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Partnership between the University and the Municipality of Mayagüez for the Development of the Required Facilities for the celebration of the 2010 Central American and Caribbean Games

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Abstract

A multidisciplinary team of students and faculty of The Civil Engineering program at the University of Puerto Rico at Mayagüez have partnered with the Municipality of Mayagüez to provide the students the opportunity to address a real world problem with a real world engineering solution methodology. As part of this process, the students developed a unique integrated engineering project design experience to design all the required facilities for the celebration of the Central American and Caribbean Games in Mayagüez on the year 2010. Over 50 students had worked as 5 independent teams composed of students having preference working in each of the following areas: Construction management, structures, transportation, water resources, environmental, geotechnical.

A summary of all the different activities the students have been involved are presented. The activities begins with the creation of the company, the feasibility analysis of the selected site for the proposed use, and the development of conceptual drawings, preliminary drawings, and final drawings, along with a cost estimate and specifications for the selected alternate solution. It must be pointed out that due to the limited amount of time, the level of construction drawings are limited to a complete set of plan drawings of the site plan, architectural, structural and transportation but without the level of detail and quality in the drawings. The mechanical, electrical and plumbing drawings are limited also to the site information. The specifications are also limited to the architectural, site and structural.

1. Introduction

The University of Puerto Rico at Mayagüez, is aware that the Municipality of Mayagüez is hosting the celebration of the Central American and Caribbean Games in the year 2010 and need to improve and construct new sporting facilities, improve the existing roadways and provide access to all sport facilities as well as lodging for all visitors and athletes. For that reason the Municipality of Mayagüez commissioned the University of Puerto Rico to perform a feasibility analysis and a complete design to be use as a guidance for the development of bid packages to be given to the developers that will be actually participating in the actual design.

2. The Capstone Experience

The capstone course in Civil Engineering is a comprehensive design experince and dressed rehearsal as an engineer, and requires the selection of an open ended design project to correlate all areas of civil engineering and related areas. It requires the interdisciplinary participation to apply the analytical process and principles of engineering and science with complete interation on the project.
The Capstone course in Mayagüez has over 50 students working each semester as independent teams composed of 10 students. Each team creates their company and they assign themselves their responsabilities in all the civil engineering disciplines according to their expertise such as construction management, structures, transportation, water resources, environmental, geotechnical.

The capstone course is divided in two phases even though is taugh in one semester having in mind that is is under evaluation to extend the course in two semesters:

First phase:

Once the teams have their company, a problem is presented by the faculty in conjuntion with the industry or government based on their needs. After studying the problem, the students began to search for all the available information and perform a field reconnaissance of the site. With this information along with either the topographic drawings or simmilar information, they start working with the development of the site development proposing different alternate solutions. Each alternate solution takes into consideration environmental, social, legal and economic impact and a comparison is made to select the feasible and economic solution.

Second phase:

After each group selects the alternate solution then the students proceed to perform the analysis and complete design which include geotechnical investiation, hydrological and hydraulic analysis if required, transportantion studies, architectural design, complete engineering design, preparation of final plans and specifications along with a cost estimate, project schedule, and compliance with code regulations and permitting regulations.

3. The Capstone Model

An open ended projectes (realistic) are posed:

- Housing needs
- Industrial/commercial needs
- Transportation needs
- Residential needs

To develop the project several companies are created each working in a differente project

Each company design and maintain a working schedule, they have meetings and submitt a progress report.
To help the process there is an external assistance through invited speakers from different sources:
Government: Representatives of the government assists the students either with conferences or through personnal interrelation to make sure the design and construction plans are in the compliance with standards, codes, permits, regulations and social/political issues.
Industry: Representatives of the industry help the faculty in posing the problem, they help the students to understand the need of an adequate project management to fulfill the time constraints and to understand when the design/built alternative could be advantageous, they also explain the students about the importance of take into account the construction constraints, business operations and global perspective.
Consultants: Professional practictioners interact with the students with lectures and personal interrelation bringing to the their attention their working experience through the analysis, design, construction, cost and scheduling in real projects.
Faculty: Faculty members of each discipline provide advice, guidance and training.

4. Description of the Project

The project consists in the development of all the facilities required to host the Central American and Caribbean Games for which the students had to provide:

- An stadium with a capacity for 24,000 people
- Two villages to host 400 persons, one of them located near the main square and another one near the airport.
- A multistory parking facilities
- Pool facilities for all water events and include facilities for diving.

All of them provided of a public transportation and with roadway improvements to satisfy the new traffic demand. After each team performs the feasibility analysis of the complete site, the selected alternate was developed in further detail leading to the preparation of plans and specifications.

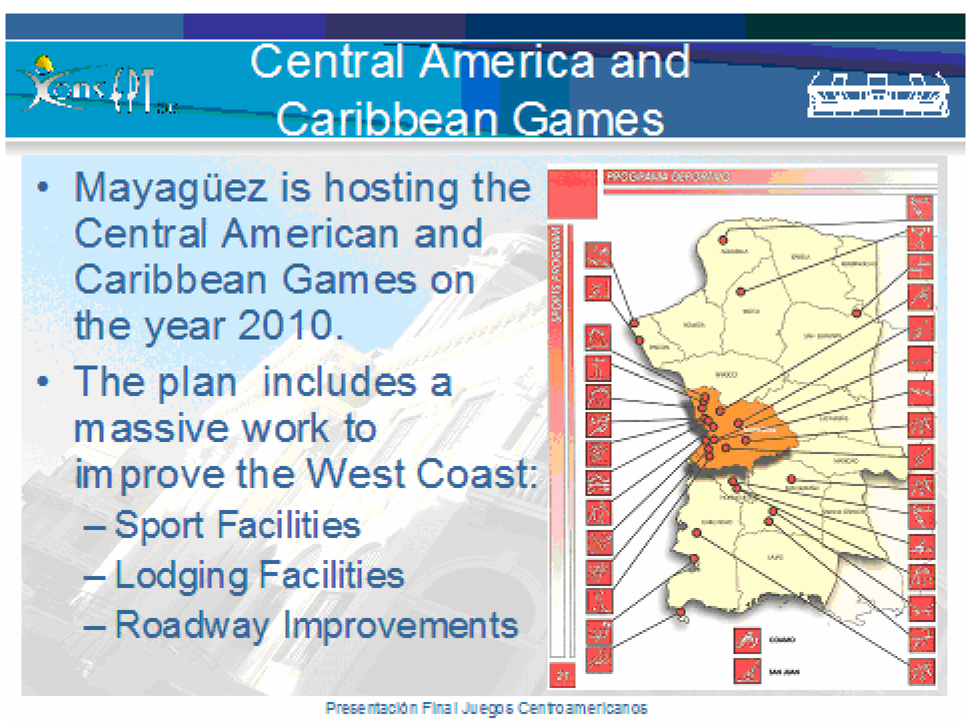


Figure No 1 Location of all Facilities

4.1 Stadium Development

The site for the development was located near the existing stadium Isidoro García, between the Road PR-2, Road PR-102 and PR-63 and has an area of 42,052 square meters. This stadium will host Track and Field events and had a capacity for 24,000 people.

Figure No 2 Location of the Stadium

During the feasibility analysis several issues were brought such as the flood. The area is classified as Zone 2 and the flood zone AE, for that zone, the base flood level elevation is 3.3 m and the actual site elevation is 1 meter over the mean sea level, among the environmental aspects, it was found wetlands near the development area, small amount of trees, few birds such as pelicans, mammals such as the Dolphin and reptiles such as the marine turtle.

In order to proceeded with the development the have to comply also with the Regulations No 13 (Flooding Regulations), Regulation No 17 (vicinity to the sea), Regulation No 25 (cutting and planting trees).

4.1.1 Roadway Analysis

The traffic congestion exceed the capacity and the geometric conditions at PR-102 do not comply with the projected estimated. The PR-63 has only was access and do not comply with the geometric characteristics and capacity to comply with the demand.

The roadway analysis included the evaluation of the traffic demand during and after the games.

During the games it is expected 6,000 Athletes from which 1,200 will arrive through PR-2 90% from the north and 10% from the south. It is also expected 18,000 spectators and 13,500 will access using the PR-2 ,38% from the north and 62% from the south

After a analysis of traffic was performed, it was recommended to make geometric changes, rehabilitate the existing pavement and use the trolley and public transportation.

4.1.2. Architectural and Structural Aspects

After evaluating the best orientation to comply with the wind direction it was decided to use the Layout presented in Figure No 3.

The stairs and seats used sustainable materials and the bathroom equipment were highly efficient in the use of water.
The exterior lighting system used solar energy with rechargeable batteries.

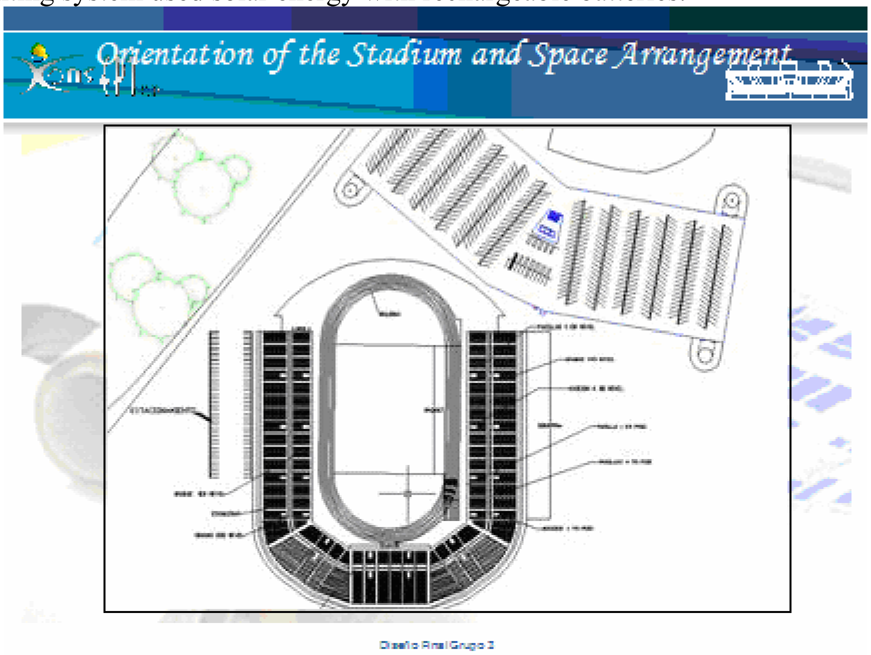


Figure No 3 Plan View

In order to perform a structural analysis a complete model of the stadium was performed using the SAP-2000 version 9 program using mainly a combination of truss systems and steel-concrete frame systems with steel beams and concrete columns. All supported by piles due to the existing soil conditions.
The structural system is presented in Figure No 4.

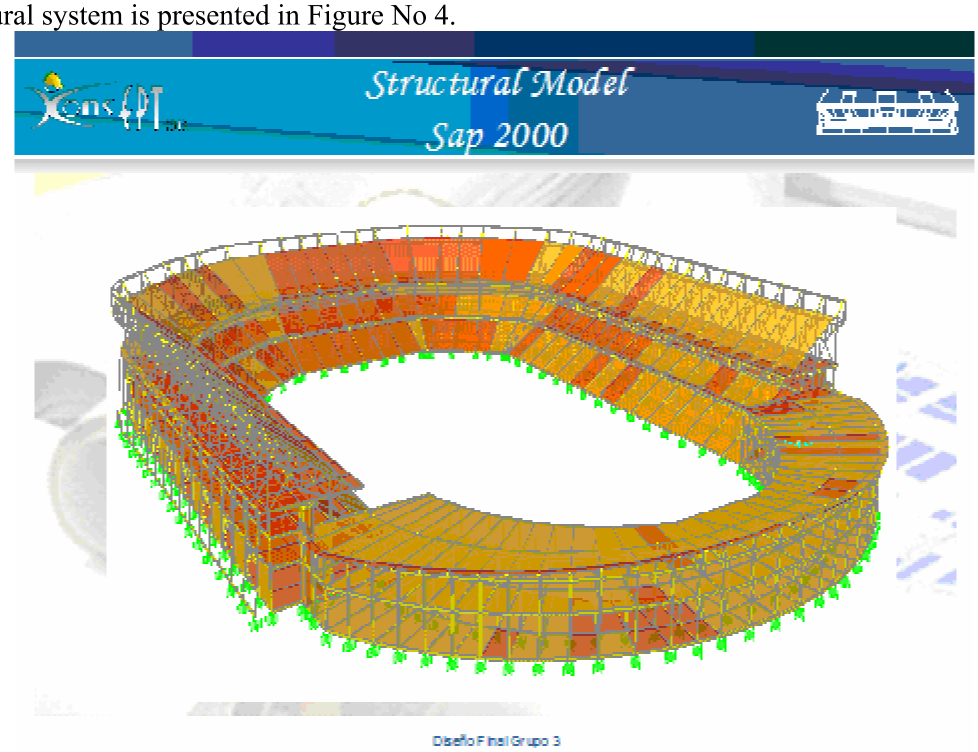


Figure No 4 Complete Structural Model

A sample of the results for a typical column and required design for the concrete column is shown in Figures No 5 and No 6

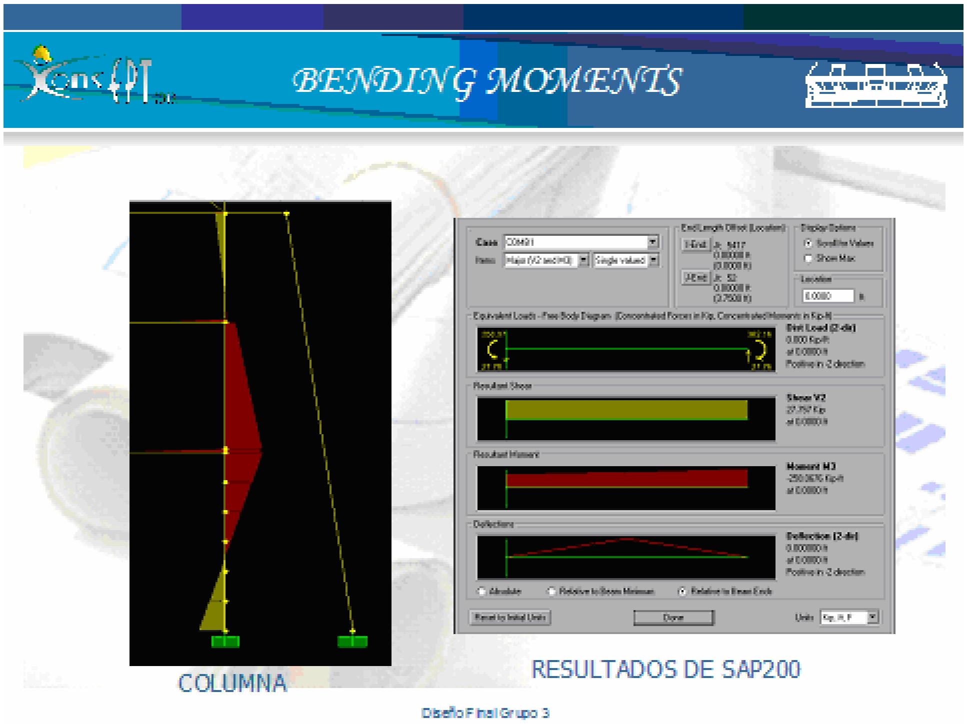


Figure No 5 Typical Bending Moments

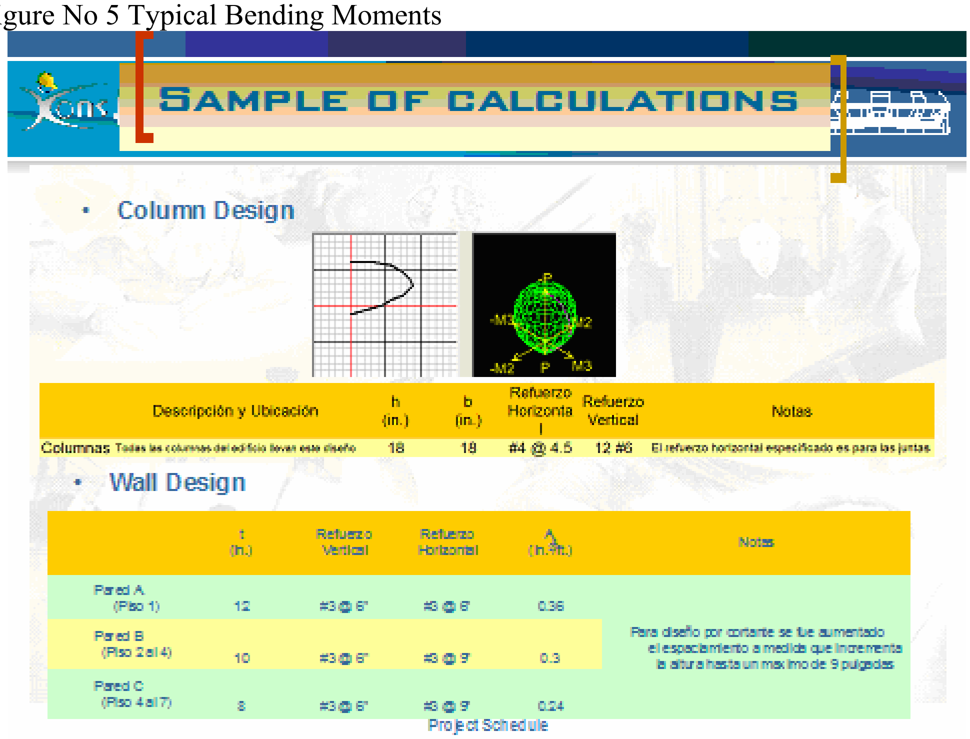


Figure No 6 Sample of Calculations

4.1.3. Water, Sanitary and Storm Water Systems

The required water demand was 450,000 gpd and the point of connection is a 8 inches pipe with a pressure of 80 psi and located in PR-102. From this point two 6 inches pipes will carry water to the proyect, considering also a water reserve of 228,000 gallons (half for the daily use and 3,000 gallons for fire protection.

The total amount of sanitary discharge is 1,575 gpd and will be connected to the 60 inch RCP pipe located in Ave. Duscombe.

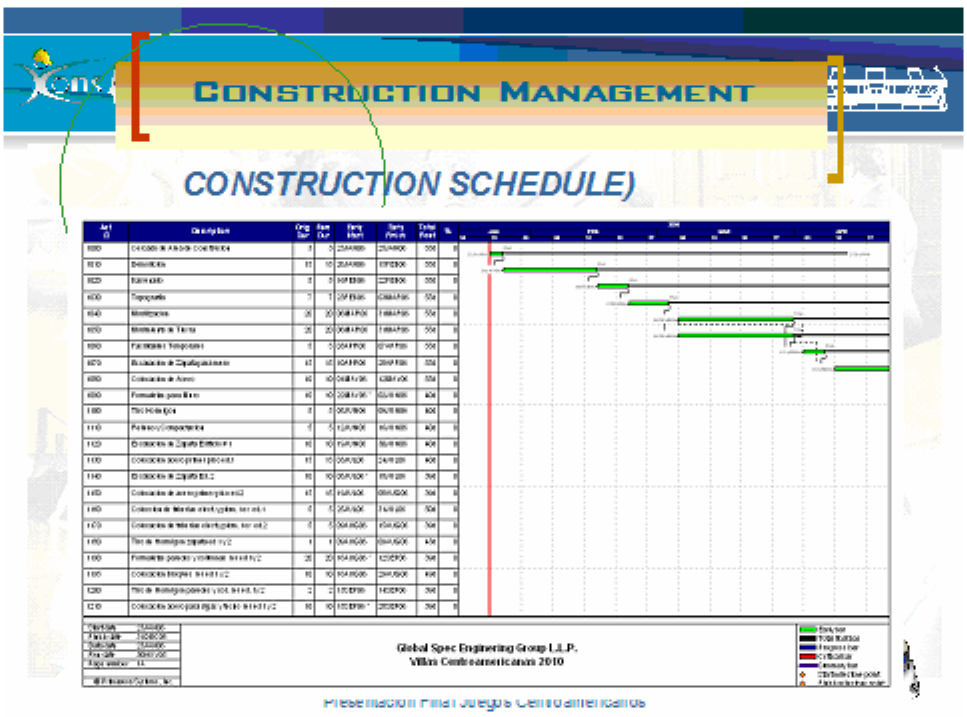
For the storm water system, it will be necessary to use a 14 inches pipes along the perimeter and an open channel.

4.1.4.. Development of a Cost Estimate and Project Schedule

The students develop cost estimates for the different stages of the project. The first cost estimate is a rough estimate using the cost per square feet with the purpose of estimate the design fees which are related to the construction cost. At later stages they improve the estimate until they finally use the information shown in the construction documents using unit prices provided by contractors or RSMeans.

For the project schedule they develop two project schedules, one for the design process and another for the construction stage.

A sample of a cost estimate and the development of a project schedule is also presented



CONSTRUCTION MANAGEMENT

COST ESTIMATE

División	Sub - División	Descripción	Cantidad	Unidad	Precio unitario				Sub-contrato	Precio Total ($)
					mat	mano obra	equipo	total		
1		**General Requirements**								
		Diseño								
		Planos Esquematicos		LS						559,466.00
		Planos Preliminares		LS						746,520.00
		Planos Finales		LS						2,424,016.00
		Servicios Durante la Construcción		LS						657,989.00
	01.45.00	**Quality Control**								
		Inspección		LS						168,000.00
	01.50.00	**Temporary Facilities and Controls**								
	01.51.00	**Temporary Utilities**								
	01.51.13	Energia Electrica	36	mensual				100.00		3,600.00
	01.51.33	Teléfono(including DSL)	36	mensual				60.00		2,160.00
	01.51.36	Agua	36	mensual				50.00		1,800.00
	01.52.00	**Facilidades de Construccion**								
	01.52.13	Oficina (van equipado y almacén, ac)	4	mensual	192.50			192.50		6,930.00
	01.52.19	Facilidades Santarias	4	mensual					60.00	2,160.00
	01.55.00	**Acceso vehicular y Estacionamiento**								
		Roads and side walks	64	SY	3.08	1.84	0.29	5.21		286.09
	01.55.26	Watchman	8	Hora					7.50	45,600.00
	01.56.00	**Barreras Temporeras**								
		Triton barrier TL-3	237	Ea.				270.00		63,990.00
	01.56.26	Verja Temporera(enlace de cadena)	1792	LF	3.45	1.49		4.84		7,441.67
		Guardia de seguridad (2 guardias)	8760	Horas					8.00	70,080.00
	01.58.00	**Project Identification**								
	01.58.13	Temporary Project Signage	1	LS						300.00
Sub Total										**4,760,339**
División	**Sub - División**	**Descripción**	**Cantidad**	**Unidad**	**Precio unitario**				**Sub-contrato**	**Precio Total ($)**
					mat	**mano obra**	**equipo**	**total**		
32		**Exterior Improvements**								
	32.10.00	**Bases, Ballasts, & Paving**								
	32.12.00	**Flexible Paving**								
		Sub-Base (Specification 301)								
		Regar material	2,432	CY	0.18	0.37		0.55		1,147.66
		Compactar	2,432	CY	3.08	0.94		4.02		8,388.36
		Base (Specification 304)								
		Regar material	1,215	CY	0.18	0.37		0.55		573.36
		Compactar	1,215	CY	3.08	0.94		4.02		4,190.73
		Surface (Specification 401)	2,554	SY	4.26	0.51	0.38	5.15		11,255.36
		Rotulación								
		PARE	10	Ea.	81.19	12.8	7.40	101.39		1,013.90
		Impedidos	9	Ea.	82.50	12.80	7.40	102.70		924.30
		Parada de Autobus	1	Ea.	73.29	12.80	7.40	93.49		93.49
		Cruce Aqui	4	Ea.	72.50	12.80	7.40	92.70		370.80
		Cruce de Peatones	4	Ea.	74.30	12.80	7.40	94.50		378.00
		No Entre	1	Ea.	86.99	12.80	7.40	107.19		107.19
		Salida Solamente	1	Ea.	80.50	12.80	7.40	100.70		100.70
		Construccion Adelante	4	Ea.	86.00	12.80	7.40	106.20		424.80
		Reciclaje	2	Ea.	87.00	12.80	7.40	107.20		214.40
		Entrada y salida de Camiones	2	Ea.	82.40	12.80	7.40	102.60		205.20
		No Estacione Zona de Carga y Descarga	2	Ea.	86.99	12.80	7.40	107.19		214.38
		Estacionamiento de bicicletas	1	Ea.	86.60	12.80	7.40	106.80		106.80
		Trabajo Adelante	4	Ea.	78.00	12.80	7.40	98.20		392.80
	32.17.13	Stop Wheels (6"x10"x6'0")	15	Ea.	37.00	8.80		45.80		687.00
	32.17.23	**Pavement Markings**								
	32.17.23.13	Layout and Painted Pavement Markings	324	LF	3.03	2.87	0.84	6.74		1,873.67
	32.18.00	Layout and paint of athletic court	352	LF	3.03	2.87	0.84	6.74		2,036.59
	32.31.00	**Fences and Gates**								
	32.31.19	Chain link for athletic court (6' high)	202	LF	2.75	1.28		4.03		1,009.66
	32.32.00	**Retaining Walls**								
	32.32.13	Cast-in-Place Concrete Retaining Walls	1,804	LF	72.50	141.00	19.50	232.65		419,700.60
	32.90.00	**Planting**								
	32.93.00	**Plants**								
	32.94.13	Landscape	25,552	SF				35.00		894,320.00
Sub Total										**1,349,759**
									Total	**52,375,848**
									Total(O&P)	**60,232,225**

Figure No 7 Cost Estimate

4.2 Village Development

The site for the development was located near the Bo Algarrobo and has an area of approximately 60,000 s.m. to host athletes and trainers during the games. The project includes the development of apartments, dinning facilities for 2,000 people, laundry, gym, green areas and a funicular system to transport athletes back and forth.

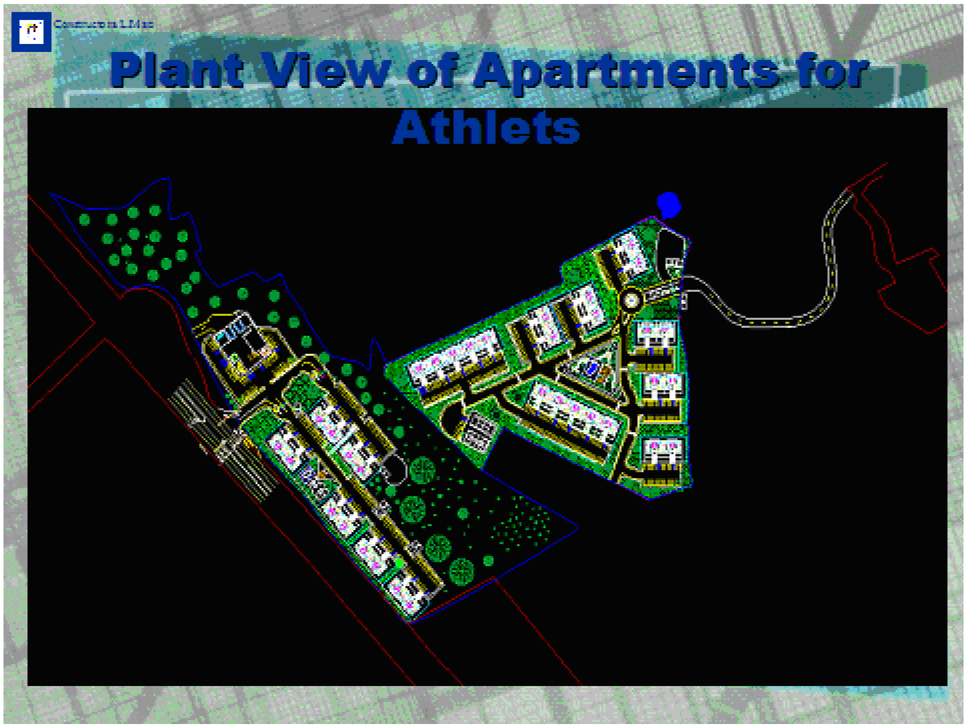


Figure No 8 Plan View of Apartments

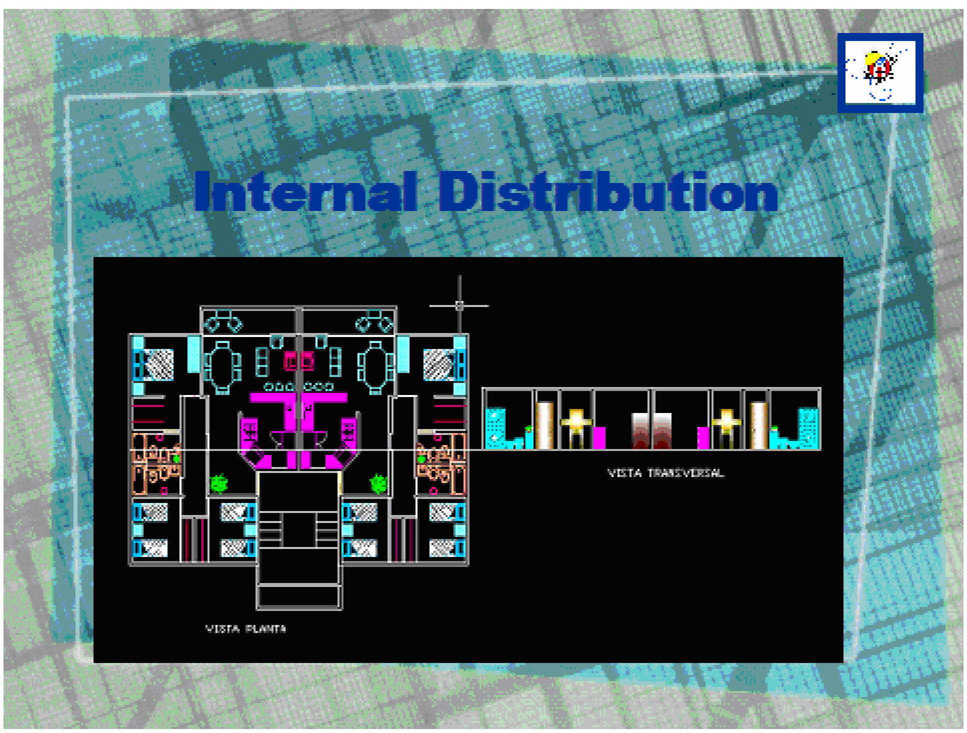


Figure No 9 Apartment Internal Distribution

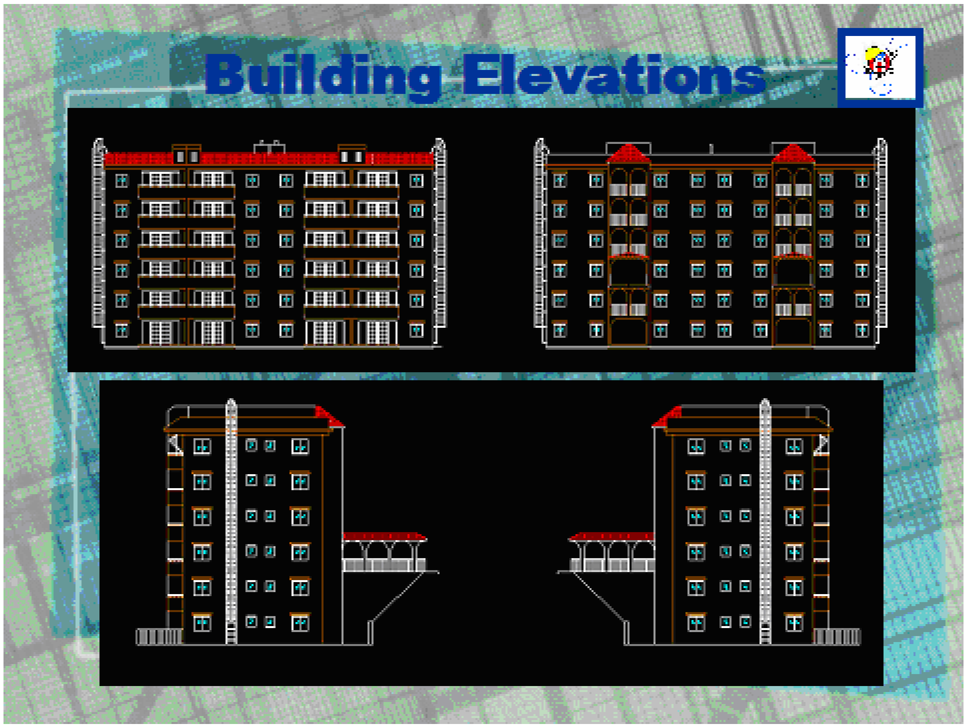


Figure No 10 Apartment Elevations

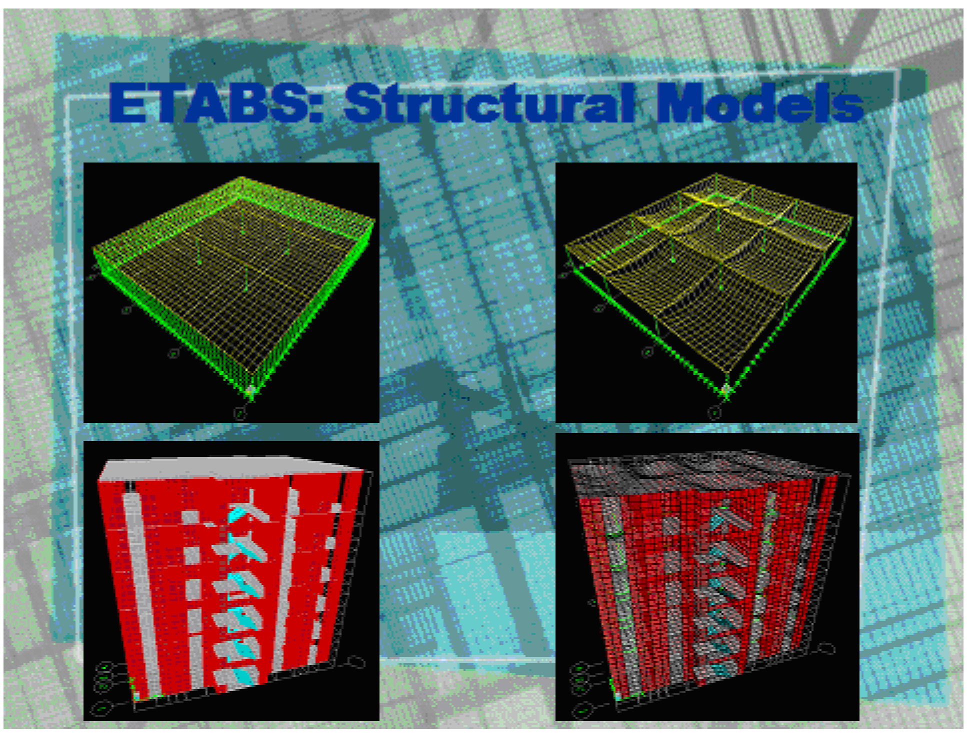


Figure No 11 Structural Model of Apartments and Dinning Facilities

4.2.1 Public Transportation

A public transportation system is provided to carry the athletes to the stadium, Olympic pool, volleyball court and villages.

Figure No 12 Routes Uses for Public Transportation

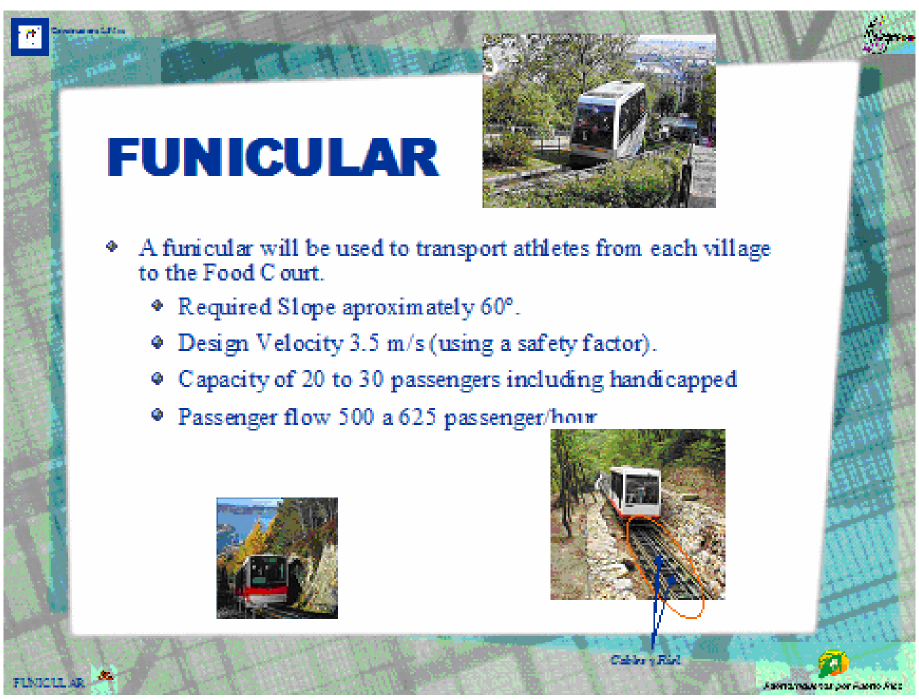


Figure No 13 Funicular System

4.3 Sustainable Design

The students are incorporating in the design the present and future concerns that will affect their environment and it is the goal to promote the use of recycling materials and performing a sustainable design. The sustainable design must include also alternate solutions for the transportation system in order to reduce pollution and land development refraining the use of automobile due to the excessive volume of cars in the island
The incorporation of sustainable solutions emphasizes also the effective management of storm water runoff, the elimination of the use of potable water for landscape irrigation, the use of on-site renewable energy systems, and the use of cross ventilation.

In the development the groups had been also encouraged to the used of sustainable design, taking into account the project life cycle performance parameters such as:

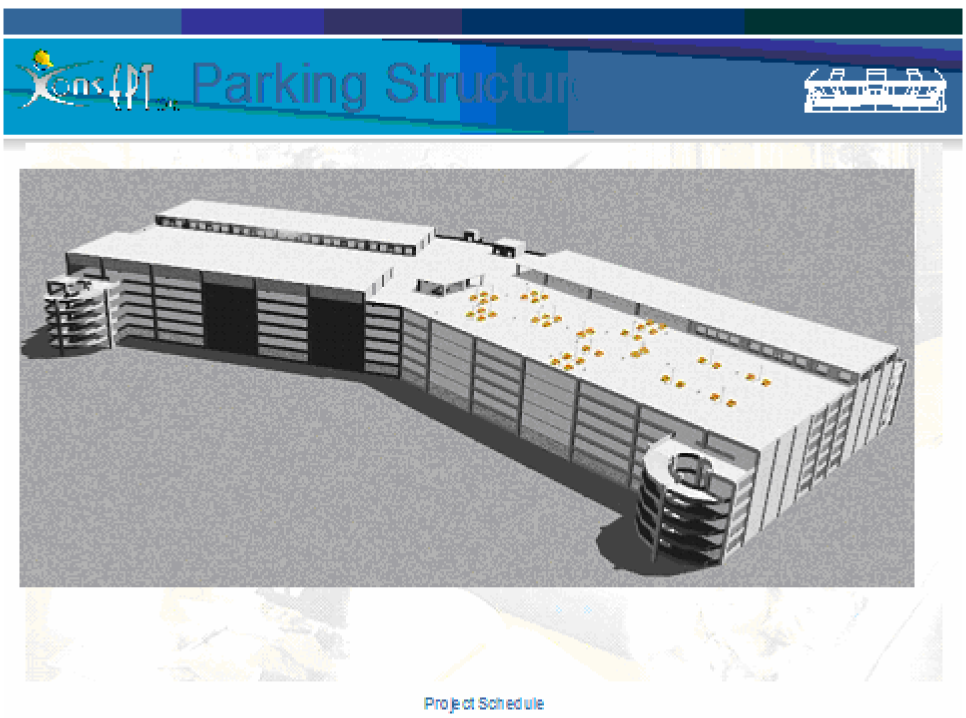
- Physical and non-physical context capabilities and response
- Function and operability
- Form
- Life Cycle cost
- Time
- Risk
- Safety and Security
- Constructability
- Procurement
- Maintainability
- Quality and Reliability
- Sustainability

4.3.1 Some Sustainable Features Included in the Design

Other features such as use of gray water, rain collection systems, trees, solar generated poles, use of recycling materials, the use of a road for bicycles and trolley system were included in this work

4.4. Other Developments

Other developments included the development of a residential building near the civic center, parking system for the stadium and an Olympic pool



5. Conclusions

The capstone design courses in the Department of Civil Engineering at the University of Puerto Rico has been effectively in giving the students the tools to work in real projects even though the actual designs are not used for construction. The interaction between the students working as a team sometimes do not work smoothly, but the students have to known they will face the same problems at the field. Due to the amount of work involved in the projects, the faculty is suggesting to increase the number of credits and offer the course in two consecutive semesters so the quality of work specially at the level of feasibility analysis and construction drawings can be improved.

6. References

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