MULTIDISCIPLINARY SMART DESIGN OF FIRE STATION 513

"Engineering Practice at the Service of our Community"

Abstract

The City approached our Senior Project class through the Senior Design Class coordinator and the Engineering in Practice Program to collaborate in the development of a smart multidisciplinary design of Fire Station 513. City requirements include a 14,000ft^2 fire station with seven drive-through apparatus parking bays. The final design of Fire Station must be LEED (Leadership in Energy and Environmental Design) Silver certified by the U.S Green Building Council (USGBC), comply with the city SMART zone code regulations, and incorporate local art.

The project was developed in two phases over two semesters. The first phase was the planning and design of the layout, which involved working with an architecture firm. Architects showed the students how to maintain awareness to aesthetic functionality while still upholding SMART and construction codes. During the second phase, teams of students worked with faculty and licensed professional engineers to address all engineering aspects for construction including environmental, geotechnical, structural, transportation, and construction management.

Benefits to Public Health, Safety, and Welfare

Fire Station 513 will bring a variety of benefits to the community covering fire emergencies, medical aid services, rescues, protection from natural disasters, car accidents, and other hazardous responses. The Fire Station 513 design is unique for two major reasons. First, it is environmentally friendly, with a LEED Silver Certified design creating a positive change in the community due to a strong integration with the neighborhood, as well as a green infrastructure design to optimize the use of energy and water. Second, it complies with the city Smart Code, which is part of an integrated long-term plan adopted by the city to promote the development of compact, walkable, vibrant neighborhoods with a healthy living environment. The considerations taken into account in the design of Fire Station 513 will serve as a model for future facilities.

Knowledge or Skills gained

Students learned a long-term career lesson that engineering practice requires working as a team in a multidisciplinary professional environment to design and build facilities to better serve their community. Professional licensed engineers mentored the students to prepare the environmental assessment, storm-water management plan, and to integrate the building site into the surrounding traffic patterns. Project managers dissected the building procedures with the students for project scheduling and cost analysis with Primavera planning software. Structural engineers taught students how to design the building structures including foundations. Several guest speakers were invited to present special topics related to the multidisciplinary design: SMART code, transferring conceptual work to software applications such as STAAD, leadership in environmental energy preservation, professional ethics, and technical writing.

MULTIDISCIPLINARY SMART DESIGN OF FIRE STATION 513

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I: Project Description

Introduction

Fire stations provide multiple services to the community like saving people from harm, offering protection, safety, and education to the public. The design of a fire station involves a multidisciplinary effort to cover all the requirements for delivering an outstanding service. The City approached our Senior Project class through the Senior Design Class coordinator and the Engineering in Practice Program to collaborate in the development of the smart design of Fire Station 513.

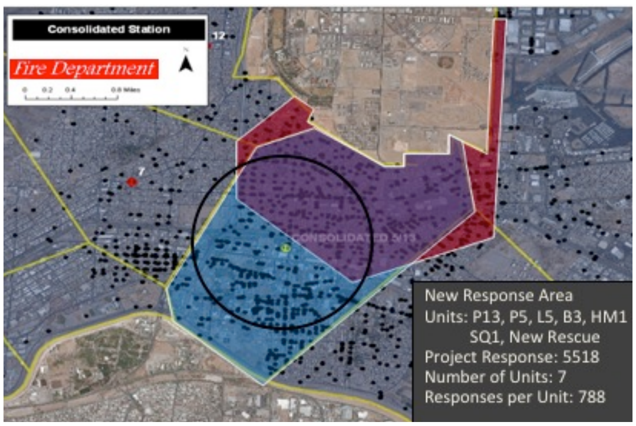

Figure 1. Area of Coverage of Fire Station 513

The need for the Fire Station 513 is the result of merging Fire Station 5 and Fire Station 13 to cover services that could not be addressed independently by those stations. These services include responding to approximately 5518 emergency calls per year within a radius of service of 1.5 miles, while reaching the emergency in less than four minutes.

Current facilities for Fire Stations 5 and 13 had reached their maximum response capacity with a very limited service area. Their buildings were old, too small for new members and without female facilities. Additionally, Fire Stations 5 and 13 did not comply with American Disability Act (ADA) requirements. The City discussed four different alternatives to address the current service needs: (a) to rebuild the stations on site, (b) to add more services to the fire stations, (c) to relocate the fire stations, or (d) to consolidate both stations into one facility. After a long debate, with the involvement of the community, the City decided to consolidate both stations into one intermediate location optimizing resources and maximizing the area of service, as shown in Figure 1.

City Requirements

City requirements for the project include a 14,000ft^2 fire station with seven drive-through apparatus parking bays. It also requires sleeping accommodation for 22 on-duty personnel and a total capacity of 66 for the three shifts. There is a need for an exterior apparatus parking for seven vehicles and off-street secured employee parking.

The design of the fire station has to satisfy several major requirements:

- Obtain a minimum LEED (Leadership in Energy and Environmental Design) Silver Certification by U.S Green Building Council (USGBC). This certification is obtained by adopting green strategies including energy efficiency, water conservation, and material resources.

- Zone Code Regulations. Fire Station 513 will be constructed in a Smart-Zone Code. The new SMART code requires the building to have frontage on a main street, with a maximum limit distance on the setbacks, 80% of the lot must be constructed, and the parking lot must be at the back of the building for aesthetic reasons.

- Incorporate public art. This requirement will be approached by having a local artist drawing a mural.

The Smart Design Process

The smart design of the new Fire Station 513 facility involved:

- Architectural Design
- Construction Management
- Environmental and Green Design
- Geotechnical Design
- Structural Design
- Transportation Design

Architectural Design

Various proposals for the architectural design were presented to the architectural firm for review. City regulations on environmental, wastewater management, and transportation were taken into consideration for the site layout and final design of the fire station, as shown in Figure 2. The final elevation view of Fire Station 513 is shown and view in Figure 3.

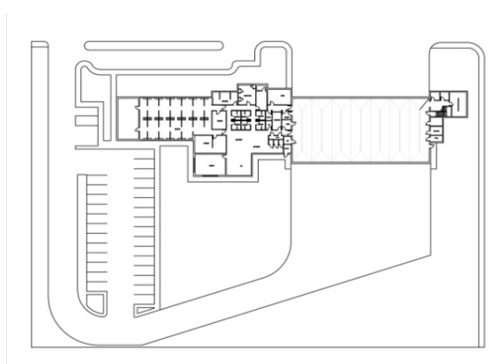

Figure 2.Final Site Layout for Fire Station 513

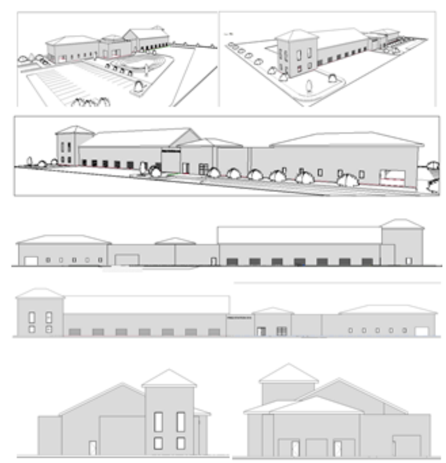

Figure 3. View of Final Fire Station 513

Construction Management

A project starts with the design phases, which include the preliminary, pre-final, and final design. Once all of the design phases are approved, the project moves to the bidding phase. A project schedule for the construction of the fire station was prepared using Primavera software (Figure 4). This project schedule will be used to manage the construction activities in an orderly manner and optimize resources.

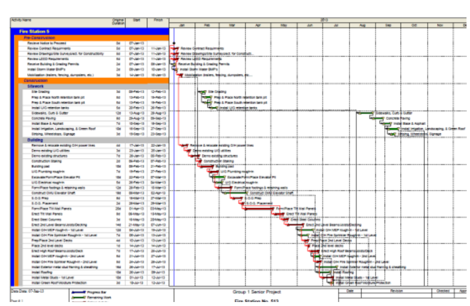

Figure 4.Schedule for Construction of Fire Station 513

A project usually takes 180 calendar days (6 months) to complete the design phase, and 240 calendar days (8 months) to build, which is a total of 14 months to complete the construction of Fire Station 513. A budget was also prepared taking into consideration the market price of the materials and labor reported in RS Means 2011. The project will be a lump-sum contract with a cost between 2.8 million dollars and 3.0 million dollars.

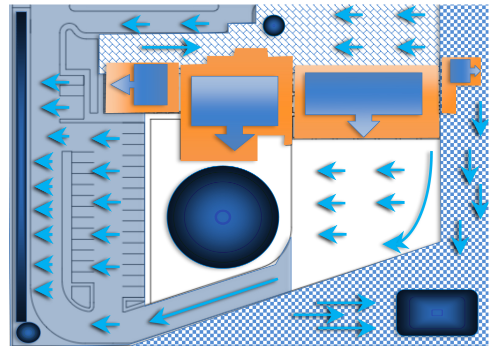

Figure 5. Surface runoff flow and concentration ponding.

Environmental and Green Design

The students prepared an environmental site assessment using standards from the American Society of Testing and Materials (ASTM), and the Standard Practices for Environmental Site Assessments: Phase I ESA Process (ASTM Designation: E1527-2000). The site is located in a SMART T4 zone, and according to the Federal Emergency Management Agency (FEMA) flood insurance rate map; the facility is located in zone “C”, an area of “minimal flooding”.

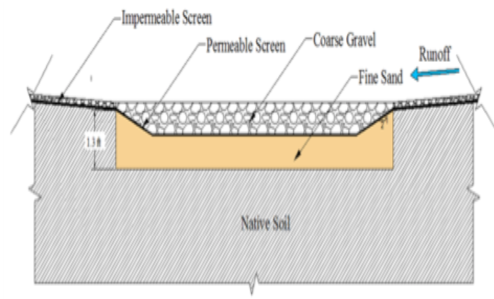

Figure 6. Detention pond for runoff control from trapezoidal river-rock channel.

According to the United States Department of Agriculture (USDA) Soils Survey, the soil was classified as Bluepoint Series (rolling). This is a very porous soil, which does not retain water and has low variations in swelling and settlement. In order to control the rise on surface run off, there will be shallow channels lined with river rocks leading to several smaller decorative ponds. Figure 5 shows the surface runoff flow direction in the site. Channels will allow the surface runoff flow rate to be hindered and directed to appropriate ponds as shown in Figures 5 and 6. For the landscaping to reflect the desert background, native vegetation and shrubs such as salt cedar, cottonwood, mesquite, fruitless plum, and cacti will be used. This vegetation will allow a high average evapotranspiration rate of 25-50 inches per year, and can retain water in its roots for long spans, which is critical to the sustainability in the surrounding environment.

To be LEED Silver certified, the project must obtain 50 to 59 points. Our final design obtained 52 points due to location, storm water management plan, landscaping, and use of sustainable materials.

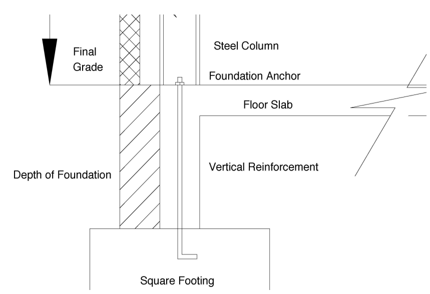

Figure 7. Typical building footing

Geotechnical

A geotechnical report from the site was prepared, including the type of soils and bearing capacity from sites nearby. The geotechnical engineer worked together with the structural engineer to determine the maximum load for the foundation design. The foundation size was determined using the Terzaghi’s equation. Two different types of foundations were used:

square footing for the steel columns and a continuous foundation for the bearing walls on the fire station. Figure 7 shows a typical footing. The ACI code was used to determine the amount of rebar needed by the foundation.

Structural

When working with the structural aspect of the fire station design, students first had to consider different building materials. The final fire station will be constructed using steel framing, concrete masonry units (CMU) bearing walls, and metal roofing. The CMU will be constructed from recycled material to contribute to LEED points. The placement of columns, beams and trusses were based on the layout of the final design. Students calculated the loadings according to the ASCE manual. These loads were used to design trusses, columns and beams for the fire station. The structural program STAAD was used to verify the loadings and stability of the structure. A 3D model of the framework is shown in Figure 8.

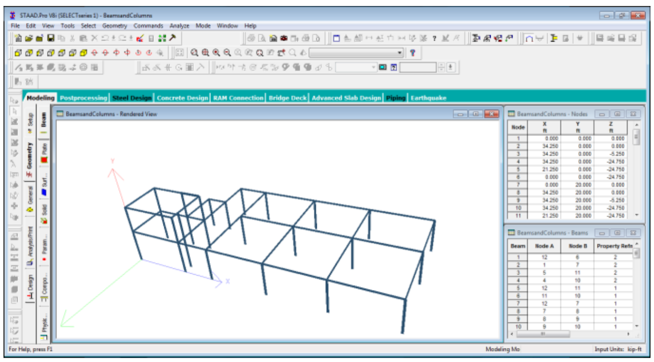

Figure 8. Beams and Columns for Gym, Storage and Bay Area

Transportation

Transportation issues, including turning radius for emergency vehicles, road conditions, and traffic of the surrounding thoroughfares were considered in the design. For the site layout, the turning radius of the fire trucks was taken into account to allow them to drive in and out of the station easily. Figure 9 shows the traffic flow of station vehicles in the surrounding streets. Both emergency and employee vehicles will enter and exit off the street located on the east side of the lot. Vehicles enter through the south side of the lot and follow a counterclockwise direction of traffic either into the apparatus bays or to the employee parking area.

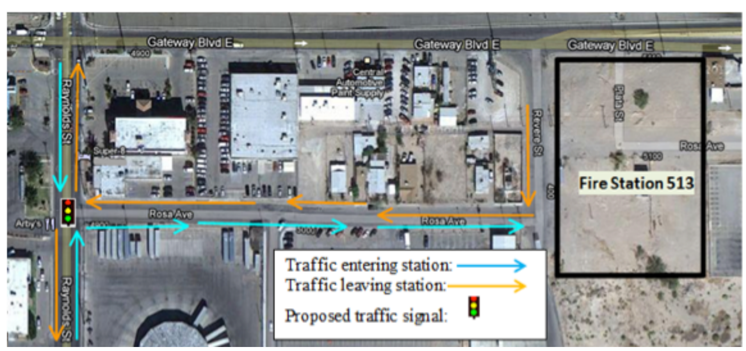

Figure 9. Traffic entering and leaving Fire Station

The conditions of the roads providing access to the station are currently inadequate to provide ample service for the large emergency vehicles and need to be retrofitted to accommodate the larger vehicles. For the station to be efficiently incorporated into the surrounding area, vehicle counts of existing traffic suggested that a traffic signal at the intersection is needed to allow the emergency vehicles to respond better to emergency calls. Moreover, emergency vehicles fitted with traffic signal preemption technology would greatly improve response times.

II. Collaboration of Faculty, Students, and Licensed Professional Engineers

This project was an excellent opportunity for faculty, students, and licensed professional engineers to collaborate on a multidisciplinary smart design of LEED Silver Certified Fire Station 513.

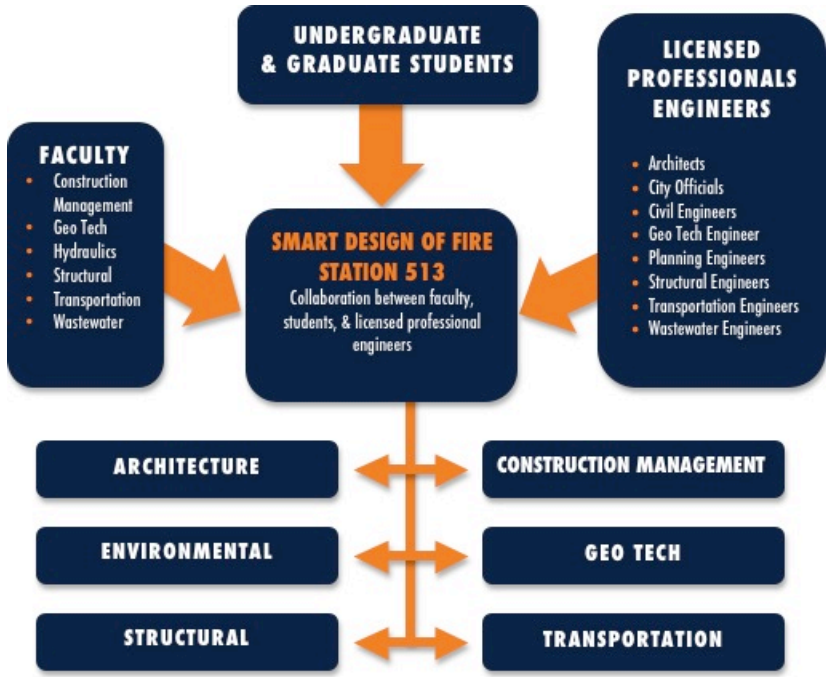

Figure 10. Collaboration between Faculty, Students, and Licensed Professional Engineers

The project was developed in two phases over two semesters. The first phase was the planning and designing of the layout of the fire station, which involved working with the architecture firm and city officers to learn building codes and permits. During the second phase, teams of students worked with faculty and licensed professional engineers, who served as mentors, to address all aspects of the smart design including environmental, geotechnical, structural, transportation, and construction management.

Additionally, over the course of the project, students had to work with planners and other city officials to ensure compliance with city codes. Because there was an existing power pole in the middle of the lot, students had to follow proper procedures and laws to create an easement for the power pole to be moved.

Figure 10 shows a schematic of the collaboration process among faculty, students, and licensed professional engineers. To ensure efficient collaboration and cooperation, weekly team meetings were held along with several presentations to update on the work progress of the fire station design.

There were also guest speakers on special topics for the design, including smart codes, permit process, and LEED requirements. This on-going interaction among students, faculty, and licensed professional engineers enabled them to gain knowledge of engineering practice, and learn communication skills, and to join the engineering network in the community.

III. Benefit to Public Health, Safety, and Welfare: A Smart Design

The development of Fire Station 513 comes with an extended variety of benefits to the community covering fire emergencies, medical aid services, rescues, protection from natural disasters, car accidents, and other hazardous responses. Having this protection system in the city helps to better manage emergencies, accidents, and provide safety, which is one of the city's most important concerns.

Fire Station 513 is a unique design for two reasons. First, it is environmentally friendly, with a LEED Silver Certified design. This will create a positive change in the community by integrating a smart location choice, strong neighborhood design, and green infrastructure for buildings, optimizing the use of energy and water, thus improving human and environmental health. Second, it complies with the city Smart Code, which is part of an integrated long-term development plan with emphasis in the creation of compact, walkable, vibrant neighborhoods that promote a healthy living environment. The Smart Code is important for a variety of aspects such as town planning, architecture, landscaping, and traffic engineering. The considerations taken into account in the design of Fire Station 513 will serve as a model for future facilities.

IV. Multidiscipline and/or Allied Profession Participation

Fire stations require broad participation of experts during the planning and design process. The design of a fire station requires the functionality of a business for the public, the durability to support the daily labor of the fire team, while preserving and maintaining a comfortable facility for the residing first responders.

This unique set of requirements allowed engineering students to interact with experts serving as mentors in architecture, construction management, environmental, traffic, structural, and geotechnical/foundation analysis. Figure 11 shows the interaction among disciplines during the development of the fire station smart design. Students understood that engineering practice requires working as a team in a multidisciplinary professional setting environment to better serve the community.

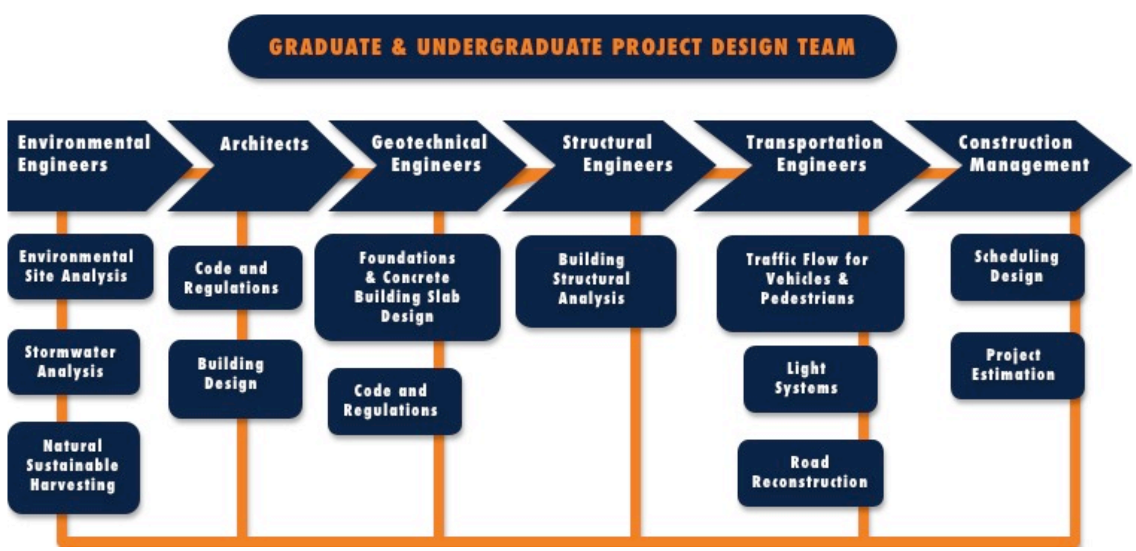

Figure 11. Interactions among Disciplines during the Development of the Fire Station Smart Design

Knowledge or Skills Gained

The development of an architectural and engineering design for Fire Station 513 created a unique learning environment for the students. Teams of students approached the project from several disciplines to account for the specific demands of the fire station design.

During the architectural design, students were faced with creating a floor plan for the fire station. With the help of professional architects, fire fighter interviews, research of existing fire stations, and modern sustainable design practices, the students were able to develop alternative floor plans for discussion. The students met with City representatives to expand their understanding on building and SMART code regulations. To create the floor plan and building designs students developed a strong knowledge of design programs such as Revit and AutoCAD architecture. Students also learned how to communicate with architects and engineers. Throughout the design approval process, the students gained invaluable insight into the work of an architect in collaboration with engineers.

Once the conceptual design was conformed to regulations, the students focused on applying their civil engineering knowledge. Professional licensed engineers mentored the students to prepare the environmental assessment, storm-water management plan, and to integrate the building site into the surrounding traffic patterns. Project managers dissected the building procedures with the students for project scheduling and cost analysis with Primavera planning software. Structural engineers taught students how to design the building structures including foundations. Several guest speakers were invited to present special topics related to the multidisciplinary design: SMART code, transferring conceptual work into software applications, leadership in environmental energy design, professional ethics, and technical writing.

Table 1 shows a summary of the specific knowledge and skills gained by the students in the different areas involved in the design of Fire Station 513.

Table 1. Specific Knowledge and Skills Gained during the Design Process of Fire Station 513

<table>
<tr><th>AREA OF EXPERTISE</th><th colspan="2">WHAT WAS DONE?</th><th colspan="2">KNOWLEDGE AND SKILLS GAINED</th></tr>
<tr><td>Architecture</td><td colspan="2">• Design Floor plan and site layout
• Assess required permits</td><td>• Design process from beginning to end
• Building and Smart codes</td><td>• Green building design and LEED Silver Certification</td></tr>
<tr><td>Construction Management</td><td colspan="2">• Scheduling and cost estimate</td><td>• Construction process
• Cost estimate of a building project</td><td>• Use of Primavera software</td></tr>
<tr><td>Geotechnical</td><td>• Parking Lot Design
• Concrete Design</td><td>• Foundations design
• Site Preparation</td><td>• Design Foundations based on loading
• Site preparation for construction</td><td>• Cut and fill calculations</td></tr>
<tr><td>Structural</td><td colspan="2">• Placement of Columns
• Design of Beams, Columns, Trusses</td><td colspan="2">• Use of STAAD software
• Required loadings</td></tr>
<tr><td>Transportation</td><td>• Reconstruction of Roads
• Traffic Flow</td><td>• Light Systems</td><td colspan="2">• Take into account use-specific condition, such as turning radius of fire trucks
• Regulatory and legal requirements for adding a traffic light to a major street</td></tr>
</table>