T.C. Williams High School

Alexandria, VA

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Structural Option

Thesis Proposal

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EXECUTIVE SUMMARY

T.C. Williams is a 3 Story 461,000 square foot high school that has recently finished construction in Alexandria, VA. This 85 million dollar building was designed to accommodate 2,500 students and features classrooms, a gymnasium, auditorium, library, cafeteria, and green roof as its prominent features.

The buildings primary structural system is comprised of steel framed beams with composite floor slabs. Lateral loads are resisted using concentrically braced frames between floor slabs, which act as rigid diaphragms. Frames use stiffness in the plane of the lateral load and act similarly to a truss to transfer the loads to the columns, which then transfer the loads to the foundation.

Due to the large budget, the structural system was designed using fairly conservative sizes, and a simple design. For the purpose of this thesis assignment two additional stories will be added to the school. A valued engineering solution that will decrease construction costs, project duration, and material usage will be emphasized.

In technical report 2 it was found that the original composite beam and slab design wasn't the most efficient design available. The cheapest solution happened to be steel joist construction, however problems with vibration makes this solution unacceptable. The system that will be analyzed further in this thesis will be composite steel joists. This system is a good compromise between the heavier, more costly steel beams and the very cheap and light steel joists. A switch to lightweight concrete will also be studied, and it shall be examined if LWC offers much savings in cost of the overall structure. The last solution that will reduce costs is the removal of exterior columns, which will be replaced by the already existing exterior masonry walls.

Designs will be carried out using various design manuals, and RAM Structural System 3D models, which will be back up with hand calculations. All loads used will be determined from ASCE 7-05.

The structural redesign of TC Williams High School will be further evaluated through breadth studies in non-structural design areas. First, a study of the buildings architecture will be undertaken, evaluating how the additional stories will affect the existing architecture. Secondly, I plan to examine the differences in cost and scheduling that will arise with an alternative structural system.

Structural System Overview

Roof System

Typical flat roof systems on T.C. Williams High School consists primarily of a Thermoplastic Polyolefin (TPO) Membrane system with rigid insulation on 1½" 22 gauge steel roof deck, supported by K-Series Steel Joists which are typically spaced 5' O.C. Typical sloped roofing systems are similar to the flat roofing systems except instead of the TPO Membrane system there is a standing seam metal roof.

Typical roofing systems over larger span areas such as the gymnasium and the auditorium consist of 3" 20 gauge steel roof deck, supported by DLH Steel Joists typically spaced 12' O.C.

Floor System

Typical floor systems consist of a steel composite deck and beam system with a 3" concrete slab on 1½" 18 gauge steel composite deck, supported by Steel Beams typically spaced 8' O.C. The concrete slab is made of Normal Weight Concrete (145 PCF) and has a minimum 28 day compressive strength (F'c) of 4000 PSI. Most typical Steel Beams are W18x35 spanning a maximum of 34' with steel studs spaced at 12" O.C. The range of steel beams varies greatly depending on specific room requirements; generally ranging anywhere from a W16x26 to a W21x44. Steel studs creating the composite action are ¾" in diameter and 3½" long.

Foundation

All main building foundations are constructed on subgrade soils improved by the installation of a 'Geopier Rammed Aggregate Pier Soil Reinforcement' system and are designed to bear on strata capable of sustaining a minimum bearing pressure of 6,000 PSF. The slab on grade consists of Normal Weight Concrete (145 PCF) and has a minimum 28 day compressive strength (F'c) of 3,500 PSI. Typical slabs are 4" thick and are reinforced with 6x6-W1.4xW1.4 WWF at mid depth. All spread and strip footings consist of Normal Weight Concrete (145 PCF) and have a minimum 28 day compressive strength (F'c) of 3,000 PSI.

LATERAL SYSTEM

T.C. Williams is separated into 6 different “buildings” through the use of ‘Fire Walls’. Both classroom towers are laterally supported with ordinary steel concentrically braced frames in both the N-S and E-W directions. The 3 story area connecting the 2 three story classroom towers is laterally supported with ordinary steel moment frames in both the N-S and E-W directions. Gymnasium and auditorium areas are supported by intermediate reinforced masonry shear walls, in all directions. The rest of the building, which includes the area between the gymnasium and auditorium sections, is laterally supported by ordinary reinforced masonry shear walls, in all directions.

COLUMNS

Steel columns are the primary gravity load resisting members of the building. They consist of Grade 50 ASTM A992 wide flange shapes, grade 46 ASTM A500 rectangular HSS shapes, and grade 42 ASTM A500 round HSS shapes. The wide flange shapes generally range from a W10x49 to a W10x68, and are the primary support for most of the building. The Round HSS shapes found connecting the two classroom wings and under the green roof, and generally range from HSS12.750x.375 to HSS16x.500.

PROBLEM STATEMENT

Due to the large budget, the structural system was designed using fairly conservative sizes, and a simple design. If two more stories were added to the top of the school, cost would become a much larger factor. Had the owner felt a need for additional stories at the time more solutions may have been explored by the design engineer. I intend to propose a value engineered solution that will decrease construction costs, project duration, and material usage. To accomplish this I will use code requirements from IBC 2006, and ASCE 7-05.

PROBLEM SOLUTION

In technical report 2 it was found that a steel joist system was the lightest and cheapest system available, however one of the major problems with a joist system is vibration. An additional option which will be examined is a composite joist system. A composite joist system should better deal with vibration while still being a much lighter and cheaper solution compared to a composite beam system. Furthermore lightweight concrete will also be examined as a possible change for a composite beam system, or with a composite joist system if vibration is still satisfactory. One of the major cost savings solutions will be the removal of exterior columns, which will be replaced by masonry walls which are already present as nothing more than a façade. All together these changes are expected to permit two extra stories to be constructed at a much cheaper cost / SF than the original design.

SOLUTION METHOD

Designs will be carried out using Joist Design manuals, the 13th Edition AISC Steel Design Manual, and RAM Structural System. When computer software is used, some hand calculations will be performed on worst case scenarios to assure the output is reliable. All loads will be those used in previous technical reports as have been interpreted from ASCE 7-05. The floor system will be designed for both strength and serviceability requirements, such as deflection limitations of masonry walls. The lateral system will be evaluated for both wind and seismic forces in accordance with the methods set forth in ASCE 7-05, and redesigned to meet the new prescribed lateral forces.

BREADTH TOPICS

The structural redesign of TC Williams High School will be further evaluated through breadth studies in non-structural areas.

First, an architectural study will be undertaken, evaluated the effects of adding two additional stories. Adding stories will have an effect on the previously designed architectural design, and considerations will need to be made to best account for the additional stories.

The second breadth option will examine a cost analysis and the schedule impact between the existing and alternative structural systems. With the addition of two stories, cost would be much more of an impact on the redesign than what it was with the original design. RS Means and Primavera will be the primary tools used in the new scheduling and design process to minimize costs as best as possible.

SCHEDULE

STRUCTURAL

1A: Recalculate Seismic and Wind forces to account for the additional building stories.

1B: Update existing 3D RAM Structural Systems model to account for actual masonry walls and openings.

1C: Examine effects of LWC on existing 3D RAM Steel Beam Model.

1D: Design a Composite Steel Joists system, using NWC and LWC.

1E: Examine effects of vibration on composite steel joists using NWC and LWC.

1F: Redesign exterior masonry walls to make them load bearing.

ARCHITECTURAL

2A: Research Codes for maximum building heights in the area.

2B: Find and examine existing design features.

2C: Architecturally account for the redesign to not have a negative effect on these features.

2D: Redesign floor plans to account for increase in column size (if needed).

CONSTRUCTION MANAGEMENT

3A: Gather information about total cost of existing system.

3B: Research total expected cost of new system for additional stories.

3C: Examine scheduling differences between existing and redesigned system.

MISCELLANEOUS

4A: Edit and Revise Final Paper

4B: Publish Final Paper

4C: Prepare and Practice Final Presentation

4D: Presentation

SCHEDULE

WEEK	DATES	TASKS
1	Jan 14 - Jan 18	1A
2	Jan 21 - Jan 25	1B, 1C
3	Jan 28 - Feb 1	1D
4	Feb 4 - Feb 8	1E
5	Feb 11 - Feb 15	1F
6	Feb 18 - Feb 22	2A, 2B
7	Feb 25 - Feb 29	2C, 2D
8	Mar 3 - Mar 7	3A, 3B
	SPRING BREAK	
9	Mar 17 - Mar 21	3B, 3C
10	Mar 24 - Mar 28	3C
11	Mar 31 - Apr 4	4A, 4B
12	Apr 7 - Apr 11	4C
13	Apr 14 - Apr 18	4D