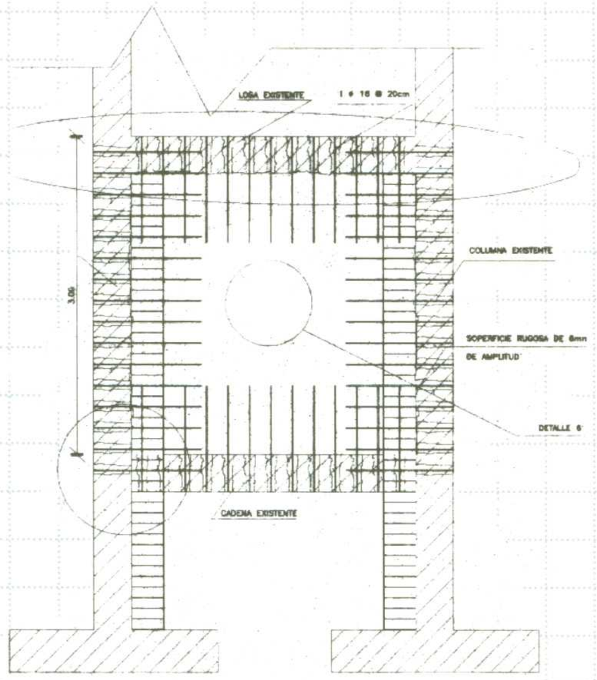


Retrofit Design Detail

Location: Sucre Street, Barrio La Loma

Year of Construction: 1952–1959

Prevalent Materials: Reinforced concrete

Total Retrofit Area: 3,080 m^2 (33,140 ft^2)

No. of Buildings Studied: 4

Estimated Cost: S/ 144,098,000 (US $57,000)

BUILDING DESCRIPTION

The Experimental Sucre elementary school consists of three- and four-story buildings of reinforced concrete frames with unreinforced masonry infill walls. Four buildings were studied in this project: a four-story structure serving as a longitudinal spine and its 3 three-story transverse blocks.

The 130-m-long spine consists of transverse portal frames with 7.5-m spans and 2.5-m overhangs, spaced every 3 m. Seismic separation spaces detach the 50-m-long central spine section from the rest of the structure. The floors are 35-cm-thick rigid slabs; the columns are connected to each other by dropped beams in the longitudinal direction only.

The three 18-m-long transverse blocks are 25 m apart and perpendicular to the spine, separated from the spine by seismic separation spaces. Each consists of seven portal frames spaced 3 m apart, with 6-m spans and 2.5-m cantilevers. A 35-cm-thick concrete beam embedded in the slab connects the two columns of each frame.

STRUCTURAL DEFICIENCIES

Experimental Sucre's beams and columns are not sufficiently strong to provide earthquake resistance to their structures. Door and window openings have created short columns. The first story of each transverse block lacks infill walls, creating a soft-story condition. The transverse buildings will likely pound against the main building during an earthquake.

RETROFIT SOLUTIONS

Shear walls will be added to the buildings in both the longitudinal and transverse directions. Two options have been proposed for constructing the shear walls. The first consists of adding reinforced masonry walls to the first floor (transverse buildings only) and replacing the walls of upper floors with properly connected reinforced masonry ones. The second design consists of adding unreinforced masonry walls to the first floor (transverse buildings only), and surface strengthening them and upper-floor walls with steel mesh and concrete. Shear walls will increase the stiffness of the portal frames and thereby mitigate soft-story and pounding hazards. Separation joints will be added between walls and columns to mitigate short-column hazards.

A complete description of these structures, their analysis, and their retrofit designs can be found in: S. Díaz and F. Ponce, *Seguridad Sísmica de los Establecimientos Escolares en la Ciudad de Quito: Escuela Sucre*. (Quito: Escuela Politécnica Nacional, 1995.)

Location: Corner of Húsares and Cabo Vinueza streets

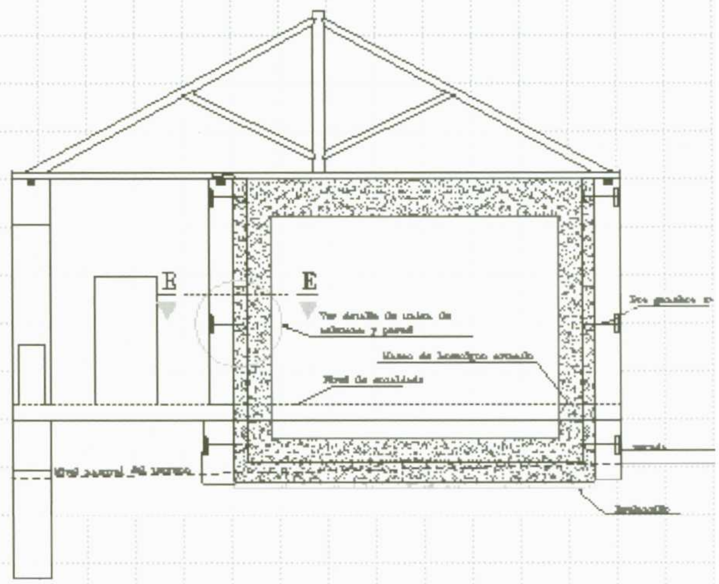
Year of Construction: Pre-1940

Prevalent Materials: Adobe, Spanish tile

Total Retrofit Area: 900 m² (9,680 ft²)

No. of Buildings Studied: 1

Estimated Cost: S/ 27,452,000 (US $11,000)



Retrofit Design Detail

BUILDING DESCRIPTION

The José de Antepara kindergarten and elementary school comprises a one-story main building consisting of various materials and structural systems, and several steel and reinforced concrete modules. The original and largest section of the main building, an elongated adobe structure, was considered in this project. The L-shaped adobe structure has 40- to 60-cm-thick bearing walls supported on stone continuous spread footings. The walls show few signs of distress. The roof consists of wood trusses aligned in the transverse direction and is covered with Spanish tiles. The trusses are connected at the top and bottom chords by stringers. A false ceiling is attached to the bottom stringers.

STRUCTURAL DEFICIENCIES

The two major problems with this building are a weakness in its transverse direction and the hazardous roof. The longitudinal walls have long, unbraced spans between transverse walls. The extreme length of the spans makes them dangerously flexible in the out-of-plane direction.

The wood roof trusses are splitting in places. The truss joints and connections to the walls are not sufficient to transfer earthquake loads. The roof lacks bracing in the longitudinal direction. These deficiencies could cause the roof structure and overlying tiles to collapse into the classrooms below during an earthquake. The roof tiles, held in place by gravity alone, could slide off the roof in an earthquake and onto the playground and sidewalk below.

RETROFIT SOLUTIONS

Two options were suggested to reinforce the structure along its transverse axis. The first consists of building in the transverse direction a 40-cm-thick, continuous unreinforced masonry wall, confined by a reinforced concrete beam and columns. This would divide a large, multiple-use classroom. The second, a less invasive design, is to construct two reinforced concrete frames in the transverse direction of the building.

The roof trusses will be repaired and their joints and connections strengthened, and cross-bracing will be added in the plane of the roof. The roof tiles will be anchored to prevent them from moving in an earthquake.

A complete description of this structure, its analysis, and its retrofit designs can be found in: E. Márquez and P. Placencia, *Seguridad Sísmica de los Establecimientos Escolares en la Ciudad de Quito: Escuela Fiscal Mixta "José de Antepara."* (Quito: Escuela Politécnica Nacional, 1995.)

Location: Between Daule, Pita, and Pique streets, Ciudadela México

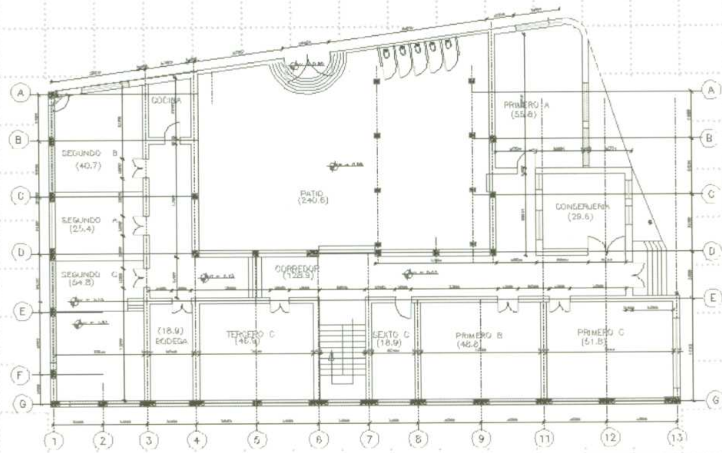
Year of Construction: 1953

Prevalent Materials: Unreinforced masonry

Total Retrofit Area: 700 m^2 (7,530 ft^2)

No. of Buildings Studied: 1

Estimated Cost: Not available



Building Plan

BUILDING DESCRIPTION

The República de Argentina elementary school consists of two buildings: a recently constructed reinforced concrete structure and the original two-story brick main building. The main building was considered in this project.

The main building is C-shaped. Because of sloping topography, the first floor contains four levels, and the second floor contains two. The unreinforced brick walls are 40 cm thick. The wood floor of the second story is supported by reinforced concrete beams that, in turn, are supported by the first-floor walls. The roof is supported by wood beams. On the second floor there are several reinforced concrete additions with lightweight metal roofs.

STRUCTURAL DEFICIENCIES

The interior and exterior unreinforced masonry bearing walls have openings that create, in effect, a hazardous short-column condition. The beam-wall connections are deficient. Since the wood beams and roof structure are supported by the walls, failure of the beam-wall connections during an earthquake would result in building collapse.

RETROFIT SOLUTION

The wall openings will be modified to reduce the short-column effect. Better connections will be provided between intersecting walls. The in-plane rigidity of the floor and roof systems, as well as the connections with the supporting walls, will be improved.

A complete description of this structure, its analysis, and its retrofit design can be found in: G. Barahona and F. Vaca, *Seguridad Sísmica de los Establecimientos Escolares en la Ciudad de Quito: Escuela Fiscal Mixta "República de Argentina."* (Quito: Escuela Politécnica Nacional, 1995.)