Design of Shelter for Under-privileged Children in Colombia

I. Project Description

Introduction

Drug dealing, delinquency and prostitution are prevalent in vulnerable neighborhoods of the city of Medellin in Colombia, South America. To break the perennial chain of crime and poverty and to provide a safe haven for the local children where they could grow and learn, a Colombian Non-profit Foundation, hereafter referred to as NPF, has established two shelters. These two shelters serve a total of 130 children providing them with food, education, medical, and psychological assistance. Because these two shelters are at capacity, the NPF is exploring building a third facility. The director of the NPF approached our university, and a civil engineering senior capstone team brought this idea to partial fruition by designing the shelter. A US engineering firm sponsored the project through financial support and by providing two licensed civil engineers to assist the team. The student team was also mentored by several practicing engineers and other allied professionals.

Client's Vision

The director of the NPF provided the team with a rough sketch of their vision for the facility as shown in Figure 1. The facility was to provide housing for 40 children, teachers, and supporting staff members; all of this in two stories of approximately 400 sq.m per floor.

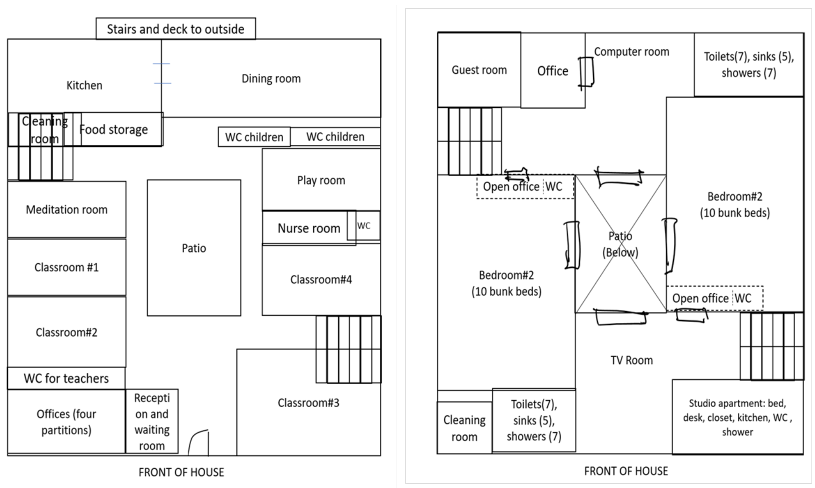

Figure 1 Client's Vision for the Facility – Plans of, First Floor (on left), Second Floor (on right)

The client requested one large classroom to serve as a multi-purpose room for various events, three additional smaller classrooms, an indoor dining area open to a center atrium, kitchen, nurse's room, meditation room, two large bedrooms for the children, office spaces for teachers and staff, a guest room and two studio apartments for permanent staff who would monitor the children at night, and computer and television rooms visibly open for staff members to supervise the children.

At the time the capstone project was in progress, the NPF did not have a lot in mind where the shelter would be built. But the NPF hoped the student work would help in fund raising. If the purchased lot had a slope, an optional basement with additional space for storage, laundry rooms, and volunteer housing was requested as part of the project design.

The design team was tasked to,

- Refine the client's vision to meet all architectural and functionality requirements of the project.
- Research engineering materials, local construction practices and applicable design codes for Colombia.
- Develop the structural design of the shelter, including a calculation package and a written report.
- Produce engineering drawings and a fly-through video with 3D rendering to be used in fundraising for the implementation of the project.

Refinement of Architectural Plans

Initially the team closely worked with a US architect to evaluate the functional requirements of each space and discussed meeting safety requirements such as proper egress on stairwells, sufficient corridor widths, and minimum square footage for various rooms. From these interactions, the team concluded that each floor had to be approximately 600 square meters per floor. The client was informed and agreed with the change.

The team developed architectural drawings using Autodesk Revit® shown in Figure 2 which consisted of the 3D view for the shelter and individual floor plans.

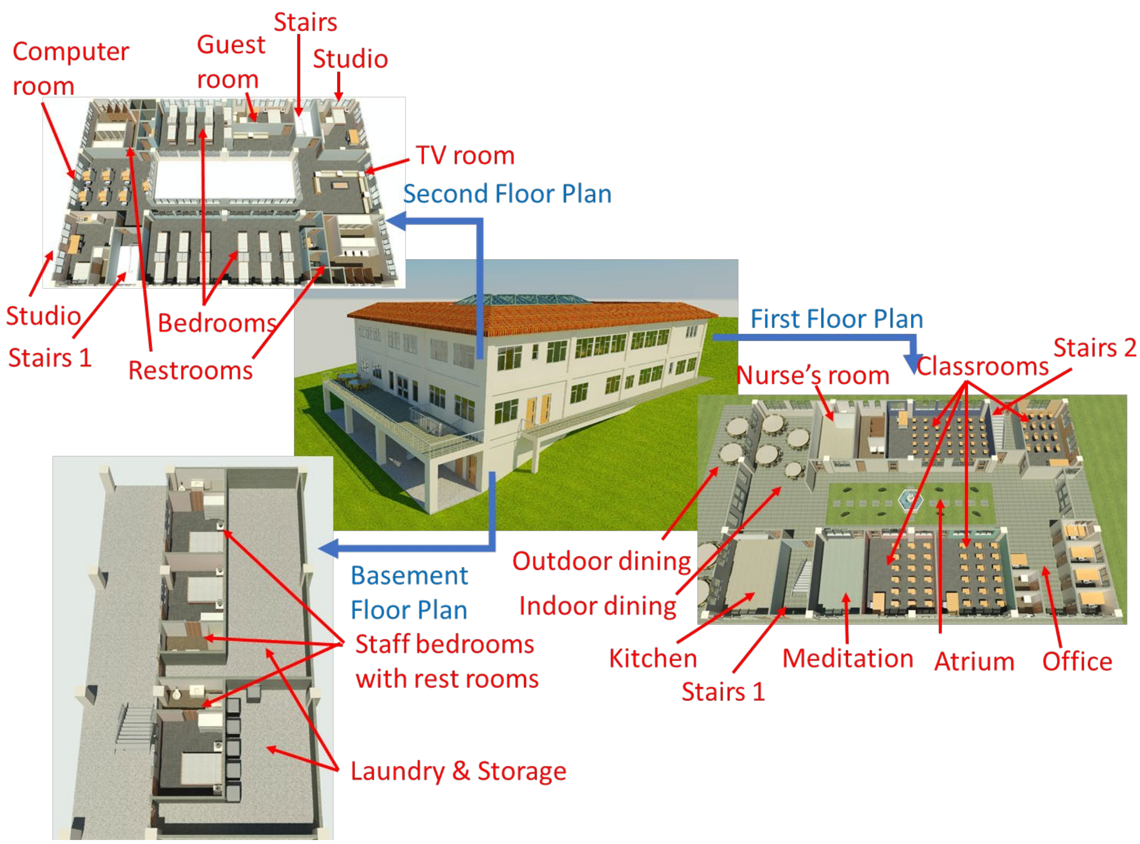

Figure 2 Architectural Drawings of Shelter using Autodesk Revit®

Research of Local Building Materials, Construction Practices and Building Codes
Through research the team found that reinforced concrete and masonry were common construction materials used in Medellin, Colombia. They also learned that because labor costs are relatively low in the region, optimization of materials is common practice. However, given that the project would be in rural Medellin, it was important for the team to make the design simple in anticipation of unskilled labor force executing the construction. The team consulted with a structural engineer in Medellin and learned about construction practices specific to the region and the type of (educational/residential) facility; they found that for the floor system it is common to use small beams (called joists) which are closely spaced in a grid pattern with a thin concrete slab on top (called "waffle slab" due to its appearance). Waffle slabs are rarely used in the US because of its labor-intensive nature. In addition, the vertical reinforcement used for joists often consists of ¼" diameter wire which are not used in the US for structural applications.

The structural design was executed following the provisions from the Colombian code NSR-10. The Building Code Requirements for Structural Concrete (ACI 318-19) was used to calculate capacities of structural members, while the American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures (ASCE 7-16) was used to cross verify the loads prescribed in the NSR-10.

Structural Design
With the architectural plans finalized and having reviewed the relevant design codes, the team started on the structural design portion of the project. Because Medellin is in a moderately active seismic region, the team decided on ordinary moment-resisting frames (OMRF) to support the waffle slab floor system. In an OMRF the lateral loads induced by an earthquake are primarily resisted by flexure and shear of the beams and columns constituting the frames. By contrast, the facility of this type in the US would use reinforce concrete walls that primarily carry the earthquake loads as shear forces.

The team first determined the member sizes based on the recommendation from NSR-10 to control deflections and to provide the required fire rating criteria. They then computed the gravity loads and seismic forces acting on the structure and used these to develop a model in the Structural Analysis Program (SAP 2000®). Controlling shear force, axial forces and bending moment on joints, beams and frames were then recorded for the different load combinations in NSR-10. Because of time limitations, the team conducted the structural design of a two-story structure, leaving out the optional basement (for which only an architectural design was provided). Figure 3 shows the moment diagram due to gravity loads for one of the SAP 2000 models developed by the team.

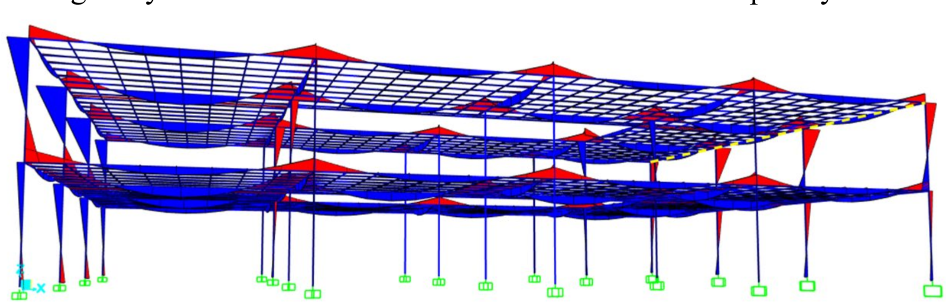

Figure 3 Structural Model Developed Using SAP2000 Software

Using the force demands from the structural model, the team determined the required reinforcement layout along the length and cross section of each structural member. They found that the column sizes were ultimately controlled by the deflection criteria set forth in NSR-10, which was significantly more stringent than ASCE 7-16. Sizing and spacing of structural members followed an iterative process, and the final dimensions are shown in Figure 4. Partition and exterior walls (not shown in Figure 4) consisted of 10 cm thick unreinforced masonry.

Reinforcement details for each of the structural member are shown in the accompanying poster.

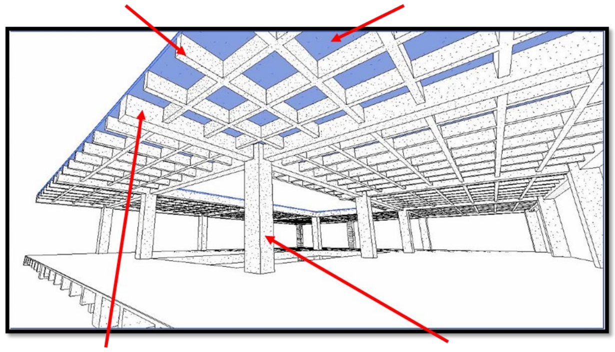

Figure 4. Structural Member Sizing of the Shelter

Fire Safety Requirements

The shelter is considered an education facility and thus the local design code, NSR-10, requires a 1-hour fire rating for all structural members for a two-story structure, giving one hour to evacuate the building. To meet this requirement, the distance between the outer surface of the concrete and the most exterior reinforcement of the member (known as "minimum concrete cover") must be greater than the value specified in the code. Based on the concrete cover that the team provided, the slab, joists, beam, column had respectively ratings of 1, 1, 2, 3-hour.

If the structure were to include a basement and become a three-story structure, the NSR-10 requires a minimum 2-hour fire-rating for all structural members. In such a situation, the team recommended increasing the thickness of the 2nd floor slab to 6 cm (instead of 5 cm). Furthermore, the team recommended in its final report that this will have minimum impact on the design of other structural elements.

Sustainable Features

The team proposed some sustainable features to the facility due to the favorable environmental conditions of the site. The region has an average rainfall of 117 inches (as comparison, the least and highest rainfall in the US are 9" and 64" in Nevada and Hawaii, respectively). They recommended that rainwater be collected in a cistern and used for gardening, toilet flushing and other non-potable uses. The region gets ample sunlight throughout the year, thus, solar panels were recommended to be installed on the roof. Because the average wind speed for the region is also favorable, a wind turbine, if installed, would provide additional power for the facility. These recommended sustainable features are presented in the accompanying poster.

II. Collaboration of Faculty, Students and Licensed Professional Engineers

The 5-person capstone team worked on this project for a whole academic year under the guidance of a faculty advisor who is a licensed structural engineer and a member of the Board of Trustees for the NPF, two licensed professional engineers from the industry in the US, a licensed professional/structural engineer in Colombia, and an industrial engineer who is the director of the NPF. The senior capstone was taught by a faculty member who is a PE.

The students met with their faculty advisor twice every week and with two industry liaison engineers from US every week. The team received feedback from an architect during the first two months of the project and met with the client (NPF director) once a month on average. The team also received sporadic feedback from a professional engineer in Colombia. The faculty advisor provided technical assistance throughout the project; both faculty members provided feedback on several drafts of the proposal in fall quarter and the final report in spring quarter. The industry engineers, in addition to mentoring the team, provided opportunities to present the project to a professional audience multiple times during the year.

In addition, the team presented their project twice to the department advisory board which consists of a dozen professional engineers from the industry – early in the academic year, they presented their project approach; towards the end of the year, they presented their final design. The team also presented their work at the local structural engineering association monthly meeting in the early stages of the project and to another team of practitioners towards the end of the year. They also presented their completed project to the US company that sponsored the project.

III. Protection of Health, Safety and/or Welfare of the Public
The health, safety and welfare of the children were the primary impetus for the project. Because the region has moderate earthquake seismic risk, the students had to consider seismic forces in design to keep the occupants safe during an earthquake. At the architectural design stage, the team ensured all safety requirements are met in terms of entrance/egress in case of emergency, while the structural design incorporated elements of fire safety. Overall, the project made the students aware of global issues.

IV. Multidiscipline and/or Allied Profession Participation
This project demonstrated a great partnership that occurs between architects and engineers. The client provided the initial vision of what they wanted in the facility; the team discussed this vision with an architect to refine the design such that it meets all functionality requirements.

Within engineering the project encompassed structural design, earthquake engineering and professional quality drafting.

V. Knowledge or Skills Gained
Students developed the following skills through this project: technical skills, oral and written communication skills, project management and leadership skills, and ability to work in a team setting and social awareness. They were also exposed to the challenges of providing engineering services to a client outside the US.

a) Technical skills
The students learned how to carry out a client's vision of a project from the conceptual stage through architectural drawings to engineering design. Through the design process they acquired the skill to use the following tools:
- Design Standards/Codes: American Society of Civil Engineers standard 7-16 (ASCE 7-16), American Concrete Institute 318 (ACI 318-19), Colombian Earthquake-resistant Building Code, NSR-10
- Drafting and Presentation Tool (Autodesk Revit®)
- Design Software: SAP2000® for structural analysis, spcol® for reinforced column capacity. Excel spread sheets for load combinations and design of miscellaneous structural members.

Students have had limited exposure to spcol®, and SAP2000® in their structural engineering coursework. But they had an opportunity to work with the software in much detail with the help of the faculty advisor. The team worked with metric units to meet the Colombian practice but included US Customary units to make it convenient to the US audience. The NSR-10 was in Spanish and the advisor translated the relevant content to the team.

b) Communication skills
The students submitted a written proposal to the NPF at the end of fall quarter, outlining their understanding of the project, scope of work, plan of implementation, and schedule. At the end of spring quarter, they submitted a final report describing the work done, engineering calculations, drawing set and other deliverables as initially agreed.

The students had the experience of working for an international client. Students had to understand the cultural and geographic differences between engineering practice in the US and Colombia.

The students completed the project entirely in the virtual environment due to the pandemic. They used the Zoom platform efficiently for meetings, presentations, and working sessions.

The students presented their project to a broad range of audience throughout the year – some of which are mentioned earlier. The academic year concluded with a virtual event where the team presented its work to the entire university community, sponsors of all capstone projects, prospective sponsors, friends, family, and alumni.

c) Project Management and Leadership skills
Each team member served as the project manager (PM) for part of the academic year. The project manager was responsible for setting up team meetings, developing meeting agendas, conducting the meetings, assigning tasks to the team members, and following up on action items. The PM was also responsible for the contacting faculty, client, and practitioners between team meetings, as needed and for keeping the project on schedule. The PM also provided a brief informal project update to the class throughout the year.

d) Global Awareness and Issues in Engineering
Students were made aware on how design constraints were different in Colombia than in the US. They learned about the local construction practices, language and cultural differences when working on international projects.

VI. Summary

A team of five civil engineering seniors designed a shelter for under privileged children in Colombia. The team received guidance from a faculty advisor, two practicing engineers from the US, all three PEs. They also received feedback from a licensed engineer in Colombia. In addition, an industrial engineer from Colombia served as the client for the Non-Profit Foundation. When constructed, the shelter will provide a haven to at-risk children. This project provided the students an opportunity to offer engineering services to a disadvantaged population while developing the team's project management skills, leadership and communication skills, an understanding of consultant-client relationships, and an appreciation for global issues.