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# IDENTIFYING AND RETROFITTING HIGH-RISK SCHOOLS IN QUITO, ECUADOR

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## ABSTRACT

A recent assessment of earthquake risk to Quito, the capital of Ecuador, concluded that many of its public schools are vulnerable to collapse during major earthquakes. In response, GeoHazards International initiated the Quito School Earthquake Safety Project in December of 1994, in collaboration with Ecuador's Escuela Politécnica Nacional and the University of British Columbia. The project demonstrated that retrofitting Quito schools to protect the lives of their occupants is affordable and inexpensive relative to a school's replacement cost. The most significant finding of the project is that the relatively inexpensive process of identifying high-risk schools and designing their retrofits generated sufficient local funding to pay for retrofit construction.

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. Fifteen high-risk school buildings were chosen by selecting Quito's high-use schools, classifying them by construction material, and determining the most vulnerable within each group. Retrofit designs were created for each of the high-risk school buildings and for two types of high-risk school modules replicated throughout Ecuador. These designs are affordable and utilize local materials and local construction techniques.

As of this writing, local funding has been committed to retrofit 11 of this project's school buildings, and to design new, earthquake-resistant school modules for use in new school construction.

## KEYWORDS

developing countries; Ecuador; Quito; retrofit; schools.

## 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. In schools, 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. They are used for social gatherings, continuing education, theater and musical productions, and sports. Schools are a measure of community well-being.

Earthquake-threatened communities need earthquake-resistant schools. When schools are closed because of earthquake damage, education is delayed and community life disrupted. Repair and construction of school buildings are difficult and expensive after an earthquake, when government resources are strained. Where school attendance is compulsory, communities have a moral obligation to provide a safe study and work environment. But most important, earthquake-threatened communities need earthquake-resistant schools to protect their teachers and children.

A recent assessment of earthquake risk to Quito, the capital of 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 of 1994, by a team of Ecuadorian and international scientists and engineers. They found that while Quito has not been struck by a major earthquake recently, it has been in the past and will be 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 Politécnica 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-Ecuadorians who have experience in 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 these objectives during the project's first year, and 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 individually 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 (handmade, sun-dried clay bricks), and ladrillo (handmade, fired clay bricks).

Because of the number and diversity of school buildings, it was not practical to evaluate the vulnerability of them all. Instead, this project focused on a sample of schools that are in high use (a large number of students using the building per day per building area), highly vulnerable to earthquakes, and representative of the three prevalent construction materials. Schools that are both in high use and highly vulnerable are referred to as "high-risk" schools.

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 determining the most vulnerable within each group. Inspectors visited 340 high-use school buildings, recording information including construction material and superficial condition of the structure. The buildings were then grouped according to construction material. Three steps were taken to determine the vulnerability of buildings in each group. First, project engineers selected a total of 60 buildings that appeared the most vulnerable. Next, each of these buildings was given a vulnerability ranking using the Applied Technology Council's "rapid visual screening" method (Applied Technology Council, 1988), adapted by project engineers to local seismicity and construction materials. Finally, detailed structural analyses were performed for those buildings, a total of

20, with the highest vulnerability rankings within each group. The analyses included an investigation of the structural system (including that of the 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 levels of earthquake ground shaking. Soils engineer determined, based on a preliminary evaluation, that none of the buildings was situated 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 modules constructed by the National Directorate for School Construction and replicated throughout Ecuador were at risk.

## RESULTS

Table 1 summarizes the 15 high-risk school buildings and the two types of school modules chosen to be retrofit. The design criteria used in this project are summarized in Table 2. Retrofit designs were created for each of the 15 high-risk school buildings and two types of school modules (Escuela Politécnica Nacional et al., 1995). These designs are affordable and utilize local materials and local construction techniques.

Significant progress has been made in strengthening Quito's high-risk schools during even the first year of this project. As of this writing, local funding has been committed to retrofit 11 of this project's school buildings. Local philanthropic organizations 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.

Table 1. High-Risk Schools

| Name of School | Number of Buildings | Construction Material | Year of Construction | Estimated Retrofit Cost (US$) |
|---|---|---|---|---|
| Ana Paredes de Alfaro | 1 | RC | 1956 | $14,000 |
| Experimental Sucre | 4 | RC | 1952–59 | $57,000 |
| José de Antepara | 1 | Adobe | Pre-1940 | $11,000 |
| República de Argentina | 1 | URM | 1953 | Not available |
| República de Chile | 4 | RC | 1945/1994 | $244,000 |
| Rio Amazonas | 3 | RC | 1978 | $39,000 |
| 11 de Marzo | 1 | Steel | Unknown | $7,000 |
| National Directorate for School Construction Module I | Numerous | RC | Various | $6/ft$^2$ |
| National Directorate for School Construction Module II | Numerous | Steel | Various | 1.20/ft$^2$ |

Table 2. Retrofit Design Criteria

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

## CONCLUSIONS

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

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