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IMPROVEMENT OF ADOBE HOUSES IN PERU: A Guide for Agencies

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IMPROVEMENT OF ADOBE HOUSES IN PERU:

A GUIDE TO TECHNICAL CONSIDERATIONS FOR AGENCIES

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IMPROVEMENT OF ADOBE HOUSES IN PERU:
A GUIDE TO TECHNICAL CONSIDERATIONS FOR AGENCIES

This booklet is designed to be an introduction to adobe construction in Peru; it provides an overview of how adobe is used today and how adobe houses can be made more earthquake resistant. The purpose of the booklet is to provide to those people who might become involved in housing programs the necessary background information upon which to base decisions relating to the formulation of plans for housing programs using adobe.

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I. INTRODUCTION

Adobe is one of the oldest building materials in the world, and the use of adobe in Peru dates back to pre-Columbian times. The ruins of many great adobe cities may still be seen today in Pachacamac (near Lima), Trujillo and Huánuco Viejo (in the central sierra). Throughout both the mountains and the coastal zones, adobe continues to be a popular building material, due primarily to its low cost and climatic suitability. As the cost of commercial materials, such as brick and block, continues to soar and the production of cement lags behind demand, adobe will continue to be one of the most widely used materials in Peru.

A. Adobe Regions of Peru

Adobe structures can be found in most every region of Peru except the jungle. The greatest concentration of adobe structures is found in the sierra regions, especially in those zones which have a distinct wet and dry season as these areas generally have better soils for making adobe blocks as well as having the grasses needed to bond the adobe bricks.

Adobe is also popular as a building material in many of the alluvial river valleys along the coast where silt deposits provide the necessary adobe soils and the water and grasses exist. However, in these areas adobe competes with quincha as the most popular form for low-cost housing. Generally, adobe structures are built in these areas by those in the upper low-income and middle-income groups -- not by the very poorest. This distinction has given adobe a somewhat higher status than quincha. Many persons living in quincha structures along the coast feel that the next step in "upward" housing is to have an adobe house.

Along the coast where wood is not so plentiful and where rain is almost never heard of, most of the roofs are flat and are made by laying a mesh of cane, bamboo mats and mud over sturdy bamboo poles. Another roof commonly found in the southern coastal areas is one made of quincha. This is simply an A-frame made of mud plastered over a lattice-work of bamboo and cane, resting on top of the adobe walls. The insulation value is high and, as rain is not a problem, this type of roof will last for many years.

The adobe houses of the sierra regions vary sharply in design from those in the coastal zones. In the mountains where wood is generally more available and where the heavy rains require a peaked roof, houses are usually built in what is known as the 2-agua or 4-agua configuration. This simply means that there are either two sides to a roof, or four. The roof pitch is usually about 30° and the roof covering is usually tile, although in some areas sod is used. Around some of the larger sierra cities such as Ayacucho, Huancayo and Huánuco, corrugated metal roofs (calamina) and corrugated asbestos roofing (Eternit) have become increasingly popular; although in the higher colder regions, tile still prevails because it provides better insulation.

B. The Building Process

Adobe houses have often been considered to be owner-built or, in the popular term, "self-help housing". While it is true that architectural and engineering input is not usually found in these houses, the label of "self-built" is not entirely correct. The construction of an adobe house, especially of one which is built correctly, requires quite a number of building skills, particularly in terms of the quality of the masonry. Thus, few adobe houses are actually owner-built. Typically, the prospective owner will contract with a mason (albañil) to build the house. This albañil is known as the maestro de obra or simply maestro. He may or may not be a full-time builder, but he has had considerable previous experience and is someone in whom the homeowner-to-be has sufficient trust to build the house.

Once the contract has been made, the construction labor is provided in various ways. The most common method is for the maestro to simply contract with other lesser-trained albañiles known as mozos or ayudantes (helpers). In some communities where extended family ties are still strong, members of the family may assist, but they are still supervised by the maestro de obra.

Another method of housing construction in many of the more traditional sierra towns is through the participation of a community group known as a faina. The faina is a more traditional extended family or clan group that assists members of a community. The faina, for instance, might participate in the building of a house for a newly-wedded son of one of the community leaders, or help rebuild a house damaged in some form of catastrophe. Normally, the faina is not used to build individual houses but rather for construction of community buildings such as schools, municipal buildings, etc.

The normal process of building must be taken into consideration by a development or relief agency seeking to initiate a housing program. Many housing agencies in Peru have attempted to use the faina or other more contemporary social groups (such as cooperatives) to build model houses. While in some cases this has been successful, generally the long construction process needed to build an adobe house (often two to three months) prohibits long-term volunteer participation; and most agencies have found it much better to simply contract with an albañil and his ayudantes for the construction of any models.

A further consideration, and one usually overlooked by housing programs, is the role of the albañil. As pointed out earlier, very few people actually build their own houses. Although they may participate in the construction activities, only the albañil is a true "self-builder". Virtually dozens of so-called "self-help" housing programs have been unsuccessful because they failed to recognize the role of the albañil. Any adobe program in Peru must concentrate on teaching the albañiles how to build a better house -- not the public at large. While certain general promotional activities are necessary in order to create an atmosphere for acceptance of any

proposed changes, programs that encourage self-help construction by families without participation by an albañil will generally find the effort wasted.

C. Demand and Perceived Status of Adobe

As mentioned earlier, adobe houses are usually considered to be a "step up" from other types of housing built of local materials on the coast. The same is true in the sierra regions where adobe competes with a building process known as tapial, and on the eastern slopes of the Andes in the high jungle where it again competes with various forms of quincha and a process known as bajareque.

The demonstrated vulnerability of adobe housing to earthquakes has not diminished the demand for adobe. After a recent minor earthquake in the southern part of the country, a survey in the coastal town of Camaná revealed that 90% of the people living in quincha houses still aspired to an adobe structure, despite the fact that 97% of the adobe houses (as opposed to 14% of the quincha structures) were damaged in the earthquake.

II. THE VULNERABILITY OF ADOBE HOUSING

Of all the housing types in Peru, only tapial structures are more vulnerable to destruction in earthquakes than are adobe structures. The potential for failure in earthquakes has been demonstrated during each of the three earthquakes of the past decade. The failure of adobe houses was the largest single cause of death in Huaraz in 1970 and in Barranca in 1974, and the only deaths recorded in the minor earthquake of February 1979 occurred in adobe houses.

Three primary factors should be considered in examining the vulnerability of adobe housing: weak points of the house; dangerous building features; and the problems of the adobe material itself.

A. Weak Points of Adobe Houses *

Studies of damaged houses following each of the earthquakes in the last ten years have shown that the adobe houses of Peru have common locations of component failure. Thus, these points of failure are the weak points of the house, and any type of new construction should take into account these locations and attempt to develop solutions to resolve the problems.

1. Corners: The corners of any building are critical, of course, but even more so in adobe structures. The forces of an earthquake shake the walls with the back-and-forth motion of the tremors. The corners usually begin to fail at the top and, as the shaking continues, the cracks move down toward the

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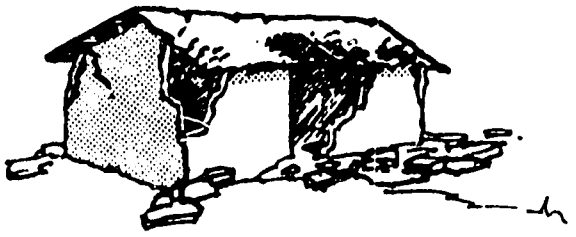
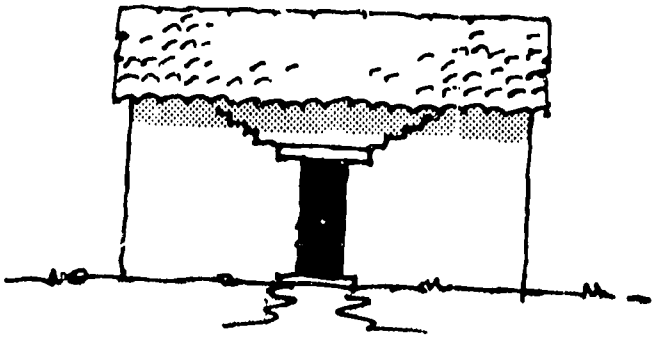
*See Appendix A for definitions of damage descriptions.

foundation. After they reach the halfway point, separation begins and, when they reach the three-quarters point (usually about one meter from ground level), the walls begin to separate and fall. This characteristic type of damage to a corner is known as vertical separation.

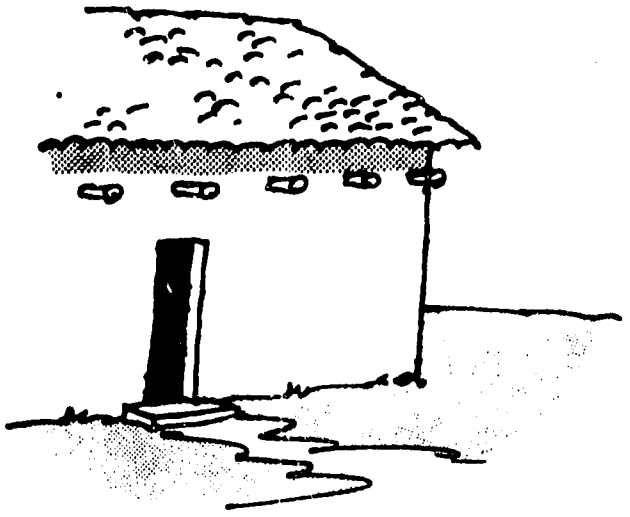


2. Lintels: The lintels placed over doors and windows in adobe houses are usually made of wood, although in some cases pre-cast concrete lintels can be purchased. Because wood (or concrete) has a different mass than adobe, it will move at a different speed in an earthquake; therefore, damage usually occurs above lintels. This characteristic form of damage is known as echelon fracture, generating upward at 45° angles from each end of the lintel. When each of the cracks reaches the top of the wall, all the adobes above the lintel are subject to displacement, and that portion of the wall usually collapses.

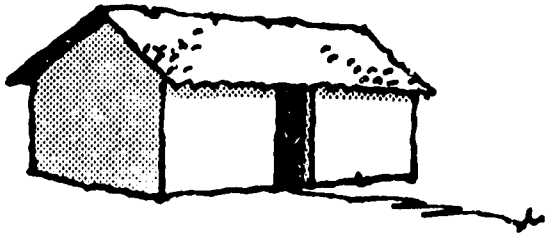


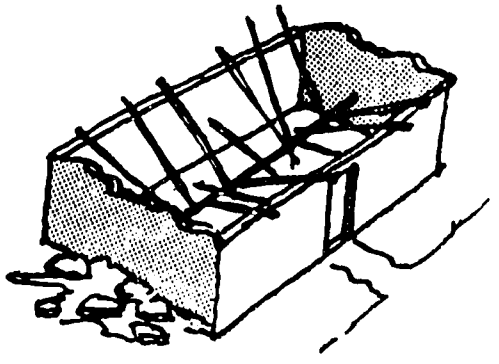
3. Roof Trusses in the Walls: The most common way of building a roof in adobe houses in Peru is to place the roof support in the wall. When the house is being built, the albañil will place a wooden beam on one of the last courses of adobe and then continue to build another one to four layers of adobe above that level. The purpose is to provide both support for the roof and an increase in insulacion. But in earthquakes this results in the transfer of earthquake forces from one wall to another, causing the roof beams to destroy the adobes

surrounding the point where the roof beam meets the wall. The result can be failure of the roof itself, the jarring loose of adobes at the contact point and, in extreme cases, the bulging out and possible collapse of the long walls of the house.



4. Gables: One of the most common adobe building practices worldwide is the construction of adobe gables to support the roof. This type of construction is one of the simplest and cheapest methods of constructing a roof; unfortunately, it is probably also one of the most lethal. In an earthquake, the roof is moved backwards and forwards along its long axis. The force of the roof moving back and forth usually destroys the gable. When the adobes that make up the gable fall, they gain tremendous force due to the distance that they drop. Adobe gables have been cited as the most dangerous part of any adobe structure.

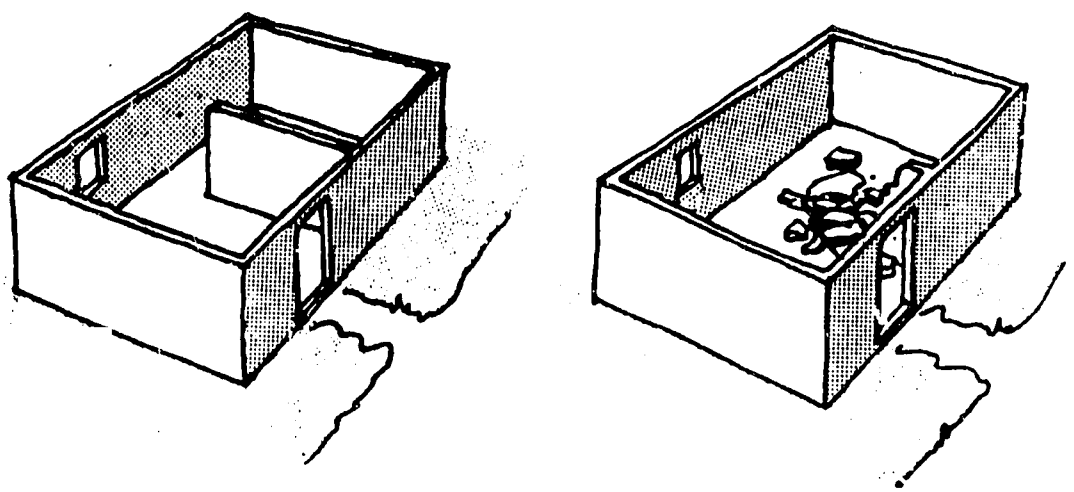




5. Roofs: The roof structure and the material used are among the most important features of any house. Earthen or tile roofs are often used in Peru. In both cases, these materials are extremely heavy. The heavy mass, shaking back and forth at the top of the building, is dangerous for two main reasons. First, it can collapse inward, trapping those on the inside. Second, as it moves back and forth, the mass creates a strong force which is added to that of the earthquake as it tries to push down the walls. Total collapse of an adobe house is often more attributable to the problem of the roof than it is to design problems of the house itself.

6. Interior Walls: Adobe houses are often built as shells with the interior walls added later. When this is done, the wall is essentially a free-standing element as it is not securely attached to the exterior walls. In smaller houses where the interior walls are built at the same time as the exterior walls, this is not a problem. But in the case of larger houses that are subdivided after the shell structure is built, these free-standing walls are a major problem in earthquakes.

Also important is the location of any doors in an interior wall. The closer the door is to an exterior wall, the more dangerous the interior wall becomes.



7. Doors: Recent studies have shown that a high percentage of deaths have occurred in houses that remained intact long enough for occupants to evacuate before total collapse. The higher mortality rate is attributable to the fact that the occupants cannot open the doors of the house because they are jammed in an earthquake. Doors which open to the outside can be more easily forced open than those which open to the inside; however, almost universally, doors are built to open toward the inside. This is due to a number of factors, mainly traditional, but in windy areas a door opening to the outside lets the outside air enter at a rapid rate, so there are logical reasons for this way of building doors. Nevertheless, in an earthquake doors can become a major barrier to safe evacuation of a house. As

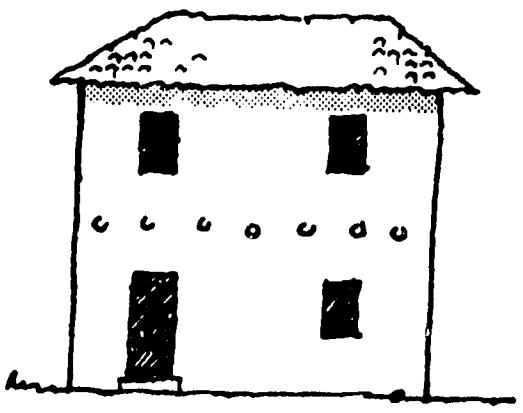
mentioned earlier, the section of the wall above the door (the lintel) is one of the most vulnerable areas of the house and, if a person is stopped beneath that area trying to force open a door, the vulnerability to falling adobes is prolonged.

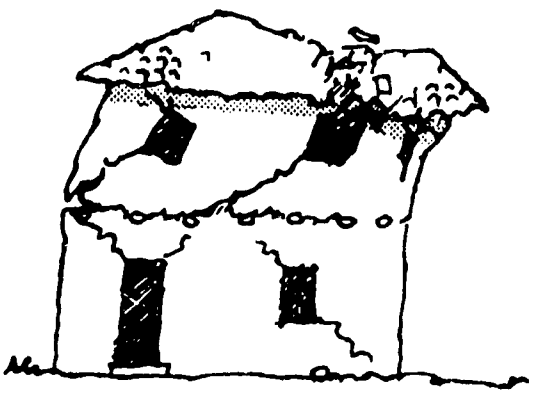
B. Dangerous Building Features

There are numerous variations in adobe houses throughout Peru. The following list describes some of the more popular features and housing styles that have been identified as being dangerous in an earthquake.*

1. Two-story Houses: Two-story adobe houses are popular in all adobe regions of Peru. They can be made safe if correctly engineered, but the vast majority of structures in Peru are not properly built or reinforced. The typical two-story houses are dangerous on several accounts. First, the walls must be fairly thick in order to support the second floor. The thickness, added to the height of the wall, increases the mass; and the heavy weight and high center of gravity combine to make the structure unstable in an earthquake.

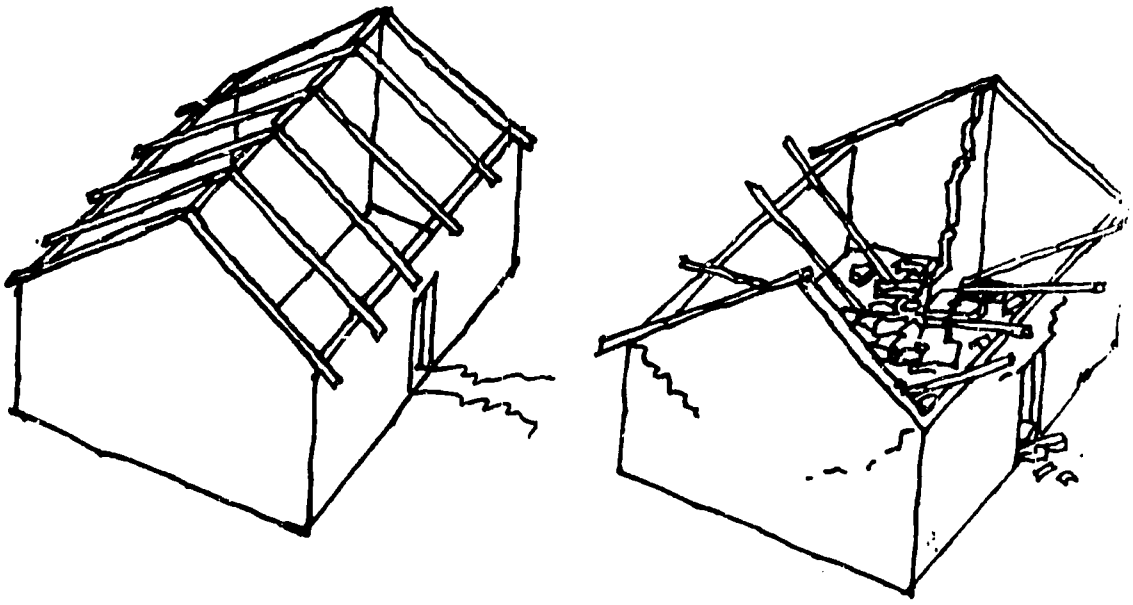
   Another dangerous feature of the two-story house is the use of wooden posts placed in the walls at the middle of the house to support the second floor. Because most of these posts are not properly fastened and do not distribute the weight of the second floor equally in an earthquake, their movement inside the adobe walls creates points where cracking begins.



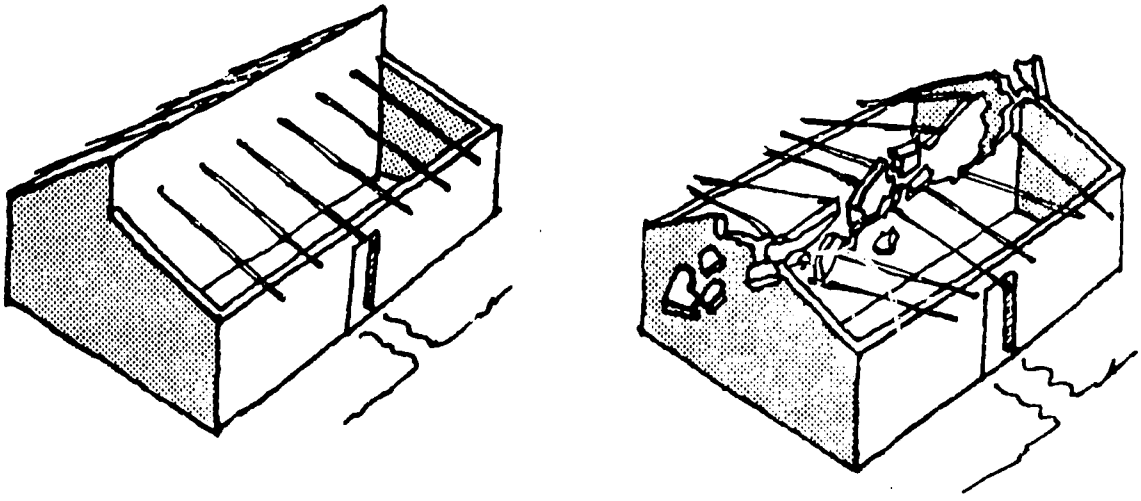


* Those listed are generally considered to be the most popular features throughout Peru. The exclusion from this list of other features found in Peru does not mean that they are either inherently safe or inherently dangerous.

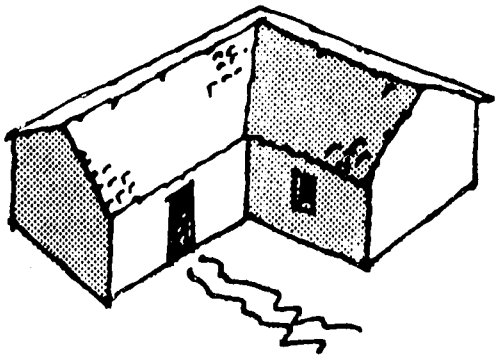
2. Using an Interior Wall to Support the Roof: This is a common and popular feature throughout the country, particularly because it reduces the need for wood in the construction of the roof. The poles that support the roof are simply laid from the top of an interior wall to the top of an exterior wall. In an earthquake, the interior wall is susceptible to damage from movement of the roof and, as the roof posts have no other form of support, in all likelihood the roof will fall to the inside of the house.

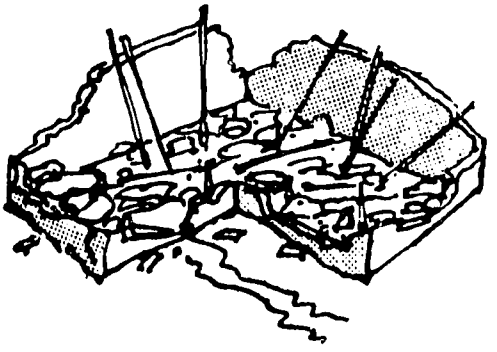


3. Split-level Roof: The type of roof design illustrated below is popular in several of the central regions of the sierra, especially around Huánuco and Huaraz. The roof is made by building a high interior wall, resting the upper part of the roof supports on the top of the center wall, and running the lower portions through the center wall. In an earthquake, those posts that run through the wall create a shear line and the adobes, and the roof above the shear line, fall into the house.

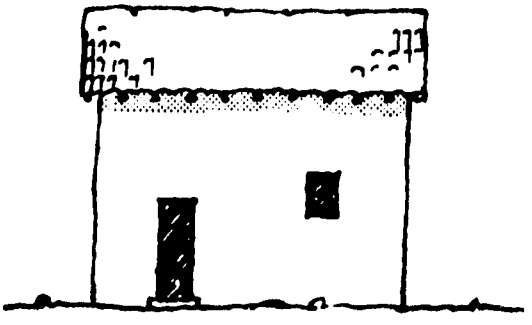


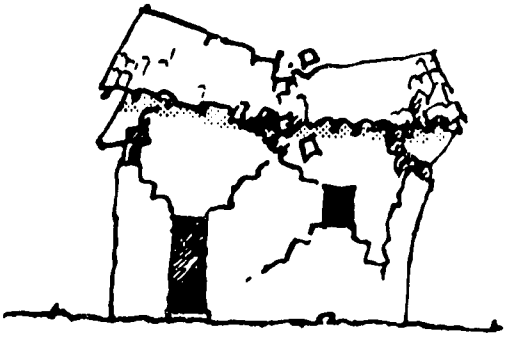
4. L-shaped Houses: The L-shaped house is found most often in urban environments. The "L" shape is dangerous because it is impossible to balance properly. In an earthquake, this lack of balance causes the house to twist on its foundation and the walls generally fall to the inside. Two-story L-shaped houses are particularly dangerous.





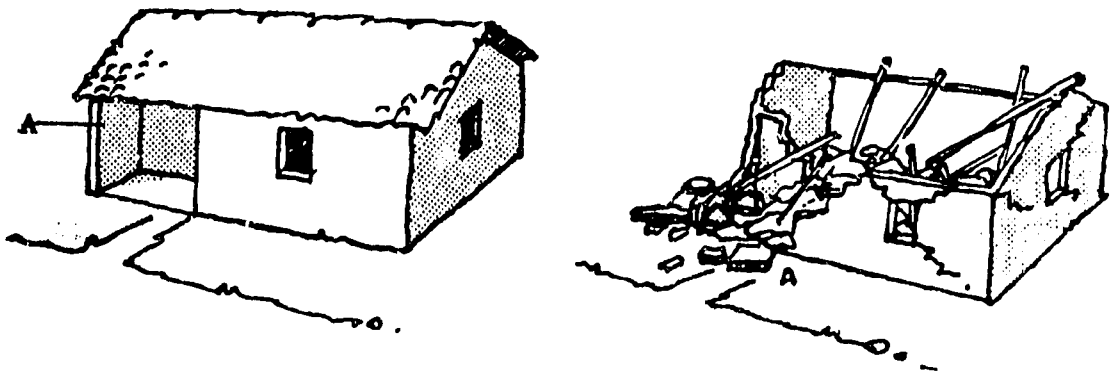
5. High-walled Houses: Throughout Peru, there are numerous single-story houses with extremely high walls. These houses often have large lofts or attics that are used for storage. In earthquakes, these houses have many of the same problems associated with two-story houses, and they are very susceptible to damage.



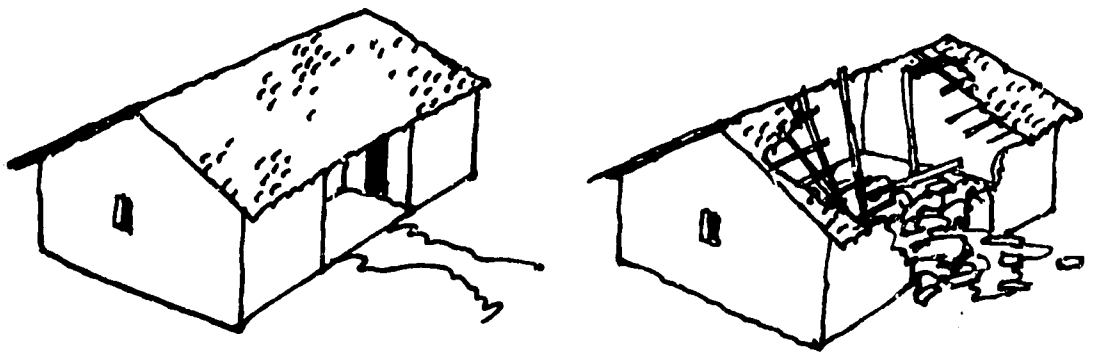


6. Open Areas in the House: There are numerous variations of porches or open rooms being built in, or added on, to an adobe house. Two of the most popular designs are illustrated below.

In the first, the house is dangerous because the main structure of the house is in an L-shape and wall "A" is supporting a portion of the roof but is in itself a free-standing wall:

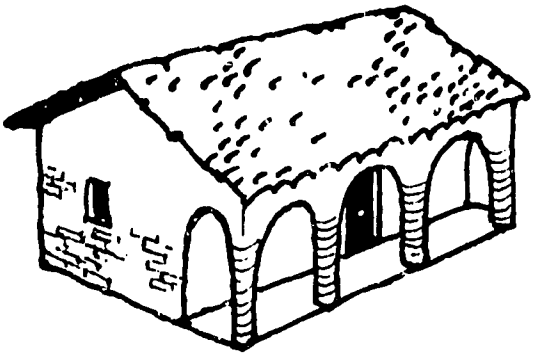


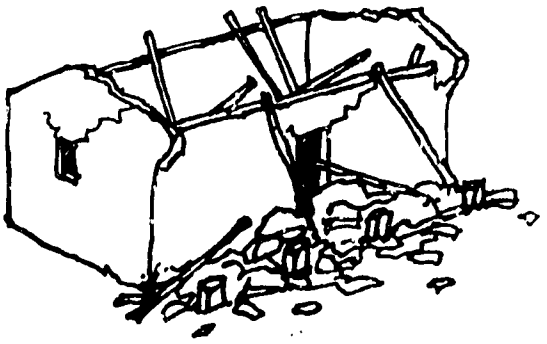
In the second illustration, the house is dangerous because it is not properly balanced:



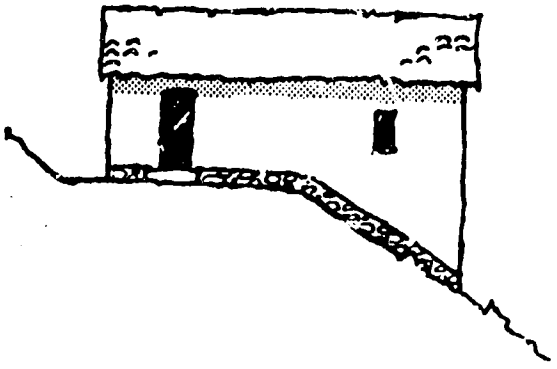
7. Adobe Columns: The use of adobe blocks rounded off to form columns for ornamental purposes is popular in the Huánuco region. It is only when the columns are used as load-bearing members to support an overhanding porch or as a portion of the roof support that they are dangerous. Failure of these columns in front of a principal exit during an earthquake could become

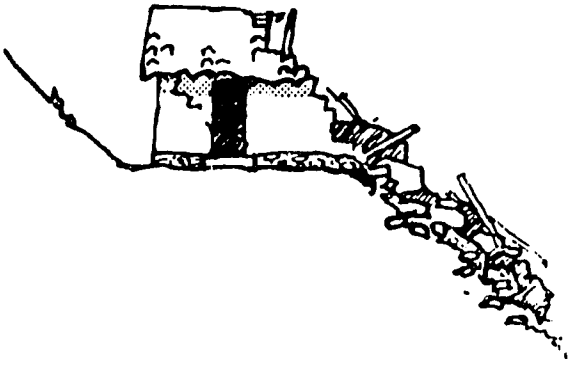
a critical factor in the survivability of the occupants.



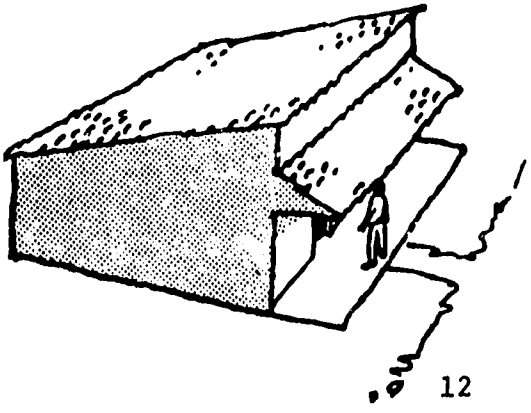


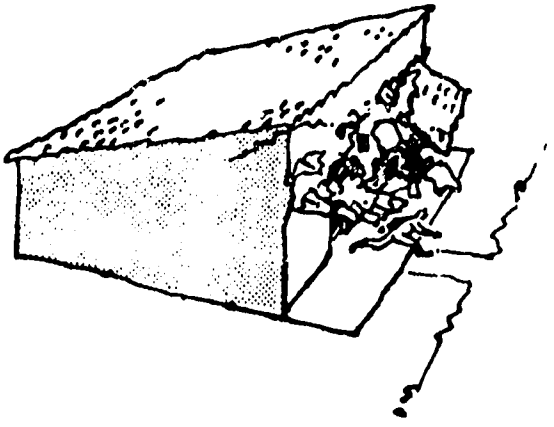
8. Split-level Houses: In many areas of the mountains, adobe houses are built to conform to the terrain, rather than excavating the terrain to form a flat platform upon which to build the structure. In an earthquake, these split-level houses are subject to slippage and total collapse.





9. Tile Awnings: On many of the structures built in mountain villages, especially those used as both residential and commercial buildings, an awning made of tile is attached to the wall over the entrance to the building. Its purpose is to provide a shaded area for people to gather outside the structure and a covered area at the entrance for protection from rain. The way that most of these awnings are built makes them highly susceptible to collapse in an earthquake.





C. Problems of Adobe Blocks

In comparison with other countries where adobes are used, the adobes made in Peru are generally not considered to be among the best. Adobe technology in Peru has entered a period of regression rather than progression, and the quality of adobes made today does not nearly equal the adobes made by the Indians of pre-Columbian times. In examining damaged houses following earthquakes in Peru, it is not uncommon to see widespread failure of the adobe blocks. Even in moderate tremors, cracks in the adobes have been observed.

The problems of the adobe blocks can be categorized in three ways:

1. Soils: Good adobe soils are found in only a few areas of Peru. In other regions, common problems are too much rock in the soil, too much clay, or too much sand. Each of these problems serves to weaken the adobe block and to reduce its lifespan. In the case of rocks and sand, it also means that the adobe is less resistant to rain and erosion problems around the base of structures can be witnessed throughout the rainy regions of the country.

2. Improper Stabilization: Adobe is usually stabilized by placing some form of fiber in the block to help bond the earth particles together. Among the stabilizers which can be used are: various grasses; wheat straw; leaves or needles from various plants; and, in the semi-arid areas, natural resins from various plants such as the maguey plant. Chemical stabilizers and industrial additives such as asphalt can be added also, but normally the families who build with adobe cannot afford these materials.

   Another stabilizer that can be used, but which sees only limited use in Peru, is cow or sheep dung (estiércol). When added to an adobe mix, dung usually improves its resistance to moisture.

   Despite the fact that the advantages of using stabilizers are well-known, the fact remains that the majority of houses built of adobe use no form of stabilization. This is especially true in the areas where tapial construction is used. The reasons most often given for not using stabilizers are their cost or the unavailability of the material needed, although in fact the real reason may be that the albañiles are not familiar with how to use the alternatives when the principal means with which they are familiar is not available.

3. Salinity: In the coastal regions where adobe is used, soils often contain high levels of salt. Out of necessity, some of the poorest people building with adobe are often forced to use saline-contaminated soils, or to build a structure made of adobes fabricated off-site on a site that has a high saline content. Salts in an adobe structure weaken its resistance to erosion and, in the case of adobe structures built on sandy sites, the salt deposits usually create problems for an adobe wall near the ground level or at the foundation due to swelling and contraction with humidity changes.

In order to counter the problems mentioned above, it is necessary to devise various means of protecting the adobes from the elements. The most common method used is to place a protective covering over an adobe wall after it is built. This stucco, usually made of lime and mud, serves as a moisture barrier and its hard surface usually protects against erosion caused by wind and sand as well as rain.

Another means of protecting the adobes, especially at the lower levels of the structure, is to build a higher and stronger foundation and, in rainy areas, to increase the roof overhang in order to reduce drip and splash damage to the foundation and the lower adobes.

III. METHODS TO IMPROVE ADOBE HOUSING IN PERU

In the previous section, the weak points of adobe housing were examined and recommendations made on how to counter these problems. Here, ways in which the problem of the structure as a whole can be tackled will be examined.

The 1970 earthquake led the Government of Peru and many private research institutions in the country to begin a long-term examination of the problems of adobe structures, with the aim of developing construction systems which would improve the performance of adobe structures in earthquakes and reduce the overall vulnerability of families living in seismic regions of the country. The most intensive research was carried out by the Ministry of Housing and Construction (Ministerio de Vivienda y Construcción), which designated a central office (today known as the Oficina de Investigación y Normalización or OIN) to be in charge of the work and coordinate the various research activities. OIN in turn worked with various universities, coordinating their research activities in the field and serving as a central information clearinghouse for all research activities. The program which was established, known as the COBE Project, has investigated several dozen different design concepts and, at this writing, the program continues. The methods discussed here are primarily a result of the COBE program and have been specifically designed to meet the various needs of adobe housing construction in Peru.

Throughout this discussion, one point must be kept in mind: adobe itself is not more inherently dangerous than any other type of building material. The way in which the material is used determines its particular vulnerability. Far more important than the quality of the adobe alone are such factors as building configuration, balance, detailing, and the use of reinforcements. In short, it is not the material that is of primary importance, but rather the way it is used.

In general, there are four categories of improvements that can increase seismic resistance. These are: adherence to basic building rules for seismic areas; use of improved wall design; proper distribution of the weight of the roof; and improved adobe fabrication.

A. Adherence to Basic Building Rules for Seismic Areas

The following principles for building in seismic areas apply to all types of structures but are even more important in construction with adobe or other unreinforced masonry:

1. Select a strong building configuration. The best design to resist the force of an earthquake is a square building. Rarely, of course, is this practical, and rectangular buildings are acceptable as long as the proportion of the long wall to the short wall is 2.5:1. Any interior rooms in adobe structures should be designed as close to being square as is possible. In no case should "H"- or "L"-shaped buildings be constructed.

2. Build the house on a strong, solid foundation. A strong foundation of rock or concrete will serve to dampen the forces of an earthquake and will help to reduce any problems caused by uneven settling of the building while the ground is in motion.

3. Balance the house. Balance means that parallel walls should be approximately equal in weight, strength and height. A simple rule of thumb is that, for every opening in one wall, there should be a corresponding opening of approximately equal area at an opposite point in the parallel wall.

4. Build lightweight walls. There is a popular misconception that thick, heavy adobe walls are stronger than thinner adobe walls. As a point of fact, the heavier the wall, the greater its susceptibility to damage in an earthquake; the lighter and thinner a wall, the greater its potential for survivability.

5. Build low walls. As a general rule, an adobe wall should not be higher than 2.2 meters. A low wall has two advantages: a lower center of gravity, and lighter weight. Both increase its survivability.

6. Build doors and windows in a safe manner. Two things should be remembered. First, doors and windows should be a minimum of 1 meter away from corners and from each other. Second, windows should not be too large as a wide opening serves to weaken the wall.

7. Reinforce the walls, especially in the corners. This will be discussed in more detail later.

8. Tie the walls together at the top with a collar beam. The collar beam serves to hold the walls together at the top and also to prevent racking, or torque, caused by ground motions creating asymmetrical forces on the walls. When properly constructed, the collar beam also helps to distribute the weight of the roof and thereby to reduce the possibility of failure at the point of contact between the roof and the walls.

9. Build a lightweight roof. The construction of a lightweight roof cannot be overemphasized. As pointed out in other sections, often the roof does more damage than any other single element in an earthquake. If a heavy roof must be used, it

must be designed in such a way as to distribute the forces and the weight equally to all the walls. Lightweight roofs are generally made of corrugated asbestos sheeting, corrugated metal roofing material, grass or palm leaves. Tiles, sod and certain types of quincha roofs are considered heavy and should be avoided whenever possible.

10. Separate each building from surrounding buildings and garden walls. The forces of one building are easily transferred to another unless adequate separation is maintained. A minimum distance of 1 meter is recommended, although this often is not possible in urban areas due to the small lot sizes. In these areas, a separation of even 5 cms. will help, but it will not prevent the possibility of one building knocking down another in an earthquake.

If these basic building rules are followed, the survivability of a house in an earthquake will increase by well over 50%.

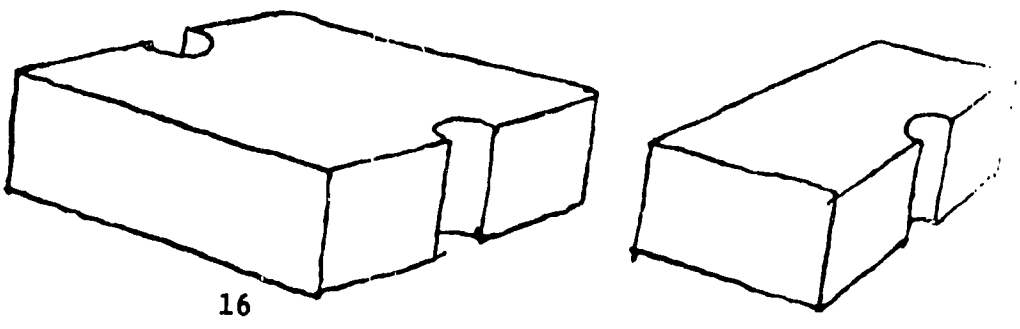
B. Improved Wall Design

There are numerous methods of reinforcing adobe walls to make them more resistant to the forces of an earthquake. However, each has its own limitations. In terms of cost, availability of materials and technical assistance required, there are three systems which appear to have a high potential for widespread use in Peru. One of these systems is already in use; one has been tried experimentally in various areas of Peru; and the third has been used with great success in the earthquake reconstruction programs in Guatemala.

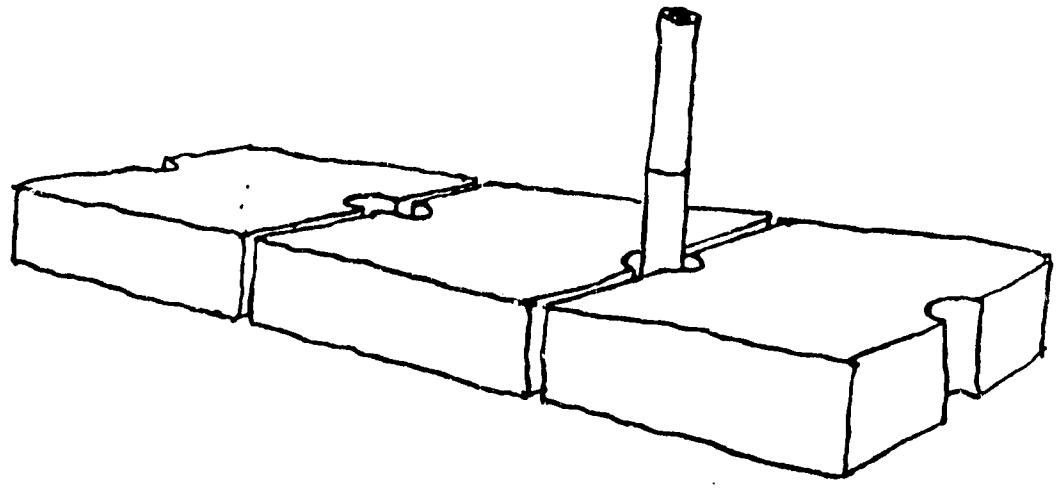
1. Reinforced concrete frame: This system is widely used in the coastal areas of Peru. It is much favored in urban areas as the use of concrete columns and collar beams permits the construction of a flat roof which, in turn, can become the floor when a second story is added later. In this system, the adobes are no longer load-bearing but are used simply as infill. This particular building method has many variations but, when properly built, provides a safe and secure house.

2. Modern Adobe (Adobe Mejorado): The Modern Adobe system was developed by the COBE Program sponsored by the Ministry of Housing & Construction. The system differs from traditional adobe construction in several ways:

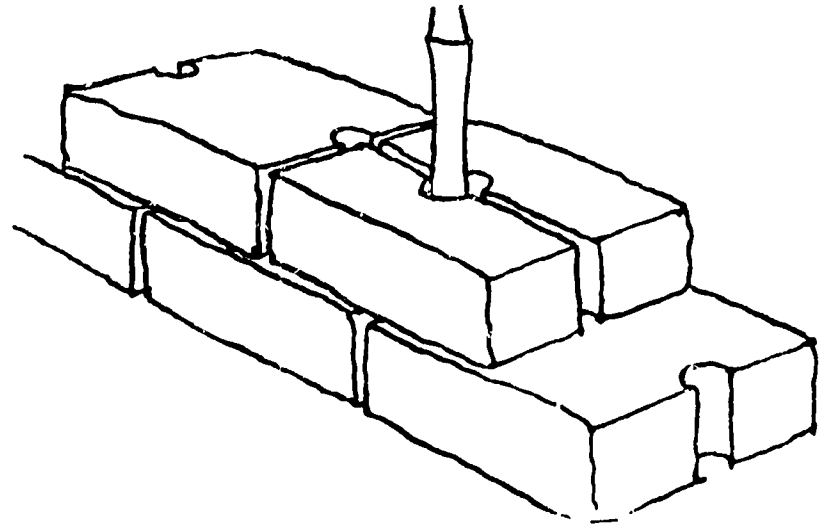
   a. In this system, two new types of adobe blocks are made. The first type is square and has a notch on two sides. The second type is simply half of the first. The two adobes look like this:



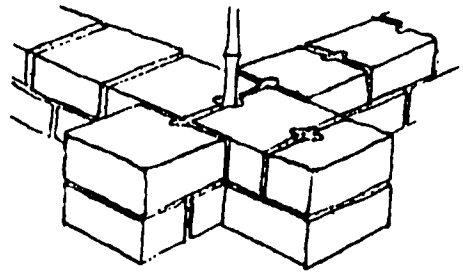
When two blocks are put together, the notches form a hole through which reinforcing rods can be passed. The reinforcing rods can be made of iron, bamboo or cane.

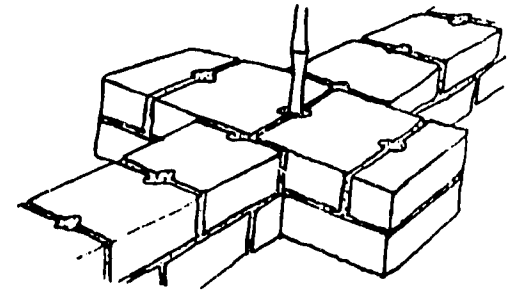


The half-adobes help make up the next level, like this:

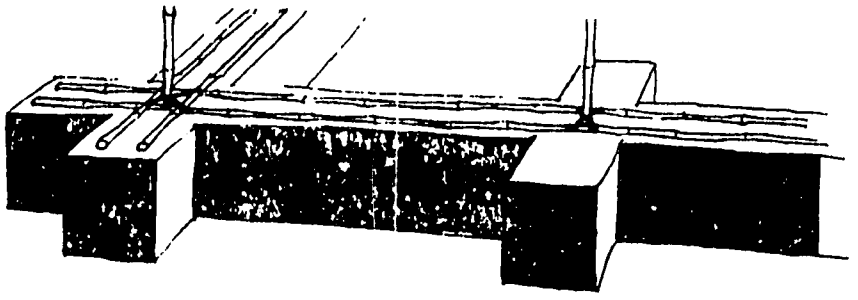


b. A second way that Modern Adobe is different is that pilasters (mochetas) are placed in the corners and at regular intervals in the walls. These pilasters help reinforce the walls and help hold them up during an earthquake. Each pilaster has a reinforcing rod inside and is made like this:



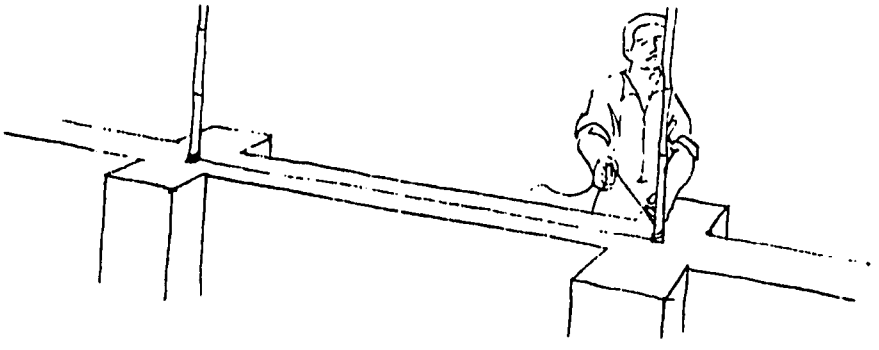


c. Modern Adobe also differs in that on every third level of adobe there is a horizontal ring beam (solera) made of the same material as the vertical reinforcing rods. Each ring beam is tied to the vertical reinforcing rod at the corner and at each pilaster.

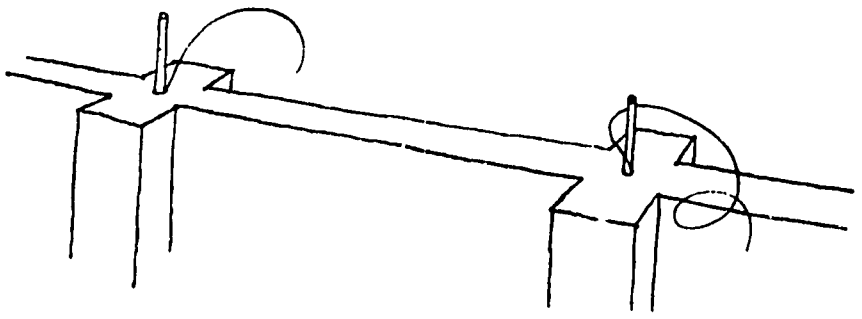


d. A fourth way that Modern Adobe differs from other systems is that, at the top of each wall, a collar beam (viga collar) is placed. This collar beam serves three purposes. First, it ties all the walls together at the top to prevent separation. Second, when the roof trusses are placed on top of the collar beam, the weight of the roof is more evenly distributed and supported. Third, the collar beam helps prevent the house from twisting when the motion of an earthquake applies asymmetrical force on the structure.

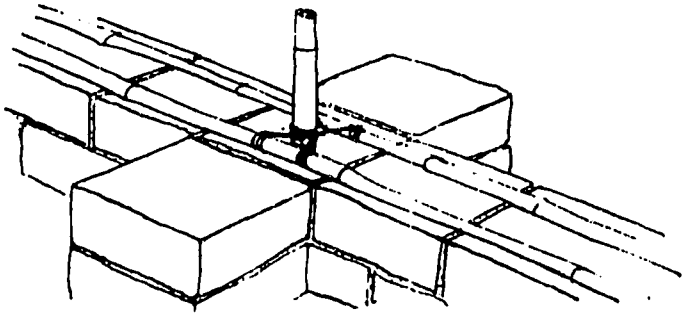
Wire is used to tie the collar beam to the wall. Before the last three or four courses of adobe are laid, a long piece of construction wire (#12 is best) is tied to each of the vertical reinforcing rods and then pulled tight and wrapped once or twice around the next closest rod.



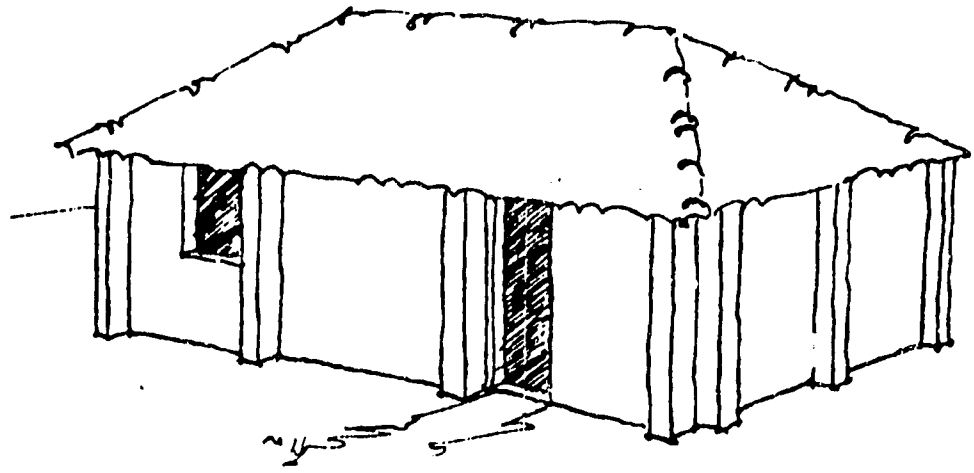
The last layers of adobe are put on top of the wire, but the free end comes up through the hole with the rod.



After the collar beam is laid on top of the wall, it is tied to the wall with the wire.



The Modern Adobe system has been used in a housing project in Chimbote, in a model house in Cañete, in a model house in Lima, and in a model house and demonstration program in Acomayo in the Department of Huánuco.

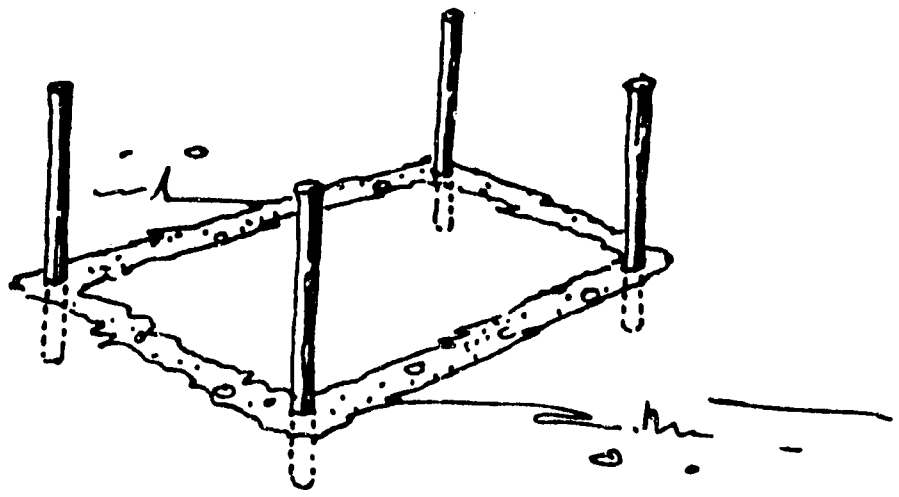


Complete information concerning the building system (including instructor's manuals and a training guide) is available upon request from the Oficina de Investigación y Normalización (OIN) of the Ministry of Housing & Construction in Lima. Additional copies of the training package are available from the U.S. Agency for International Development and from the Engineering Department of the Catholic University of Peru.

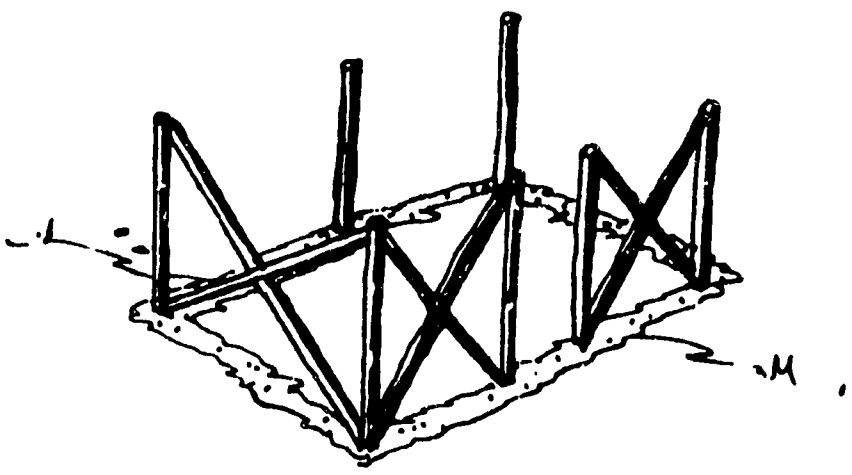
The system has several advantages in that it relies entirely upon the use of local materials and the additional cost requirement to use the Modern Adobe system represents probably no more than 2% of the total cost of the house. It also can be used in those areas where wood is scarce.

The disadvantages to using this system are that the system requires rather precise masonry work and that the adobes themselves are a departure from the traditional rectangular form.

3. The cross-brace system: The cross-brace system was developed as a means of converting load-bearing adobe walls to non-load-bearing. To build a wall using this system, strong posts are placed in the corners. The posts are treated with some form of wood preservative and then inserted approximately 1 meter into the ground.

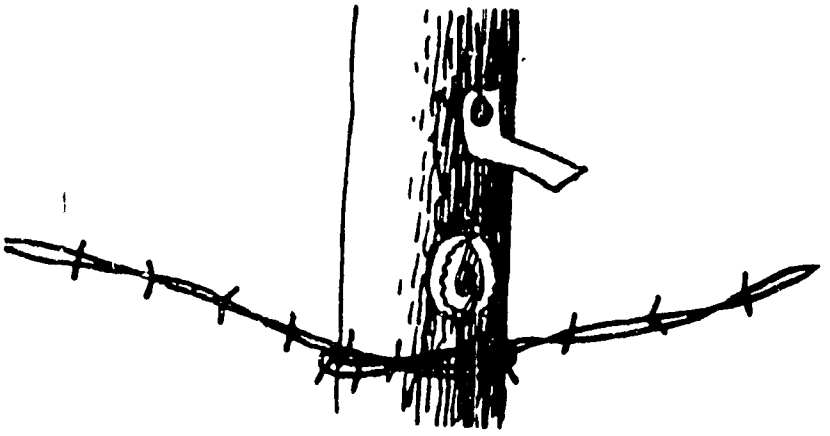


A post is placed at each point where an interior wall will meet an exterior wall and at each side of a door or window. Next, cross-braces are added between the posts.

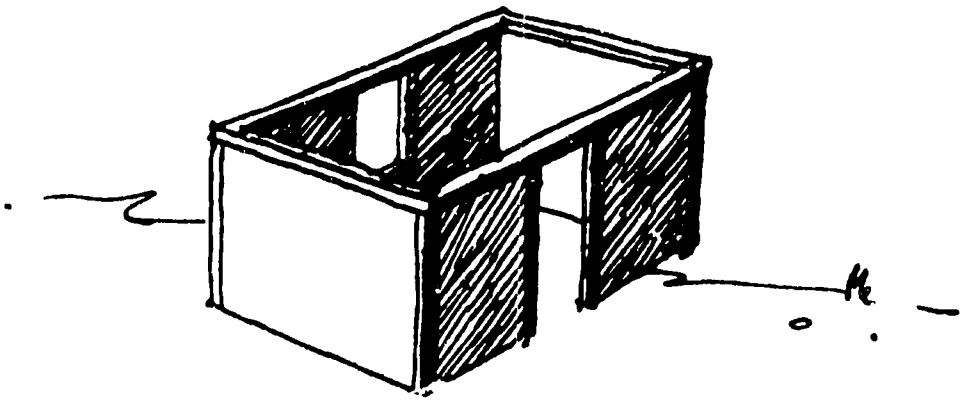


If the posts are close together, two small cross-braces may be added. The basic idea is to divide the house into a series of squares, with each side being equal to the height of the wall. Materials which can be used for cross-braces include wood, construction wire, barbed wire, cable or iron. The braces may be placed so that they are either inside or outside, or if enough material is available, on both sides of the wall. However, if they are placed on the inside of a wall, this gives an added measure of security as it helps prevent the wall from falling inward.

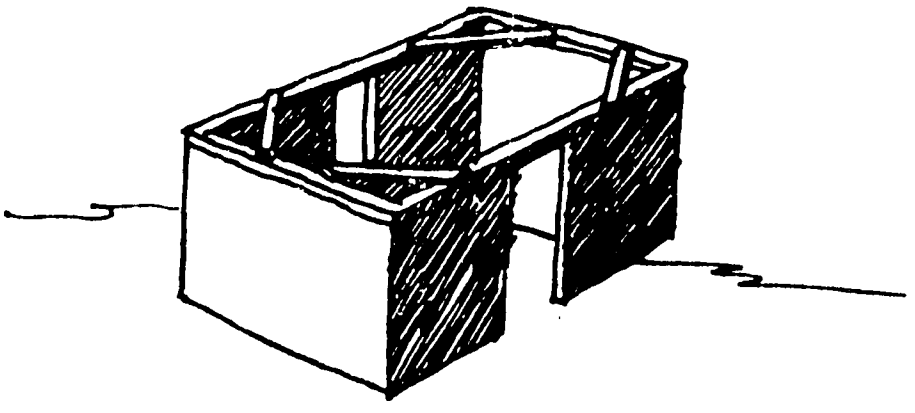
As another added measure of security, wire is often run horizontally between the posts at every third or fourth layer of adobe. This serves to provide horizontal reinforcement which helps hold the wall together.



All the walls are tied together at the top by means of a ring beam made of the same material as the corner posts.



Once the ring beam has been attached, small corner braces are attached diagonally at each corner to provide additional support and to help prevent torque effect.



The primary advantage of the cross-brace system is that it can be used with almost any type of adobe. It does not require a change in the form normally used.

Two disadvantages are the heavy reliance on wood and a greater sophistication required in carpentry skills on the part of the builder. Wood preservation is also a consideration in many areas, especially near the high jungle on the eastern slopes of the Andes. In the high sierra, however, where eucalyptus trees are used in construction, the system would be ideal and wood preservation would not be a great problem.

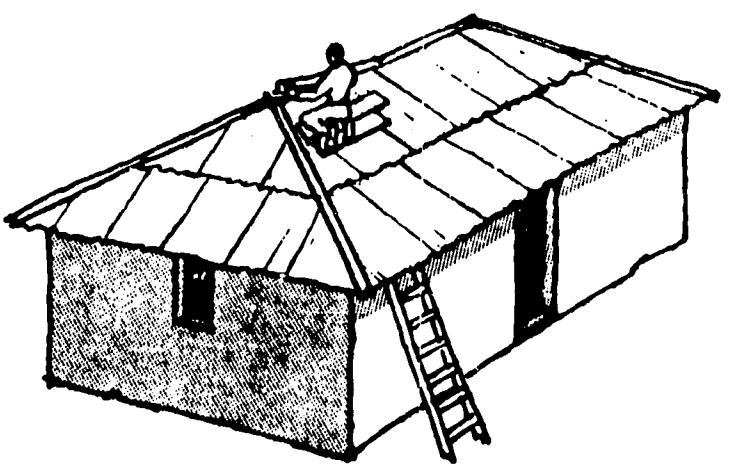
The major disadvantage is the added cost of using the wooden columns and braces, which in some areas may add 20%-25% to the total cost of the house.

OXFAM, World Neighbors and the Save the Children Federation all have packages of training materials that outline how to use the cross-brace system, and their addresses are included in the appendices of this booklet. At the time of this writing, each of these organizations has contact with persons who can provide technical assistance or demonstrations in how to use the cross-bracing technique.

C. Improved Roof Design

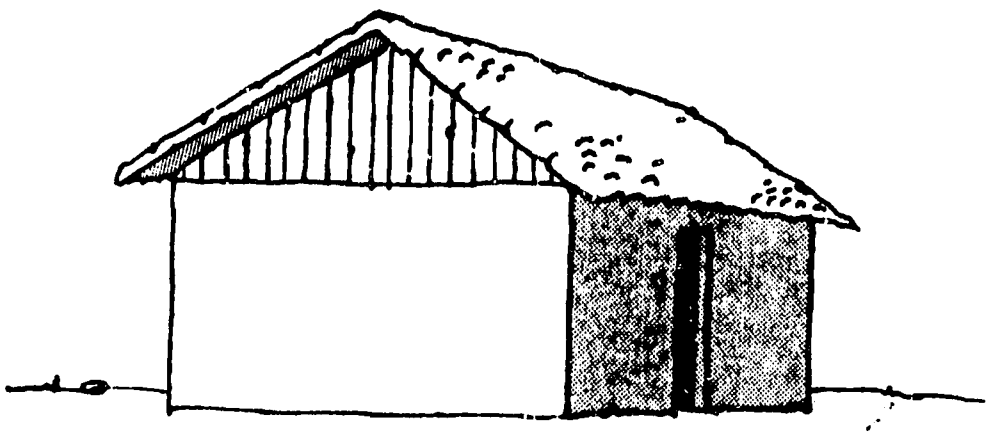
In Peru, most of the roofs are unintentionally built in such a way that they will either fail in an earthquake or promote the failure of other components of a house. In order to reduce damage, several alternatives can be chosen.

The best type of roof to use in an earthquake area is a four-sided roof (4-agua).



The first advantage of using this roof is that the trusses more evenly distribute the weight of the roof and thereby the forces which are caused by an earthquake. Second, it requires less reinforcing and therefore is of lighter weight. Third, the use of this type of roof means that all walls will be of equal height, thus the house will be easier to balance. Fourth, it eliminates the need for a gable.

If a gable-style roof must be used, it too should be constructed with trusses. At each end where a gable is to be built, a lightweight gable should be constructed. It can be made of wood, quincha or stucco covering a wire mesh.



Note that the roof designs recommended above all utilize a truss placed on top of the ring beam and do not rest directly on top of the adobe.

D. Improved Adobe Fabrication

In every part of Peru, the adobe needs to be made stronger. In each case, it will be up to the assisting agency to determine the best means of stabilizing the particular soil in the area where the agency is operating. There are no universal solutions to the problem. A great deal of research has been done by OIN and other organizations in an attempt to determine practical, low-cost stabilizers that can be used throughout the country, but each one has its own limitations. The best guide is to determine what is used locally and what the available alternatives are.

One commercial material shown to have considerable value in improving the resistance of adobe to water is asphalt. OIN and the National Engineering University have carried out extensive tests on various types of asphalt and have determined that an asphalt known as RC-250 is generally suited for use in the sierra regions as well as certain

coastal regions. The asphalt cannot be used in a salty soil, however. Asphalt is not widely used due to its cost, although if purchased in bulk and distributed at a subsidized price, the cost could be greatly reduced and the product made attractive to a larger number of users.

OIN has developed a series of booklets that explain how to use asphalt in the production of stabilized adobe. Copies are also available from the U.S. Agency for International Development, the National Engineering University, the Catholic University of Peru, and from a private housing group known as INIAVI.

IV. STRATEGIES

The normal process of building houses in Peru is fairly sophisticated, involving a larger number of factors than are generally seen by persons not familiar with the process. Thus any intervention in the process must be taken with careful consideration of the consequences. A detailed examination of strategies and approaches which can be used in both pre- and post-disaster programs can be found in the papers, "Strategies and Approaches Which can be Used by Voluntary Agencies to Provide Post-Disaster Shelter and Housing" and "Scenario for a Housing Improvement Program in Disaster-Prone Areas". In summary, however, it can be stated that one of the best ways for an agency to help make better housing is to provide those materials and technical expertise that normally are not available but are required in order to change the normal building practices.

One example of this approach would be for an agency to determine its goal (e.g. to make the houses safer by reducing the weight of the roof) and then be prepared to assist homeowners in obtaining lightweight roofing material and by providing technical assistance to show how the new roof should be constructed. If the agency wishes to intervene by making stronger, more resistant adobes, it could provide the stabilizer that is needed. It has been generally found that people in the community will respond to financial incentives as long as no long-term obligations are required. Thus, material subsidies have been shown to work better than long-term low-interest loans.

Finally, the point of intervention is probably just as crucial as the changes which are being encouraged. If an agency wants to create change in housing, it must concentrate its efforts on both those who build the houses (by showing them the safer techniques) and those who must pay for the houses (the homeowners). A great number of innovative strategies and approaches have been used in the past, and it is left up to the individual agencies to select one which is best suited to its needs.

V. TECHNICAL RESOURCES

Agencies seeking technical assistance for housing programs in Peru have a limited number of technical resources in the country from which to choose. These include:

A. Oficina de Investigación y Normalización (OIN)

OIN has been designated the coordinator of all adobe research activities within the country. It is also the Ministry of Housing's appropriate technology link to other A.T. resources in the housing field. OIN is the depository for training aids developed under the COBE Program and, in addition, has numerous other booklets, pamphlets and technical materials dealing with the topic of adobe construction. Adobe research has also been conducted on the premises of the OIN facility. Several model houses and different roofing schemes have been erected to show visitors some of the techniques of earthquake resistant construction and adobe stabilization that are available.

In general, however, OIN cannot provide extensive technical assistance beyond the provision of these training manuals or the answering of certain technical questions. Their inability to leave Lima for extended periods of time also severely hampers any potential role they have in providing technical ausistance.

B. National Engineering University (Universidad Nacional de Ingeniería)

The University has been involved in various aspects of the COBE research, especially in evaluating proposed stabilization methods and, to a limited extent, in configuration. However, few of the professors involved have had extensive field experience except in the construction of the model houses in the COBE Program, and neither the professors nor the graduate students involved in this research can devote extensive time away from the campus to provide ongoing technical assistance.

C. Engineering Department, Catholic University (Departamento de Ingeniería, Pontificia Universidad Católica del Perú)

This department has also participated extensively in the COBE research. Most of their work has involved the testing of various reinforcing systems. The work done at the Catholic University is both practical and thorough, and the personnel associated with this program are probably some of the best technical resources on adobe anywhere. The three main researchers have demonstrated their willingness to assist, when possible, for limited periods of field work, although their actual field experience to date is still limited to field observation and participation in the construction of model houses.

D. U.S. Agency for International Development

The U.S.A.I.D. Office of Engineering and Office of Housing & Urban Development have been involved in sponsoring the adobe research program since 1971. The Office of Engineering has been more closely involved than any other office of U.S.A.I.D. and, at this writing, several of the personnel have taken a personal interest in various aspects of the research program, especially the stabilized adobe work. The Office of Engineering is one of the depositories for the technical and field training manuals developed by the COBE Program and is a source of information about other housing activities

in the country. At this time, the U.S.A.I.D. Mission does not provide direct technical assistance to any housing program, although they may help an agency contract for such services.

In addition to the above-listed in-country resources, the following organizations have had extensive experience in adobe construction in Peru and are familiar with various aspects of the problems:

1. INTERTECT

2. Carnegie-Mellon University

3. International Institute of Housing Technology, California State University/Fresno

4. National Bureau of Standards

5. University of New Mexico

6. Foundation for Cooperative Housing

Appendix B lists contact information for those organizations and individuals who can provide further information, including those mentioned in this booklet, and Appendix C lists bibliographical resources.

FCC:jwp

APPENDIX A

Damage descriptions are defined as follows:

Superficial cracks:	Non-structural cracks in the stucco covering of buildings.
Fracture:	A crack occurring in the wall material.
Separation:	Visible evidence that materials or components have separated and are no longer bonded together (most often where adobes have fallen out of the wall).
Displacement:	The movement of a wall material out of position.
Collapse:	When more than 25% of a wall or roof has fallen.

Damage may be expressed as a percentage of the cost necessary to repair a structure in comparison to the total value of the house, as follows:

Less than 10% of total value:	superficial or light
11% - 50% of total value:	repairable
Over 50% of total value:	damaged beyond repair

APPENDIX B

GUIDE TO OBTAINING INFORMATION ON HOUSING IN PERU

Organizations in Peru:	Contact:
Oficina de Investigación y Normalización (OIN) Ministerio de Vivienda y Construcción Carretera Panamericana Norte Km. 16.900 Lima, Perú	Ing. Raquel Machicao
Department of Structural Engineering Universidad Nacional de Ingeniería Casilla 1301 Lima, Perú	Dr. Ricardo Yamashiro Dr. Javier Pique
Departamento de Ingeniería Pontificia Universidad Católica del Perú Lima, Perú	Ing. Julio Vargas Neumann
Fundación para la Vivienda Cooperativa c/o U.S. Embassy Lima, Perú	
Banco de la Vivienda del Perú Jr. Camaná 616, 8° Piso Lima, Perú	
INIAVI (Instituto de Investigación para la Acción en Vivienda) Lima, Perú	
U.S. Agency for International Development c/o U.S. Embassy Lima, Perú	Ing. Edilberto Alarcón
Comité Nacional de Defensa Civil Esquina Calles 1 y 21 Urb. Corpác San Isidro Lima, Perú	
National Agricultural University of La Molina Lima, Perú	Ing. Urbina Barreto

Instituto Geofísico del Perú Avenida Arequipa 701 Apartado 3747 Lima, Perú	Dr. Daniel Huaco Dr. Ernesto Deza
National University Mayor of San Marcos Faculty of Sciences University City Lima, Perú	Dr. Enrique Silgado
Vecinos Mundiales Michigan 460 Rinconada - La Molina Lima, Perú	Mr. Edward Ruddell
ORDEZA Huaraz, Perú	
ITINTEC Lima, Perú	

Organizations in the United States:	Contact:
INTERTECT P.O. Box 10502 Dallas, Texas 75207	Mr. Frederick C. Cuny
Advanced Building Studies Program Carnegie-Mellon University Schenley Park Pittsburgh, Pennsylvania 15213	Professor Volker Hartkopf
International Institute of Housing Technology California State University Fresno, California 93710	Dr. Horace Schorling
Building Research Division Center for Building Technology National Bureau of Standards Washington, D.C. 20234	Dr. S.G. Fattal
Office of Engineering U.S. Agency for International Development Department of State Washington, D.C. 20523	Mr. James J. Claps

College of Engineering
University of New Mexico
Albuquerque, New Mexico 87131

Dr. William A. Gross, Dean

For Information about the Cross-Brace System:

OXFAM
Oficina Regional Para Centro America
Apartado 268
Antigua Guatemala
Guatemala, C.A.

Mr. Reggie Norton

Vecinos Mundiales (World Neighbors)
Apartado 243
Antigua Guatemala
Guatemala, C.A.

Mr. Paul McKay

Alianza para Desarrollo Juvenil Comunitario
(Save the Children Alliance)
3a Calle 7-28
Zona 10
(Apartado Postal 2903)
Guatemala City
Guatemala, C.A.

Mr. Tom Lent

INTERTECT
P.O. Box 10502
Dallas, Texas 75207

Mr. Frederick C. Cuny

APPENDIX C

BIBLIOGRAPHICAL RESOURCES

Informe de Avance de la Investigación Sobre Construcciones de Adobe:
"Parte 1: Caracteristicas del Suelo-Cemento y de la Caña de Guayaquil" (Octobre 1971)
"Parte 2: Estudio de Vigas de Suelo-Cemento Reforzadas con Caña de Guayaquil y de Modelos de Muros de Adobe Sometidos a Cargas Perpendiculares a su Plano" (Diciembre 1971)
"Parte 3: Estudio Sobre Losas de Suelo-Cemento Reforzadas con Carrizo y Encuentros de Muros de Adobe" (Enero 1972)
"Parte 4: Resistencia de Vigas de Suelo-Cemento Reforzadas con Carrizo" (Enero 1972)
"Parte 5: Estudio de Muros de Adobe Sometidos a Cargas Horizontales" (Enero 1974)
Departamento de Estructuras y Construcción, Universidad Nacional de Ingeniería, Lima, Perú.

Construyendo con Adobe, Instituto de Investigación y Acción para la Vivienda (INIAVI), Lima, Perú, 1976.

Adobe Estabilizado: Informe Técnico, Ministerio de Vivienda, Lima, Perú, 1977.

El Adobe Estabilizado, Ministerio de Vivienda, Lima, Perú, 1978.

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