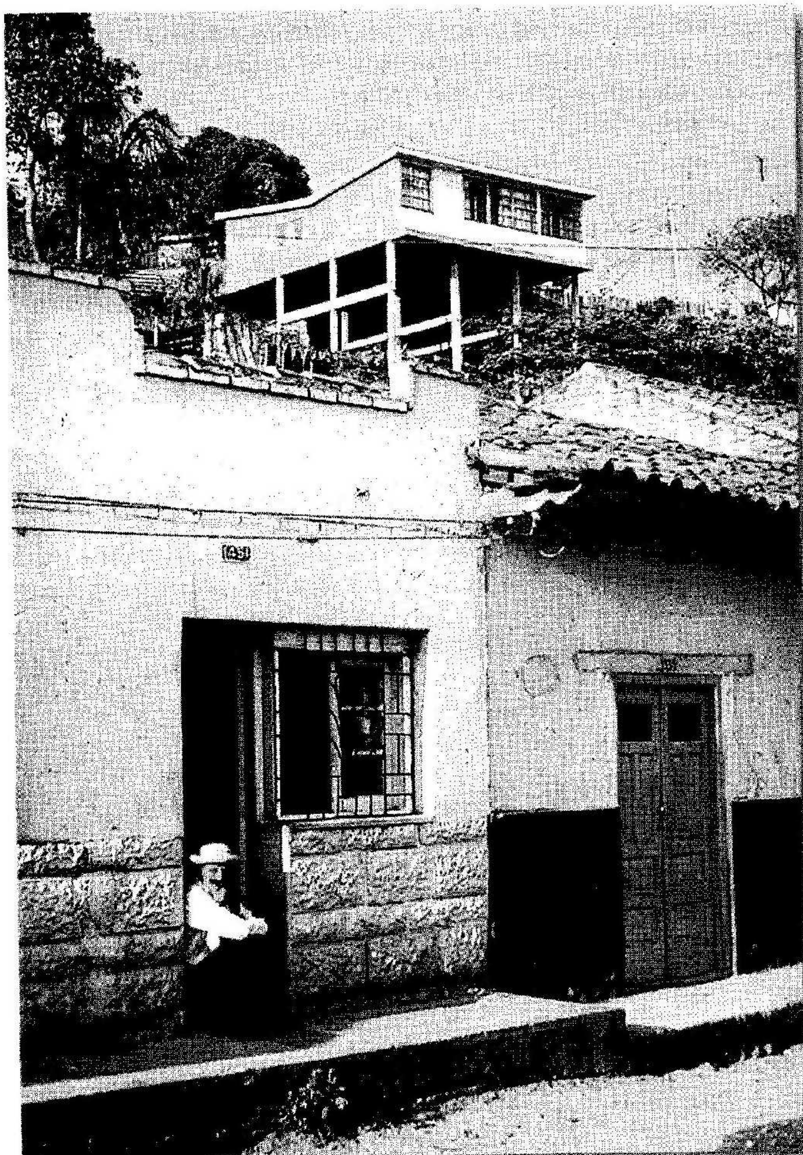

Latin American homeowners face problems with unstable slopes and earthquakes as well as wind and water

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IDENTIFYING AND RETROFITTING HIGH-RISK SCHOOLS IN QUITO, ECUADOR

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Introduction

Schools play a vital role in every community. They teach civics, educating citizens of their rights and duties. They foster an appreciation of culture through study of literature and the arts. Students learn the lessons of history, the discoveries of science and the rewards of public service. Schools benefit the economy by providing a skilled and literate work force. The buildings are used for social gatherings, continuing education, sport, theatre and musical productions. Schools provide a measure of community well-being.

Earthquake threatened communities need earthquake-resistant schools. Education is delayed and community life disrupted when schools are closed by earthquake damage. Repair and construction of school buildings are difficult and expensive after an earthquake when government resources are strained. In places where school attendance is compulsory, communities have a moral obligation to provide a safe study and work environment. Most importantly, earthquake-threatened communities need earthquake-resistant schools to protect their teachers and children.

A recent assessment of earthquake risk to Quito, Ecuador, concluded that many of its public schools are vulnerable to collapse during major earthquakes (GeoHazards International et al, 1994). That assessment was made over a period of two years (ending in May 1994) by a team of Ecuadorean and international scientists and engineers. They found that while Quito has not been struck by a major earthquake recently, such events have occurred in the past and will recur in the future. They recommended that Quito's public school buildings be evaluated and, if found vulnerable, strengthened.

In response, GeoHazards International initiated the Quito School Earthquake Safety Project in December of 1994. GeoHazards International collaborated with Ecuador's Escuela Politecnica Nacional and the University of British Columbia in defining the project. Two advisory committees provided general project oversight: the Policy Advisory Committee, consisting of local government officials responsible for school construction, and the Technical Advisory Committee, consisting of non-Ecuadoreans who have experience of school safety or retrofit procedures. The project had three objectives:

- Evaluate the vulnerability of Quito's public schools to earthquakes;
- Design affordable means of strengthening a sample of those schools that are vulnerable, and
- Strengthen the sample of vulnerable schools.

This paper describes progress in meeting those objectives during the project's first year as well as findings relevant to future similar efforts.

Methodology

Quito's public schools comprise a large and diverse collection of buildings. There are more than 700 schools and many consist of several separate buildings. Some are converted warehouses or homes, some are purpose-designed structures and others are groups of modules. Today, all public schools are constructed by the National Directorate for School Construction using reinforced concrete or steel modules. There are three prevalent school construction materials: reinforced concrete, steel and, in older schools, unreinforced masonry. Unreinforced masonry includes cement block, adobe (hand-made, sun-dried clay bricks) and ladrillo (hand-made, fired clay bricks).

The large number and diversity of the school buildings made it impractical to evaluate the vulnerability of them all. Instead, this project focussed on a sample of schools that are in high use (that is, a large number of students using the building per day per building area), are highly vulnerable to earthquakes and are representative of the three prevalent construction materials. Schools that are both in high use and highly vulnerable are referred to as "high risk".

The process of choosing this sample and evaluating the vulnerability of its schools consisted of selecting Quito's high-use schools, classifying them by construction material and lastly determining the most vulnerable within each class. Inspectors visited 340 high-use school buildings, recording information including construction material and superficial condition of the structure. The buildings were then classified according to construction material. Three steps were taken to determine the vulnerability of buildings within each group. First, project engineers visited the 60 buildings that appeared most vulnerable from the initial classification. Each of these buildings was given a vulnerability ranking using the Applied Technology Council's (1988) "rapid visual screening" method, adapted by project engineers to local seismicity and construction materials. Finally, detailed analyses were performed for the 20 buildings with the highest vulnerability rankings within each class.

The analyses included investigation of the structural system (including foundation) to evaluate the location, size and connection details of all structural elements. Structural deterioration was also documented. Dynamic analyses were completed for each building, considering various intensities of ground shaking. Soils engineers determined, on the basis of preliminary evaluations, that none of the buildings was built on unstable soils.

As a result of this process, project engineers identified 15 individual high-risk school buildings. They also concluded that the two types of school module constructed by the National Directorate for School Construction, replicated throughout Ecuador, were also at risk.

Results

Table 1 summarises the 15 high-risk school buildings and the two types of school module chosen for retrofit. The design criteria used in this project are summarised in Table 2. The retrofit design created for each building or module used local materials and techniques and are affordable by the community (Escuela Politecnica Nacional et al., 1995).

Table 1 : High-Risk School

Name of School	Number of buildings	Material	Year of construction	Retrofit cost ($US)
Ana Paredes de Alfaro	1	RC	1956	$14,000
Experimental Sucre	4	RCPu	1952-59	$57,000
Jose de Antepara	1	Adobe	Pre-1940	$11,000
Republica de Argentina	1	URM	1953	Not available
Republica de Chile	4	RC	1945/1994	$244,000
Rio Amazonas	3	RC	1978	$39,000
II de Marzo	1	Steel	Unknown	$7,000
Module 1	Numerous	RC	Various	$6/ft^2.
Module 2	Numerous	Steel	Various	$1.20/ft^2.

Table 2 : Retrofit Design Criteria

Peak Ground Acceleration	Return period (from historical seismicity)	School Retrofit Criterion
0.06g	20 years	Minimal nonstructural damage, no structural damage
0.09g	100 years	Moderate nonstructural damage, no structural damage
0.26g	500 years	Structural damage but no collapse

Significant progress has been made in strengthening Quito's high-risk schools during even the first year of this project. As of this writing, localfunding has been committed to retrofit 11 of this project's school buildings. Local philanthropic organisations and businesses have expressed interest in sponsoring additional school retrofits. Most important for Ecuador's rapidly growing population, US AID-Ecuador and Ecuador's National Directorate for School Construction have agreed to sponsor the design of new, earthquake-resistant school modules. These designs will be used for school construction throughout Ecuador.

Conclusions

This project demonstrated that retrofitting Quito schools to protect the lives of their occupants is affordable and inexpensive relative to replacement costs. The most significant finding of the project is that the relatively inexpensive process of identifying high-risk schools and assigning their retrofits generally generated sufficient local funding to pay for the retrofit construction.

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