THE EFFECTS OF THE 1976 GUATEMALAN EARTHQUAKE ON EARTHEN HOUSES IN GUATEMALA

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ABSTRACT

This paper reports on what has happened to earthen structures in twenty-six Guatemalan communities studied over a four-year period since the 1976 earthquake. The data were obtained from three waves of personal interviews with 1472 randomly sampled household heads. The results show that adobe, which was the primary housing material before the earthquake was heavily damaged in that event. As a consequence the number of adobe structures and of other earthen structures has been drastically reduced. The people of Guatemala individually and because of agency housing programs have abandoned adobe as a building material and turned to concrete block and wood.

Surviving earthen structures have not been improved substantially and remain with largely the same structural features as before the earthquake. The greatest improvement is in the use of corner posts or columns in the walls but most of these are made of untreated crude logs or lumber, subject to rot and terminte damage. Little information on aseismic housing seems to have spread either within the earthquake area or in the unaffected areas surrounding it. A program to spread information on how to use adobe in aseismic designs needs to be conducted along with one to assist citizens to acquire the resources necessary to improve the earthquake vulnerability of houses.

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Dr. W. T. Farrell and Dr. JoAnn K. Glittenberg are co-principal investigators of the larger project from which these data derive and contributed substantially to conceptualization and data collection related to it. Thomas E. Edwards and Walter G. Peacock assisted in all stages of the larger project.

This paper reports on the results of a three-year longitudinal study of the 1976 Guatemalan earthquake. Specifically it examines what has happened to housing in twenty-six sample communities and urban neighborhoods between the pre-earthquake period and 1980. The focus is specifically on earthen buildings as compared to other types of housing.

The data upon which this research is based were obtained from personal interviews with a random sample of household heads in three separate interviews conducted approximately one year apart. The first interview was conducted in 1978; the second in 1979; and the third in 1980. Data on pre-earthquake housing were obtained during the first interview which took place two years after the earthquake. Retrospective questions were used to determine pre-earthquake housing characteristics and to obtain data on what damage was caused by the earthquake to various housing features. The characteristics of subsequent housing structures were obtained by a combination of interview questions and on-site inspection by interviewers. It is useful to think of this study as furnishing data on five time periods, as shown in the following table.

1. T_1 Pre-earthquake (Feb. 3, 1976)
2. T_2 Earthquake (Damage on Feb. 4, 1976)
3. T_3 Post-earthquake 1978
4. T_4 Post-earthquake 1979
5. T_5 Post-earthquake 1980

Data on T_1, T_2, and T_3 were obtained in the first interview and data on T_4 and T_5 were obtained in separate interviews conducted a year and two years later. A final note which may prove useful is the fact that the second interview at T_4 was conducted with only a 15 percent sample of the households interviewed on the first interview.

Sample

The sample for this study was drawn to meet several criteria. First, some sample units (either communities or urban neighborhoods) were selected to represent units which were within the area heavily affected by the earthquake and others were selected to represent matching units outside the affected area. These two groups of communities, for convenience, are called an experimental group (those heavily affected by the earthquake) and a control group (those only slightly affected or totally unaffected by the earthquake).

Sample units were also selected to represent communities of various size and political status and to represent communities that are primarily Indian or primarily Ladino in population. Thus the pattern outside Guatemala City was to select communities to represent department capitols, municipos and aldeas which were Indian and Ladino. In Guatemala City a special case exists. There is no other city to serve as a control for it. Furthermore, insufficient financial resources existed to do a random survey of the entire city. Therefore four neighborhoods which represent different kinds of reconstruction housing areas were selected as sample units. Two represent planned housing developments, one for Ladinos and the other originally for Indians. A third represents a spontaneously generated refugee shanty-town and the fourth a government refugee style temporary housing development.

INTERNATIONAL WORKSHOP

EARTHEN BUILDINGS IN SEISMIC AREAS

IMPLEMENTATION

The following individual made a keynote presentation:

Eric Carlson
UN Centre for Human Settlements
Nairobi, Kenya

The following individuals acted as Session Chairmen:

Mary E. McKay
Applied Technology Associates
McLean, Virginia

Babar Khan Mumtaz
Development Planning Unit
London, UK

Stephen O. Bender
OAS/Program of Regional Development
Montevideo, Uruguay

Table of Contents

Implementation

In each sample unit maps were drawn and a random sample of households interviewed. These same households were interviewed on successive interviews in a panel style design. All interviews were conducted at the housing site by a team of eight well-trained female Guatemalan interviewers. Where necessary, interpreters were used to translate between Spanish and an Indian dialect. It is important to remember in interpreting the findings that all data are based primarily on interviewee responses and not on engineering or architectural data collected by experts.

Change in Housing Types

In order to simplify the analysis of data revealing changes in housing styles, a housing typology based on wall-roof combinations was derived from the data. This typology is used in Table 1 to show changes in housing between the pre and post earthquake periods for the experimental group, control group and the city.

The first thing to note is the fact that the experimental group (earthquake impacted communities) contained 83 percent adobe walled houses in the pre-earthquake period as compared to around 40 percent in the control group. In the experimental group most adobe walled houses had tile roofs, while in contrast, most had lamina (corrugated galvanized steel) roofs in the control group. This seems to indicate that a trend towards abandoning adobe as a building material and tile as roofing may have been more advanced in the control group than in the experimental group before the earthquake.

The second fact to note in Table 1 is that by 1980 only about 11 percent of the buildings in the experimental group had adobe walls. Of these, only about seven percent had tile roofs. This represents a difference of 72 percent in the number of adobe housing units in a four year period. In comparison, the control group had dropped to 29 percent adobe walled buildings from a pre-earthquake 40 percent. The larger decrease in the experimental group of course reflects the destruction of adobe buildings in the earthquake and their replacement by non-adobe structures. In the control group little damage was suffered in comparison and a proportionately larger number of adobe structures survive. However, it is evident that control group members are also abandoning adobe as a wall material at a relatively rapid rate. Commensurate with the reduction in adobe as a wall material is the abandonment of tile for roofing and the substitution of lamina for it.

These changes in housing style are the consequence of both individual decisions and large-scale agency programs. Agency programs in particular featured either wooden structures, houses constructed of concrete block, or of half block-half wooden walls. These agency programs are reflected in changes observed in the experimental group where wooden structures increased from 0.75 to 23.37 percent; block from 1.74 to 24.70 percent; and half and half from 5.35 to 16.57 percent. These same sorts of trends, however, are reflected in the control group where no agency housing programs existed, but to a lesser extent. There changes are the consequence of individual decisions instead of outside agency policies.

Changes in the city reflect the same sort of trend observed in the experimental and control groups. Because of our sampling method, however, these data must be interpreted differently. Only new housing areas to which people had moved after the earthquake were studied in the city. Therefore, no one is living in the same house as before that event. In three of the four city samples all houses were "agency built" and none were adobe. In one area all were of wood; in two others all houses were of concrete block with lamina roofs. Only in the squatters settlement were buildings self-built or self-designed. Most of these fell into the patchwork category - meaning that they were made of scraps of any available material.

What this table does show is that 206 out of the 320 people studied in the city formerly lived in adobe structures, or about 64 percent of them.

Damage to Various House Types

In order to determine the amount of damage suffered by each household, the household head was asked to rate the damage to various house features on the following scale.

Damage Score	Damage Category
0	None
1	Slight (requiring only minor repairs)
2	Heavy (requiring extensive repairs)
3	Destroyed (needing complete rebuilding)

Table 2 shows damage scores for the average damage to the walls of a house by each house type. A score of 3.00 would mean the walls were destroyed; a score of 2.00 that they were heavily damaged, etc. With respect to adobe houses with tile roofs the figure shown in the table is 2.38. In other words, for the 410 such houses, the average damage to the walls was between "heavy" and "destroyed." The table also shows the average wall x roof damage. The figure 2.29 means that when damage to wall and to roof are averaged for the 410 adobe houses with tile roofs, the result shows that they suffered between "heavy damage" and "destroyed." Similar figures are presented for the control group and for each house type. These figures indicate that the control group suffered only slight damage on an average, while the experimental group suffered from very heavy to slight damage, depending on house type.

Adobe structures stand out as those suffering the greatest damage, while wood, block and thatch stand out as suffering only slight damage. Another thing that is apparent is that bajareque structures (cross-woven sticks attached to posts and filled with earth) fared considerably better than plain adobe. Another point which is surprising is the apparent fact that adobe buildings with lamina roofs fared slightly worse than those with tile roofing. This difference is significant for damage to walls but not for damage to the roof. In other words, there is a significant difference in the amount of damage suffered by adobe walls when they have lamina or tile roofs with the lamina roof being associated with greater damage. This may be due to the use of heavier timbers to support the roofs of houses using tile for roofing.

In Table 3 earthen and non-earthen structures are compared with respect to damage. Earthen structures include houses with walls constructed of (1) adobe, (2) bajareque, (3) tapia, or (4) half adobe and half light weight upper wall material. Non-earthen houses consist of all others. For the entire sample, including the control and experimental groups, as well as the city, earthen structures suffered much heavier damage (2.12) than non-earthen ones (0.64). The difference is highly significant statistically. Furthermore, this difference holds up in all sample groups. Even in the control group, where the damage was characteristically light, earthen buildings suffered significantly more damage.

It should be noted that almost all of the earthen buildings in this sample were constructed of adobe. As a consequence these figures are heavily influenced by this type of structure.

Housing Features Combined with Earthen Structures

During the first interview data were collected concerning certain structural features of houses. Among the features studied were the following: (1) foundations, (2) columns or corner posts, (3) vegas or beams, (4) solera or roof plate and (5) cross bracing in the walls. Respondents were asked if their house contained such a feature and what material was used in constructing it. Tables 4 through 8 show the information obtained for pre and post-earthquake earthen structures.

First, with respect to foundations, most earthen structures either had no foundation, or one made of adobe or packed mud before the earthquake (55.61%). About seventeen percent had foundations of loose stones. Only about 20 percent had more stable foundations. Two years after the earthquake the proportion of earthen buildings with no foundations or with one of adobe or packed mud, had decreased to 52.40 percent and two years later to 45.61 percent. More structures show up as having stone, rock or cement foundations in 1978 and in 1980. There appears therefore to have been a slight improvement in the stability of foundations used in adobe buildings since the earthquake.

The use of columns or corner posts as shown in Table 5 has considerably increased. Before the earthquake over 75 percent of all earthen structures lacked corner posts. By 1978 only 35 percent were without them. This may be due to the greater survivability of adobe structures with such a feature rather than to the introduction of this practice in the post earthquake period. The greatest increases in the use of a given material for use in corner posts occurred with respect to rough logs or crude lumber, however. Since they are subject to rot and termite damage, the benefit may be only temporary. There is little support for the idea that stronger, more durable materials are being employed for this purpose.

Almost all houses made of adobe or other earthen materials used vegas or beams at the top of the walls running from front to rear. As shown in Table 6, almost all of these were made of rough logs or crude lumber before the earthquake. Since then, the proportion using more substantial materials has increased slightly, but not significantly.

Similarly, almost all earthen houses (91%) employed some type of plate or solera at the top of the walls to support the roof. Most were made of some form of sawed or milled lumber or of untreated logs. The proportion using each material has changed little since the earthquake, although it appears that more are using crude logs instead of milled lumber. (See Table 7)

Finally, cross bracing of any sort is very rare in earthen structures in Guatemala. Before the earthquake 94 percent lacked this feature. Since the earthquate proportionately fewer earthen houses employ any form of cross bracing. The change, however, is minor. (See Table 8)

The above discussion leads to the conclusion that except for a greater use of crude corner posts, there has not been much change in the structural features of earthen houses in Guatemala since the 1976 earthquake. In large part, this may be due to the fact that in the experimental group earthen buildings have dramatically decreased. People seeking greater earthquake protection are seeking it by abandoning adobe as a building material, rather than by improving adobe structures. Most of the earthen structures remaining after the earthquake that are shown in the above tables are located in the control group area which lies outside the area experiencing the destructive effects of the earthquake. Here little information concerning earthquake resistance and earthen structures may have penetrated. A later section of this paper will examine the information people received concerning aseismic construction.

Damage to Earthen Structures Having Various Features

It is possible, given the data discussed above,to examine what respondents reported in terms of damage to earthen structures with various types of structural features. For example, what do the data show concerning what happened to earthen buildings without foundations or with foundations made of less stable materials such as adobe, packed mud or loose stones as compared to those with foundations of concrete, reinforced concrete, or rock and cement? Table 9 shows the results of this comparison.

As can be seen, our data show no difference in the amount of damage suffered by earthen buildings with different types of foundations. This is probably due to the fact that few of them contained columns or corner posts to attach them to their foundations.

A similar procedure can be followed with respect to how the presence or absence of support columns or corner posts affected the damage suffered by earthen buildings. Table 10 shows damage figures for earthen structures in the experimental group that used any kind of corner post or support column against those that employed none at all. This table shows that earthen buildings with corner posts suffered significantly less damage than those without them. This is true of wall and roof damage considered separately or together. Nevertheless, buildings with corner posts of the type used by the people in this survey (crude logs or rough lumber) still suffered rather heavy damage. On our scale it comes very close to "heavy damage" as opposed to "light damage" or "none."

The only other feature on which there were enough cases to test an hypothesis was "solera." The solera, as defined for our study, consists of the plate at the top of the wall upon which the roof structure rests. When houses with no solera, or with one made of crude logs or lumber, were compared to those made of milled lumber or concrete, either reinforced or not, the results shown in Table 11 were obtained. This table seems to show that houses with more elaborate soleras suffered more damage than those with simpler cruder ones. A test was made to examine those with no solera at all against those with them and similar results were obtained. Houses without soleras suffered less damage than those with them. When houses with soleras were examined to see how the presence or absence of corner posts affected damage, it was found that having corner posts or not having them did not affect the amount of damage if a house had a solera. In short, our data seem to show that earthen structures with some form of solera or plate at the top suffered more damage than those without them. This also seems to have been unaffected by the type of roof on the house. For example, when houses with soleras were compared on whether or not they had tile roofs or non-tile roofs, it was found that there was no difference according to the type of roof.

It must be remembered that these data are the result of a survey by a team of interviewers who recorded the evaluations of householders concerning damage suffered by their houses and also reported the structural features of these houses. It is hard to imagine a psychological or attitudinal bias that would affect nearly 500 respondents in such a way that they would tend to misreport damage to houses with a given structural feature. We are left with the conclusion that soleras, as employed in Guatemala, produced greater damage than would occur without them.

Information Received and Actions Taken Concerning Aseismic Construction in Housing

During the first interview respondents were asked two questions designed to determine their perceptions of aseismic housing construction. First, they were asked what they had heard about how to make houses safer in an earthquake. Later they were asked if they had done anything to improve the earthquake safety of their homes and what it was that they did. Table 12 gives a tabulation of answers to these questions.

First, it is important to note that respondents volunteered these responses. They were not asked, for example, if they had heard that steel reinforcement in walls was a good thing. Instead, they had to supply the answer without prompting from the interviewer. The question asking what they had done to improve the safety of their home was asked in a similar fashion.

The most significant bits of information in Table 12 are that almost 73 percent of all respondents said they had heard nothing concerning the improvement of earthquake resistance in housing and almost the same percentage said they had done nothing to improve the aseismicity of their homes. When the control and experimental groups are compared, the data show that only slightly more people in the experimental group (heavily impacted communities) heard advice on this subject than in the control group. (Eexperimental Group about 29%; control group about 25%) The city sample shows the smallest proportion of people claiming to have heard something (24%). This is probably the result of the fact that the sample here consists of people who were completely rehoused by agency programs or by the founding of a squatters settlement. They were people without land, mostly renters, from the poorest segment of the city's population, making them an especially disadvantaged group. They were less likely to have access to mass media. Most of them were also rehoused by agency programs where advice on aseismic construction was not featured.

There is a much larger difference, however, between the control and experimental groups in how many respondents reported doing something. In the control group 79 percent said they did nothing as compared to 67 percent in the experimental group. The comparable figure for the city is 84 percent who did nothing.

These data show that surprisingly few respondents claimed to have heard anything about aseismic construction. More discouraging is the fact that even in the earthquake impacted area two-thirds did nothing to improve their situation. In the surrounding lightly impacted area of the control group, over 78 percent did nothing to improve the earthquake resistance of their houses. In other words, a relatively small spill-over of activity from the earthquake area to improve aseismicity in non-impacted areas occurred.

When the types of advice heard and the types of actions taken are examined in detail, it appears that the most frequent sorts of advice heard were: (1) use concrete columns (8.62%); (2) use block or brick for wall material (6.52%); (3) don't use adobe (5.98%). No other advice was heard by as many as 5 percent of the sample. The most frequent actions taken were: (1) use of wood bracing (7.61%); (2) use of concrete columns (6.73%); and (3) non-use of adobe (3.60%).

When those who received information on improvement in the earthquake resistance of their housing were asked where they obtained their information, the data shown in Table 13 were obtained. This table shows that the most frequent response was that they already knew what was safer before the earthquake (14.95%). After that the major source of information was from the informal network of neighbors and relatives (12.02%). Talks given by agencies reached only 6.72 percent and agency publications only 1.83 percent. In the experimental group proportionately more people (9.08%) obtained information from agency talks or from agency pamphlets (2.99%) than in the control group or city. Likewise, more obtained information from the informal network (13.06%). Interestingly enough, radio and television were the major sources of information in the control group (11.21%) after "previous knowledge," but radio and television were reported by only 3.11 percent in the experimental group and 3.44 percent in the city as their sources of information. This probably reflects the fact that control group members obtained almost all of their information about the earthquake's effects indirectly through the mass media since they were not first-hand witnesses to the event. On the other hand, experimental group members and members of the city sample were in the midst of the destruction and knew first-hand what was going on. They may not have listened to radio and television reports as frequently for this reason.

At any rate, this table seems to show that, to be effective, an information program concerning housing improvement in a disaster occurring in a country like Guatemala should be conducted on a face-to-face basis within the disaster area itself, using the informal network as a primary means of spreading information. The mass media seem to be of dubious value for this purpose. Television in particular is ineffective since it requires a power source which is apt to be destroyed and the set itself may be easily damaged. Furthermore, in poor areas there are likely to be few televisions available to begin with.

Furthermore, it is apparent that in Guatemala an educational program aimed at disseminating information on aseismic housing features, especially as they relate to earthen buildings, is needed if the future earthquake vulnerability is to be reduced. This must be accompanied by a governmental program designed to assist citizens to obtain the materials necessary to follow the practices prescribed by the educational program.

The situation is even more acute outside the high impact area of the 1976 earthquake than within it. In the impacted area changes in housing have occurred in the direction of safer housing, but in the surrounding unimpacted areas, housing remains largely as it was before February 1976. A future earthquake in these areas is highly probable and consequences similar to those of 1976 can be expected unless some change in housing takes place. The farther away from 1976 we get the less likely lessons learned then will be applied to improving older structures and the more likely a new occurrence of a disaster becomes.

This research shows that the primary adaptation of people in Guatemala to earthquake vulnerability has been to abandon the use of traditional earthen buildings and to shift to the use of concrete block and wood as primary building materials. Wood is a scarce and expensive commodity. The country is already faced with a deforestation problem because of the use of wood as the primary fuel used in cooking. Concrete block is expensive, and if used improperly, as dangerous as adobe.

A more desirable solution to the problem of aseismic housing would be to find a cheap and effective means of improving the aseismic qualities of adobe. Some have suggested an emphasis on bajareque construction or the use of adobe de canto. Sporadic efforts by some agencies to promote these ideas have so far shown little success outside of a few communities where the programs were highly concentrated. Whatever program is chosen must match the spread of technical information with methods to make the financial and material resources necessary to carrying them out available on a widespread basis.

TABLE 1

House Types Before and After the Earthquake in the Control and Experimental Groups

House Types (wall x roof)	Experimental Group: Pre EQ House (1976)		House Time 3 (1978)		House Time 5 (1980)		Control Group: Pre EQ House (1976)		House Time 3 (1978)		House Time 5 (1980)		Guatemala City: Pre EQ House (1976)		House Time 3 (1978)		House Time 5 (1980)	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Adobe-Tile	410	51.00	54	6.71	49	7.25	59	16.95	29	8.33	23	7.52	20	6.25				
Adobe-Lamina	255	31.72	32	3.98	26	3.85	81	23.28	79	22.70	65	21.24	186	58.13				
Wood-Lamina or Duralita	6	.75	209	25.00	158	23.37	21	6.03	38	10.92	30	9.80	46	14.38	101	31.56	87	32.46
Block-Lamina or Duralita	14	1.74	128	15.92	167	24.70	25	7.18	45	12.93	61	19.94	27	8.44	150	46.88	129	48.13
Bajareque-Thatch	34	4.23	11	1.37	7	1.04	9	2.59	4	1.15	5	1.63	1	.31				
Bajareque-Tile	14	1.74	16	1.99	10	1.48	10	2.87	9	2.59	5	1.63	1	.31				
Cane-Thatch	14	1.74	16	1.99	13	1.92	45	12.93	31	8.91	20	6.54	1	.31				
Cane-Lamina, Duralita	8	1.00	54	6.72	44	6.51	36	10.34	37	10.63	31	10.13	5	1.56				
Patchwork-Any Roof	3	.37	68	8.46	41	6.06	1	.29	9	2.59	4	1.31	10	3.13	45	14.06	40	14.92
Half Block or Half Adobe-Half Light Material	3	5.35	128	15.92	112	16.57	13	3.74	19	5.46	19	6.21	6	1.88				
Other	43	5.35	88	10.94	49	7.25	48	13.79	48	13.79	43	14.05	17	5.31	24	7.50	12	4.48
TOTAL	804	100.00	804	100.00	676	100.00	348	100.00	348	100.00	306	100.00	320	100.00	320	100.00	268*	100.00
Missing Cases Due to Attrition			-		128		-		-		42							

* 52 of the original 320 cases were unavailable for reinterview.

TABLE 2

Average Damage To Various Types of Walls and Wall Roof Combinations in the Experimental, Control Group and City.

House Types (wall x roof)	Experimental Group					Control Group					Guatemala City					Total, Experimental, Control & City				
	Wall Damage			Average Wall-Roof Damage		Wall Damage			Average Wall-Roof Damage		Wall Damage			Average Wall-Roof Damage		Wall Damage			Average Wall-Roof Damage	
	N	Mean*	St. Dev.	Mean*	St. Dev.	N	Mean*	St. Dev.	Mean*	St. Dev.	N	Mean*	St. Dev.	Mean*	St. Dev.	N	Mean*	St. Dev.	Mean*	St. Dev
Adobe-Tile	410	2.38	.92	2.29	.88	59	.98	.91	.88	.88	20	2.65	.49	2.52	.57	489	2.13	.99	2.22	1.02
Adobe-Lamina	255	2.58	.73	2.41	.90	81	.74	.73	.44	.56	186	2.42	.77	2.17	.96	522	2.02	1.11	2.23	.99
Wood-Lamina or Duralita	6	0.00	0.00	0.00	0.00	21	.04	.22	.02	.11	46	1.11	.98	1.01	.97	73	.64	.91	.72	.95
Block-Lamina or Duralita	14	.57	.85	.39	.79	25	.20	.50	.12	.33	27	.91	1.07	.70	.96	66	.41	.78	58	.89
Bajareque-Thatch	34	1.71	1.17	1.44	1.19	9	.44	1.01	.44	1.01	1 1	1.00 1.00	-- --	.50 .50	-- --	44	1.22	1.21	1.41	1.23
Bajareque-Tile	14	1.64	1.22	1.68	1.17	10	.50	.97	.55	1.01	1	3.00	--	3.00	--	25	1.28	1.25	1.24	1.27
Cane Thatch	14	.50	.94	.46	.91	45	.24	.68	.21	.62	1	0.00	--	0.00	--	60	.27	.70	.30	.74
Cane-Lamina, Duralita	8	1.88	1.36	1.81	1.41	36	.17	.61	.12	.53	5	2.20	1.30	2.20	1.30	49	.61	1.15	.65	1.16
Patchwork-Any Roof	3	1.33	1.53	1.33	1.44	1	1.00	--	.50	--	10	1.60	.84	1.20	.89	14	1.18	.95	1.50	.94
Half Block or Half Adobe-Half Light Material	3	1.33	.57	1.00	.87	13	.23	.44	.12	.72	6	2.00	1.26	1.92	1.36	22	.73	1.09	.86	1.08
Other	43	1.74	1.27	1.69	1.17	48	.48	.71	.33	.53	17	1.18	.95	.97	.89	108	.98	1.09	1.09	1.16
TOTAL	804	2.27	1.02	2.15	1.03	368	.50	.78	.38	.67	320	2.01	1.04	1.79	1.12	1472	1.80	1.21	1.66	1.22

*0 = No Damage, 1 = Slight Damage, 2 = Heavy Damage, 3 = Destroyed

Table 3

Damage to Earthen and Non Earthen Buildings in the Experimental, Control Group and Guatemala City

	0 None		1 Slight		2 Heavy		3 Destroyed		Total		Mean	t	d.f.	Significant Level
	No	%	No	%	No	%	No	%	No	%				
CONTROL GROUP														
Non Earthen	131	86.75	12	7.95	6	3.97	2	1.32	151	100.0	0.20	- 7.30	342	.0001
Earthen	91	46.19	73	37.06	25	12.69	8	4.06	197	100.0	0.75			
Total	222	63.79	85	24.43	31	6.91	10	2.87	348	100.0				
EXPERIMENTAL GROUP														
Non Earthen	38	58.46	11	16.92	6	9.23	10	15.38	65	100.0	0.82	-10.99	72	.0001
Earthen	40	5.42	77	10.42	178	24.09	444	60.08	739	100.0	2.40			
Total	78	9.72	88	10.95	184	22.89	454	56.47	804	100.0				
CITY														
Non Earthen	36	33.64	30	28.04	28	26.17	13	12.15	107	100.0	1.17	-11.28	165	.0001
Earthen	4	1.88	23	10.80	63	29.58	123	57.75	213	100.0	2.43			
Total	40	12.50	53	16.56	91	28.44	136	42.50	320	100.0				
TOTAL SAMPLE														
Non Earthen	205	63.47	53	16.41	40	12.38	25	7.74	323	100.0	.64	-23.62	561	.0001
Earthen	135	11.80	173	15.08	266	23.15	575	50.04	1149	100.0	2.12			
Total	240	23.17	226	15.35	306	20.79	600	40.76	1472	100.0				

TABLE 4

Foundations of Earthen Buildings

Foundation Types	Pre Earthquake House 1976		Post Earthquake House 1978		Post Earthquake House 1980	
	#	%	#	%	#	%
None	141	12.27	123	29.57	76	24.76
Adobe	461	40.12	88	21.15	61	19.87
Packed Mud	37	3.22	7	1.68	3	0.98
Loose Stones	197	17.14	79	18.99	73	23.78
Rock or Cement	222	19.32	94	22.60	76	24.76
Concrete - No Reinforcement	5	0.44	3	0.72	2	0.65
Reinforced Concrete	6	0.52	3	0.72	3	0.98
Other	6	0.52	5	1.20	2	0.65
No Information	74	6.44	14	3.36	11	3.58
TOTAL	1149	100.00	416	100.00	307	100.00

TABLE 5

Columns or Corner Posts in Earthen Structures Before and After the Earthquake

Types Columns or Corner Posts	Pre Earthquake House T_1 1976		Post Earthquake House T_3 1978		Post Earthquake House T_5 1980	
	#	%	#	%	#	%
None	865	75.28	147	35.34	114	37.13
Rough Logs	154	13.40	162	38.94	110	35.83
Treated Logs	0	0.00	1	0.24	2	0.65
Crude Lumber	98	8.53	83	19.52	61	19.87
Treated Lumber	0	0.00	3	0.72	3	0.98
Unreinforced Concrete	5	0.44	2	0.48	2	0.65
Reinforced Concrete	12	1.04	14	3.36	11	3.58
No Information	15	1.30	4	0.96	4	1.30
TOTAL	1149	100.00	416	100.00	307	100.00

TABLE 6

Beams or Vegas in Earthen Structures Before and After the Earthquake

Types Beams or Vegas	Pre Earthquake House T_1 1976		Post Earthquake House T_3 1978		Post Earthquake House T_5 1980	
	#	%	#	%	#	%
None	1	0.09	1	0.24	0	0.00
Rough Logs	390	33.94	157	37.74	111	36.16
Treated Logs	5	0.43	5	1.20	4	1.30
Crude Lumber	740	64.40	250	60.10	188	61.24
Treated Lumber	8	0.70	3	0.72	2	0.65
Metal	0	0.00	0	0.00	1	0.33
No Information	5	0.43	0	0.00	1	0.33
TOTAL	1149	100.00	416	100.00	307	100.00

TABLE 7

Solera in Earthen Buildings

Types of Solera	Pre Earthquake House 1976		Post Earthquake House 1978		Post Earthquake House 1980	
	#	%	#	%	#	%
None	99	8.62	38	9.13	22	7.17
Milled Lumber	746	64.93	252	60.58	188	61.24
Concrete	3	0.26	0	0.00	0	0.00
Reinforced Concrete	13	1.13	8	1.92	4	1.30
Metal	0	0.00	0	0.00	0	0.00
Untreated Logs	269	23.41	118	28.37	92	29.97
No Information	19	1.65	0	0.00	1	0.33
TOTAL	1149	100.00	416	100.00	307	100.00

TABLE 8

Cross Bracing in Earthern Structures Before and After the Earthquake

Type of Cross Bracing	Pre Earthquake House T_1 1976		Post Earthquake House T_3 1978		Post Earthquake House T_5 1980	
	#	%	#	%	#	%
None	1083	94.25	404	97.35	294	96.08
Wire	25	2.18	4	0.96	4	1.31
Wood	34	2.96	5	1.20	5	1.63
Iron or Steel	2	0.17	1	0.24	1	0.33
Other	2	0.17	0	0.00	0	0.00
No Information	3	0.26	2	0.48	2	0.65
TOTAL	1149	100.00	416	100.00	306	100.00

TABLE 9

Differences Between Earthen Structures with Stable and Less

Stable Foundations in Amount of Damage Reported

Foundation Type	Average Wall and Roof Damage	Average Wall Damage	Average Roof Damage
None, Adobe, Packed Mud or Earth, Loose Stone	2.29	2.39	2.18
Rock & Cement, Concrete, Reinforced Concrete	2.23	2.35	2.11
t	.5635	.4103	.6193
df	737	737	737
Probability	.5732	.6817	.5359

TABLE 10

Differences in Damage to Earthen Structures with and without Corner Posts or Support Columns

Corner Posts	Average Wall-Roof Damage	Average Wall Damage	Average Roof Damage
Without	2.33	2.44	2.23
With	1.97	2.11	1.82
t	3.3101	3.0092	3.2712
df	146	143	152
Probability	.0012	.0013	.0013

TABLE 11

Average Damage to Earthen Structures With Various Types of Solera

Type of Solera	Average Wall-Roof Damage	Average Wall Damage	Average Roof Damage
None, Untreated Logs or Crude Lumber	2.10	2.18	1.99
Milled Lumber, Concrete, Reinforced Concrete or Metal	2.39	2.50	2.28
t	-4.0002	-4.0858	-3.4626
df	564	535	589
Probability	.0001	.0001	.0005

TABLE 12

Advice Heard and Actions Taken Concerning Improvement in Earthquake Resistance in Housing

	Control Group				Experimental Group				Guatemala City				Total			
	What Heard		What Done		What Heard		What Done		What Heard		What Done		What Heard		What Done	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Nothing	260	74.71	274	78.74	568	70.65	537	66.79	243	75.94	270	84.37	1071	72.76	1081	73.44
Stronger Foundation	10	2.87	12	3.45	26	3.23	38	4.73	12	3.75	0	0.00	48	3.26	50	3.40
Non-Tile Roof	8	2.30	5	1.44	26	3.23	18	2.24	4	1.25	2	0.62	38	2.58	25	1.70
Wood Bracing	7	2.01	19	5.46	22	2.74	71	8.83	4	1.25	22	6.88	33	2.24	112	7.61
Concrete-Columns	29	8.33	24	6.90	81	10.08	74	9.20	17	5.31	1	0.31	127	8.62	99	6.73
Block or Brick Walls	24	6.90	9	2.59	50	6.22	20	2.49	22	6.88	0	0.00	96	6.52	29	1.97
Non-Adobe Walls	19	5.46	5	1.44	48	5.97	40	4.98	21	6.56	8	2.50	88	5.98	53	3.60
Reinforced Adobe Walls	2	0.58	2	0.58	27	3.36	8	1.00	0	0	0	0.00	29	1.97	10	0.68
Safer House Site	0	0.00	0	0.00	3	0.37	3	0.37	1	0.31	1	0.31	4	0.27	4	0.27
Light Upper Walls	2	.58	3	0.86	19	2.36	19	2.36	8	2.50	0	0.00	29	1.97	22	1.50
More Space Between Houses	0	0.00	0	0.00	0	0.00	1	0.12	0	0.00	0	0.00	0	0.00	1	0.07
Balanced Door Placement	0	0.00	0	0.00	3	0.37	0	0.00	0	0.00	0	0.00	3	0.20	0	0.00
Doors Open Out	0	0.00	0	0.00	0	0.00	0	0.00	1	0.31	0	0.00	1	0.07	0	0.00
Smaller Door	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Lower Walls	3	0.86	1	0.29	7	0.87	8	1.00	0	0.00	0	0.00	10	0.68	9	0.61
Other	24	6.90	10	2.87	33	4.10	24	2.98	17	5.31	18	5.62	74	5.03	52	3.53
PERCENTAGE BASE	348	100.0	348	100.00	804	100.00	804	100.00	320	100.00	320	100.00	1472	100.00	1472	100.00

TABLE 13

Sources of Information Concerning Housing

Safety or Earthquake Resistance

Source of Information	Control Group		Experimental Group		Guatemala City		Total	
	#	%	#	%	#	%	#	%
None Heard	260	74.71	568	70.65	243	75.94	1071	72.76
Neighbor or Relative	34	9.77	105	13.06	38	11.88	177	12.02
Talks Given by Agency	7	2.01	73	9.08	19	5.94	99	6.72
Radio-Television	39	11.21	25	3.11	11	3.44	75	5.10
Newspapers	6	1.74	2	0.25	3	0.94	11	0.74
Agency Pamphlets	0	0.00	24	2.99	3	0.94	27	1.83
Previous Knowledge	45	12.93	135	16.79	40	12.50	220	14.95
Other	1	0.29	0	0.00	3	0.94	4	0.27
Percentage Base	348	100.00	804	100.00	320	100.00	1472	100.00