T.C. WILLIAMS HIGH SCHOOL

ALEXANDRIA, VA

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STRUCTURAL OPTION

BUILDING INTRODUCTION

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BUILDING INTRODUCTION

T.C. Williams is a 3 Story 461,000 SF high school in Alexandria, VA, designed to accommodate 2,500 students. The architects and engineers on the job were Moseley Architects. It was later constructed by Hensel Phelps. Construction was completed during the summer of 2007, and later opened in the fall of 2007.

The building utilizes a composite slab with decking on steel frame construction. Due to the large size of the school, it was separated into six different 'buildings' using expansion joints. All together these six buildings have 4 different lateral resisting systems, the most common being Steel Concentrically Braced Frames. The others include Steel Moment Resisting Frames, and both Ordinary and Intermediate Masonry Shear Walls.

Buildings separated by expansion joints are located on the next page. Buildings A and B are the ones under analysis. These buildings are the known as the classroom wings, and contain classrooms, labs, and offices. They were chosen for analysis since they are the only sections of the school where a change in height could be justified. Building C contains the cafeteria, library, and green roof. Building D contains many miscellaneous rooms, including some classrooms and mechanical systems. Building E contains the gymnasium and locker rooms. Finally, building F contains the auditorium and stage.

An original design of the school was done using ASD, while this technical report focuses on the design using LRFD. Due to both the difference in design methods, and the difference in building codes used, small discrepancies between my calculations and those of the engineer are expected. In no way does this report make the claim that any of the designer's approaches, assumptions, calculations, or resulting designs are incorrect or unsuitable.

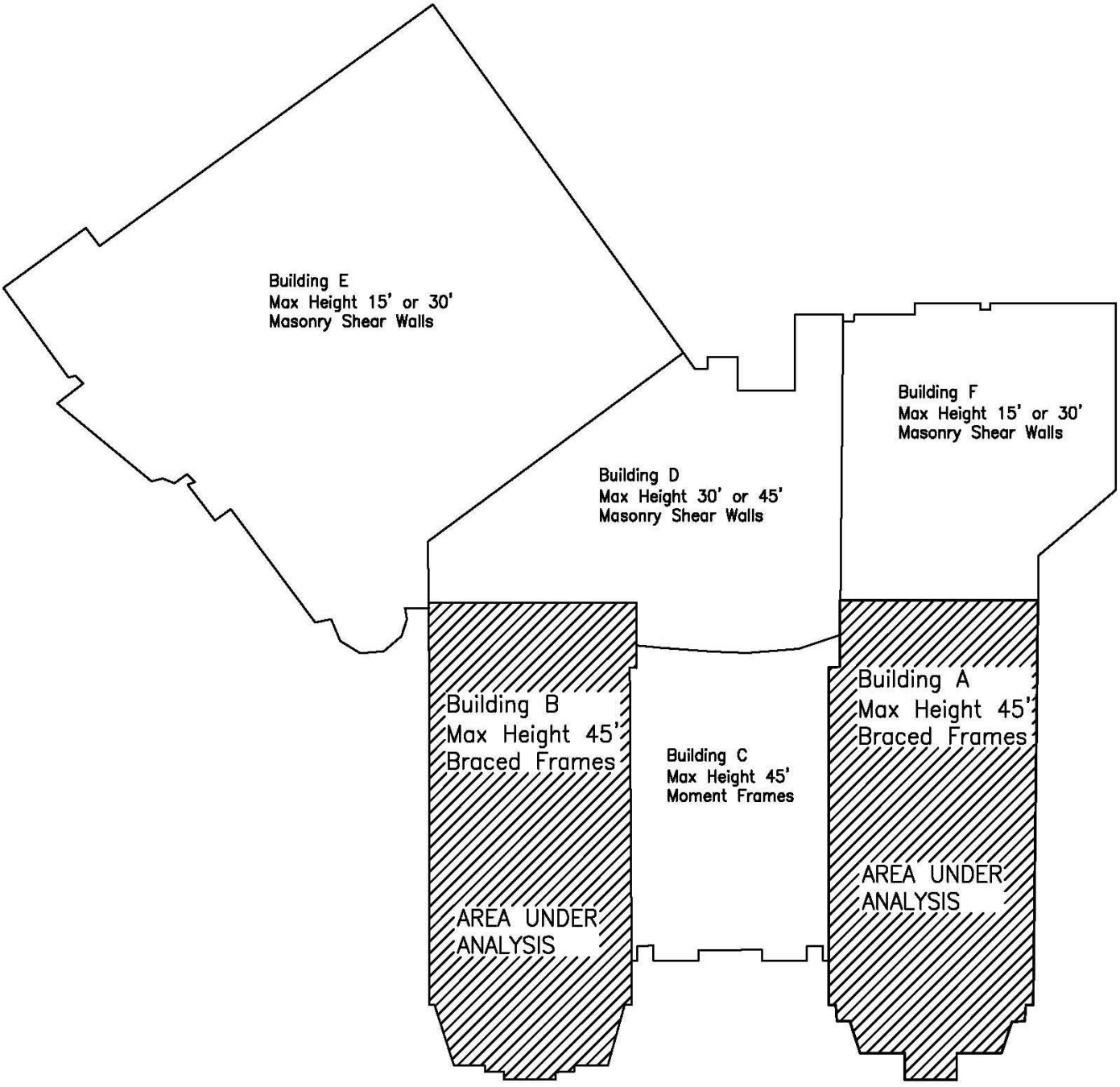

Figure 1 - Overal Building Plan

BUILDING BACKGROUND

GENERAL BUILDING DATA

- **Building name**: TC Williams High School
- **Location and site**: 3330 King St Alexandria, Virginia
- **Building Occupant Name**: TC Williams High School
- **Occupancy or function types**: High School ~ 2,500 Students
- **Size**: 461,000 SF
- **Number of stories**: 3
- **Primary project team**
  - **Owner**: City of Alexandria, VA
  - **General Contractor and CM**: Hensel Phelps
  - **Architects**: Moseley Architects
  - **Engineers**: Moseley Architects
- **Dates of construction**: July 02 2004 – June 21 2007
- **Overall Project Cost**: $87,000,000
- **Project delivery method**: Design Build – GMP
- **Zoning** : Commercial

ARCHITECTURE

Architecture Concepts:

- TC Williams High School was originally designed with a very modern feel, but the owner decided a more traditional look was desired. The TC Williams High school was then redesigned with a traditional look that took various designs from other buildings in the general area. Natural light was also a major factor in the design, and 70% of the rooms have an outside view.
- The other architecture concept the building was designed around was a Green Design. The building achieved a LEED rating of silver. Some of the main LEED designs included a 450,000 gallon Cistern, and a small green roof. The cistern will be used to provide water for the chillers, air conditioning, and toilets. The Green Roof will be used as a learning tool, as well as to collect additional rain water for the cistern.

Figure 2 - Green Roof

STRUCTURAL

The foundation of the building consists of both strip and spread NWC (145 PCF) footings with a compressive strength f'c = 3,000 psi. The foundations are constructed on sub grade 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 typical floor is a composite system consisting of a 3" concrete slab on 1½" 18 gage steel composite deck, supported by Steel Beams typically spaced 8' O.C that vary in size. The 3 story classroom sections of the building consist of a steel braced frame construction, while other lateral force resisting systems range from Masonry Shear Walls to Steel Moment Frames. The typical roof consists of 1½" 22 gage steel roof deck, supported by K-Series Steel Joists which are typically spaced 5' O.C.

LIGHTING / ELECTRICAL

The classrooms are lit with 54W T5 HO 277V Pendant fixtures, while the corridors are lit with 32W T8 277V Recessed fixtures.

A 480 Y / 277, 3 phase, 4 wire primary feed services the building. Two main 4000 ampere, 3 phase switchboards distribute the required power to the electrical loads throughout the building. The building contains a total of (24) 270V panel boards, and (67) 120V panel boards. The life safety system is backed up by two 800kW, 480V, 3 phase 60 Hz, diesel fueled generators.

MECHANICAL

There are a total of 17 roof top air handling units with a combined capacity of 229,100 CFM supply conditioned air to the majority of spaces. An additional 4 indoor air handling units combine for 40,355 CFM supply of air to the auxiliary gymnasium, east and west commons areas and the remaining spaces in the Eastern Classroom wing. These units employ the use of enthalpy wheels to recover total energy. Four natural gas-fired condensing boilers, with capacities of 1.68 million BTUH, heat water from 120˚F to 160˚F. Water is cooled to 38˚F by two, 600 ton water cooled, electrical chillers. Two 750 ton cooling towers condense the R-123 refrigerant so that it can be re-circulated through the chillers which will accept the heat from the systems chilled water lines. An additional water unit heater and an electric heater service the mechanical and equipment rooms respectively.

A five zone, wet pipe sprinkler system services T.C. Williams High School. Each zone covers approximately 50,000 sq. ft. A 100 hp vertical in-line fire pump produces a flow rate of 1,000 GPM with a total head pressure of 120 psi. A mixture of sidewall and pendant sprinkler heads will service the spaces while concealed heads are required in all the stairwells.

CONSTRUCTION

Hensel Phelps is the CM on the job, and had working under a design build guaranteed maximum price contract. Construction started in July of 2004, and construction was completed in June of 2007. The old school which currently resides next to the new school is still currently under deconstruction.

FIRE PROTECTION

The steel in the building is protected with spray on fireproofing rated for 1 hour for floor, and column members, and 1 hour for roof members. The floor slab has a required 1 hour minimum fire rating. A fire alarm system with automatic sprinklers is in place throughout the school.

TRANSPORTATION

There are three main elevators located in the 3 story classroom sections. They are all for public use. There is one service elevator located in the classroom section for private use.

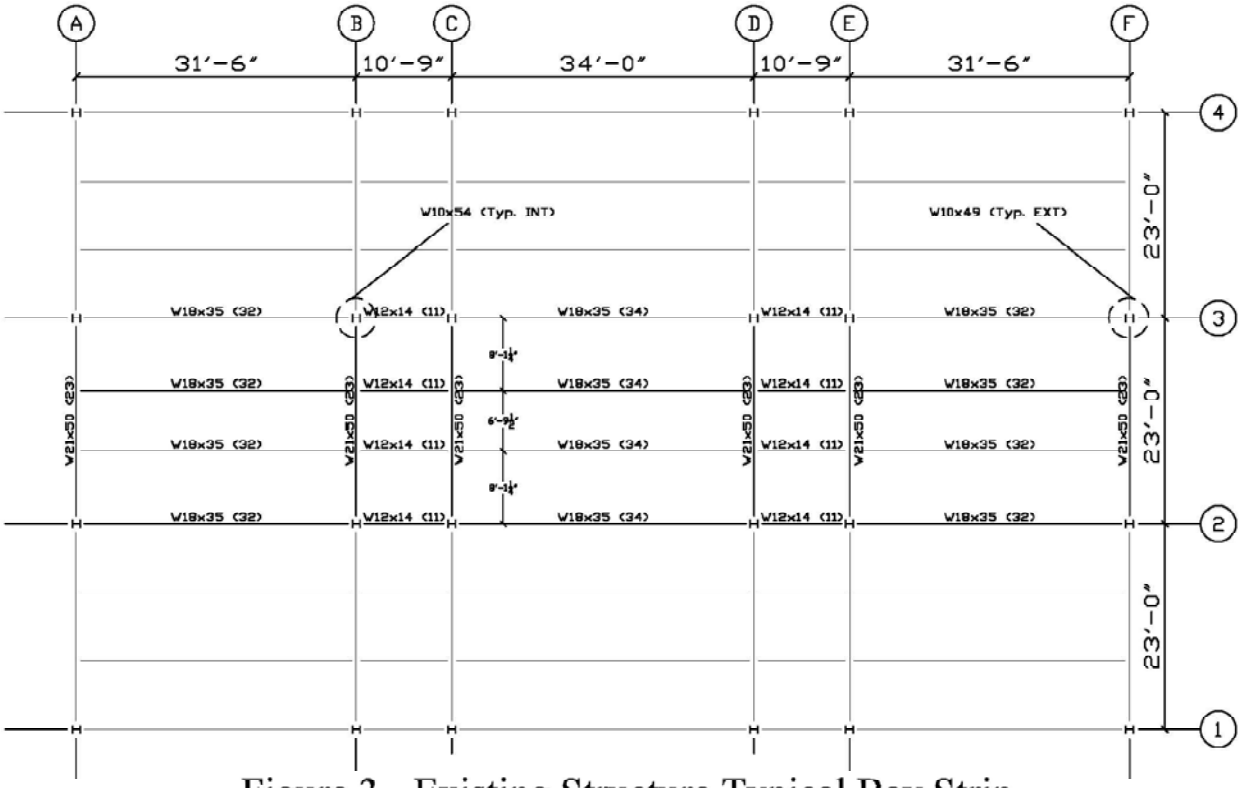

Figure 3 - Existing Structure Typical Bay Strip

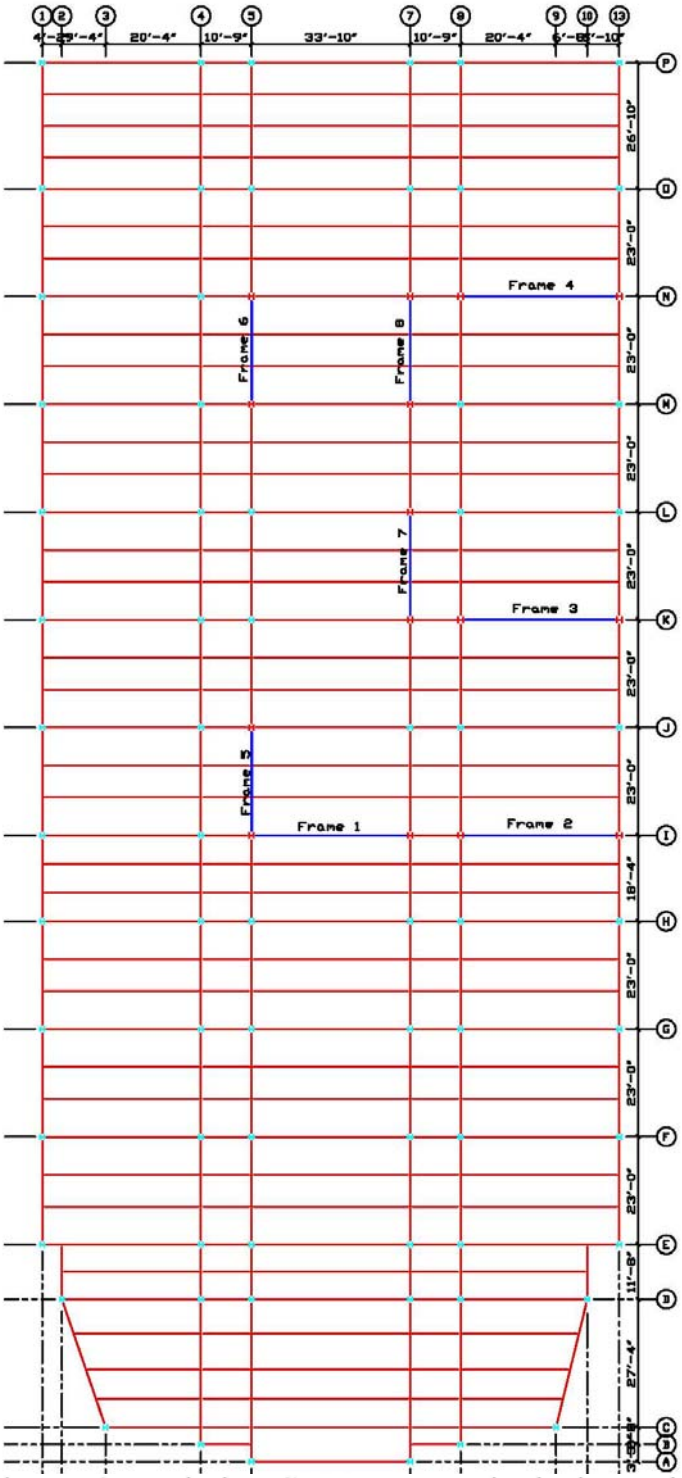

Figure 4 - Existing Structure Typical Floor Plan

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 6 inch rigid insulation on 1½" 22 gage 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 topping 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 sub grade 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.

CODES

ORIGINAL DESIGN CODES:

Virginia State Building Code (VUSBC), 2000 Edition

International Building Code (IBC), 2000 Edition

American Society of Civil Engineers (ASCE-7), 1999 Edition

Building Code Requirements for Structural Concrete (ACI 318-95)

Standard Specifications for Structural Concrete (ACI 301-96)

AISC Code of Standard Practice for Steel Buildings, 2000 Edition

AISC Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design, 1989 Edition

THESIS DESIGN CODES:

International Building Code (IBC), 2006 Edition

American Society of Civil Engineers (ASCE-7), 2005 Edition

AISC Steel Construction Manual, LRFD, 13th Edition

THESIS DEFLECTION CRITERIA:

TOTAL = L / 240

LIVE = L / 360

CONSTRUCTION = L / 360

STRUCTURAL MEMBER SUPPORTING MASONRY WALLS = L / 600

Drift = L / 400

LOADS

SUPERIMPOSED ROOF DEAD LOAD	THESIS DESIGN
TPO Membrane / S.S. metal Roof	3 PSF
4"-6" Rigid Insulation	2.5 PSF
Ceiling Finishes	5 PSF
Mechanical / Electrical	6.5 PSF
Sprinklers	2.5 PSF
TOTAL	19.5 PSF

SUPERIMPOSED FLOOR DEAD LOAD	THESIS DESIGN
Ceiling Finishes	5 PSF
Mechanical / Electrical	7.5 PSF
Sprinklers	2.5 PSF
TOTAL	15 PSF

TYPICAL ROOF LIVE LOAD	THESIS DESIGN	CODE REFERENCE
Minimum Roof LL	20 PSF	ASCE 7-05 Section 4.9.1
Ground Snow Load (Pg)	25 PSF	IBC Figure 1608.2
Importance Category III	Is = 1.10	IBC Section 1604.5
Exposure Factor	Ce = 1.0	IBC Table 1608.3.1
Thermal Factor	Ct = 1.0	IBC Table 1608.3.2
Flat Roof Snow Load	19.25 PSF + Drift	IBC Section 1608.3
Drift	Varies	ASCE 7-05 Section 7.7

FLOOR LIVE LOADS	THESIS DESIGN	ORIGINAL DESIGN	ASCE 7-05 MIN VALUE
Classroom	50 PSF	50 PSF	40 PSF
First Floor Corridor	100 PSF	100 PSF	100 PSF
Above First Floor Corridor	80 PSF	80 PSF	80 PSF
Offices	50 PSF	50 PSF	50 PSF
Light' Storage	125 PSF	125 PSF	125 PSF
Mechanical	150 PSF	150 PSF	n/a
Green Roof	100 PSF	100 PSF	n/a
Library Stacks	150 PSF	150 PSF	150 PSF