THE ACAPULCO, MEXICO, EARTHQUAKES OF MAY 11 AND 19, 1962

By Reuben W. Binder[1]

ABSTRACT

The importance of instrumentation of structures for recording ground motions, measuring story displacements with time, and obtaining period readings before and after earthquakes is pointed out. Velocity spectra of the East-West component of the May 11, 1962, shock are given. Displacements and story shears are cited for the 1st, 25th, and 39th stories of the Latino Americana Tower for the July 28, 1957, and May 11 and 19, 1962, shocks. Although the necessity of instrumentation is a major thesis of the paper, the value of comprehensive data obtained from observation is given due consideration. Also discussed in the paper is the problem of recognizing (or failure to recognize) soil conditions and cumulative damage from successive earthquakes.

Reports on damage in Mexico City in 1957 have been published, but little information has been forthcoming about earthquake effects in Acapulco in that year. Perhaps this presentation will provide some understanding about the seismic situation as far as Acapulco is concerned.

As is known, instrumental records as to story displacement during the 1957 earthquake were obtained in the Latino Americana Tower in Mexico City and the results were widely reported. Significant information has been furnished for the 1962 earthquakes by Dr. Leonardo Zeevaert. Fig. 1 gives a comparison of the displacement data and the calculated seismic story shears for the May 11 and May 19, 1962, and the July 28, 1957, earthquakes.

On May 11 and May 19, 1962, earthquake ground motions were recorded in the basement of Latino Americana Tower, shown in Fig. 2. Ground motion records were also obtained at Alameda Park, not far from Latino Americana Tower, on a strong motion instrument also operated by the University of Mexico. Information thus recorded by instruments, approximately 1/3 of a mile apart, provides positive data which become significantly useful as the basis for a broad yardstick and for analytical and research purposes. It is most gratifying to report that velocity spectra (with 4 different percentages of damping) based on information obtained from these ground motion records were completed in July, 1962, approximately two months after the two major shocks.

It is known that, prior to this time, the formulation of spectra was a very tedious and time-consuming process. Now the development of a computer program and the use of large-size computers have made possible this

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significant achievement of accelerating the process for obtaining sprectrum values. Fig. 3 shows the velocity spectrum of the NW component of the May 19, 1962, Latino Americana basement record. Spectrum has been defined as any quantity, such as velocity, acceleration, or displacement, which is plotted as a function of a given period or frequency or may be likened to an influence diagram. Velocity spectrum is defined as a measure of the maximum relative velocity between the ground support and the mass of a single degree of freedom spring-mass system of given natural period and damping. Acceleration and displacement spectra may be readily obtained from the data of the velocity spectrum.

Since ground motion records were not obtained for Acapulco, the question arises as to how a comparison can be made between the 1957 and 1962 tremblors. This is a key question since it focuses attention upon the importance of obtaining accurate and pertinent data for use in reporting an earthquake and of using this information for progress in research and engineering. The necessity of securing instrumental records cannot be over emphasized if progress in the seismic field is to continue.

In the 1962 earthquake, there was considerable damage, structural and non-structural, in Acapulco. On-the-scene observations and reports received from numerous sources are such that one would hazard the conjecture that the ground motion at Acapulco in terms of horizontal acceleration was very mild although residents in various walks of life report intense vertical motion. In the absence of ground motion records, there is no recourse but to attempt to make a meaningful report on the basis of observed damage, in many instances substituting judgment for records. It is interesting to note that a prominent engineer in Mexico observed that the damage in Mexico City resulting from the May 19 tremblor was limited to buildings already cracked on May 11 and that in many instances cracks reopened and widened on May 19 where they had been painted or repaired with plaster.

Period measurements on structures before and after all earthquakes represent a valuable tool in appraising damage since the observable damage does not necessarily indicate what has taken place in unexposed areas in a structure. That there is accumulation of damage from each earthquake is a matter that requires much attention. Lengthening of periods after an earthquake is certainly a probable indicator of internal damage, whether damage is visible or not. For use in evaluating possible damage in the future, W. K. Cloud of the U.S.C.G.S. has obtained period readings in Mexico City and Acapulco of a number of structures since the May 1962 shocks. Having made the point about the value of measurements, it must still be said that ground motion records without data from observation would be of restricted value.

Granted that damage studies are quite important in evaluating the response of earthquake ground motions and in accumulating competent and important empirical data, it is questionable if meaningful information as to the extent and type of ground motion can be satisfactorily rationalized or explained from such observations. That varied explanations as to cause can be offered was made evident in the discussion by a number of outstanding structural engineers as they endeavored to determine the underlying reason for a specific type of column fracture; this will be discussed later in the paper. Had strong motion instruments been installed in Acapulco on both soft and firm soils, the ground motion records might have given some of the basic data necessary for an explanation of the cause of the location of the column fracture.

Additional loss of valuable information due to the absence of instruments should be noted. Records in Acapulco might have shown the influence of the distance from the epicenter to the damaged areas and also the magnification of earthquake waves on various types of soils. If instruments had been present in this region, the opportunity for sound research would be enlarged and the planning of reasonable rehabilitation and repairs could be undertaken with greater insight. One might say that our knowledge accelerates as our academic tools are developed or that valid records could outweigh many expert opinions.

Along with the matter of instruments, the subject of soils was of majo interest. From present data, it can be said that the damage on soft ground, where earthquake ground motions created differential movements, was far more extensive than the damage on well-consolidated firm or hard soils where the differential movement (if present) went unnoticed. Rigid buildings on soft ground appeared to suffer more than flexible buildings. Soft ground includes loosely consolidated granular fill and alluvium of little cohesion, such as is found along the beach front at Acapulco.

A question arises as to whether these differential movements may be associated in certain situations with soil failures. Attempts were made to determine if soil failures as such did actually take place. Equally important in determining soil failures is the influence of foundation design and other related details.

Some of the major buildings were along the famous Aleman Boulevard where it borders the beach. It is known that the beach sand was taken up and used as fill in a number of places in this area.

As an example of the evidence of displaced soils and of settlement, Fig. 4 shows a site where a displacement of approximately 3" took place. By noting the displacement of soils, it can be concluded that little or no compaction was used in placing the fill material at several sites and that this probably was the cause of some extreme damage.

A building which from a casual glance seems undamaged is often quite different when one gets close to the building or enters it, and observes the severe damage which makes the structure seem almost a total loss.

Along the beach front there were umbrellas which provided protection from the intense rays of the sun as one enjoyed the beautiful scenery and all that goes with it in this lovely bay. Fig. 5.

Figs. 6 and 7 show a covering immediately adjacent to these grass umbrellas. This is a structure with long, round columns and short, rectangular columns. What happened to it during the earthquake? The short, rectangular, stiff columns were damaged, either top or bottom or a combination of top and bottom, while the long, limber columns were apparently unaffected. Granting that some of the structures may have been designed for wind, certainly insofar as seismic vibrations are concerned they were often weakened because of the failure to recognize the importance of rigidities, particularly of so-called non-structural elements. When rigidities are placed without regard to the response to an earthquake ground motion, extensive damage can and did result. This can be stated as the abuse of the use of rigidities, a lesson that is sometimes difficult to put across, particularly to those not accustomed to the daily routine of seismic design.

Along Aleman Boulevard, at the beach, there was some typical and non-typical damage. It might be presumed that in many instances damage would be typical for the same type of structure; however, this is often not the case because, among other things, workmanship is far from being uniform. This was particularly true in this area, as was seen by the varying damage pattern. Fig. 8 shows damage for the 1962 shocks which is non-typical because an expansion joint between two structures at right angles was used as a good place to dump excess pour material.

The column fractures shown in Fig. 9 are not as dramatic as some that might be shown; dramatic shots generally prove the dictum that poor use of materials, lack of design, inadequate supervision, etc., are often the facts of life in earthquake damage areas.

Fig. 10 shows the very interesting sine curve in the top chord of a steel truss, i.e. a joist, which may have provided the relief to keep this one-story structure from collapsing. The force exerted on the one-story structure had probably been provided by the motion (i.e. contact) from the adjoining eleven-story structure.

Prior to May, 1962, a landmark on Aleman Boulevard was the monument graced by the beautiful Diana shown in Fig. 11. The earthquake shock was too much for Diana; she was upset and probably got a good bath when thrown from her pedestal.

Moving down the Boulevard, Fig. 12 shows damage to a penthouse and to exterior parapet framing. It is believed that higher modes of vibration may have contributed to this damage.

At one site on the Boulevard, Fig. 13 shows a structure after the May 11th shock and the same structure after the May 19th shock.

Fig. 14 shows a mass of ruins. Fortunately, enough pressure had been placed upon the management of this particular structure to close the place down before the May 19th shock.

The Field Act and the rules and regulations of the Division of Architecture of California with regard to the safety of children in public schools has been reported in the First World Conference. Legal responsibility for safety is placed with the school district. Consequently, school buildings in California which were not designed to be earthquake resistant according to present standards are checked by structural engineers, with the decision for rehabilitation, or demolishing and re-building, resting with the school district. In Acapulco, of four schools in the area studied, two schools were so seriously damaged as to require them to be completely or partially demolished, the third school was repaired, and the fourth suffered only minor damage. Had the structures been controlled by legal responsibility, the possibility of extensive damage would probably have been substantially minimized.

Fig. 15 shows the school which was partly collapsed and Fig. 16 shows one which was seriously damaged and which was torn down. Fig. 17 shows the third structure under discussion, a secondary school in which there are many column fractures. This three-story school structure was damaged in the 1957 shock, after which the third-story columns were enlarged. In the 1962 shocks, column fractures developed in the first and second stories, at the top or bottom or at both top and bottom, except for one case in the first story where a fracture occurred in the center of the story. Naturally, this fracture became a subject of much consideration and discussion by engineers.

The trend of these discussions is illustrated by excerpts taken from letters written by two outstanding engineers. The first letter reads in part:

> "An engineer was assigned the task of determining the cause of the mysterious cracks in the secondary school column. His verdict: mainly torsion...The curtain wall did not reach all the way up but left a space for a window. Somehow it was tied to...the column. Why should the crack form at that elevation? For one thing, if due to torsion it could form anywhere...But judging from what we saw in the second story it was a fairly haphazard business. This may have sharply localized the main crack. The picture is clearer if we think in terms of alternating torsion..."

> The reply reads in part:

> "With regard to the possibility of torsion explaining the cracks in the column, my only reaction at the time I looked at the building was that it could not have been overall torsion of the structure. However, it could very easily have been torsion in isolated portions corresponding to unbalanced forces acting on the curtain walls...In any event, there are still some difficulties in explaining the Acapulco damage incidents. I am still convinced there was a much higher vertical effect in Acapulco than in Mexico City and that this contributed to damage to the columns...in Acapulco...There is also an influence of the foundation conditions which may have contributed to a greater torsional effect in a number of buildings. I do agree...that torsion would have permitted the crack to form anywhere in the column, and flexure could not explain the position of the crack. Some force had to be exerted on the column at the location of the crack, but this might have come from the curtain wall if it was firmly attached.

> "Naturally my understanding of the Acapulco secondary school

becomes clearer as my memory of the facts becomes dimmer! I must confess that at the time I was completely confused and I almost wished I had never seen the building."

It may be concluded that the absence of ground motion records probably contributed to the confusion.

It may be of interest to mention that on one of the visits to the secondary school, in addition to observing and studying the column fractures, there was observed (1) loose soil displaced at the first floor by the earthquake ground motion and (2) a water table was located approximately 6 feet below the first floor and about 1 foot above the top of the pad of the spread footings.

Several questions come to mind. How much damage was caused by horizontal acceleration and how much by vertical acceleration? How would the structure have responded if a more effective first floor slab had been placed on well-consolidated soil and the slab had been firmly attached to the columns? What was the influence of the 1957 repairs in the top story of this structure? Was there no visible damage in the lower stories as a result of the 1957 shock? One can put all these factors together and get a complicated damage picture. Ground motion records might have given us a better quantitative breakdown.

A question may be posed as to whether the cracking of many columns at the top or bottom of a story, or at both top and bottom, resulted primarily from flexure. It might be suggested that other basic considerations may be involved. However, further conjecture could become boring.

Since the three schools previously discussed were closed for repairs or were being demolished, classes were held out of doors.

A fourth school not far from those described above had a minimum of damage. Fig. 18 shows this building, a framed structure with curtain dado walls. A close inspection indicated that the frame was undamaged and that only the curtain walls and crosswalls showed some damage in the form of diagonal cracking. Following careful inspection, classes continued uninterrupted.

A matter which merits serious consideration in regard to earthquakes is the question of soils. Fig. 19 shows a bluff of rock formation, an area which suffered little, if any, damage. If one marked on a geological map the locations of the structures which were seriously damaged, partially damaged, barely damaged (from visual and critical observation), etc., one would conclude that the effects of ground motions on these buildings varied according to geology, soil conditions, and foundation design, along with other items previously mentioned. One observer commented that the greatest damage occurred where structures or foundations were located on "false" soils.

Again returning to a topic previously discussed--the value of instrument records and the loss to scientific and engineering groups in furthering research when instrument records are not available--it should be made abundantly clear that, while the observations in this paper are on the Mexico earthquakes, the point at issue is a generalization which applies to all countries. We must, therefore, be especially grateful to those of our colleagues who had installed instruments in Mexico City and who were generous enough to share with us their records and other findings.

With recording instruments installed at strategic spots, with computers accelerating the rate of processing findings, with qualified engineers refining their methods of observation, and with public officials cooperating in code development and enforcement, citizens who live in areas subject to seismic disturbances can feel increased assurance that such organizations as IAEE and other like groups will continue to provide leadership in developing knowledge for seismic design which will make it possible to provide the public with a greater degree of safety.

Appreciation is expressed for the generous assistance given to the author by Luis Esteva, Emilio Rosenblueth, and Leonardo Zeevaert, of the Institute of Engineering, University of Mexico, and Carlos Correa and Guillermo Guerrero of Mexico City.

References

1. Zeevaert, L. and Newmark, N. M., "Aseismic Design of Latino Americana Tower in Meciso City," Proceedings of the First World Conference on Earthquake Engineering, Berkeley, California, 1956.

2. Esteva, L., "The Earthquakes of May 1962 in Acapulco," Mexican Society of Earthquake Engineering, Vol. 1, No. 2, December 1963.

3. Rosenblueth, E., "The Earthquake of 28 July, 1957 in Mexico City," Proceedings of the Second World Conference on Earthquake Engineering, Tokyo, Japan, Vol. 2.

4. Rosenblueth, E., "Aseismic Provisions for the Federal District, Mexico," Proceedings of the Second World Conference on Earthquake Engineering, Tokyo, Japan, Vol. 3.

5. Zeevaert, L., "The Development of Shear Displacement Meters and Accelerometers to Measure Earthquake Forces in Buildings," 1962 Proceedings, Structural Engineers Association of California.

6. Jennings, P. C., "Velocity Spectra of the Mexican Earthquakes of 11 May and 19 May, 1962," Earthquake Engineering Research Laboratory, California Institute of Technology, December, 1962.

7. Zeevaert, L., "Strong Ground Motions Recorded During Earthquakes of May 11 and 19, 1962, in Mexico City," Bulletin of the Seismological Society of America, February, 1964.

LATINO AMERICANA TOWER

DISPLACEMENTS AND COMPUTED FORCES OBSERVED DURING EARTHQUAKES ON JULY 28, 1957 AND MAY 11 & 19, 1962

NORTH - SOUTH

STORY	APPARATUS: COEFF. OF MAGNIFICATION	SPRING CONSTANT	JULY 28, 1957: 2A cm.	JULY 28, 1957: Δ cm.	JULY 28, 1957: FORCE TON	MAY 11, 1962: 2A cm.	MAY 11, 1962: Δ cm.	MAY 11, 1962: FORCE TON	MAY 19, 1962: 2A cm.	MAY 19, 1962: Δ cm.	MAY 19, 1962: FORCE TON
39	5.68	19.0×10^3	–	–	–	1.85	0.163	31	1.65	0.145	27.6
25	4.53	36.0×10^3	5.32	0.587	211	2.55	0.281	101	2.05	0.226	81.3
1	4.77	78.4×10^3	6.08	0.637	500	–	–	*350	3.40	0.356	280

EAST - WEST

STORY	APPARATUS: COEFF. OF MAGNIFICATION	SPRING CONSTANT	JULY 28, 1957: 2A cm	JULY 28, 1957: Δ cm.	JULY 28, 1957: FORCE TON	MAY 11, 1962: 2A cm.	MAY 11, 1962: Δ cm.	MAY 11, 1962: FORCE TON	MAY 19, 1962: 2A cm.	MAY 19, 1962: Δ cm.	MAY 19, 1962: FORCE TON
39	(4.94) 6.98	19.0×10^3	4.42	0.448	85	4.60	0.330	62.7	—		
25	5.32	36.0×10^3	6.86	0.645	232	4.30	0.404	145	1.90	0.179	64.3
1	–	784×10^3	–	–	–	–	–	–	–	–	–

* ESTIMATED FROM MAY 19, 1962. FORCES IN METRIC TONS.

N-S 25TH STORY	E-W 25TH STORY	N-S 1ST. STORY
MAY 19, 1962 / MAY 11, 1962 = 81.3/101 = 81%	MAY 19, 1962 / MAY 11, 1962 = 64.3/145 = 44%	MAY 19, 1962 / MAY 11, 1962 = 280/350 = 80%
MAY 11, 1962 / JULY 28, 1957 = 101/211 = 48%	MAY 11, 1962 / JULY 28, 1957 = 145/232 = 56%	MAY 11, 1962 / JULY 28, 1957 = 350/500 = 70%
MAY 19, 1962 / JULY 28, 1957 = 81.3/211 = 37%	MAY 19, 1962 / JULY 28, 1957 = 64.3/232 = 28%	MAY 19, 1962 / JULY 28, 1957 = 280/500 = 56%

DEAD LOADS - TONS	MAX. C%: JULY 28, 1957	MAX. C%: MAY 11, 1962	MAX. C%: MAY 19, 1962
1ST STORY - 15,454	3.2	2.3	1.8
25TH STORY - 4,147	5.6	3.5	2.0
39TH STORY - 655	13.0	9.5	4.3

FIGURE 1

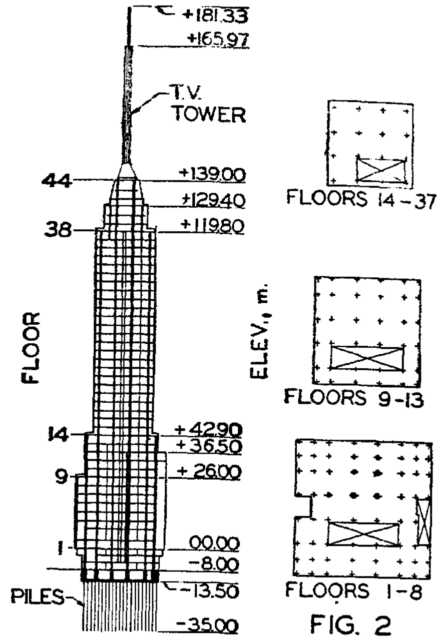


FIG. 2

2. Elevation and Cross-Sections of Latino Americana Tower

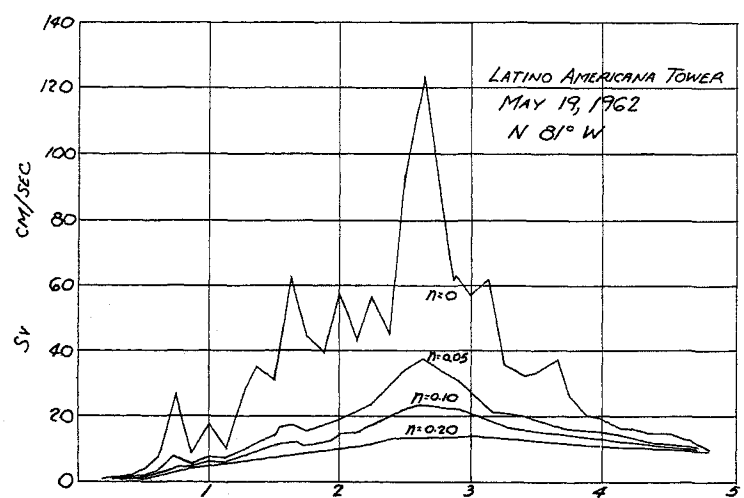
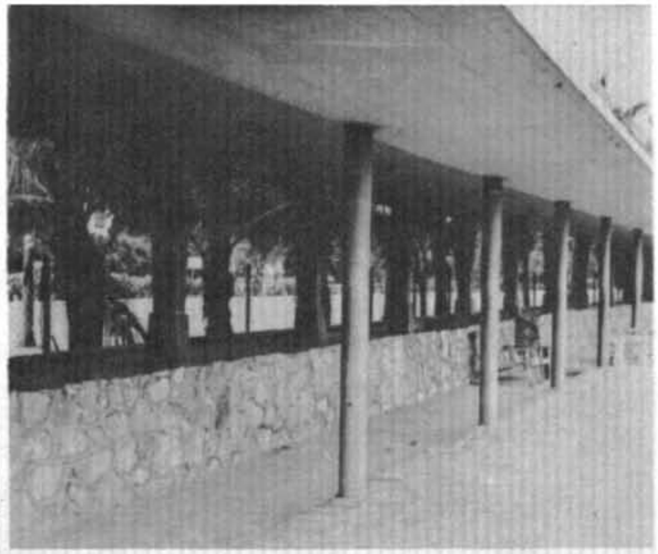


FIGURE 3

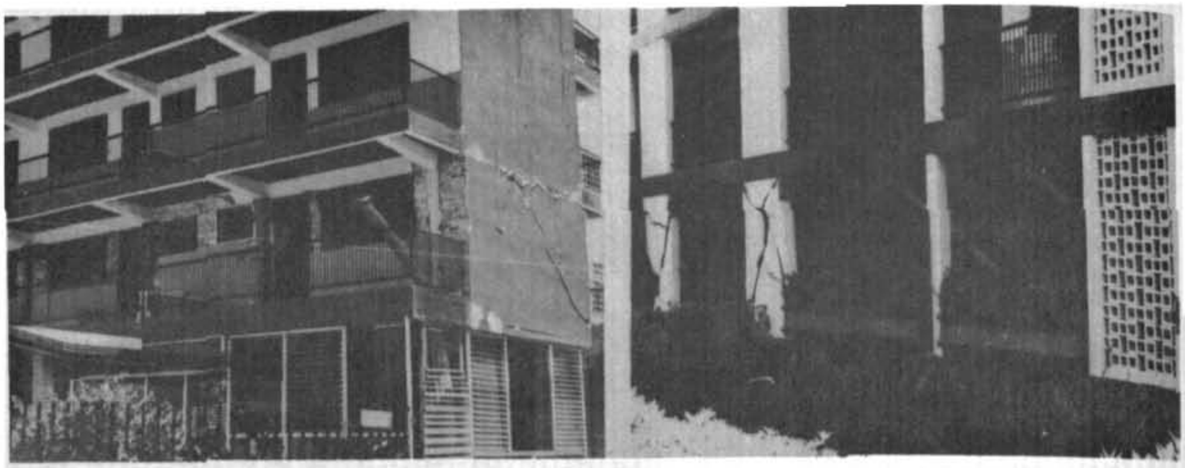
FLOOR SETTLEMENT
FIGURE 4



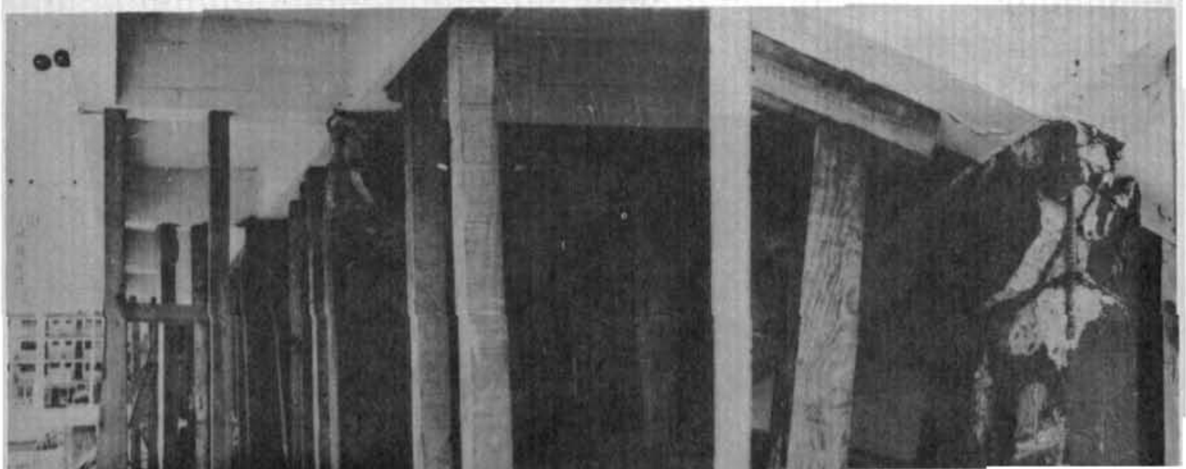
UMBRELLAS AND COVERED WALKWAYS
FIGURE 6

FIGURE 5 UMBRELLAS

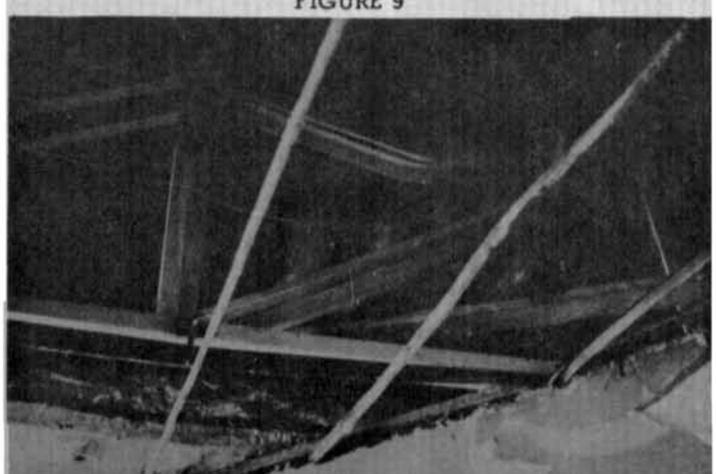
FIGURE 7 COVERED WALK DETAIL



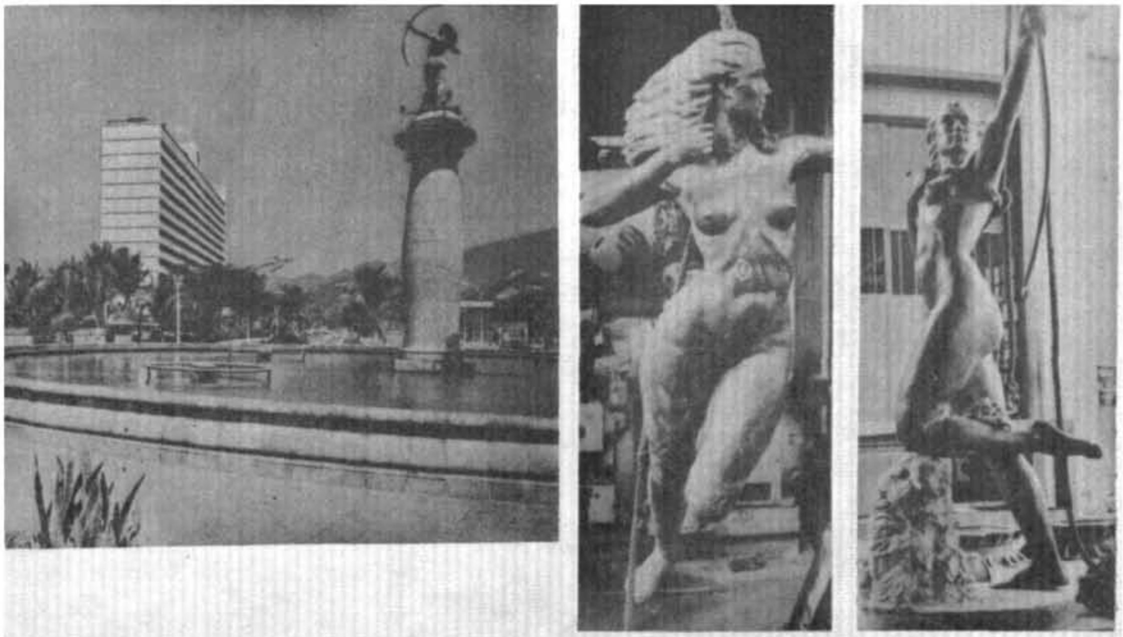
NON-TYPICAL DAMAGE
FIGURE 8



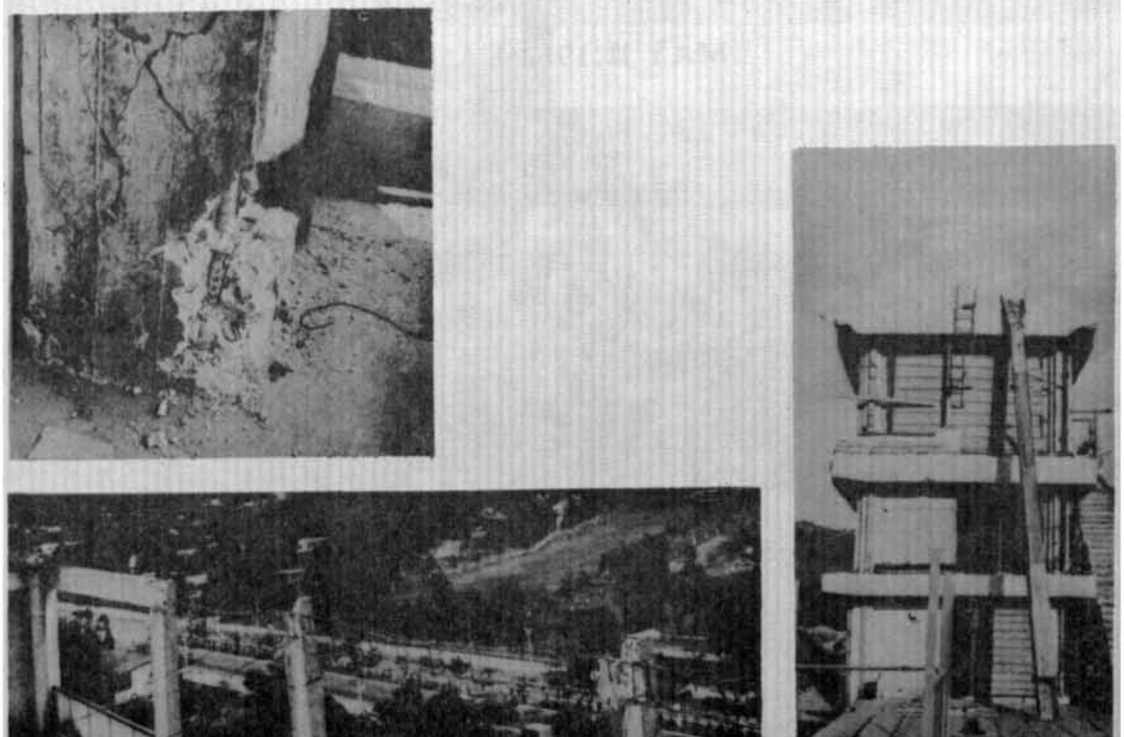
COLUMN FRACTURES
FIGURE 9



TRUSS CHORD
FIGURE 10



DIANA UNDONE
FIGURE 11



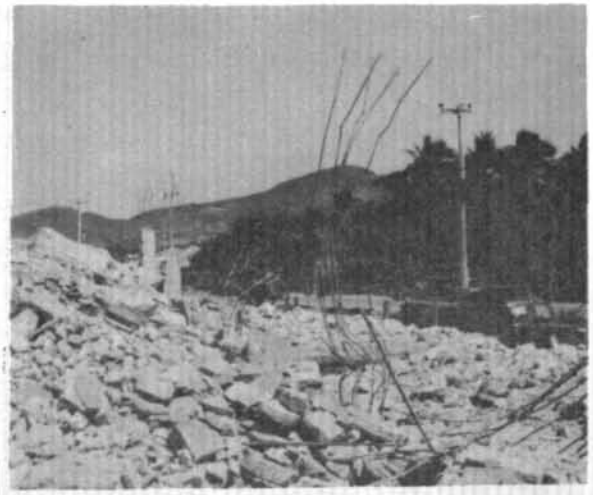
PENTHOUSE AND PARAPET
FIGURE 12

FIGURE 13

MAY 11, 1962 DAMAGE

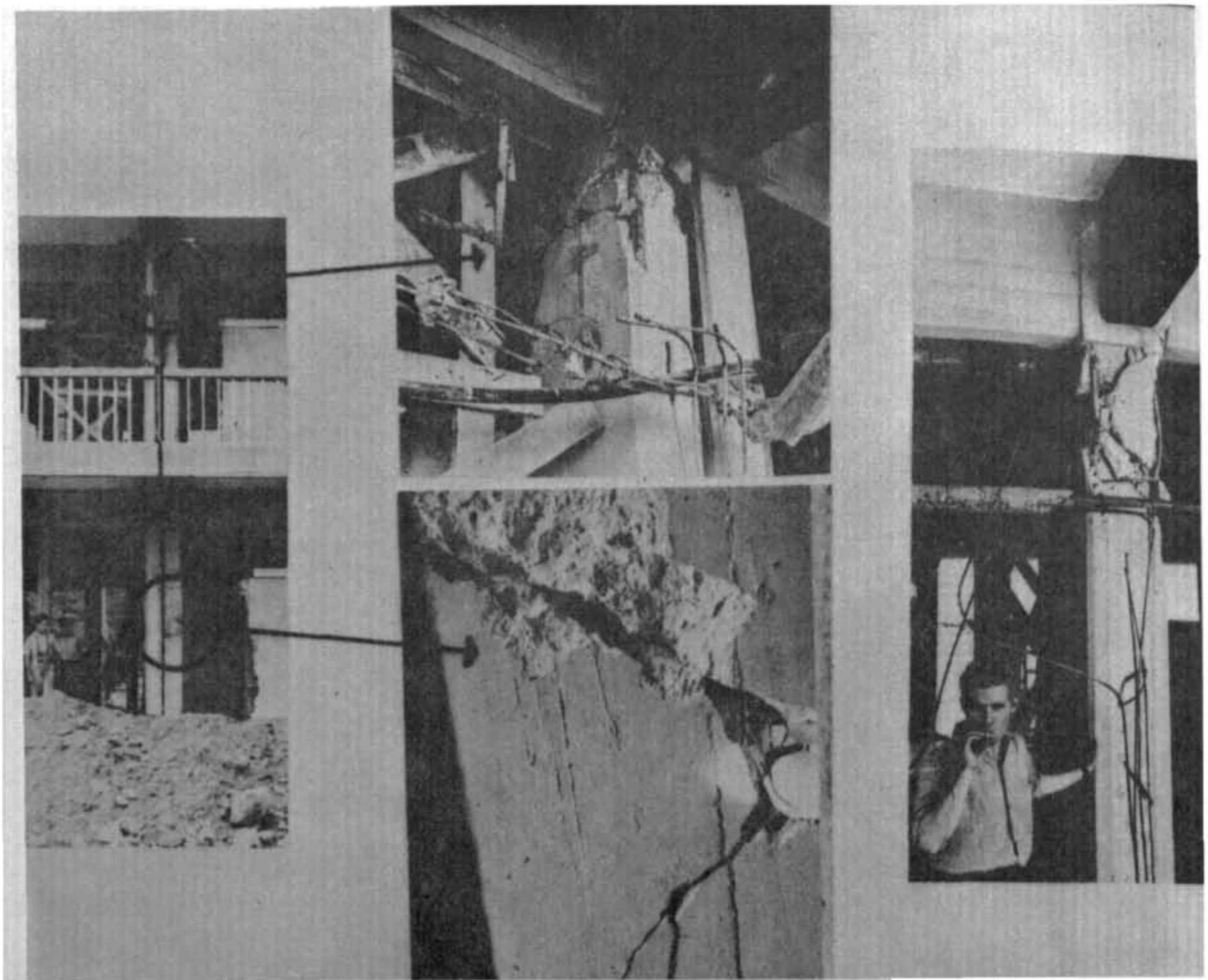
MAY 19, 1962 DAMAGE

THEATRE
FIGURE 14

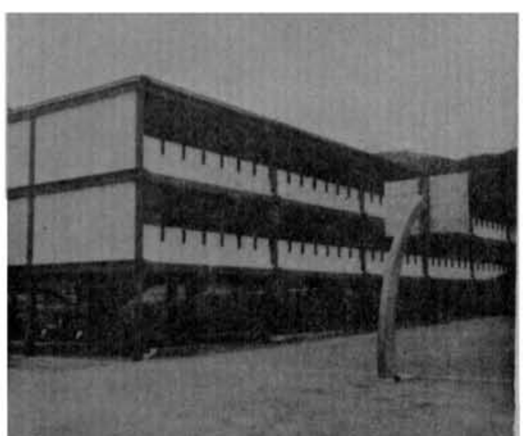


PARTIALLY COLLAPSED SCHOOL
FIGURE 15

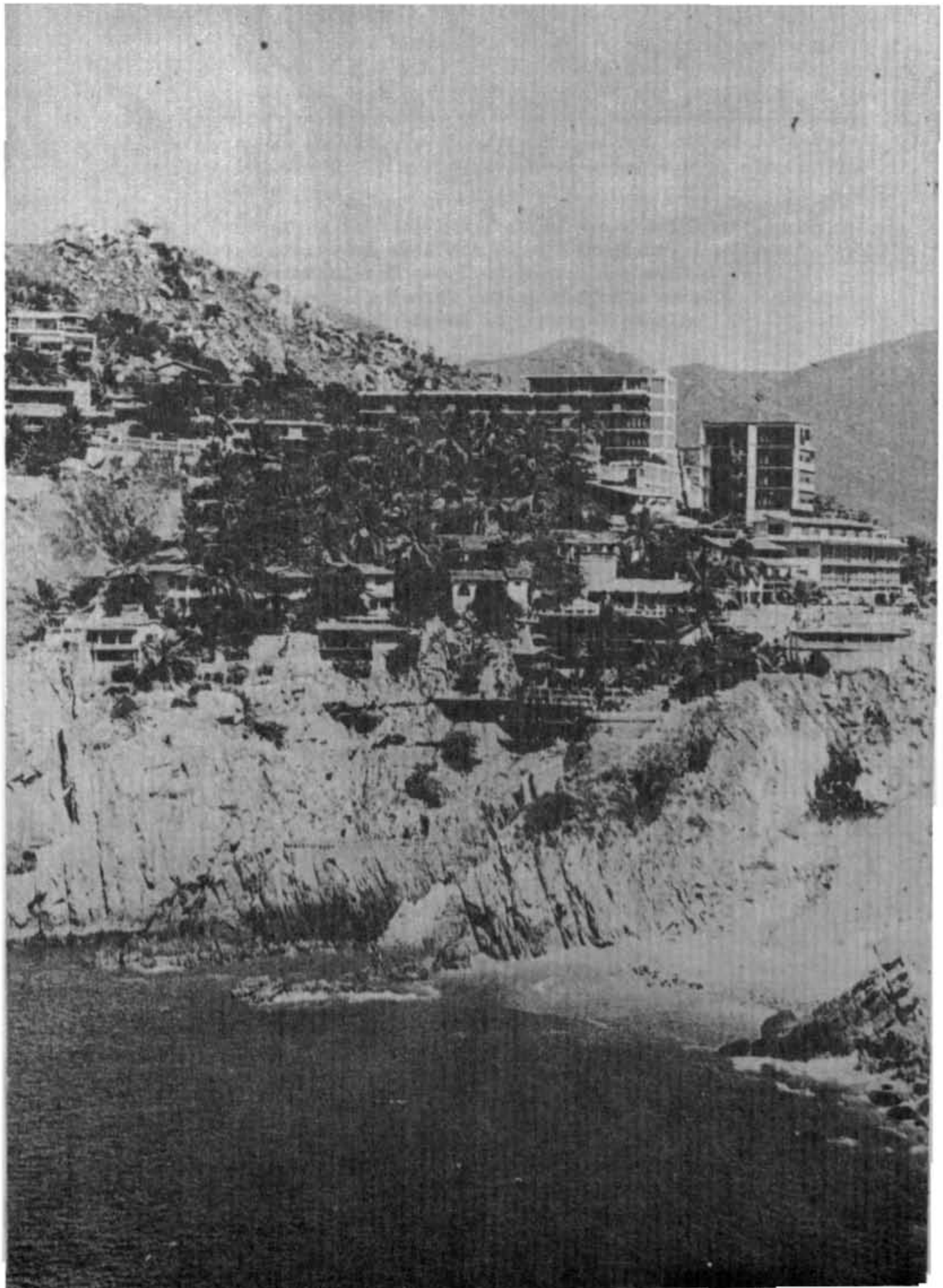
DAMAGED SCHOOL
FIGURE 16



COLUMN FRACTURES IN SCHOOL BUILDING
FIGURE 17



UNDAMAGED SCHOOL
FIGURE 18



STRUCTURES ON FIRM SOIL
FIGURE 19

THE ACAPULCO, MEXICO, EARTHQUAKES OF MAY 11 AND 19, 1962

BY R. W. BINDER

AUTHOR'S COMMENT: I am pleased to report that immediately prior to this afternoon's session I was fortunate enough to receive some collateral data from Dr. Leonardo Zeevaert, Consulting Engineer of Mexico City.

He asks that I express his regrets that commitments prevented his attendance; he further asks that I convey his best personal regards to mutual friends and sends his regards and best wishes for a successful conference.

Dr. Zeevaert supplied the following data for the July, 6, 1964, Mexican earthquake as to inter-story displacement obtained for the 39th story of the Latino Americana building of Mexico City.

Date of Earthquake	Story Displacement E-W, Δ, cm	Force Ton
July 28, 1957	0.448	85.0
May 11, 1962	0.330	62.7
July 6, 1964 *	0.272	51.8

* Dr. Leonardo Zeevaert's letter of January 25, 1965, to R.W. Binder.

QUESTION BY: JOHN C. MONNING - U.S.A.

Comment concerned importance of second line of defence to resist an immediate strong after shock after brittle first line of defence loses its ability to resist earthquake forces on buildings.

AUTHOR'S REPLY: The question as stated is quite interesting. As Mr. Monning knows, if the first line of defence is not properly conceived engineeringly, the second line of defence could be in for serious trouble. I would suggest that the first line of defence should be designed to perform satisfactorily on the basis of sound engineering over and above a considered theoretical analysis; if so conceived, the second line of defence acting in concert and harmoniously with the first line of defence, could probably take care of the unexpected.

Having seen considerable earthquake damage in many areas, it seems important that earthquake engineering be so soundly conceived that arbitary analyses or unusual assumptions are not necessary to explain away the earthquake damage.

Symmetry and simplicity of the total structure wherein the design encompasses the science and technology of dynamic analysis together with experience and good sound engineering judgment, with special attention given to all details, would contribute greatly to a first line of defence including the contribution of a considered second line of defence.

Progress in earthquake engineering will be made in stages, as knowledge is contributed and given considered engineering judgment, by engineering societies that are continuously keeping abreast of earthquake engineering and allied sciences.

QUESTION BY: C.M. STRACHAN - NEW ZEALAND

Could the author give some idea of the relative density of the granular soils which behaved satisfactorily during the Acapulco earthquakes?

AUTHOR'S REPLY: I am unable to answer this question with specific quantities. The paper by Luis Estava (to which I have referred) discusses soils, in a general way, at some length. In general, it may be said that for granular soils there were considerable differences from the visual viewpoint. Buildings with presumably good foundations in granular soils behaved very well; on the other hand, buildings with similar conditions but with poor foundations behaved very badly.

As Mr. Strachan knows, to get satisfactory results, granular soils should be well confined.