Section 6: Analysis #1 – Concrete Columns with Steel Trusses Vs. Glulam Structural System (Structural – Breadth Topic #1)

6 – 1 Problem:

Unlike the steel structural system in the recreation center, the natatorium has been designed using a glulam structural system. It is unusual for a natatorium to use a glulam structural system. Additionally, glulam is significantly more expensive than concrete and steel and presents unique challenges during construction. The designer insists that structural steel, even with special coatings, corrodes and deteriorates in the humid environment of natatoriums.

Figure 6-1.1 - Natatorium with steel structural system. Courtesy of Penn State

6 – 2 Goal:

Determine the structural and economic feasibility of using a steel structural system in place of the currently designed glulam system in the natatorium, including identifying the durability of steel and glulam in a natatorium's humid environment.

Figure 6-1.2 - Gymnasium with glulam structural system. Courtesy of Structure Mag

6 – 3 Analysis Method:

1) Determine the durability of concrete, steel and glulam structural systems in a natatorium environment, including all maintenance issues and costs.
2) Design a structural concrete and steel system to replace the glulam system.
3) Calculate the cost savings associated with using a structural concrete and steel system
4) Analyze the schedule impacts of using a structural concrete and steel system
5) Consider the constructability effects of using structural concrete and steel

6 – 4 Resources:

1) Penn State OPP – Chris Musser
2) University of Virginia Capital Projects
3) University of Maryland Capital Projects
4) University of Houston Capital Projects
5) RS Means 2009 Cost Data
6) R.M. Rodgers – Miles Parks
7) Designers with experience in glulam and concrete and steel structural systems in natatoriums.
8) MS Project
9) Pearland Recreation Center and Natatorium project team.

6 – 5 Durability of Concrete, Steel and Glulam:

Initially the objective of this analysis was to design a completely steel structural system in the natatorium. As research of the steel structural system progressed, it was suggested by structural engineers at a number of university's capital projects groups that a structural system consisting of concrete columns and steel girders/joists be used instead. Paint on steel chips very easily and when exposed to water (like the bases of columns would be) the steel would begin to rust. Alternatively, if concrete was used the only concern would be water penetrating the concrete and rusting the rebar. Since the bases of the columns will not be saturated with water this scenario can be ignored. Similarly, since the steel joists and girders would be located up in the ceiling, the chance of paint being chipped on them would be very low. Additionally, the only water concern would be humidity which should not cause the steel to rust, especially if the paint on the steel is not chipped.

6 – 6 Structural System Re-Design:

After a concrete and steel structural system was decided upon it was necessary to design the system. The system was designed using the 2003 International Building Codes shown in **Table 6-1.3 – 2003 IBC Structural Loads**. The roof slope was set at 3:12.

Table 6-1.3 -2003 IBC Structural Loads

Type of Load	Design Load
Roof	20 lb/SF
Dead Weight	20 lb/SF
Wind	120 mph for 30 sec gust – exposure C – importance factor of 1.15

The resulting design consisted of (468) 25' 14k1 joists at 4' o.c. These joists rest on (14) 140' 104SLH22 girders at 25' o.c. The steel system rests on (28) 10" X 10" square concrete columns with 4-#5's. The design calculations as well as the Steel Joist Institute and Concrete Reinforcing Steel Institute sizing sheets that were used are attached in **Appendix 6.** It is important to note that throughout this system redesign it was assumed that the CMU walls in the natatorium would support the structure laterally.

6 – 7 Cost Analysis:

Once a new structural system was designed it was necessary to determine the cost implications of this design modification. To do this RS Means 2009 Cost Data was used. Using this cost data, a total system cost of $469,738 was obtained. This was a $600,262 savings over the $1,070,000 glulam structural system (supplied by R.M. Rodgers, glulam contractor on project) that it replaced. An additional $30,000 was incorporated into the steel system to cover extra connection costs (plates for column-beam connection, etc.) Cost calculations as well as RS Means cut sheets are included in **Appendix 6**.

6 – 8 Schedule Analysis:

A schedule analysis was performed to analyze the effects of this new system on the construction schedule. It was discovered that there was no effect on the schedule. As shown in the modified schedule (shows only the portion of the schedule that included this modification) in **Appendix 6**, the concrete columns are poured while steel is being erected on the Recreation Center and when steel erection is completed on the Recreation Center, the erectors simply continue work on the building with erection in the Natatorium. Prior to the system modification, the steel erectors would have been done once the Recreation Center was complete and the glulam erectors would begin their structural system erection by erecting the glulam members. The only difference with the modified system is that instead of the glulam erectors working on the Natatorium following completion of the Recreation Center's steel, there would be steel erectors erecting steel in the Natatorium.

6 – 9 Constructability Analysis:

Modification of the structural system makes it more easily constructible. The 100 Ton truck crane that was used to erect steel in the Recreation Center would already be on site and would be able to lift all the steel members in the natatorium so no additional cranes would be needed. Additionally, a constructability challenge with the glulam system was the erection of the arches, particularly aligning the bolted connection to the footer. By using the concrete columns this concern could be neglected. Another benefit of this new system is that it would eliminate the need for a glulam subcontractor and would therefore result in one less subcontractor that needs to be on site and managed.

6 – 10 Conclusions and Remarks:

Modification of the natatorium structural system from glulam to steel and concrete resulted in a cost savings, no schedule change, and a more easily constructible building. The objective of this analysis was successful in identifying a preferable alternative to the as-designed natatorium structural system.