Location: Rocafuerte and Cumandá streets

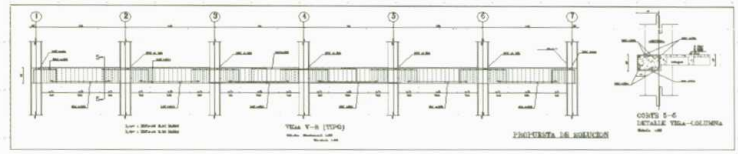
Years of Construction: 1945 and 1994

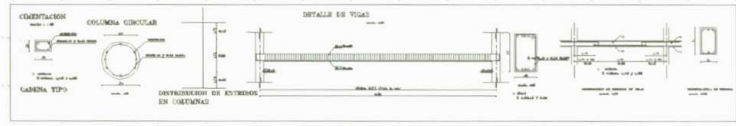
Prevalent Materials: Reinforced concrete

Total Retrofit Area: 2,130 m² (22,920 ft²)

No. of Buildings Studied: 4

Estimated Cost: S/ 618,698,000 (US $244,000)





Retrofit Design Detail

BUILDING DESCRIPTION

The República de Chile elementary and high school consists of four reinforced concrete-frame buildings (Blocks 1 through 4) with unreinforced masonry infill walls. Blocks 1, 2, and 3, built in 1945, are two stories. Block 1 has a total floor area of 1,090 m² (11,730 ft²). Block 2, square-shaped in plan with a total floor area of 240 m² (2,580 ft²), is used for circulation between the other three blocks. Block 3 has an area of 600 m² (6,460 ft²) and is of construction similar to Block 1. Blocks 1, 2, and 3 have rectangular and cylindrical columns, some of which are dangerously slender. Piers of ciclópeo (large-aggregate) concrete support the columns, and stone footings support the walls. There are no tie beams between piers. Block 4, a one-story structure built in 1994, consists of concrete frames only in the transverse direction. It has a floor area of 200 m² (2,150 ft²).

STRUCTURAL DEFICIENCIES

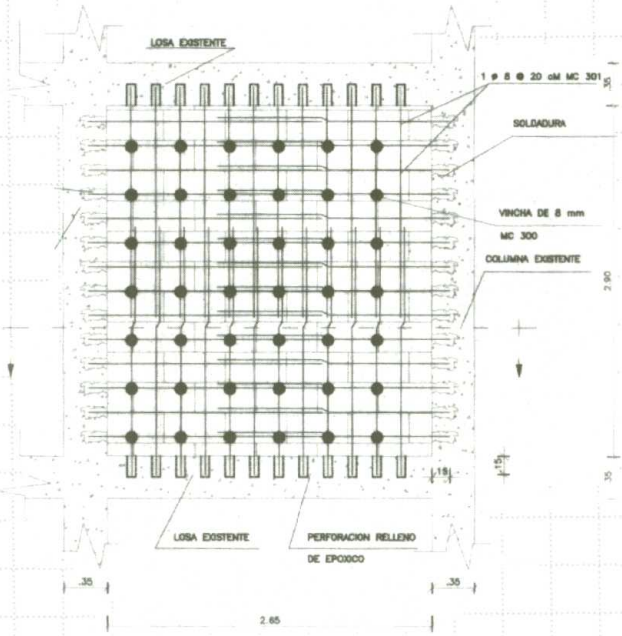
The slab reinforcement and the reinforced concrete columns have deteriorated from exposure to water. In some areas the concrete contains soft aggregate or construction debris. The buildings contain short-column hazards, and the weak infill walls will likely crack and collapse during a strong earthquake. These buildings are not able to resist strong or long-duration earthquakes. Many ceilings contain unanchored clay tiles, which could fall during an earthquake.

The columns of Blocks 1, 2, and 3 contain smooth reinforcing steel. Slender cylindrical columns on the ground floor of Block 2 are not aligned with the corresponding columns on the second floor, resulting in a discontinuity between the columns and beams. Many beam spans are unusually long, and the beam distribution is inefficient. Block 4 lacks structural frames in the longitudinal direction, substantially diminishing the structure's ability to resist earthquake forces.

RETROFIT SOLUTION

Because the República de Chile school was built without an earthquake-resistant structural system, the frames of Blocks 1, 3, and 4 will be completely redesigned. Due to the extremely poor design and condition of Block 2, it will be demolished and rebuilt. The ceiling tiles in all classrooms will be removed and replaced with lightweight, secured panels.

A complete description of these structures, their analysis, and their retrofit design can be found in: R. Arellano and J. Espinoza, *Seguridad Sísmica de los Establecimientos Escolares en la Ciudad de Quito: Escuela República de Chile*. (Quito: Escuela Politécnica Nacional, 1995.)



Retrofit Design Detail

Location: Avenue Alonso de Angulo, Barrio de la Villaflora

Year of Construction: 1978

Prevalent Materials: Reinforced concrete

Total Retrofit Area: 1,600 m² (17,220 ft²)

No. of Buildings Studied: 3

Estimated Cost: S/ 98,000,000 (US $39,000)

BUILDING DESCRIPTION

The Río Amazonas high school consists of 12 two- and three-story reinforced concrete buildings and one steel-frame building, all constructed between 1978 and 1985. This project considered three reinforced concrete buildings constructed in 1978: the two-story, C-shaped main building, and 2 three-story peripheral buildings.

The symmetric wings of the main building consist of a series of portal frames, each 3 m apart and with construction joints every 9 m. Beams embedded in the floor slab connect the frames in the longitudinal direction. The central part of this block contains a two-story passageway consisting of solid slabs supported every 3 m by columns. The staircase module is located in the middle of the main building.

The two peripheral buildings are of designs similar to the main building except that they have three stories and portal frames spaced every 4 m. Each building has a detached staircase module in the center, connected by 1.5-cm construction joints.

STRUCTURAL DEFICIENCIES

The original building designs did not consider lateral forces. Inadequately connected portal frames in the longitudinal direction do not provide sufficient stiffness or strength to transfer properly lateral loads during an earthquake. Construction joint separations are too small and could permit pounding during an earthquake. Window and door openings and mid-height partition walls create short-column conditions. The staircase modules show excessive deflection.

RETROFIT SOLUTIONS

Additional structural elements will be added to the buildings in order to increase their longitudinal stiffness. Two options are recommended: strengthening the unreinforced masonry infill walls by replacing them with reinforced masonry walls with proper connections to the concrete frames, or surface strengthening the existing walls with steel mesh and reinforced concrete. Separation joints will be added between walls and columns to mitigate short-column hazards. Supporting elements will be added to control deflection of the staircase modules.

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 Río Amazonas*. (Quito: Escuela Politécnica Nacional, 1995.)

Location: Panamericana Sur, at La Internacional

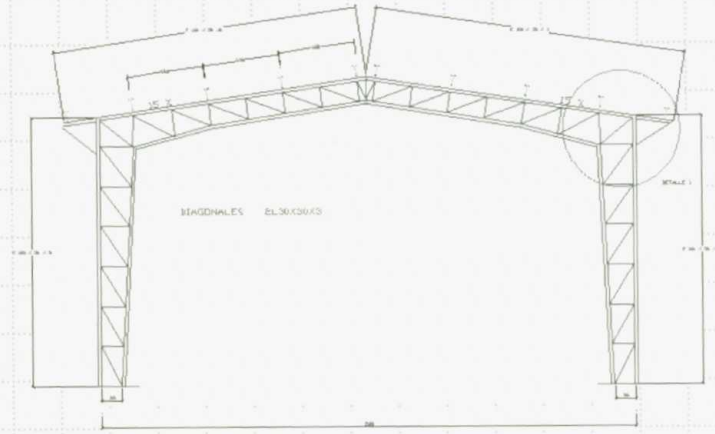
Year of Construction: Unknown

Prevalent Materials: Steel

Total Retrofit Area: 380 m² (4,090 ft²)

No. of Buildings Studied: 1

Estimated Cost: S/ 16,718,000 (US $7,000)



Retrofit Design Detail

BUILDING DESCRIPTION

The 11 de Marzo high school, originally a warehouse, is a two-story steel-frame building with unreinforced masonry infill walls. It consists of eight rigid frames in the transverse direction and two braced frames in the longitudinal direction. The first floor uses wide-flange columns, the second uses tubular columns.

STRUCTURAL DEFICIENCIES

Because the unreinforced masonry infill walls are much stiffer than the steel frames, the wall-frame interaction could result in major damage to the frame during strong ground shaking. The bending capacity of the first-floor beams is low, and the beam-column connections in the longitudinal frames are not sufficiently rigid, potentially resulting in sudden collapse of the structure during an earthquake. Several steel members are corroded.

RETROFIT SOLUTION

Separation joints will be added between walls and columns. The bending capacity of the first-floor beams will be increased with proper reinforcement. Beam-column joints of the longitudinal frames will be reinforced to ensure continuity and proper frame action. Corrosion problems will be mitigated, and exposed steel members will be painted to prevent further corrosion.

A complete description of this structure, its analysis, and its retrofit design can be found in: J. Vintimilla, *Seguridad Sísmica de los Establecimientos Escolares en la Ciudad de Quito: 11 de Marzo*. (Quito: Escuela Politécnica Nacional, 1995.)