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INTRODUCING LIMITED IMPROVEMENTS IN VERNACULAR HOUSING AFTER THE 1987 ECUADOR EARTHQUAKE:

PROGRAM CONSTRAINTS ON SUSTAINABILITY

Draft for Review

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ECUADOR STUDY

INTRODUCTION

Earthquakes in March 1987 rocked the Inter-Andean Valley, collapsing or damaging housing on the steep and often unstable slopes as well as homes in the villages at the base of these soaring mountains. According to both written reports and recent interviews, the initial stages of response were uncoordinated and slow.

- Much of the early aid was inappropriate and poorly distributed. Unnecessary clothing and unfamiliar food items were donated. Distribution was in city centers and along roads, so that many of the donated items did not reach the people in need and too little effort was made to get this assistance to those in the remote, high areas who had suffered most.

- Offers of concrete, brick and prefabricated metal houses raised great expectations in many rural communities. Some residents tore down repairable houses in order to qualify for a new home. Many of the initial offers never materialized.

- As is often the case, the emergency and early reconstruction periods were characterized by: duplication of effort; pursuit of conflicting, inappropriate or incorrect technologies; contradictory program approaches; and perhaps even competition for "victim" clientele. This created confusion for leaders at the community level and for earthquake victims.

- There was a general neglect of repair needs; most projects focused on new house construction.

- Some evaluations of the response point to an increased local dependency on aid institutions for housing assistance, as opposed to the self-reliance fostered by development activities that had been long-established in the area.

At this level, analysis of the reconstruction would suggest that another man-made disaster simply followed the natural disaster. However, this devalues the assistance provided by many dedicated and interested persons who did provide critically-needed aid during a period of calamity and confusion. The purpose of this report is to look more closely at the activities of one of the contributors in that effort, the Centro Andino de Acción Popular (CAAP) which quickly designed and put into action a post-earthquake reconstruction program that included a training component to improve the construction practices used in rebuilding typical highlands houses.

The Centro Andino de Acción Popular is an Ecuadoran non-profit organization involved in training and motivating the people of the Andean Mountains of Ecuador to find

solutions to their conditions through collective action and empowerment. It works towards this objective by providing training and working on agricultural and community development activities. While its principal office is in Quito, CAAP has maintained a strong presence in the north-central area and operates a regional training center at the edge of the town of Cayambe.

CAAP's post-earthquake program was undertaken in a number of dispersed communities in the Cayambe region, part of the Ecuadoran *sierra* northeast of Quito. This study examines the regional context, the opportunities and issues confronted by CAAP, from the perspective of the sustainability of their program activities.

CONTEXT

A. Environmental

Ecuador covers approximately 283,520 square kilometers, straddling the equator on the Pacific coast of South America between Peru and Colombia. The country has four geographical zones: the coastal plains (*costa*), the Andean highlands (*sierra*), the tropical lowlands which merge into the Amazon jungle (*oriente*) extending eastward from the Andes, and the small, unique and volcanic Galapagos Islands.

The *sierra* region encompasses about one-quarter of Ecuador's territory. This region has two parallel mountain chains (Western and Eastern Cordilleras) running roughly north-south down the length of the country. Along the narrow, central Inter-Andean plateau formed by these mountains are numerous basins and volcanoes. About 30 volcanoes -- nine of them young and many capped with an extensive snow and ice cover -- line this "Avenue of Volcanoes" which encompasses the capital and second largest city, Quito, along with hundreds of market towns and dispersed agricultural communities. A number of active fault systems intersect in this highly-populated valley.

Up to 90% of the forest cover has been stripped from the steep western slopes of the Andes in order to develop these areas for agriculture. The burning of fields in many areas to encourage new growth for grazing has removed much of the natural vegetative cover. These activities have increased vulnerability to both climatic changes and erosion. The soil cover on many slopes is thin, so that mud and debris slides often leave large expanses of exposed bedrock. The opening of virgin jungle for oil exploration has led to road construction, new settlements, environmental degradation and contamination. Much of this construction exhibits little regard for the risk from natural and man-made hazards.

The country as a whole has a long and diverse disaster history including extensive floods, flash floods, droughts, earthquakes, volcanic activity and tsunamis. The average return period for earthquakes is approximately 4 years.[1] However, the region so badly

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OFFICE OF U.S. FOREIGN DISASTER ASSISTANCE
DISASTER HISTORY REPORT

DISNO	STR DT	DECL DT	REG	COUNTRY	TY	KILLED	AFFECTED	HOMELESS	K$ DAMAGE	COMMENTS
42101	42		SA	ECUADOR	EQ	200	0	0	0	WESTERN ECUADOR
** FY = 42						200	0	0	0	1 record(s).
49103	49/08/05		SA	ECUADOR	EQ	8,000	100,000	0	20,000	PELILEO/AMBATO
** FY = 49						8,000	100,000	0	20,000	1 record(s).
64012	64	64/03/01	SA	ECUADOR	DR	0	600,000	0	0	WIDESPREAD
** FY = 64						0	600,000	0	0	1 record(s).
66002	65/04	65/07/01	SA	ECUADOR	FL	0	50,000	0	4,000	DAULE RIVER VALLEY
66044	66/05/15	66/06/01	SA	ECUADOR	LS	50	0	0	0	QUITO-SANTO DOMINGO RD.
** FY = 66						50	50,000	0	4,000	2 record(s).
87025	68/10/14	68/10/16	SA	ECUADOR	FI	0	800	492	134	COLIMES (GUAYAS PROV.)
87043	67/02/08	67/02	SA	ECUADOR	FL	0	20,000	400	100	MILAGRO; 100 INJ.
** FY = 67						0	20,800	892	234	2 record(s).
68106	67/08		SA	ECUADOR	EP	36	528	0	0	POLIO; GUAYAQUIL & AREAS
** FY = 68						36	528	0	0	1 record(s).
69033	69/05	69/05/08	SA	ECUADOR	EP	400	40,000	0	0	EQUINE ENCEPHALITIS; PLAYAS AREA
** FY = 69						400	40,000	0	0	1 record(s).
70047	70/04/08	70/04/17	SA	ECUADOR	FL	20	140,500	0	500	GUAYAS, EMERAL, MANABI
** FY = 70						20	140,500	0	500	1 record(s).
71018	70/11	70/11/01	SA	ECUADOR	FL	0	10,100	0	20	2 FLOODS: IMBABURA PROVINCE (70/11/00); GUAYAS PROVINCE (71/03/00).
71024	70/12/09	70/12	SA	ECUADOR	EQ	29	60,000	27,992	4,000	LOJA PROVINCE; 120 INJ.
71106	71/03/09		SA	ECUADOR	LS	20	8	0	0	QUITO
** FY = 71						49	70,108	27,992	4,020	3 record(s).
72001	71/07	71/07/01	SA	ECUADOR	FL	0	2,400	0	50	N.E., PUTUMAYO R.
** FY = 72						0	2,400	0	50	1 record(s).
76012	75/12	75/12/01	SA	ECUADOR	VO	0	0	0	0	VOLCANIC ACTIVITY; COTAPAXI
76105	75/07/08		SA	ECUADOR	VO	0	0	0	0	EL SANGAY
76123	76/04/09		SA	ECUADOR	FQ	10	0	0	4,000	ESMERALDAS
76172	76/07/11		SA	ECUADOR	LS	60	0	0	0	ESMERALDAS
** FY = 76						70	0	0	4,000	4 record(s).
77002	76/10/04	76/10/07	SA	ECUADOR	EQ	10	20,000	0	0	COTOPAXI (S. OF QUITO)
77008	77/01	77/01/06	SA	ECUADOR	EP	0	300	0	0	TYPHOID; W. PORTIONS OF QUITO
77130	76/12		SA	ECUADOR	VO	1	20,000	5,000	0	COTOPAXI
** FY = 77						11	40,300	5,000	0	3 record(s).
80115	80/06/18		SA	ECUADOR	EQ	6	0	0	0	GUAYAQUIL; 40 INJ.
** FY = 80						6	0	0	0	1 record(s).
83008	82/11	82/12/30	SA	ECUADOR	FL	307	700,000	0	232,100	5 PROVS./ENTIRE COAST
83150	83/04/27		SA	ECUADOR	LS	100	0	0	0	CHIMBORAZO
83172	83/07/11		SA	ECUADOR	AC	119	0	0	0	PLANE CRASH; CUENCA
** FY = 83						526	700,000	0	232,100	3 record(s).
84100	84/09/18		SA	ECUADOR	AC	60	500	500	0	NEAR QUITO; PLANE CRASHED INTO RESIDENTIAL AREA; 75 INJ.
** FY = 84						60	500	500	0	1 record(s).
85024	85/02/28	85/03/03	SA	ECUADOR	FI	0	800	0	0	BRUSH FIRE; ISABELA IS., THE GALAPAGOS; POPULATION CENTERS & UNIQUE SPECIES THREATENED
** FY = 85						0	800	0	0	1 record(s).
87021	87/03/05	87/03/08	SA	ECUADOR	EQ	300	150,000	0	0	CARCHI, IMBABURA, PASTAZA, AND NAPO PROVINCES; HOUSES AND BRIDGES DESTROYED; ROADS BLOCKED; OIL PIPELINE DAMAGED
87140	87/04/03		SA	ECUADOR	LS	100	6,000	0	0	COCHARCAY; MUDSLIDES BURIED AT LEAST 3 BUSES ON COASTAL HIGHWAY
87189	87/09/22		SA	ECUADOR	EQ	2	0	0	0	AMBATO; THREE TREMORS; 8 INJ.
** FY = 87						402	156,000	0	0	3 record(s).
89189	89/06		SA	ECUADOR	FL	35	30,000	30,000	0	HEAVY RAINS CAUSED FLOODS AND LANDSLIDES
** FY = 89						35	30,000	30,000	0	1 record(s).
90187	90/08/10		SA	ECUADOR	EQ	8	0	0	0	QUITO, POMASQUI
** FY = 90						8	0	0	0	1 record(s).
91123	91		SA	ECUADOR	EP	800	72,000	0	0	CHOLERA, ESP. IN LOWLAND AND COASTAL PROVS.; FIGS. AS OF 07/01/92
** FY = 91						800	72,000	0	0	1 record(s).
92031	92/03/24	92/04/08	SA	ECUADOR	FL	22	125,000	80,000	0	10 PROVS., INCLUDING GUAYAQUIL; TORRENTIAL RAINS DESTROYED AGRICULTURAL LAND, DWELLINGS, & ROADS; 16,000 TO 18,000 FAMILIES AFFECTED
** FY = 92						22	125,000	80,000	0	1 record(s).
COUNTRY = ECUADOR						8,893	2,148,934	144,384	284,904	34 record(s).

damaged in the 1987 earthquake had not suffered from quakes of this intensity for about 30 years.

The contrast between the *costa* and *sierra* regions -- in terms of geography, economy, social custom, religion, ethnicity and politics -- has often played a major role in the direction of the country's development.

B. Social

1. Social Divisions:

The indigenous population of Ecuador consisted of numerous groups, many briefly brought together under Incan rule prior to the arrival of the Spanish conquistadors in the 16th century. The descendants of these native cultures are today collectively identified as *indigenas*. The new arrivals were *blancos* or Europeans and, to a lesser degree, *negros* or Africans. Over time, the mixing of these diverse populations created a new *mestizo* group. This ethnic mixture characterizes the majority of the country's inhabitants.

Although the Spanish established their language as the official one, the significant number of native people and their isolation preserved Quechua as a parallel language, with Spanish predominating in the cities and Quechua in rural communities. As basic primary education becomes more common throughout the nation, Spanish gains the advantage.

Ecuador is also strongly divided on the basis of the distribution of wealth. Prior to the exploitation of oil resources, the economic wealth of the country was traditionally determined by land ownership. At the start of the colonial period, the indigenous population occupied the land on a communal basis, based on a hierarchial class system. The Incan civilization had an aristocracy, an administrative class, an artisan group and the larger general population which provided the human resources for agricultural and military activities. The Spanish conquistadors usurped the rule of the Incas and assumed ownership of the land. Large landholdings were given to the explorers, the Roman Catholic church and the early settlers. Over the years as the flow of new settlers slowed, and they and their offspring intermarried with the native population, many of these large holdings were divided. Today the old land caste characteristically owns the most productive lands, with the poorer segments of society relegated to the less productive hillsides or generally smaller, inefficient holdings.

The pattern of concentrated landholding and wealth continued through the years to define the distribution of the national wealth and power. This platform of land wealth allowed the oligarchy to assume control of the financial and industrial base which evolved in later periods. However, as Ecuador developed an economic and industrial capacity, the distribution of wealth did permit the rise of an urban middle class.

In the last fifty years, the flow of migration from the rural communities to the urban centers has become a significant factor. These new urban residents sought to obtain a greater share of the national wealth, as represented by the material wealth and basic services such as jobs, health services, water, etc., available in cities and towns. Today, continued migration and natural urban population growth feed the expansion of the urban centers. The move to the urban environment has brought about considerable improvement in some areas in the lifestyle of the migrants. Yet the basis for this improvement unfortunately has more to do with the impoverished position of the rural areas than with the overwhelming superiority of the urban society. The changes in Ecuadoran society have been dramatic, but the changes have not yet brought about a reasonable distribution of resources.

The composite of the socio-economic character of Ecuador can best be described by the classical triangular social construct. At the apex is a small landholding and capital class with considerable wealth and political influence. Just below this is an expanding urban working class. Characteristically, this group aspires to middle-class life and material wealth, but its claim is so recent that its hold is very tenuous. By far the largest group consists of lower-income city-dwellers and rural agricultural society. Yet its share of the national wealth in all sectors -- be it in the political sphere, in education, health care, or in access to public services -- is adversely disproportionate. Added to this construct are the critical roles of the military and the church as dominant political and social players.

2. Demographics and Housing Needs:

At the time of the 1987 earthquakes, the country had close to 10 million inhabitants, with the population fairly evenly divided between urban and rural areas.[2] During the last twenty years, the cities of Quito and Guayaquil have experienced the largest population increases, with substantial growth as well in other urban areas. During this same period, the rural areas exhibited a population growth rate which has been offset by considerable outflow to the urban areas. The number of households was estimated at 2.1 million in 1988 and is projected to be 3.77 million by the year 2008. Household size at a national level has shown a general tendency to decrease over the last two decades, with more substantial decreases in the urban areas than in the rural communities.

Population size and household formation growth have outraced the production of new housing units in both quantitative and qualitative terms. From 1963-1985, the Ecuadoran government added approximately 72,000 housing units (including not only new units but also rehabilitated ones) to the national housing stock. Of this total production, 97.6% were urban. In rural areas, 1,773 units were added; only 600 of these were new units -- an average of 27 per year or one for every 2,170 people. As the rural population was said to be growing by 33,000 per year, about 7,000 new homes needed to be added each year.[3] So there was a severe housing shortage already at the time of the earthquake.

It was estimated that there were some 1,576,441 units for some 8,060,712 people in 1988. Only fifty-five percent (55.1%) of the housing stock was determined to be

"adequate"; this reflected an increase from the 45.1% cited for 1982.[4] Major factors for determining "adequacy" relate to access to public services such as water and sewer services, as well as the size and condition of a house.[5]

The vast majority of housing stock is produced not by the formal sector but by informal activities of households resolving their housing needs incrementally. It is built outside of the regulatory process with no building control or professional input.

3. The Cayambe Region:

In the region of this study's focus, the town of Cayambe is located some forty minutes by paved road from Quito. The town center sits at the edge of a mountain valley. The valley floor and the lower reaches of the mountain are dominated by larger ranches and mechanized cash crop farms. Progressing to the summits, the plots are smaller, tilled by wooden plows drawn by oxen or humans, and dedicated mainly to potatoes and small herds of sheep. The distribution of wealth and power follows the classic lines described above: the rural indigenous population remains figuratively at the bottom with a small share of the wealth and power, despite recent politicization of the rural *campesino* or farmer vote.

The 1987 population of Cayambe was estimated to be approximately 46,580, of which just over 60% were considered to be rural with the remainder living in the towns of the region.[6] The majority of the inhabitants are either *mestizos* or *indigenas*, with the indigenous population concentrated in the rural settings. The number of people in a typical household is slightly higher than the national average but usual for a third-level urban center with widespread rural communities. Spanish is the more dominant language in the urban environment and Quechua is used more extensively outside the towns. There has been a substantial break-up of the haciendas from colonial times; however, the pattern of land ownership exhibited in the area still relegates the largest segment of the population to small, inefficient, remote and sometimes exhausted parcels of land

In the presence of economic hardship, and as many more families are tied to the national economy, many have become increasingly vulnerable. In urban areas, families seeking the opportunities of city life often find dreams unfulfilled; the isolation, cruelty and hardship of the city can be far worse than the poverty of their rural roots. The family unit of the rural poor is particularly at risk due to the growing absence of the men from the daily life of the family. Facilitated by improvements in roads and public transport, many travel to the cities or to agricultural areas of the *costa* in search of jobs. Many men from the earthquake-damaged areas around Cayambe spend their weekdays in Quito, earning a living in the urban formal or informal economy and returning to their homes on the weekends to tend to their families, their farms or other pursuits. Some actually live in the city, seldom returning to their rural homes. In their absence, responsibility for care of the children, home, animals, tools for their livelihood, crops and/or production of items for market, falls on the women.

C. Economic and Political

Under military rule for much of its modern history, Ecuador has a tradition of strong, centralized authority. The election of conservative President Febres Cordero in 1984 was the first in 25 years when one civilian government constitutionally transferred power to the next. But his pursuit of free market policies and autocratic approach eroded his support, and the opposition Democratic Left gained control of the National Congress in the mid-term elections of 1986.

Prior to 1972, bananas had been the leading export product of Ecuador. The opening of the Amazon oil fields brought a degree of prosperity to the country but also a high level of dependency on this one revenue source (over half of total export earnings). By 1980, the rising GDP had slowed from over 9% to under 7%; foreign debt was around $4 billion and inflation was approximately 15%. When oil prices dropped in 1982, the country was unable to make payments on its foreign debt, said to be over $6.6 billion. By 1983, inflation had risen to over 50%, unemployment was high, and economic activity was down 3.5%. New international credit was withheld until Ecuador could reach an agreement with the IMF on restructuring its economy.

The victory of conservative interests in the 1984 elections was based on a platform of encouraging foreign investment, reducing government regulation, promoting private enterprise and freezing land redistribution. The Febres Cordero government did decrease the rates of inflation and unemployment, the economy grew, and the World Bank announced the granting of new loans to the country. But falling oil prices complicated the Government of Ecuador (GOE) and International Monetary Fund (IMF) adjustments, and opposition to the social impact of the government's austerity measures grew. Oil provided over 62% of their export earnings and usually about 50% of tax revenue; for every dollar drop in the price of a barrel of oil, the country expected to lose about $68 million in 1986 export income. Annual economic growth dropped to below two percent. A large deficit was incurred and the trade surplus fell.[7]

Ecuador's Oil Exports in Millions of Dollars:[8]

1980	1551
1985	1926
1986	983
1987	724
1988	976
1989	1147
1990	1488 (est.)

In January 1987, two months before the earthquakes, disaffected air force troops held the president and some 30 members of his military staff hostage for a day, releasing them after an imprisoned general was released. There was an unsuccessful move to impeach the president after his release.

In February 1987, a month before the earthquakes, Ecuador confirmed that it was unable to meet interest payments on the national debt. Total foreign debt was by this time over $8 billion, and oil accounted for 70% of export earnings. Thus at the time of the earthquakes, both the political and economic situations were deteriorating and there was no cushion of resources to help them either meet internal cash needs or pay on their foreign debt.

Natural disasters also took their toll on the national treasury. The El Niño floods of 1982-83, which affected approximately 700,000 people in the coastal areas, disrupted transport and agriculture. Major export crops were severely reduced. Again in 1987-88, El Niño-related widespread flooding damaged infrastructure and added to the burden on already meager resources. A month after the March 1987 earthquakes, landslides caused extensive damage and 100 deaths.

In the early 1980s, annual inflation had been around 20%; by 1983 it was 45%, rising later to 100%. On the basis of projected oil revenues, the country had borrowed fairly heavily. Failure of the economy led to increasing debt, inflation and devaluation at the national level. At the family economy level, the worst damages were to the urban poor and middle class. In rural areas, inflation brought on the negative consequence of increased production costs, lower real income and dwindling markets.

By 1988, Ecuador was listed as one of the 15 most heavily indebted nations in the world.[9] The presidential elections which took place in January 1988, just less than a year after the earthquakes, resulted in the democratic left taking power.

D. Housing Process

1. Local Technology:

Vernacular housing varies from region to region, reflecting topography, climatic conditions, availability of materials and technology, and external influences. In the Cayambe region, earth is the most common building material, used in many forms such as wattle-and-daub, adobe and rammed earth as well as the more modern manufactured brick.

- **Bajareque.** Wattle-and-daub, known locally as *bajareque*, was quite common in the northern *sierra* region during the period before the conquest. These houses were often round, small and roofed with straw, as documented from the 16th century.

Bajareque is made by erecting a framework of poles, then weaving branches or canes horizontally into the framework as a base for a mud plaster. Today there is little new *bajareque* construction. There is generally a lower prestige or social value attached to this construction system, and increasing costs and scarcity of wood for the laths make consideration of *bajareque* less likely, although its lightweight character has long been known to make it safer in earthquakes.

- **Adobe.** Adobe construction is based on the fabrication of sun-dried earth blocks. The earthen blocks or bricks are laid in place and bound to each other with a mud mortar. Adobe construction is found in many parts of Ecuador. Its acceptability is based on the suitability of the soil, the level of expertise available, and issues of status within the social-cultural milieu. In the Cayambe region, adobe holds a position just above *tapial* and below burnt brick and concrete block construction in terms of material preference. Many older structures are built of adobe, particularly in towns. It is often seen in mixed-material structures such as those where room or second-story additions are made to an existing building. Adobe is also often used to construct a gable above a *tapial* end wall.

- **Tapial.** Rammed earth or *tapial* techniques were originally used by the Spanish colonists to build walls for delineating and protecting private property (a European concept brought to a country where land was customarily communal). When haciendas took in the local population as laborers, the workers were allowed to build simple structures of *tapial* to house themselves. Over time, this *tapial* construction became the most common and accepted building type in the Cayambe region.

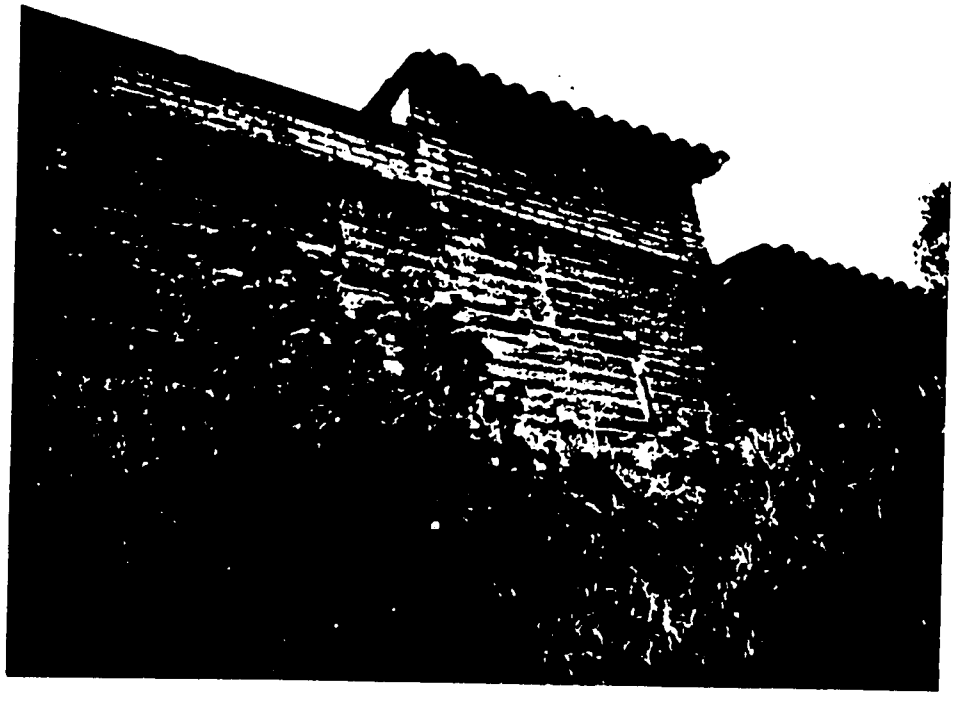
  Tapial construction is essentially a cast-in-place process consisting of filling a wooden form with moist earth, compacting it, and moving the formwork to make the next segment, thus building up walls layer by layer. Soil is sifted or sorted to discard large stones or hard clods, but no other preparation is usually carried out. The process of compaction is intended to increase the solidity of the wall segments. Soil compacted with the optimum moisture content to maximum density maintains its stability even if it is later saturated with water.

  There are many examples of ancient *tapial* walls still in good condition, some with the equivalent height of two- and three-story buildings. But in rural areas such as Cayambe, good construction practice has been lost to varying degrees. In the *sierra* region, the soil has a very high clay content, requiring the addition of sand to reduce the incidence of cracking from expansion and contraction; yet sand often is not used, at least in part because it is not readily available.[10] Buttresses were used in the past to strengthen earthen walls, but few are visible in modern *tapial* construction. *Tapial* blocks are frequently set one above the other, creating a continuous vertical joint and thus a roof-to-ground weakness in the walls. Houses in the area are fairly typically built without foundations or moisture barriers, allowing moisture to slowly weaken the structure as it percolates upward from the ground through the walls.

Typical rural houses in Cayambe region:

Old *tapial*, adobe and thatch structure on steep hillside.

Multi-story home along road near Cayambe with several layers of *tapial* and top story of brick.



Typical *tapial* home near Olmedo,
with farm implements stored on the rear wall.

The introduction of *tapial* and adobe construction techniques by the Spanish resulted in significant changes in local building practice. Rectangular and square configurations became common, and clay tiles began to replace the traditional thatch on the roof. Adobe initially became the construction system of choice and still remains common in the towns. By the 19th century, the local population of Cayambe had switched almost entirely to use of adobe or *tapial* construction for their houses, relegating their *bajareque* structures to farm usages. Those who changed to *tapial* found not only that this system was inexpensive but also that it eliminated the necessity of using wood in the walls.

Today there is a strong preference for more modern materials such as brick. The cost of *tapial*, however, weighs heavily in its favor in many rural areas, as can be seen in the current cost estimates below:

Current Estimated Cost of Building Types:

Tapial	70,000 sucres per square meter for rural house
	170,000 sucres per square meter for urban house
Adobe	170,000 sucres per square meter
Bajareque	185,000 sucres per square meter
Wood Frame with Brick Infill	195,000 sucres per square meter
Concrete	374,000 sucres per square meter

At the recent exchange rate of 1900 sucres = US$1,
a 50-square-meter house would thus cost:

Tapial	US$1842.00 in rural areas; US$4473.50 in urban areas
Adobe	US$4473.50
Bajareque	US$4868.50
Wood Frame with Brick Infill	US$5131.50
Concrete	US$9842.00

2. Cayambe's Housing Character:

In the region where CAAP, FUNHABIT and others initiated post-earthquake reconstruction projects in 1987, the social, political and economic life of the communities must be understood in terms of both the earlier colonial hacienda tradition and the

topography of the valley and steep mountain lands farmed for centuries. After the conquest, land was largely held in estates worked by Indian labor, not only from the local area but also brought in from other areas like Guayaquil.[11] From traditions of communal labor and land, and individual acceptance of labor and produce debts owed to the Inca government, *campesinos* became the mainstay of almost an indenture system wherein private ownership of land, goods and people accrued to their colonial masters. As mentioned earlier, these workers were allowed to erect simple *tapial* buildings for shelter.

As the population moved off the haciendas or established independent holdings, the techniques of *tapial* construction followed. The *tapial* housing design found today has changed little over the last three hundred years. Most are one-story homes, although along the roads two- and even three-level structures can be seen in some areas. The typical house is rectangular with approximately forty-eight square meters of space; many have porches or entries as part of this space. There are few openings for windows and the houses are consequently dark and poorly-ventilated. The door may be the only operative aperture for the entire structure. Roofs are generally either two-sided (gabled) or four-sided (hipped). Some buildings have a mud plaster or other finish applied to the walls to increase resistance to erosion or simply to provide a cosmetic or decorative touch.

The interior space is often a single, large room, which is divided by the functional arrangement of simple, sparse furniture and equipment. The preparation of food is often done inside the building on either an open fire or simple stove. The rafters provide storage space for personal belongings, and farm implements are often hung on the outside walls.

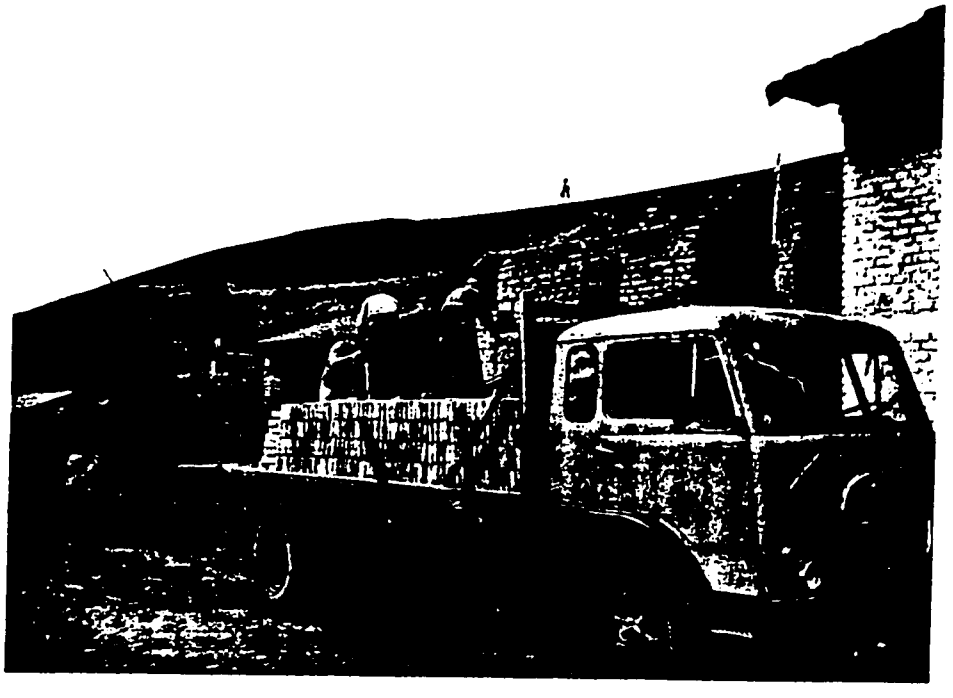
Differences in construction styles and materials in the region reflect the fact that approximately 78% of the *indigena* population were tied to the hacienda system, while only about 22% remained "free" in 1700-1800.[12] The earliest tradesmen and artisans who were independent of the hacienda's control generally lived in the towns. Their housing choices -- likely to be either *tapial* or adobe with tile roofs -- were adapted to the urban scene with smaller plots and street orientations.

In the twentieth century, burnt brick and later concrete block construction were introduced. These materials are now the materials of choice in most towns, and there is evidence that this trend is extending to the rural communities. Confined masonry (concrete frame with brick infill) is becoming common for new construction in some towns, along with various mixtures of rammed earth, adobe, brick or block. Styles along the roads too reflect access to a wider variety of materials and design choices.

In some parts of the country, corrugated metal sheets are now commonly used, but this is not the case in the Andean highland areas affected by the 1987 earthquake. Here most roofs are made of tile. The traditional thatch roofs are increasingly relegated to the most humble and rural structures. In part, this is due to the lack of available thatch material and construction skills, but there is also a decided preference for tiles. The truss system is often insufficient for the heavy tiles used for the roof covering.

A typical lot in or near a village might include not only a new (post-earthquake) house but also the remains of the old damaged one (often used to store farm equipment, materials or supplies, or to house other family members) and another shed for animals.

Loading bricks from a local brickmaker near Juan Montalvo.



Throughout Ecuador, building materials are often of poor quality. Although considered by many to be inherently stronger than other materials, local concrete block is frequently weak, as is the brick which may have been processed using inadequate temperatures and furnaces.

3. The Building Process:

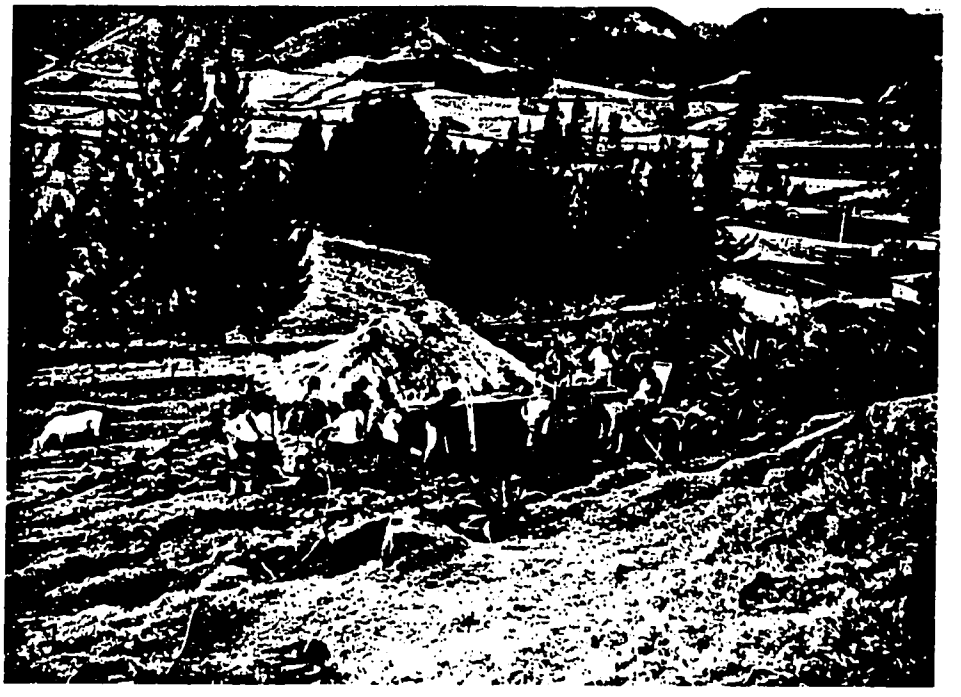
The vast majority of Ecuadorans are responsible for resolving their own housing needs. Construction is primarily financed by the homeowner, and both economic and social considerations play a major role in determining not only what will be built but how.

Many households simply purchase and stockpile building materials over time, as they can afford to buy and transport them. The process may involve cash-saving, collection of raw materials, self-manufacture of building elements, and/or the purchase of manufactured materials. Construction may be achieved by the occupants themselves or by contracted labor. Increasingly, people rely on construction practices that combine contracted expertise and self-help, for example, where a skilled *maestro* (individual contractor-mason) is hired to undertake the building process, assisted by unskilled or semi-skilled family and/or friends. In many areas, the traditional communal labor practice of forming a *minga* of family, friends and neighbors is often relied on not only for individual home-building but also for building community infrastructure. This practice is stronger in the rural communities and losing ground in the urban environment.

Construction styles and material choices are increasingly influenced by the urban styles seen by families and workers who travel to the cities. The styles or elements of styles are copied without the benefit of professional input.

The actual building takes place when the family or the *minga* can put aside other activities and focus on construction. For the agricultural community, construction of shelter or community projects is often left for periods after the harvest; not only does this period offer the time needed, it also allows the household to "pay" the *minga* with food and *chicha* from the fruits of the harvest. It is becoming more difficult to define the traditional building periods, however, as more of the men complete their harvest and leave for other jobs in cities or farms elsewhere. In Cayambe and other depressed rural situations where the man of the household is working outside the community, construction takes place over a longer period of time, usually on weekends or on completion of his job away from home. In urban situations where greater productivity is obtained by continuing in other economic activities (including and particularly where women heads-of-household are involved), the household will contract with a *maestro* and provide unskilled family labor.

Land holdings in many areas are small. At death, if not before, the parents' land must be divided among all inheritors equally. The encumbrance does not pass to the inheritors, however, who can do whatever they want with the land they have inherited; many holdings are thus sold and become part of larger farms, or are worked cooperatively within a



Minga beginning construction of *tapial* house. Hillside site above old thatched house is only partially prepared where the first wall is being formed and compacted in straight forms.

family. In spite of various land reform efforts, there remains some rural opposition to taking formal title to land because of the tax burden assumed.

4. Building Codes:

Building codes have no influence outside the small formal sector in major cities. The permitting process may serve to generate tax revenue and fines for non-compliance with plans, but not to regulate building quality.

A review of the national code (based on the Los Angeles code) was performed and recommendations made for revisions to reflect the Ecuadoran situation and risks, but no follow-up has been undertaken and apparently no support has been forthcoming from external sources.

5. Building Skills Training:

Vocational education plays a fairly negligible role in the building process. Most of those who build receive training only in the sense that they may have worked on a construction project in the past. Construction jobs are generally subject to high turnover and variations in pay scales. Employers do not want to be obligated for governmental social costs, and the availability of cheap labor further suppresses the improvement of the work force.

THE EARTHQUAKE OF MARCH 1987

A. The Earthquake and Its Impact

On the night of March 5, 1987, two earthquakes (6.0 and 6.8 on the Richter Scale) struck the northeast part of Ecuador. The epicenters were in Napo Province, but the quakes affected a 30,000 sq. km. area of the *oriente* and Inter-Andean regions including mountains up to 5,800 meters high. Hundreds of tremors followed over the next few months. Heavy rainfall during the two months prior to the earthquakes had saturated the earth and added to the instability of the volcanic and other soils on the steep slopes. Landslides and other slope failures were particularly common in the mountainous areas around Reventador Volcano, east of Cayambe. Massive mud slides, rock falls and flooding swept away 30-40 km. of the Trans-Ecuadoran oil pipeline and combined with flood waters to cut the highway connecting Quito with the eastern jungle and oil fields.[13]

Assessment efforts initially focused on the epicentral area near Reventador Volcano. Losses were greater from the slides, debris flows and flooding than from the ground-shaking caused by the quakes, particularly in this eastern region. In Napo Province, roads and bridges were destroyed, causing many people to sustain major agricultural losses because

they were unable to transport crops to market or because access to their lands was cut off. The damaged oil pipeline conveyed almost all of the oil from the eastern fields to a port near Esmeraldas and was not repaired until August 1987. Losses were estimated to be approximately $1 billion; disruption of the flow of oil is said to have deprived the country of 60% of expected export revenue. Damage to the oil pipeline also meant loss of tax revenues and income to local workers until the pipeline could be repaired. On the other hand, the world might have paid little attention to the event had there been no break in the pipeline and consequent ripples through international markets.

The earthquakes caused extensive damage to housing and community buildings in the *sierra* region. In the three provinces of Pichincha, Imbabura and Carchi, approximately 60,000 homes were believed to be damaged or destroyed; this represented almost 82% of the total 73,261 houses affected in all zones, with 44% estimated to be in urban areas and 56% in rural areas, mostly in mountainous areas north and south of Quito. Damages were particularly heavy between the towns of Cayambe and Ibarra. In this region 3,000 houses were believed to have been destroyed and 15,000 seriously damaged.

An estimated 47,828 people were said to be homeless, out of a total of 58,470 reported to be homeless in the entire disaster area.[14]

A UNESCO/CERESIS team assessed damage to historic buildings in Quito and Ibarra, reporting that about 7,000 houses were damaged or destroyed, of which approximately 50% were earthen structures. Most of the houses did not collapse totally but were severely weakened from wall or roof failure.

In Baeza and nearby areas, people who had moved from wood to concrete block construction suffered a great deal of loss due to poor construction practice. One-story reinforced concrete barracks and mess halls suffered extensive cosmetic damage and damage as well to reinforced concrete beams.[15]

Primary and secondary damage from the earthquakes had a devastating economic impact on the country. Within a week, the government (already embarked on a course of fiscal conservatism and austerity) instituted a series of stringent economic measures designed to conserve national cash resources and counteract the usual post-disaster price rises.

The earthquakes affected a very dispersed population. This, and the fact that general elections were soon to be held, complicated both the development and implementation of response activities. Immediately after the earthquakes, on March 14th, the president imposed price controls, sparking general strikes by workers and students. Under these austerity measures, prices for fuel and public transportation were raised and basic food prices were frozen. For example, the cost of gasoline went from the equivalent of US$.33 per gallon to US$.60 per gallon. Political opponents accused the president of focusing entirely on the economic situation and ignoring the impact on the Ecuadoran people.

B. Typical Building Damages

In the Ibarra-Cayambe region where construction was mostly of *tapial*, adobe, and, to a lesser extent, *bajareque*, as well as brick and concrete block, damages and losses were generally higher in *tapial* construction. The most common construction type in the area of this study was a one-story house with *tapial* walls and wood roof structure covered with clay tiles or sometimes thatch. Assessments noted the following damage as typical:

- collapse at the corner joint;
- wall separation where joints lined up vertically;
- poor connection between the roof and the walls;
- wall failure at the base;
- collapse of gables.

THE CAAP RURAL HOUSING RECONSTRUCTION PROJECT

After the earthquakes of March 5th and 6th, it appeared that the recovery activities in Cayambe would not be significant, given the moderate damage. Outside the urban area, in remote and scattered rural settings, the situation was very different. The initial reaction of the rural residents was to seek safety away from the possibility of building collapse during the ongoing tremors. Many households slept under simple, makeshift thatched shelters in their fields. After the initial shock and the danger appeared to have subsided, the rural population initiated contacts with its neighbors in Cayambe. At this point, CAAP and the local authorities began to gain insight into the extent of damage in outlying regions.

At the time of the earthquake, CAAP had already been engaged in development activities for twelve years in the Cayambe region, so that their participation in post-earthquake recovery was not unexpected. As an initial response, CAAP distributed blankets and plastic material obtained in local markets. This served to provide some immediate protection to the population and their harvest. This also enabled CAAP to conduct a damage and needs assessment in direct contact with the stricken population. Based on early reports by rural inhabitants, the local authorities and social institutions met to discuss an appropriate recovery program. According to CAAP accounts, it was in these sessions that the local institutions (CAAP, local government and the Roman Catholic Church) defined the areas of influence for coordinating recovery activities. The essential element of the plan was to allow each organization to work with those communities where they had prior experience and ongoing commitments.

Also in this early stage, earthquake reconstruction advance teams from outside the community arrived. Offers of help and assistance were made by numerous officials from governmental and relief organizations. By all accounts, the local population was impressed by the display of support offered. Local institutional efforts were put on hold as the victims and their leadership sorted out the multiple and often impressive offers from outsiders. Local village and rural leaders prepared lists of the victims and the damages to their homes. In presenting these lists, the victims anticipated immediate assistance. This was not the case. It can be argued that some of the offers were never real, such as that proffered by politicians during a pre-election period. Other, more concrete support was complicated by protocols, bureaucracies and logistical considerations. At the local level, the delays could not be understood. Within days, frustration set in and many families started rebuilding on their own.

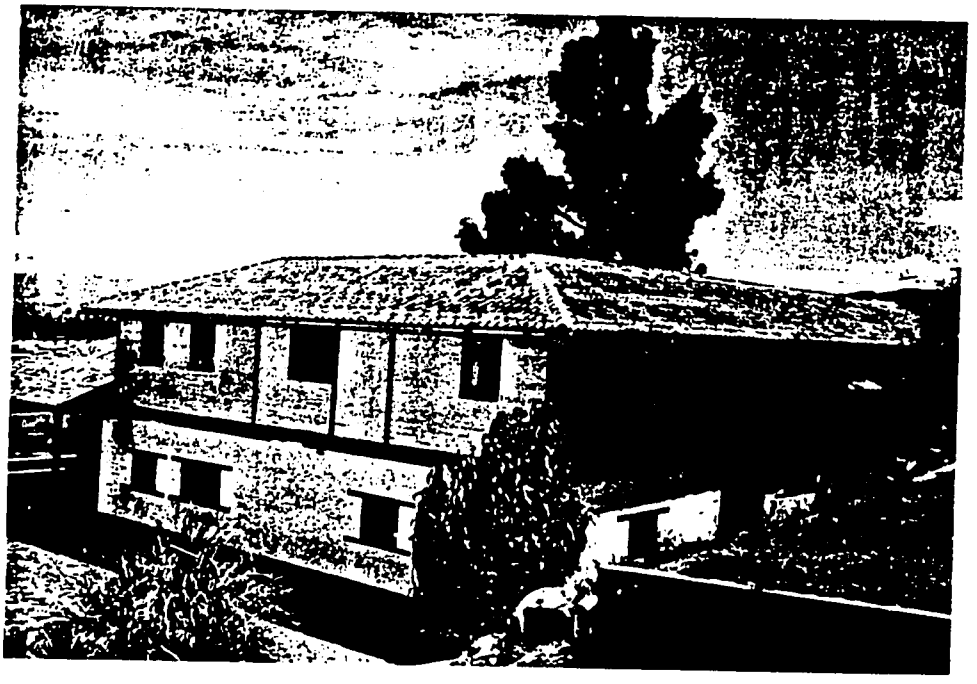
CAAP participated in a second distribution of plastic sheeting, this time a more substantial material from AID/OFDA, and this interaction with the residents set the stage for re-opening the suspended dialogue between CAAP and the community.

As CAAP considered possible responses to the housing needs, it also eliminated a number of options. For example, the literature suggests that from the beginning, CAAP ruled out the use of model house construction as an element of a housing reconstruction program because it was felt that building models would be too expensive, that the population was too dispersed and roads too bad to make this approach practical, that it would take far too long, that it would be socially divisive, and that it would be a "top-down" approach.

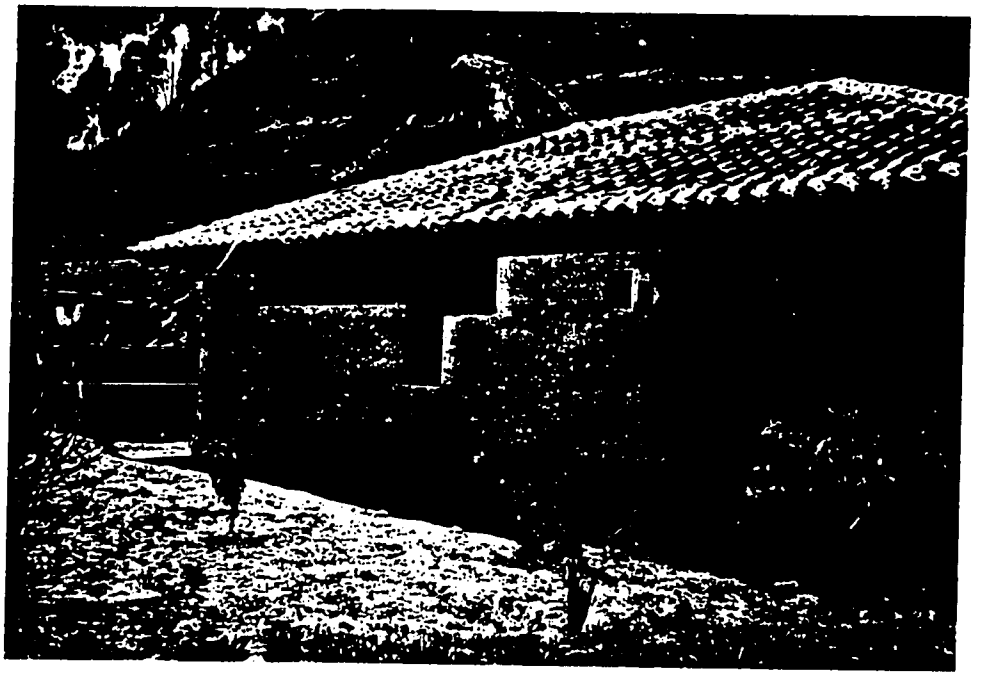
They also decided against establishing a credit program. They had seen prior programs initiated in rural areas where the population had no experience managing formal credit, and the results had crippled the program's progress. A credit program would require a considerable organizational realignment and an educational element for both CAAP and the communities. CAAP itself would have needed to enter into the credit/financial structure and train staff to generate and manage a credit portfolio. And there would have been a long delay in marketing credit to the unaccustomed rural population. In many rural communities, when credit is available it is limited to what are consider "productive economic ventures" such as the purchase of agricultural land or supplies for planting; it is not customarily used for what are considered "passive" economic activities related to shelter. The basic mechanism of credit -- that is, the distribution of resources based on the ability to pay rather than on need -- was viewed as unjust. In a time of great need such as the earthquake disaster, credit would be viewed as inequitable and divisive.

With regard to the physical construction elements of the program, CAAP had no previous housing experience, so they contacted the Centro Sinchaguasin to assist with the technical matters. The Centro Sinchaguasin was a local resource and technology center near the small market town of Pujili in the Andean province of Cotopaxi, about 2 hours south of Quito. It was a small experimental station for appropriate technologies and agricultural ventures. The Centro already had a rural housing improvement project underway at the time

Local school for *indigenas*, a project of Centro Sinchaguasin built in Pujili about 4 years ago, has first floor of improved *tapial*, second of *bajareque*.



A second building next to the Pujili school is built with a small unfinished wall section to show its *bajareque* construction. Old thatched structure is at rear up the slope.



A demonstration house of improved *tapial* at Centro Sinchaguasin, currently used by a visiting technical advisor.

of the earthquake, attempting to find solutions to local housing problems -- specifically, ways to make housing more available, affordable and desirable. The techniques they used were traditional ones with limited improvements, e.g. solar latrines, colored cleanable floor and wall treatments, internal chimneys suitable for thatched roofs, etc.; and door, window and furniture fixings suitable for earthen buildings. With actual project demonstrations on site, the Centro was a model showroom. Postcards were used to promote housing improvement techniques; each had a photo on one side and simple description and contact information on the back. People were encouraged to come see these projects and technologies.

The Centro had support from British non-governmental sources (primarily CAFOD). In response to CAAP's request for technical advice, Centro Sinchaguasin provided the services of a British volunteer, an architect already working in the country. The architect began this collaboration with the CAAP team and local community leadership by assisting in the inspection of damaged properties.

A. Program Planning

CAAP established the following criteria for program planning:

- Return to permanent activities as soon as possible.
- Assist all the victims in the project areas.
- Involve local participation in planning as well as implementation.
- Maximize use of low-cost local materials and skills.
- Reduce/eliminate exposure related to delays of production and transport of non-local elements.
- Begin at the earliest moment.

1. Return to the organization's permanent activities as soon as possible:

CAAP was unprepared to deal with the emergency needs of its target population. Then and now, CAAP pursues its traditional development agenda; the occurrence of a national disaster is not factored into its projects. A disaster in personal terms for the victims, the earthquake was also viewed as a set-back in terms of the real needs and focus of the communities and consequently to CAAP's institutional objectives. CAAP willingly took on the humanitarian effort by re-allocating its limited resources. But as these funds were spent on the emergency, less was available for "real" development activities that formed the organization's core. This emergency course of action caused some institutional friction and fostered a desire to return to their traditional development activities as quickly as possible.

In addition, many of the options for assistance to the communities were viewed as potentially damaging to the self-reliance their normal programs were intended to support. CAAP was engaged in development activities to capacitate and empower the rural poor -- the most economically, socially and politically depressed segment of Ecuadoran society. Its

philosophical view was directly opposed to the colonial paternalism which created and fostered a dependent population, in part by the dispensing of favors and charity. Today charity without a balancing amount of responsibility on the part of the beneficiaries can re-enforce the paternalistic qualities and communal inaction on which the old colonial system thrived. Nevertheless, CAAP was prepared to veer off their "development" course, based on an acute awareness of the devastation added by the earthquake to the already difficult lives of the rural poor.

2. Assist all victims:

This same philosophical perspective played a role in defining who CAAP would assist. CAAP leadership did not wish to be accused of favoritism, or of offending its constituency, nor did the local leaders wish to politicize or to create any divisiveness related to their role in reconstruction. CAAP viewed this stance as being supportive of the communal norms and interest, as opposed to donor considerations of fairness or ease of administrating. Yet this decision could have tremendous budgetary consequences. If the earthquake response was to be equal, given the scale of the damages, the program parameters had to be well-defined and within the limits of CAAP's financial capabilities. In turn, this surely played on the technological issues that were confronted.

3. Involve local residents in decision-making and implementation:

In the written material on the events of the earthquake, considerable importance is given to the involvement of local people in the consideration of alternatives and in the decision process. CAAP had a long-term commitment to community empowerment and gave considerable weight and latitude to local opinion. For example, CAAP held back its program efforts, at the request of the local leadership, so that the local population could review and discuss the external offers of aid. We also see this in the delegation of direct supervision of the paid construction technicians to the local leadership and a number of other actions such as leaving responsibility for design decisions to the families.

Nevertheless, much of the recovery program revolved around questions and matters outside the knowledge or capabilities of the program beneficiaries, so that many decisions were in fact made by CAAP, particularly with regard to the amount of financing available and its allocation to project components. In addition, participation in the decision-making process is not a strong part of the character and tradition of the rural poor in the Andean region; it is more common for them to follow the lead of a recognized authority. So the program evolved as participatory but with a mix of both bottom-up and top-down decision-making.

How this sometimes conflicting mix -- broad participation, limited participatory experience, and unusual circumstances in an emergency situation -- played itself out during the program is difficult to reconstruct today. After the passage of some years, the relationship between the sponsoring organization, the community leadership and the project

participants appears to reflect a pragmatic interpretation of the management of the program elements. It can be concluded that local involvement was not the paramount program factor but nevertheless it was a critical one.

4. Maximize use of low-cost local materials and skills, and reduce or eliminate exposure related to delays of production and transport of non-local elements:

Both financial and time considerations suggested to CAAP that the physical recovery program had to maximize the use of local materials. Concrete block and burnt brick products were dismissed. Block was not produced locally and some believed the type of block made in the country was too fragile for the difficult terrain of this region. Brick, while manufactured locally, was expensive and too much time would be required for local suppliers to fabricate sufficient quantities to meet the post-earthquake needs. Logistical considerations also influenced the elimination of brick as a prime building element. The geography of the dispersed landholdings with limited access made transportation of building supplies difficult at best. These combined considerations suggested that industrialized materials such as block and brick were not acceptable based on the high initial cost and the added transportation costs. Wattle-and-daub was not felt to be an acceptable system; the absence of adequate wood lath and skilled labor would have made this technology difficult if not impossible to implement. Given these factors, the focus for an appropriate, locally-available building material turned to rammed earth.

5. Begin at the earliest moment:

With rebuilding beginning in the communities, CAAP saw the need to develop their program quickly to take advantage of the victims' impetus to rebuild. To delay would mean CAAP would lose the opportunity to impact the quality of rebuilding.

Another factor in their consideration of timing was the expectation that a surge in building activity would occur a month or so after the earthquake, between the harvest and planting seasons. This period of May through September was the traditional building season in the region. Unfortunately, wet weather complicated not only the construction efforts during this usually dry period but also transport schedules. This period was also becoming more important as a time when the men, having completed the harvest, would leave for Quito or the coast to earn extra money before planting season began. So CAAP's attempt at careful timing was not so successful as they had hoped in this regard.

There was one more factor that timing could influence. CAAP had already experienced the confusion that other donor organizations represented in the earliest days after the earthquake. To delay its recovery program activities would open the door to alternate players to intervene in the reconstruction and long-term activities which CAAP had with the target communities.

B. Resources

CAAP's desire to curtail their recovery efforts was closely related to the re-allocation of its own resources. The willingness of CAAP's funding institution, the German development agency Agro Acción, to allow reprogramming of existing program grants was critical. With their authorization, CAAP was able to immediately re-channel the available funds to a reconstruction program. Re-allocation of these funds, however, would have a direct impact on ongoing CAAP development activities; the amount of funding available from this finite "pot" of resources would be considerably reduced by the demands of the disaster program. Today it is clear that this consideration influenced program planning decisions. Availability of these funds enabled a quick start but also meant a short-term commitment to what in hindsight at least were perceived as activities quite separate from "development".

No other substantial funding was made available to CAAP, beyond that provided by Agro Acción. The disaster response agreement between Agro Acción and CAAP provided a framework but not the technical details of response/recovery activities; the pre-existing relationship and funds already committed allowed CAAP the freedom to define the recovery program, to develop it quickly, and to avoid the bureaucratic delays that characterized many other projects. As no other funds were available, this fund also had to be managed in such a way that it could assist all the targeted earthquake victims defined by CAAP.

There were other key resources that contributed to implementation of the CAAP recovery program. An un-quantified resource was the communal administrative input. Having an existing organizational infrastructure and extensive contacts in the communities proved invaluable to CAAP in planning and implementing the program. All but one of the communities to whom the project was presented chose to participate. This commitment to participate carried significant obligations. Community responsibilities included organizational and administrative tasks and local transportation.

The other side of this communal equation was the support of the participating families and friends, often in the traditional *minga* activity of working together. The contributions of family, friends and neighbors proved invaluable and essential to achieving the impressive record of construction improvements with limited financial resources and a short time frame. Some families also contributed additional building materials that were applied directly to producing their respective houses.

The final un-quantified quality is the work and dedication of the CAAP and Centro Sinchaguasin staff.

C. Technical Considerations and Innovations

The planning process, the magnitude of the recovery program, and the limited resources available to CAAP continually required the participants to focus on the tasks and work to be done. In historical terms and in the wake of the earthquake, many households were rebuilding using rammed earth. This suggested that consideration be given to what people were doing on their own with *tapial* and how to make it better. Devising improvements to rammed earth construction required a thorough examination of what had gone wrong, as well as some knowledge of ways to strengthen this type of construction.

CAAP and Centro Sinchaguasin assessed the damaged rammed earth structures, finding that the most common damage occurred because:

- typically there was little site or foundation work;
- the building corners fell out, leaving the rest of the walls unsupported and unrestrained;
- the joints in the walls frequently lined up from one layer to the next, allowing cracks to open up from the top straight to the bottom;
- there was a poor connection between the roof structure and the walls, and often the roof structure was not sufficiently rigid itself.

Many factors contributed to the damage, including:

- use of an inadequate soil mix for wall construction;
- deterioration of the lower portion of the walls where moisture weakened the wall material;
- lack of a ring beam;
- use of mixed materials;
- disuse of traditional good construction practices;
- influence of urban forms that were copied in rural areas without sufficient knowledge of how to use/support/tie together the materials;
- insufficient maintenance.

Information on improved earthen construction technology was available. Improved techniques were being tested and applied in other countries; however, not much had been

done in Ecuador. A series of conferences were held on the topic, most relevantly a Latin American Regional Workshop held in Lima in 1983, and this information was slowly being networked through the region.[16] Shortly thereafter, a Latin American Center for the Study & Dissemination of Earth Construction (CLEDTIERRA) was formed in Lima, with an Ecuadoran engineer as one of its directors. Just before the March 1987 earthquakes, a symposium on earthen structures was held in Quito, involving both local and international experts in discussions and planning of new initiatives in Ecuador.[17] Materials on earth construction technologies published by CRATerre apparently were available in the country and may have been a primary source for technical information on improving rammed earth structures. A description of the L-shaped mould to form corner elements was part of that available information.

Not only was the British architect at Centro Sinchaguasin aware of some of these activities and resources; he also was familiar with the content and lessons learned of a post-earthquake construction training program in N. Yemen several years earlier. His knowledge of this experience was reflected in the early choices made regarding program direction and parameters in his capacity as technical advisor to CAAP. Technical information was also gathered from an Ecuadoran engineer on such details as the appropriate mix of sand needed for the specific soil types in the project area.

Economic factors strongly influenced many decisions at this early stage of damage assessment and program design, such as those pertaining to the quality of the earth mixture, the structural integrity of the corner joints, and the union of the wall with the roof structure. In addition, the technical advisor believed that the program would be more successful if the number of new techniques promoted was kept to a minimum.

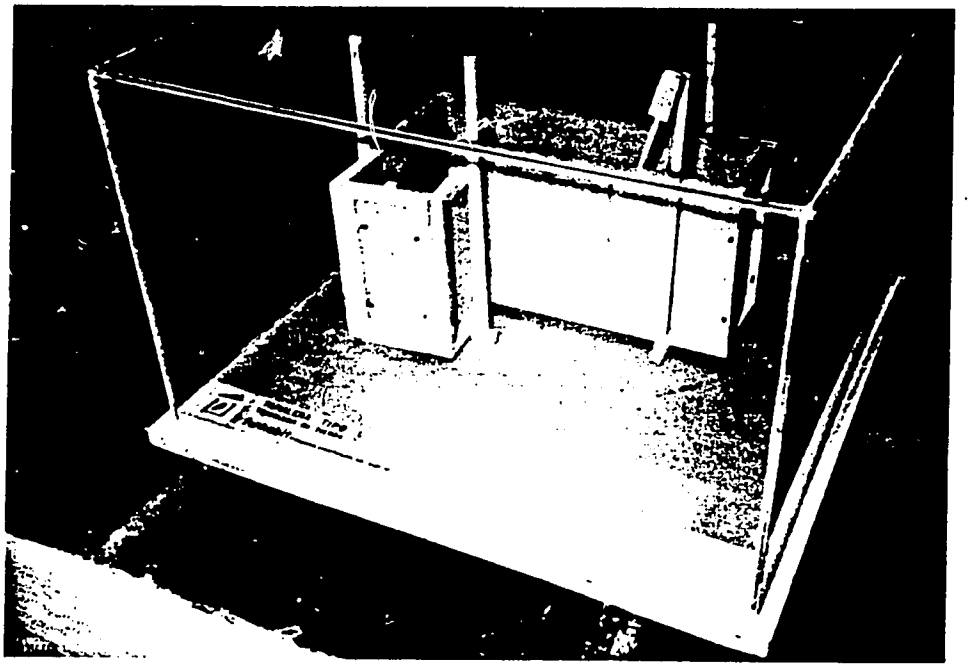
1. Rammed Earth Mixture:

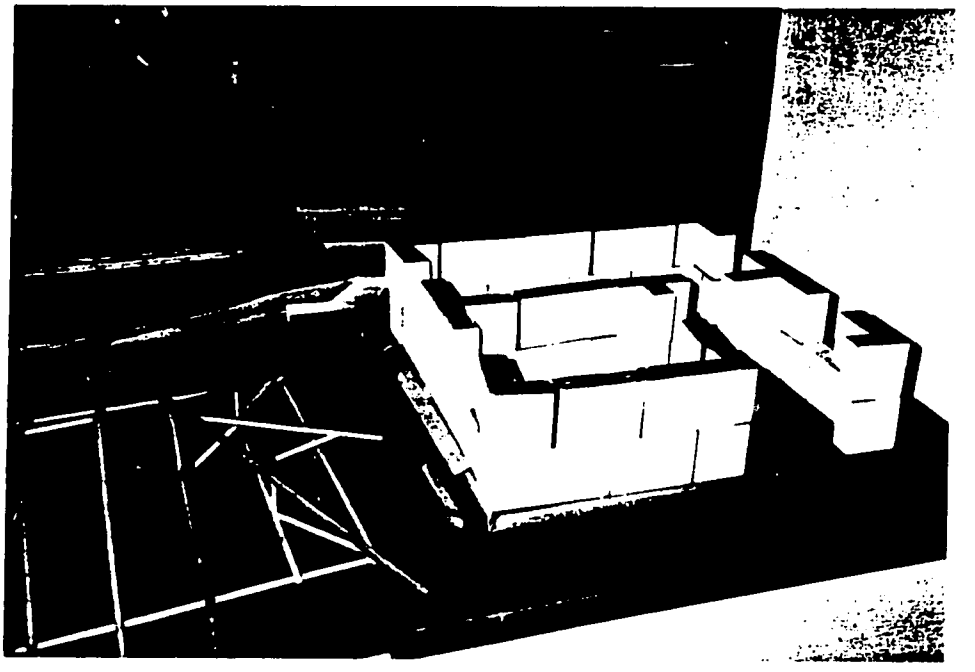
   Achievement of the appropriate blend or quality of earth required the addition of sand to the local clay. Sand deposits are not abundant in the Cayambe region, and the considerable cost for purchase and transportation of this material would have severely cut into the funds available for the program. From these considerations, it was determined not to attempt to improve the quality of the earth mixture.

2. L-Shaped Corner Mould:

   CAAP focused on other ways to improve the output as well as the logistical questions of production. The main innovation selected was to cast the corners of the house as a single unit, i.e., to eliminate the joining of walls at the corner which was seen after the earthquake to be a major weak point in *tapial* structures. Although this technique had been used elsewhere, it was not familiar to Ecuadoran builders and required the fabrication of a special formwork or mould in which the earth would be tamped to form a corner. An "L"-shaped mould was selected because the asymmetrical form (one leg twice the length of the other) would serve an additional structural purpose.

FUNHABIT's scale models of L-shaped corner mould and improved *tapial* construction system, Centro de Tecnologias, Guayllabamba





Use of this mould would strengthen the corner by moving the joint away from that point; and, if the mould was flipped for succeeding layers, the joints in the walls would also be staggered, thus removing the weakness created by building *tapial* elements one directly above the next.

One technical change was made to the design: a 150mm chamfer was added to the inside of the corner in order to reduce the stress concentration generated by a sharp corner.[18] When the new mould was introduced in the first builder training class, suggestions were sought from the builders during the practice sessions and improvements incorporated into the design, such as extension of the ribbed elements on the outside of the mould to enable their use as a step-ladder and grab-bar to facilitate handling.

3. Roof Structure:

The CAAP program dealt with the structural weakness detected at the junction between the roof and walls by recommending construction of a tie or ring beam. The traditional roof simply sat on the huge *tapial* walls without significant anchoring or joining of the two, and the earthquake damage assessments also noted a lack of rigidity in the roof itself. Since the residents clearly wanted tile roofs, and many in fact had salvaged tiles from their damaged homes, CAAP choose to promote the one fundamental improvement that would provide the most benefit to traditional construction: incorporating a wooden ring beam and setting this into a channel cut in the top of the earth wall.

D. Organization and Coordination

CAAP was allocated the largest physical area for reconstruction. Initially this was some 560 sq. km. comprising 72 communities of widely-dispersed housing, with 1,300 houses to rebuild. Later the project added other another twelve communities. This brought the total to eighty-four communities and a grand total of 1,916 units. Within the first ten days after the earthquake, CAAP had sorted out many of the financial, technical and operational considerations and begun the initial program elements. The program was to include building education, a took kit for each community, salary for a master builder for each community for 6 months, and a standard contribution of roofing material to each family.

The already-existing community organizations provided the basis for the organization of the recovery work. In each of the communities, the existing leadership was relied upon to coordinate the program. This rural leadership often reflected the local perception of prestige and status and would frequently be confirmed with official appointment as the political-administrative leaders by the municipal authorities in Cayambe. The first responsibility of these community leaders was to develop a list of families which had suffered household damages. They also supervised the community contribution of labor and organized the work

crews. Local leaders also participated in the receipt and distribution of tools and materials. Given the number of communities participating in the program, the topography of the program area, and the small size of the CAAP program staff, it would have been a herculean task without immense responsibilities being met by the local people themselves and their local leadership.

Beyond the communal level, another critical organizational element was the work group of volunteer labor, commonly known in Ecuador as a *minga*. In the recovery program, the *mingas* included the earthquake victims as well as family, neighbors and friends who helped one another in the rebuilding of each other's homes. Each household was to be responsible for providing labor and for making their own decisions regarding what would be built with the materials made available by CAAP. The standard materials package, based on a typical house of 48-54 square meters, consisted of clay tiles and the wood elements.

The overall CAAP program was run by four local workers with technical support from one Centro Sinchaguasin architect (a second architect assisted in conducting the courses). They in turn supported and supervised 103 technicians in coordination with 84 community organizational leaders.

E. Training

CAAP had little shelter experience and was not in a position to hire significant "outside" expertise. The program recognized the value of traditional local skills and labor, and designed training that was appropriate to their abilities. The training was directly related to the technology used, and this was already directly premised on the use of local skills and customs. CAAP structured its training based on the methodological dictum that only limited items should be introduced to current practice.

CAAP and the community leaders identified and trained local master builders or *maestros tapialeros* as rammed earth construction technicians. These local technicians then assisted the work groups in accomplishing the required construction tasks. CAAP initially undertook the practical training of some forty individuals in the improved *tapial* construction techniques, use of the L-shaped corner mould and ring beam. Later, similar training and direct apprentice experience were provided to additional technicians as the program expanded into other communities.

Once the training was completed, a local technician was assigned to each community for six months, with a salary paid by CAAP. On a daily basis, the technicians were under the supervision of the local community leadership. At the same time, the technicians also received direction and supervision from the CAAP architects.

CAAP did not develop any significant new educational or reference materials for use by the program participants. The local technicians, leadership and families were encouraged to visit the houses during and after construction. In typical fashion, word-of-mouth probably

proved to be the best advertisement for the CAAP program and the technical innovations introduced.

F. Material Purchases and Logistical Support

The decision to rely on rammed earth as the basic building material relieved CAAP from considerable procurement activities and costs. The major elements purchased were the tile roofing material and the wood elements for the roof structure. CAAP also purchased and provided to the communities a basic kit of tools and equipment related to the reconstruction task, such as wheelbarrows, spades, trowels, tampers, etc. Basic carpentry tools were also provided, along with the appropriate training or skills upgrading for their use in roof construction. Critical to the provision of the communal tool kit was the fabrication, production, and permanent loan to each of the participating communities, of *tapial* formwork: straight and L-shaped moulds.

The logistics of getting the required materials to remote locations was achieved with two transport trucks and additional portage provided by the municipal government. This contribution by the local government was very effective for the CAAP program. The provision of transportation reflected the effectiveness of local leadership in understanding the difficulties and making coordinated contributions to the work and the earthquake victims themselves. Once the materials had been brought to a central location, the participating families were responsible for transporting them to their building sites.

G. Implementation

Direction and supervision of the field technicians was provided by the two project architects. With over eighty communities to oversee and considerable distances between construction sites, the supervision was neither consistently provided nor could it have always been timely. In practical terms, the daily direction came from the local leadership within the community. CAAP also maintained its presence within the community via the program promotor or coordinator. Again, while these people could be supportive, it could not have reflected a commitment of any substantial time to the twenty scattered rural areas to say they directed the project efforts. At the local level, the community leadership and organization while parochial was critical; they played key roles in organizing work crews and speaking for the community with the relief agents. However, even here the attention of local leadership was limited by time, distance and the personal dynamic of each relationship. This would suggest that the greatest direction and incentive for the speed of project activities came from family groups. This is highlighted by the fact that there was no standard house plan; therefore, each family planned and guided their construction process.

The first L-shaped mould was built in 10 days. This was followed by an initial training course for builders from 40 communities to learn about the new techniques, build a house, comment on the process, and incorporate any suggested improvements. Immediately after the course, the technicians were placed in the field. Here the daily scheduled activities

of the technician were coordinated by the local leadership. CAAP personnel undertook strategic visits for consultation, coordination and supervision. Once a technician was assigned to a family, he had to work with the family to satisfy the specific site conditions and the particular requirements of their design, the available materials and labor. People who had salvaged materials or who had other resources might choose to build larger houses than the unit afforded with the donated materials.

The family and neighbors were responsible for clearing and preparing the site. The program provided that the technician would work with the family and *minga* in setting up and casting the four principal corners of the house in one day. The technician would then be free to assist a second family. During the technician's absence, the family and *minga* would set up and cast the remaining wall sections. Upon completion of the first tier, the technician would return, set and cast the four corners of the second tier. Once again, the technician would move on to another household, returning to inspect the work and contribute to the construction of the roof. This would suggest that a team of 10-12 people working as a *minga* would construct the *tapial* walls within 2-4 days of work, although this was not necessarily consecutive, and the tile roof was raised in 4-6 days.

H. Project Results

Initially, CAAP planned to assist with reconstruction of 1,000 houses in the parish of Cangahua. More detailed assessment expanded this number by 293. Later 451 houses in Ayora and other communities in Juan Montalvo, and 72 houses in Cotacachi, were added. By July 1987, five months after the earthquake, 330 houses had been completed and another 360 were partially complete, waiting for roofing materials. After 6 months, the CAAP program resulted in construction of 1,500 of the targeted houses in 80 communities. In the end, CAAP helped residents in 84 communities rebuild 1,916 damaged homes in eight months.[19]

Four training courses were held, with a total of 103 participants. Seventy *maestros de obra* were paid to supervise the rebuilding.

A number of problems were encountered during the life of the project, such as: delays in acquisition of materials; rain and other hindrances to transport; material loss due to climate/transport/packaging, etc.; influence of other, different types of assistance in the same areas. Most frustrating may have been the constant need to maintain open communication and good relationships with the residents and community organizations in the face of the avalanche of widely disparate aid programs and heightened expectations. In spite of the problems encountered, CAAP successfully defined and executed an appropriate earthquake recovery program in terms of its program criteria; it was effective in dealing with significant scattered sites with minimum supervision in a relatively short span of time immediately after the earthquake.

- The CAAP program maximized use of the available resources, utilizing both its own and those within the community, to meet its objectives.

- CAAP satisfied the target population by facilitating the rebuilding process to obtain basic shelter within the means available. The time frame of the CAAP program was immediate and consistent with the perceived needs of the victims. Other programs were unable to get underway so quickly. Ecuadoran state institutions, allied with international agencies, initiated 4 separate projects, only one of which started building within the first 6 months after the earthquake. Even now, the Banco Ecuatoriano de la Vivienda (BEV) continues to operate a reconstruction program (UADT), announcing in Oct. 1993 that 184 houses were planned for indigenous communities in rural areas around Otavalo, with assistance from the European Economic Community. Prior to this time, 483 houses had been built with active participation of the beneficiaries.[20] Another government effort was a rural housing project directed and funded by the Ministry of Social Welfare, the InterAmerican Development Bank, and UNDP/UNCHS-Habitat. Initially a 2-year project, at the end of that period it had resulted in construction of 356 of the 400 single-family houses planned and 5 rather than 4 communal houses, at 4 sites in three provinces. Bureaucratic delays pushed the start date of this "emergency" project more than a year after the earthquake.

- The CAAP program provided reasonably "improved" building engineering that could be expected to reduce future damages from similar events.

- Introduction of the L-shaped corner mould was an appropriate and sound recommendation; it strengthens the corners, and the asymmetric formwork when inverted on succeeding layers staggers the wall joints. The addition of chamfered edges was to reduce the degree of stress at the corner, although its contribution as an anti-seismic technique could not be confirmed.[21]

- The topography of the region, and the dispersed character of much of the housing, combined with the small staff available, made monitoring difficult. At least in part due to the inability to supervise construction closely, some program elements were ignored or performed incorrectly.

- Despite the training and supervision, it is believed that no consistent modification was made to the roof structure in the CAAP program. There appears to have been little real understanding conveyed of the engineering principles related to the function of a ring beam. Some people use a supporting beam on the long sides of the house, but this incomplete usage does not function as a ring or tie element, only as a roof support. One opinion expressed was that the ring beam did not catch on because people thought continuing it around under the gable ends would destroy the bond between the wall and gable materials. Others simply state the belief that the traditionally massive walls will support the roof, or that the improved structural integrity afforded by the L-shaped corners is sufficient.

- Promotion of a concrete foundation was abandoned early in the program planning process. CAAP says that this technical recommendation (common in an area where moisture can percolate up through earthen walls) was dropped because introduction of concrete breaks the natural bond between tamped earth walls and tamped subsoil base. It should also be noted that use of a concrete foundation would have increased the costs for home construction in terms of materials, training and supervision in an area where it is non-traditional. Other programs did build with concrete foundations, but self-built *tapial* homes under construction now can be seen to have only minimally-prepared sites and no foundation.

- CAAP is out of the shelter business. It has no organizational affinity to shelter issues, nor to the technology it promoted during the earthquake recovery program. A follow-up review of the project several years after the earthquake noted that CAAP was continuing with a wide-scale rural housing improvement program, but this program tackled issues of environmental health unrelated to basic construction or seismic considerations.[22]

SUSTAINABILITY ISSUES

A. Project Design

The CAAP project was an effective emergency response by a non-profit private development organization. The project was not truly a housing education effort in the sense that the establishment of improved technology was a major goal. Getting the people rehoused in as short a time as possible with limited resources was the overriding objective -- which was met by implementing a project that included training in modest basic improvements. The training was provided and was effective in terms of imparting the practical construction information needed to accomplish the construction goals. But there were insufficient trained *maestros* to oversee all the construction (complicated by the scattered sites and multiple designs), and many homes were rebuilt with little improvement from the pre-earthquake standard.

The project presents a clear model of a local organization reacting to an emergency by quickly setting up a rehousing project that would be low in cost, appropriate, participatory, and executed within a short time frame. With access to the experience of a technical advisor, the project was developed utilizing a methodology that could contribute to improved building practice over the long term, but within a framework of limited short-term objectives. These short-term objectives drove much of the decision-making concerning what materials would be used, what improvements would be introduced, and how long the project would continue. It is obvious that some of the program organizers welcomed the opportunity to make long-term contributions and provide appropriate solutions to address the issues of affordable and safe low-income housing. It is equally clear that there was much concern about the siphoning of funds and staff energy from ongoing development activities. In the

end, CAAP achieved its primary objectives but did not establish an alternative construction model for the communities.

One staff member feels in hindsight that many of the more "top-down" programs actually represented local trends and desires more and that, if CAAP had been a larger organization with more resources, it would have developed a more effective program that offered improved building techniques for more than one structural system.

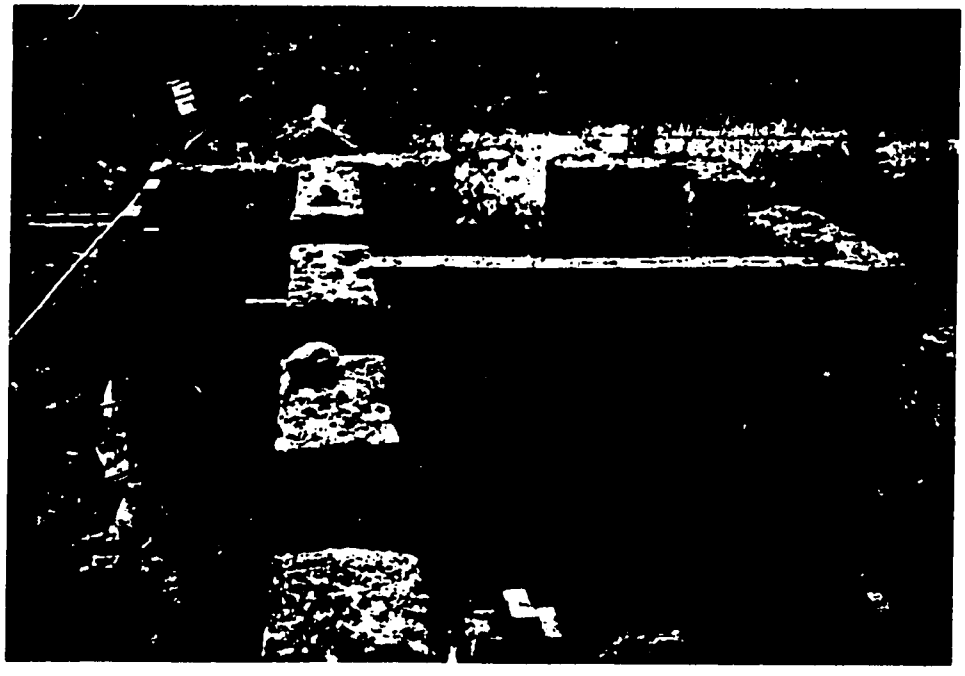
B. Replicability

Although use of the mitigation techniques was not required for participation in the project, the project did attempt to facilitate and promote their use by providing training and orientation, by paying the *maestros*, by providing basic materials and tools, and particularly by furnishing the L-shaped corner mould. There is evidence that some people in the region have continued to use the special formwork when they built new *tapial* houses, their availability thus ensuring that some homes have replicated at least the staggering of joints in the walls. However, where the L-shaped moulds have not been made available by community leaders, or where they have deteriorated over time to the point of requiring replacement, people have returned to the traditional use of straight formwork for both walls and corners. It appears that cost of fabrication of the special formwork is not within the means of a low-income family -- those for whom rammed earth construction remains an appropriate and affordable option.

In a 1992 evaluation visit, the program technical advisor observed people building with their own resources using the L-shaped mould, so he felt that this technique to strengthen the corner of common rammed earth buildings had become part of the building vocabulary of the area.[23] However, this study revealed little current use of the improved rammed earth technology, for reasons of cost or speed of construction or whatever.

Other post-earthquake reconstruction programs also used the L-shaped corner mould (JNV, FUNHABIT/CARE, et al). FUNHABIT, for example, says they have trained over 2,000 people (professionals as well as local craftsmen) since the earthquake in improved *tapial* techniques. In Pujili where FUNHABIT has taken over operation of the Centro Sinchaguasin, over 200 trained people can be found in the community, and school facilities have been built of *tapial* using the L-shaped corner mould, with a second story of *bajareque*. The FUNHABIT shelter program is based on donations and there is no current budget for housing, so these builders are for the most part not engaged in *tapial* construction. (FUNHABIT has facilities for and continues to promote training and testing of alternate technologies, with primary support from AECI/Agencia Española de Cooperación Internacional.)

Another structure being added to the "yard" by a homeowner not far from Pujili. Photos show the common process of collecting and storing materials next to the house, using mixed materials, building incrementally. Note L-shaped corner components in each photo. Owner has also built small concrete water catchment tanks uphill near the road and now will irrigate the field near his house using a gravity system, garden hoses and sprinklers.



Making thin cement roof tiles at FUNHABIT's Centro de Tecnologias, Guayllabamba.

Water tanks for tiles in front of *bajareque* demonstration house.

While the technology (e.g., L-shaped corner mould, ring beams) was taken up by a number of other post-earthquake reconstruction projects sponsored by international, governmental and non-governmental organizations, it has not been institutionalized in any national sense. None of the national or international housing financial institutions specifically provide funding for building with earthen materials. With the exception of a few scattered earthen building projects in the country, the knowledge and skills acquired during the reconstruction period remain limited to the individuals involved. So the L-shaped corner mould, even though introduced in a number of programs, has not even achieved parity with, much less replaced, common vernacular construction practices.

The cultural and economic values within the broader society are working against the continued use of vernacular and even improved methods of earthen construction. Brick and concrete construction appear to be making significant in-roads in terms of preference. This preferred status appears to be based on the desirability of "modern" styles and the assumed durability of brick and concrete. Even when used improperly, the perception is that these "produced" materials are superior to the traditional "natural" materials of earth and wood. Wall formwork and wood ring beams are not part of this more modern construction system, so that most of those trained in proper rammed earth strengthening measures find little demand for these particular skills. The trend toward the use of brick and concrete block, which was accelerated by use of these materials in many other post-earthquake reconstruction projects, is a significant negative factor in the sustainability of the improved *tapial* technology.

C. Training

Training continues to be available through FUNHABIT, which now operates the Centro Sinchaguasin as well as a Centro de Tecnologias in Guayllabamba (half-way between Quito and Cayambe). However, they currently have no funding for housing construction activities, to promote earthen construction and to maintain the skills in active building. FUNHABIT, for example, offers earthen building courses for local builders and architectural students, including several workshops which bring in international expertise. But there is less and less demand for the skills of this cadre of trained builders. The poorest residents who continue to use *tapial* do not hire technical assistance.

—At the professional level, there are a few people (especially at FUNHABIT and several universities) who have maintained their interest and contacts, expanded their knowledge in this field and can provide an ongoing if under-utilized and under-funded resource.

Even though a number of post-earthquake projects used similar technology, no other public efforts have been made to provide training and it is not included in formal professional or vocational construction curricula. SECAP (the Servicio Ecuatoriano de Capacitación Profesional) has the institutional capability and physical set-up; however, their focus is on technical capacitation in conventional construction methods and materials, primarily

reinforced concrete. While governmentally supported, SECAP is dependent on cost-sharing with the formal construction sector and program participants. Those who build in the non-formal sector generally cannot afford this type of training. On its own, SECAP is not likely to contribute to mitigation in informal and rural construction.

D. Cost

CAAP chose to work with rammed earth as the most affordable and acceptable building system for the communities in its project areas. There was little cost associated with *tapial* construction beyond the family's time and labor, the food and drink provided to a *minga*, and the acquisition of roofing materials. Given this attractive financial position and general familiarity with the product, *tapial* was viewed as an acceptable solution. However, local building practices had deteriorated by the time of the earthquake, and improvements were deemed necessary.

The few improvements in the building system promoted by CAAP incurred some additional cost in an area where the residents have many other demands on their meager resources. Thus CAAP financed the materials and tools, and the salaries of trained *maestros* to provide the needed technical assistance, during the project. Without this assistance, the range of affordability would have been substantially reduced. And in fact many residents currently building with *tapial* have chosen not to make the extra investment in terms of fabricating new L-shaped corner formwork or adding a ring beam.

While the obvious trend is to the use of more expensive building materials, much of this can be explained by some increase in income earned in urban areas and invested in the rural homesite, by the incremental nature of normal construction, and by the increased accessibility of these materials. With the growing integration of the rural and urban economies, there is more social exchange. Skills and activities formerly considered to be urban are making their way out to small towns and villages, and there is tremendous growth in small enterprises such as producers and suppliers of local building materials. Also, in contrast to the perspective of external donor organizations who view acquisition of a house as a discrete activity, most low-income families collect materials over a period of time and thus build incrementally as resources allow. Because there is no real limitation on the amount of time they can take to build the new structure, those who want to invest in more expensive and desirable materials often do so over a long period of time. The expectation that a short-term post-disaster housing reconstruction project focused on one traditional material would be able to alter normal housing acquisition behavior is thus likely to be misplaced, even when costs are minimal.

E. Institutional Sustainability

For CAAP, the social objectives took priority over technology promotion; they felt that the motivating force both for them as an organization and for the community was to return to normal activities as quickly as possible. Also, CAAP currently has no funding for

New houses built after the earthquake by various agencies: many have concrete frames with brick infill. Two-story style is unusual for this area.

New brick construction next to post-earthquake brick house.

Two-story concrete-framed brick house built by an agency for a family required to move down out of the hills in order to obtain the home. No stairs were built for the house. Beneficiary family is now building a 2-story block addition on the weekends when the husband returns from working in Quito.

housing and housing has never been a principal organizational concern. Since the Cayambe region attracted much NGO attention after the earthquake, CAAP has redirected many of its activities to other areas where resources are scarce.

While CAAP never intended to remain active in housing construction, the Centro Sinchaguasin had been involved in promoting improvements to low-cost vernacular housing prior to the earthquake and continues even today. Under the auspices of FUNHABIT, the Centro remains involved in this field but is generally limited in terms of funds to more upscale projects and those which attract donor financing to the organization. FUNHABIT and governmental literature do maintain rammed earth construction within the vernacular of shelter, but marginally at best.

The fact that communities aspire now to more modern materials -- likely influenced not only by increased commerce with Quito but also by housing types built by other post-earthquake projects in the same area -- also has reduced demand for assistance and information regarding *tapial*. Those who continue to build with rammed earth are often those with no extra money to pay for technical assistance from organizations such as FUNHABIT or from local *maestros* trained in the program.

Despite the roles played by CAAP and FUNHABIT, Ecuador has provided limited opportunities for private development organizations (PDOs) to contribute to preservation and development of affordable housing. At the time of the earthquake and even today, there is a limited role for PDOs to play in the formal shelter sector in programmatic terms and even less in the financial sphere. In the same way, there are no programs or initiatives which encourage or support PDOs to establish themselves within the housing sector to serve as technical service organizations and address affordable housing issues during the high quantitative and qualitative shortfall of this basic necessity. The existence of technical service organizations would complement traditional market and governmental efforts. Private non-profit technical service organizations could also facilitate and support other PDOs, similar to the provision of technical support by Centro Sinchaguasin to CAAP. They could make meaningful contributions to the pressing demand for shelter in normal times as well as during moments of crisis.

CONCLUSIONS

- There has been a transfer of resources to rural community residents in terms of new and sometimes better houses, construction tools, and community organization experience. However, there is little evidence of sustained application of the technical innovations in current building.

- In terms of technical sustainability, working with a construction system that is being passed by in the trend to more "modern" materials appears to act as a major constraint. Many of those people currently building are upgrading, so there is a

missed opportunity to impact workmanship with these other materials. The trend to more modern materials, usually copying urban styles without acquiring or upgrading building skills, means that many new buildings in this high-risk area are vulnerable.

- The availability of funding and ability to reallocate it quickly was key to the success of the CAAP project, as was the existing organizational infrastructure and extensive contacts in the communities which enabled design of a locally-controlled and directed reconstruction plan.

- Once project funding ceased, there was no local or national money to pay for the assistance/supervision of a trained *maestro*, to fund repair or replacement of the special formwork, to pay the salary of community outreach staff to promote the system and explain its importance.

- The FUNHABIT center trained 200 masons in rammed earth technology but for the most part they are idle. The organization needs a reliable stream of resources and broad array of options/level of participation to expand their program activities.

- The CAAP project, and CAAP's activities in the communities in general, received high grades from local residents.

- Insurance did not play a role in the quality of housing. Only about 7% of private homes are said to be insured and contractors/builders are not held liable for poor construction in any case in a natural disaster. Also, the emphasis is not on property insurance, and most especially not on the residential market of low- or moderate-income housing. Insurance may protect the financial transaction but not the property; it is solely a mechanism to protect the lender from loss of the financial investment.

- Building codes had no effect on the scattered rural housing of the project area. Even now in Quito, more than 40% of the building stock is not controlled by the municipality. Beyond the permit process, little inspection ever occurs.

- Codes have been reviewed and proposals for more appropriate standards made, but no further action has been taken.

- Current USAID Housing Guaranty programs do not include hazard risk reduction concerns, and mitigation is not a central concern in the country despite national initiatives in this regard. National development plans do now include topics relating to mitigation.

- Conventional training institutions do not deal with traditional (vernacular) construction techniques, nor are there standards to maintain quality in construction of these housing types. Young men learn construction skills mostly by traveling to the cities and taking unskilled jobs at construction sites, learning as they go.

- In the 1980s, about 72% of housing units were provided by the informal sector -- a strong argument for supporting training and skills upgrading programs for rural builders as well as urban construction laborers.

- The structural housing deficit is one million units with 60,000 new units needed each year.

ENDNOTES

1. Coburn, Spence 1992, p. 3.

2. Population as of 1991 was estimated to be approximately 10,800,000 with 55% urban.

3. Dudley et al, 1988, pp. 62-63.

4. Jarrin and Serrano 1989.

5. The greatest gains were found in the urban areas of secondary cities; the principal deficiencies of the rural communities were cited as the absence of sanitary facilities and other infrastructure. Other findings showed an increase of water service coverage from 33.4% to 45%; in electrical services coverage went from 41.2% to 62%; in sanitation availability went from 33.3% to 46.1%; and sewerage systems services access changed from 28.1% to 33%. These findings masked the deterioration in the metropolitan areas (Quito & Guayaquil) based on the increase in number of households from natural population growth and migration to these areas.

6. Dudley et al, 1988, pp. 121-122.

7. Committee on Natural Disasters 1991, p. 109; and Facts on File Yearbook 1987.

8. World Economic Survey 1991, p. 239.

9. Today foreign debt is still high but bringing it under control has been a major focus of the government. About a quarter of the national budget is earmarked for foreign debt reduction. The cost of money is very high -- interest being currently advertised as between 40-50%, depending upon the length and type of loan. In Oct. 1993 it was announced that monthly inflation was 3.13% or 31.5% on an annual basis, down from over 58% last January. [El Comercio, Oct. 30, 1993, Quito.]

10. It was estimated in Pesillo, for example, that they needed 60% sand, 25% clay and 15% lime to make a good *tapial* mix using local soil.

11. In 1910, President Eloy Alfaro decreed the confiscation of the lands held by religious orders. But there was strong opposition to this step, which limited the effective distribution of these lands. The agrarian reform lands were generally placed under agricultural cooperatives or leased until 1964 when the governing Military Junta initiated the transfer and titling to individual farmers. Yet by the mid-1960s, less than 1% of the landholding units in the country still controlled half of all the land in production.

12. Dudley et al, 1988, p. 130.

13. Flooding of the rivers was caused primarily by the mud, rock and natural vegetation deposited into the stream beds as a result of the earthquake-induced slope failures and landslides. As this mass was carried downstream, flooding resulted from both debris-

formed blockages and from "hydraulic" damming where narrow bedrock constrictions in the channels caused backups in the flow, upstream flooding and sedimentation.

14. Committee on Natural Disasters 1991, p. 140.

15. Committee on Natural Disasters 1991, p. 97.

16. Three workshops were held in all, with major funding from the National Science Foundation and AID/OFDA: an international meeting in Albuquerque, 1981; a Latin American Regional Workshop in Lima in 1983; and a Middle East & Mediterranean Workshop in Ankara, 1986. Informal networking was strengthened by the formation of an International Working Group on Improvement of Earthen & Low-Strength Masonry Buildings in Seismic Areas which included on its newsletter mailing list over 300 people worldwide representing both technical and socio-economic concerns in this field.

17. Mulligan 1987.

18. Dudley, "A Rural Housing...", 1987, p 24.

19. Dudley 1988.

20. "Comunidades de Otavalo recibieron viviendas", Hoy, 26 de Octubre de 1993, Quito, Ecuador.

21. Houben and Guillaud 1984, p. 208.

22. Dudley 1992.

23. Dudley 1992.

ACRONYMS

AECI	Agencia Española de Cooperación Internacional (Spain)
AID	Agency for International Development (U.S.)
BEV	Banco Ecuatoriano de la Vivienda
CAAP	Centro Andino de Acción Popular
CAFOD	Catholic Fund for Overseas Development
CBO	Community-based organization
CLEDTIERRA	Latin American Center for the Study & Dissemination of Earth Construction
CRATerre	Centre de Recherche et d'Application - Terre
FUNHABIT	Fundación Ecuatoriana del Habitat
GDP	Gross domestic product
GOE	Government of Ecuador
IMF	International Monetary Fund
JNV	Junta Nacional de la Vivienda
NGO	Non-governmental organization
OAS	Organization of American States
OFDA	Office of U.S. Foreign Disaster Assistance, AID
PDO	Private development organization
PMP	Prevention, Mitigation & Preparedness program, AID/OFDA
RHUDO	Regional Housing & Urban Development Office, AID
SECAP	Servicio Ecuatoriano de Capacitación Profesional
UADT	Unidad de Apoyo a los Damnificados del Terremoto, BEV
UNDRO	United Nations Disaster Relief Coordinator (Office of the)
USAID	[see AID]

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