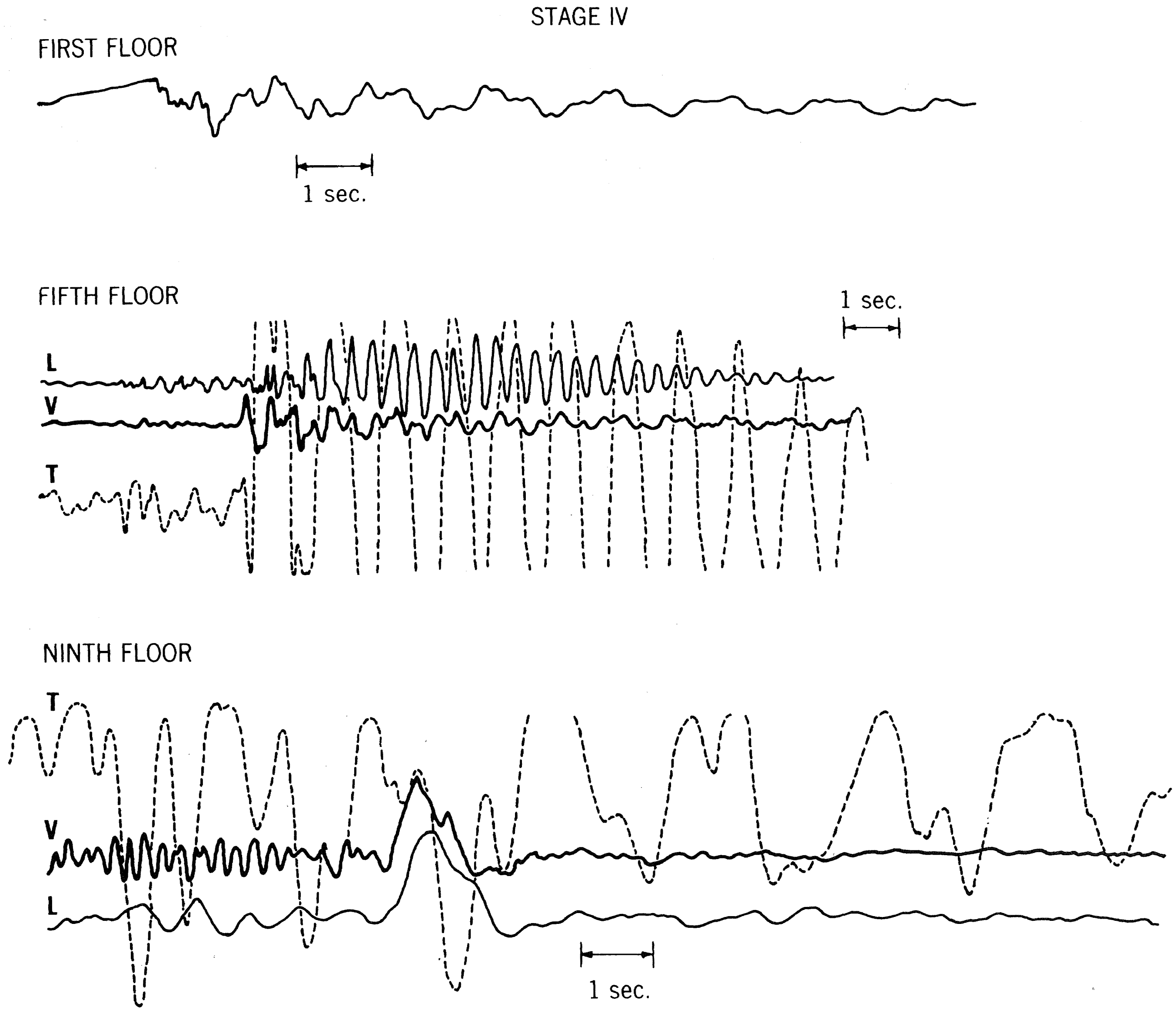

Figure 3. Sample recordings at the 1st, 5th, and 9th floors of the Palace Corvin Building.

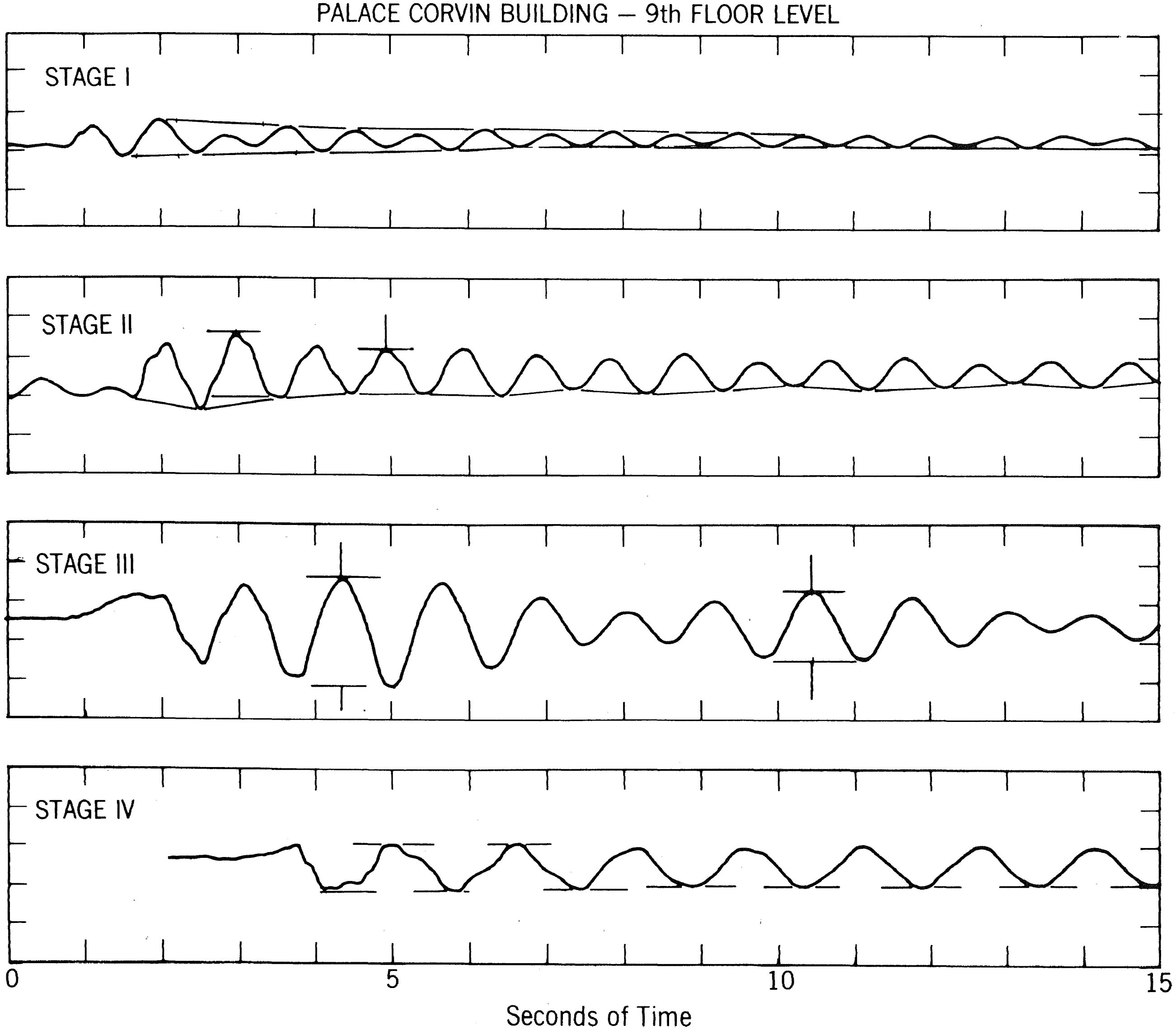

Figure 4. Sample recordings for Stages I, II, III, and IV of the Palace Corvin Building, at the 9th level.

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