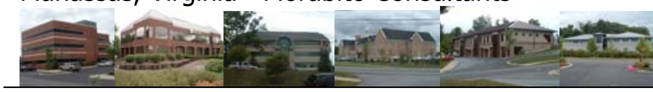


EXECUTIVE SUMMARY

The Signal Hill Professional Center is a four story suburban office building thirty miles west of Washington along Interstate 66. A typical prototype of Northern Virginia suburbs, this building features 68,000 square feet, including four aboveground floors of open office areas and one underground parking area. Where the parking area extends beyond the footprint of the office structure, a driveway wraps around the building, providing access to the first floor.

What is not typical of this building is that it incorporates a composite steel system over its typical 20’-0” x 30’-0” bay to accommodate larger spans, heavier loads, and smaller floor section depths. Though aesthetically it may resemble surrounding office buildings, structurally, most buildings in the area are concrete. Where height restrictions in nearby Washington dictate that most new office buildings and residences use concrete systems to reduce floor section depth, the corresponding construction field and local labor have come to specialize in concrete. Therefore, with these regional influences combined with complicated connections between the undulating parking area and first floor diaphragm, it seems quite unusual that this building would be designed in steel.

Therefore, as a Senior Architectural Engineering Thesis Project:

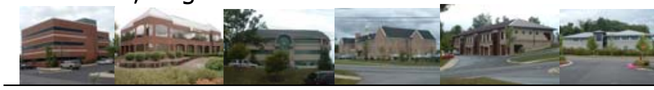
- The Signal Hill Professional Center will be redesigned as a flat-plate concrete system. The benefits of this system, from reduced vibrations to simplified connections to smaller floor section depths, will be compared to the benefits of a composite steel system. The architectural implications of a new column layout must be assessed.
- To improve the sustainability and livability of the structure, a green roof system will be added to the already-flat roof, which should improve thermal resistance, reduce runoff, and add additional space to the building. Both the steel and concrete system will be assessed for their ability to accommodate this alteration in terms of gravity and lateral loads. The possibility of access to the green roof will become an architectural consideration.
- Using the M Group Architects, Morabito Consulting Engineers, and R.S. Means as resources, a material takeoff and estimate, along with an approximate construction schedule, will reveal which system is most efficient for the given suburban office building design problem.

INTRODUCTION

The Signal Hill Professional Center is a four story suburban office building thirty miles west of Washington, DC along Interstate 66. A typical prototype of Northern Virginia suburbs, this building features four floors of open office areas and underground parking.

Though from the outside, it looks similar to many nearby office buildings, it features a steel structure, which is less typical for this particular area. Where height restrictions in nearby Washington dictate that most new office buildings and residences use concrete systems to reduce floor section depth, the corresponding construction field and local labor have come to specialize in concrete.

This analysis will consist of two parts: a comparison of steel design to flat plate concrete design to establish which system is most effective despite pressures from the local construction industry, and an investigation of the ease with which a green roof can be incorporated into the building structure to increase its sustainability in an already sprawling location.



EXISTING SYSTEMS

An addition to the Manassas, Virginia Town Center, the Signal Hill Professional Center is a 68,000 square foot office building. Above grade, the building extends four stories with a 75'-0" x 165'-0" footprint, while below grade, the building extends into a one story parking structure with a 110'-0" x 200'-0" footprint. Where the underground parking area extends beyond the boundaries of the office structure, a driveway wraps around the building, which both supports large fire engine loads and undulates to mimic the gradual 20'-0" downward slope along the site.

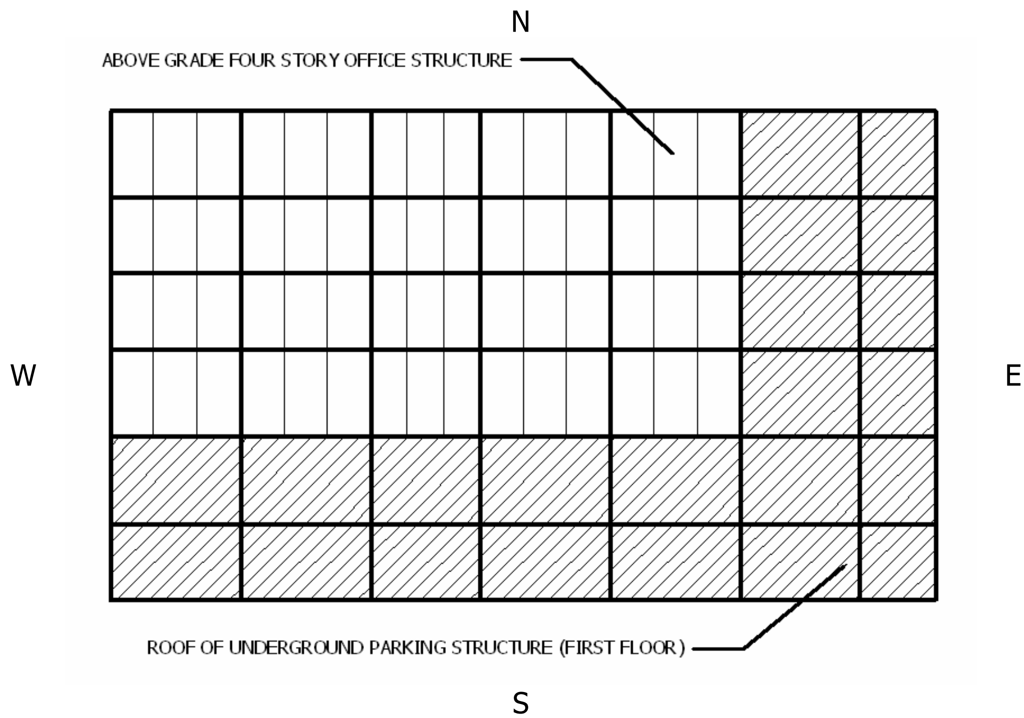


Figure 1. Simplified Floorplan with Office Building and Parking Structure illustrated.

Architecture. Like many suburban office structures, the four floors of office space are generally open, oriented around a central corridor space with three elevators and two stairwells. The first floor is more rigidly divided into an east and west section; structural and finish features at the east section have already been designed for a bank. The architectural layout in general does not reflect the structural layout; supporting columns do not coincide with partitions. Floor to floor heights are 13'-4", though drop ceilings provide an 8'-0" ceiling height within the offices.

Gravity Load Structural System. The Signal Hill Professional Center employs a composite steel system, which can support larger loads over longer spans with a relatively light structure. Loads for this structure assumed an open office floor plan, 250 psf fire engine live loads throughout the parking deck, and snow amounts appropriate to Northern Virginia.

- In the four-story office structure, bays are generally 20'-0" x 30'-0", with beams spanning in the shorter direction, spaced 10'-0" on center. Supporting a 3" composite deck with 3.5" lightweight 4000 psi concrete, beams are generally W10x15, resting on W18x35 girders.
- In the parking structure, where beams must support relatively large live loads, bays are similar in size to the office structure, if not smaller. Beams are more closely spaced at 5'-0" on center. Supporting a 2" composite deck with 4.5" normal weight 4000 psi concrete and an additional 4" of asphalt, beams are generally W10x15 or W10x19, resting on girders ranging from W16x26 to W24x76. To accommodate the slope of the site, beams and girders supporting the driveway are angled, connecting to the first floor diaphragm through a system of coped flanges and welded W6 hangers.
- The roof structure is non-composite, with a similar layout to the composite beams in the office structure. Supporting a 3" non-composite deck, beams are generally W12x16 supported by W18x40 girders.

Though this system was proven through a RAMSteel analysis to be sufficient for the given loads, buildings in the greater Washintgon, DC area are primarily concrete due to availability of local labor and talent.

Lateral Load Structural System. Since few walls are continuous from the fourth floor down through the parking structure, a system of moment frames was used for lateral resistance rather than shear walls. These extend on the exterior walls of the aboveground floors, with a total of eight moment-frame bays on the east and west sides, and four on the north and south sides. Beams and girders along these frames were significantly larger than those supporting primarily gravity loads; beams range from W14x22 to W21x44 and columns range from W12x40 to W12x96. In the underground parking area, these moment frames either continue down to shallow footings beneath the slab, or are anchored to 24" x 24" piers adjoining the basement wall through an anchor plate. This design assumes that the basement wall will also act as a shear wall in lateral load resistance.

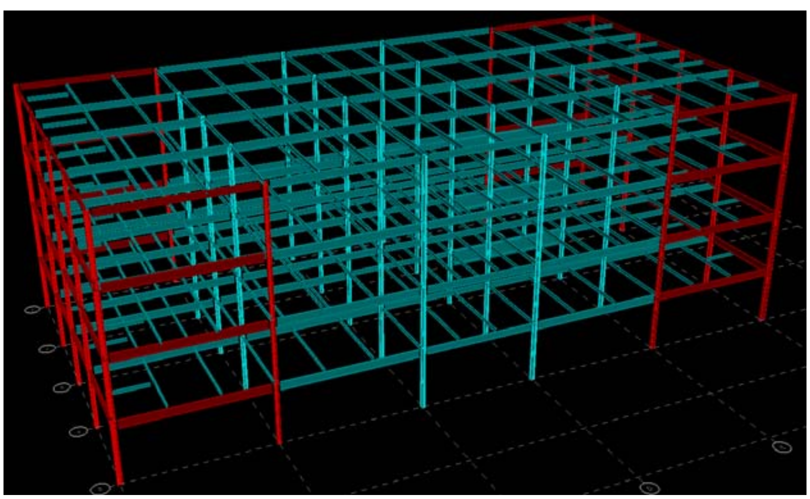
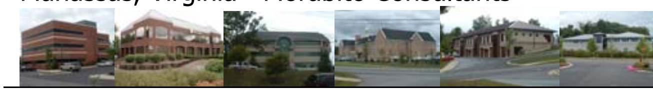


Figure 2. Diagram of Upper Four Floors, with Moment Frames highlighted in Red.



Foundation Structural System. Foundation walls are poured from 3000 psi concrete, and are generally 1'-6" thick and 13'-4" high. Walls and columns rest on a shallow foundation system of strip and square footings.

Mechanical/Electrical/Lighting Systems.

- The HVAC system uses two rooftop units which separately serve the east and west sides of the building through separate duct networks. Though diffusors are laid out in the corridors and lobby, eventual diffuser layout in the open offices are left to the tenants.
- A separate room houses the electrical conduits and panelboards. Both a 277/480V and 120/208V system is available at each floor and an extra panelboard is provided for expansion.
- Though basic T8 fluorescent lamps are provided for safety in office areas, lighting layout and selection is left to the tenants.
- Four risers are used to distribute plumbing throughout the building. While one is used to serve the public bathroom area adjacent to the corridor, the remaining three are distributed throughout the open office areas for future expansion.

PROBLEM STATEMENT

Through an analysis of multiple alternative floor systems, including non-composite steel, steel joists, one- and two-way concrete slab, and concrete pan joists, it was determined that the existing composite steel system worked very effectively to minimize material usage, floor section depth, and building weight. However, the use of a composite steel system in Northern Virginia is quite unique. Where height restrictions in nearby Washington DC dictate that most office buildings and residential structures take advantage of the narrow floor section depths of a concrete slab, construction methods throughout the surrounding area reflect a demand for concrete rather than steel buildings. Therefore, labor for steel construction may be scarce and more expensive.

Additionally, the use of moment connections in moment frames as a lateral load resisting system further reduce the viability of a steel system. These connections are expensive and time consuming, requiring skilled labor. In a similar vein, the complicated connections at between the undulating parking structure and the first floor diaphragm, which use welded hangers and coped beams, would require very skilled labor to construct. Given that labor for concrete construction in the area already outnumbers labor for steel construction, these connections may be even more expensive for Northern Virginia.

DEPTH STUDY

Concrete Structural Redesign. When considering a concrete structural system, a previous analysis of various concrete designs revealed that Concrete Pan Joists would be the most effective with regards to material usage, building weight, and floor section depth. However, this analysis only considered the given 20'-0" x 30'-0" bays. Due to their rectangular size, these bays made two-way concrete slab construction less viable as an alternative.

Given that the cost of construction methods is the main focus of this redesign, rather than reducing building weight or material usage, the more complicated pan-joist construction immediately becomes less viable. Since local labor is most accustomed to the more-easily constructed flat plate system, this building will be redesigned as such. This redesign will require:

- A new structural grid to make it easier to incorporate a two-way slab. Given the current 75'-0" x 165'-0" dimensions of the building, a possible new size would be 25'-0" x 23'-6" bays.
- Sizes for concrete slabs and supporting columns under both open office and parking structure loads.
- A lateral load analysis using concrete moment frames. Concrete weighs significantly more than steel, so the controlling seismic lateral load will increase. Since Northern Virginia does not experience large wind or seismic loads, and since the building is only four stories tall, monolithically poured slabs and columns throughout the structure should be sufficient under given lateral loads. This also eliminates the need for costly steel-connected moment frames.
- An analysis of the exterior fiberglass wall panels and the effect their load has on torsion forces on the concrete frame.
- Consideration for the connections between the undulating parking structure and the first floor diaphragm. Sizes and reinforcement for large transfer beams adjoining the parking structure must be determined.

In addition, the implications of wide columns and a new column grid on office layout must be assessed for space usability.

Methods. To achieve these objectives, concrete and reinforcement design will conform to ACI 318 codes. An initial estimate of slab size would be quickly assessed through ADOSS while a final building model using these sizes will be created on ETABS to assess the total effect of gravity and lateral loads on the complete structure. Special analysis of connections between the undulating parking structure and first floor diaphragm will be completed through hand calculations.

Information provided by Mark Bowles at the M Group Architects and Smith/Midland technical specifications for the pre-cast "slender wall" system will be used to assess architectural considerations such as layout and connections to fiberglass exterior wall panels.

BREADTH STUDIES

Through an analysis of constructability and sustainability, the convenience of a flat-plate system will be compared to a steel system under both given loads and a green roof.

Cost/Schedule Analysis. Upon redesigning the given building as a concrete system, an analysis of cost and construction time using R.S. Means and information from the local architect will be completed. This analysis will require:

- Steel and Concrete material takeoffs and corresponding material costs
- Estimated length of construction
- Local material-related information from the architect and engineer

By ignoring the conditions of the local construction industry, this will show if concrete is actually a more economically efficient system to be used in the Washington suburbs, or if its use is dictated primarily by availability of labor.

Sustainability. Given that this building is in the suburbs of an already sprawling city, it is important that new architecture reflects the need for sustainability. One method to incorporate both economy and livability would be a green roof system, which can raise insulation values in the roof section, reduce water runoff from impervious surfaces, and provide a livable rooftop space. This analysis will require:

- Determination of a green roof system and associated weight.
- Redesign of the roof system for greater dead and live loading.
- Architectural adjustment to allow access to the roof garden area.

Using the greater thermal resistance of soil and plants, a brief discussion of the implication of a green roof on mechanical loads and therefore sizing of the heating and cooling system will be provided.

SUMMARY OF TASKS

Task A – Concrete Redesign

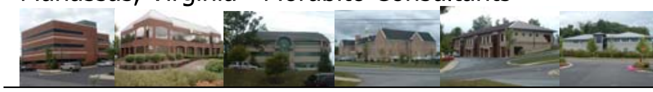
1. Review two-way concrete system estimates for given loads; establish optimal bay sizes and spans based upon space usability.
2. Using ADOSS and given loads, determine preliminary concrete and reinforcement sizes for columns and slabs.
3. Determine new lateral (seismic) loading from new building weight.
4. Build a model on ETABS to be analyzed as a concrete frame for lateral loadings.
5. Hand-design connections between undulating parking structure and first floor diaphragm using ACI 318.
6. Design new connections for the pre-cast exterior Slender Wall system.

Task B – Implementation of Green Roof System

1. Research possible green roof system and determine loads for fully loaded green roof.
2. Determine a new structural system capable of supporting these loads.
3. Assess the effect of the green roof on lateral loads and determine if the concrete or steel lateral system could resist them.
4. Calculate the thermal resistance of a green roof system and compare to the current steel deck and ballast system.
5. Assess implications on the architectural system and possible access to the roof.

Task C – Cost/Schedule Analysis

1. Calculate Steel and Concrete material takeoffs using R.S. Means
2. Determine an approximate construction duration based upon these takeoffs.
3. Using information from Morabito Consulting Engineers and the M Group Architects, assess the viability of each system independent of regional construction preferences.



PROJECTED SCHEDULE

Week of	Proposed Tasks
9 Jan	International Home Show in sunny Orlando, Florida
16 Jan	A1, A2
23 Jan	A3, A4
30 Jan	A3, A4
6 Feb	A5, A6
13 Feb	B1, B2
20 Feb	B3
27 Feb	B4, B5
6 Mar	Spring Break Training at Camp Bob, South Carolina
13 Mar	C1, C2, C3
20 Mar	Technical Report
27 Mar	Presentation Development / Technical Report Editing
3 Apr	Final Paper due Wednesday, 5 April
10 Apr	Presentations begin Monday, 10 April