

Executive Summary

Thesis Proposal

The Renick Education Building located on campus at North Carolina A&T State University in Greensboro, NC is a braced frame steel structure with concrete shear walls. The north wing's fifty-two foot long cantilever, shown below, defines a gateway for anyone entering campus from the adjacent road. This cantilever is constructed out of various wide flanges and steel rectangular tubes linked to the shear walls. Much of the cantilever is carried by two massive trusses, but it demands bracing in the perpendicular direction to deal with seismic and wind loads. The floor system consists of a composite metal deck layout, with shear studs and concrete providing the strength. Below it all is a shallow foundation system that also includes concrete caissons that are typically twelve feet deep.



Renick Building has a complicated jumble of members and materials that create a difficult construction procedure. The proposal which will be discussed over the next semester describes a “what if” scenario. What if the Renick School of Education Building's cantilever truss was built out of reinforced concrete instead of steel wide flange members? What effects would this new structural system have on this architectural blueprint? Will it be more cost effective? Can it be designed and built in a reasonable amount of time? These issues and many others will be resolved in this proposed thesis report to be completed by April 2006.

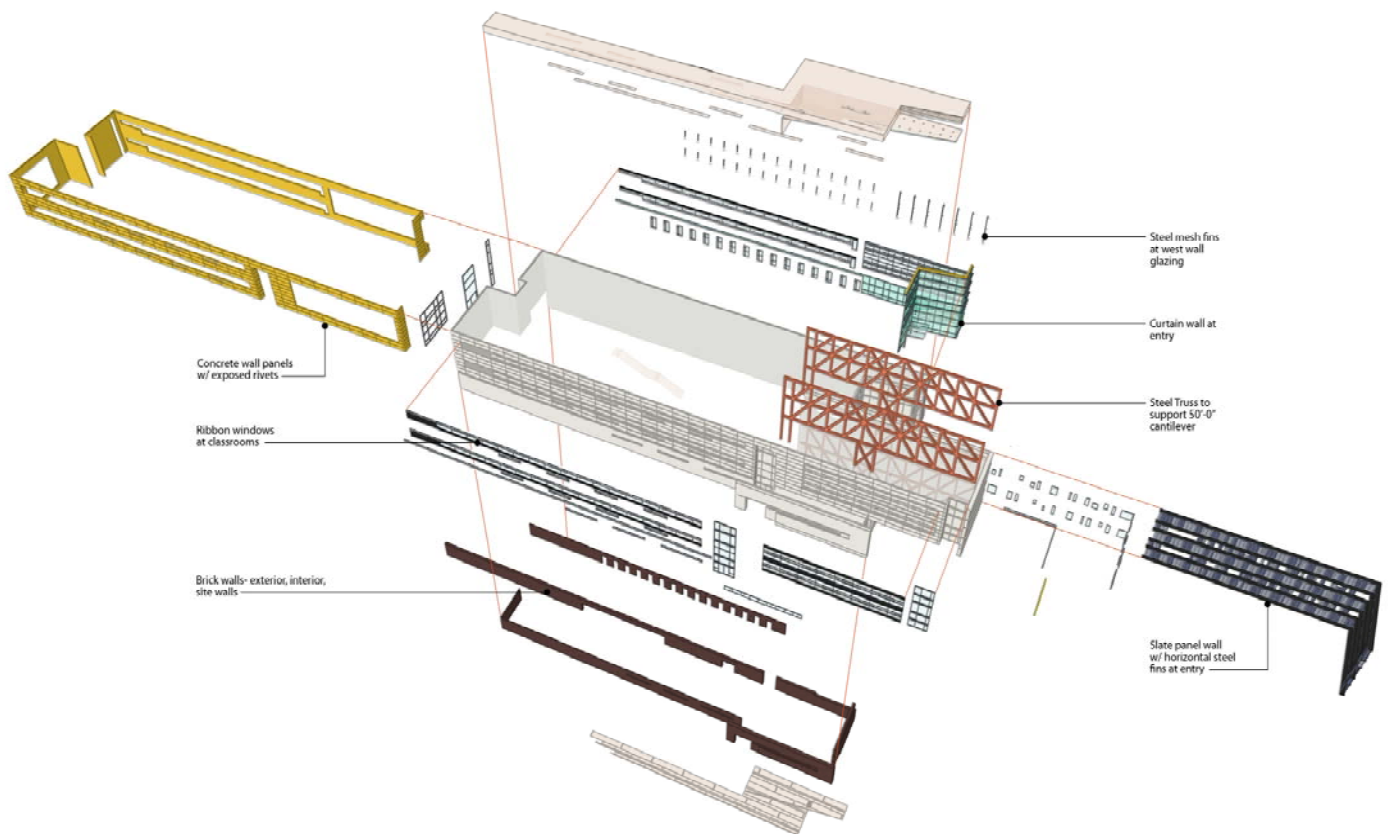
**James C. Renick School of Education Building
Thesis Proposal**

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Introduction

The Renick School of Education Building, located at North Carolina A&T State University in Greensboro, N.C., is classified for instruction and business uses. The 64,000 square foot building has three stories of classrooms and assembly halls, permanent and partitioned offices, and a few laboratories. The primary structural element in the building is a two story high, 52 foot long cantilever and the immense trusses that support it. To isolate this portion of the building, an expansion joint was needed to contain the cantilever's forces within its own structure. This way, the remainder of the Renick Building would only require providing support for itself. For this report, I will refer to the two sections as the northern and southern wings, the northern part including the cantilever. The diagram below shows a detailed sketch of the building's framework.



EXTERIOR ENVELOPE DIAGRAM

Structural Proposal

The northern wing of the James C. Renick School of Education Building's structural system is significant because of the massive cantilever that extends above the sidewalk as a gateway to the central campus of North Carolina A&T State University. The Freelon Group architects threw around a few ideas, including supporting the cantilever with a single column at the very end of its span. But these ideas were put to rest bearing in mind that the preferred design (shown below) is far more intriguing to the everyday person.



Renick Building's Northern Wing - Framing plans are located in Appendix F.

However, architecturally, the north building's huge cantilever wide flange trusses pose a few issues. Most of the interior space on the second and third floors of the cantilever is offices, including one for the NC A&T State University's Dean of Education. Since the structure takes up so much space, there is a great loss of potential external light. Although during design, it is possible the architects chose to demonstrate the shear mass of the structural elements. Nevertheless it could create a brutal impression on the students of North Carolina A&T State University. I propose to analyze some other possible cantilever structural systems and compare them to the current steel trusses. Whether the potential to replace the trusses becomes an opportunity or not, I will gain a broader knowledge of the various capabilities of building materials arranged so to span large lengths unsupported. The basis of my comparisons will range not only structural techniques, but additional architectural engineering breadths, including:

Architectural Fundamentals: such as maximizing external sunlight for energy savings and applying deflection resistance techniques to preserve the building façade.

Construction Management: such as a cost analysis to compare prices of the building's structural elements as well as construction time and labor issues.

Another reason why the current structure might not hold up as the optimum design is long erection time. The floor systems in the truss portion of the building consist of a steel braced frame with

composite steel beams. These beams have shear studs welded in place to help create the composite action with the reinforced concrete floor slab. The welding of shear studs requires a great amount of time and man labor, unless it can be done in the shop and the members are shipped to the site already completed. Either way, the concrete must still be poured on site, and will require approximately 28 days to cure before further work can be completed on the structure. And with the pressing schedules of a state university's calendar, time is of the essence.

The major concerns will of course be structural engineering design. The final thesis report will eventually challenge each separate structure to support its respective live and dead loads plus provide substantial strength against lateral loads without forming excessive deflections or stresses amongst its members. Reverberations along the length of the cantilever must be kept minimal as to not effect the office personal who will occupy the second and third stories of the Renick Building.

Below is a tentative schedule for the spring semester when the bulk of this thesis research will be completed.

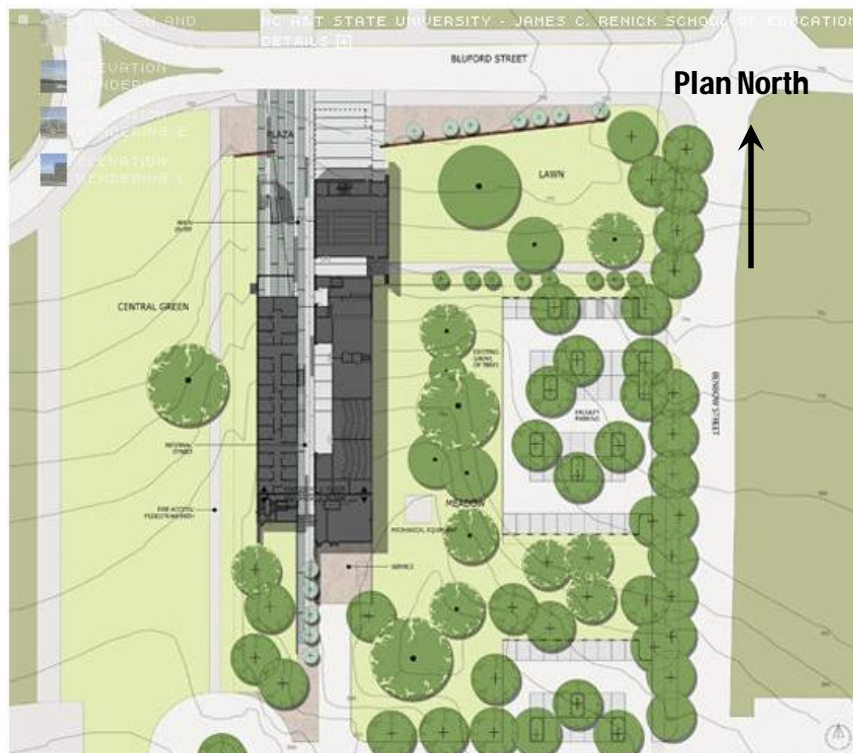
Important Dates		
Jan	9	Classes Begin - Research Concrete Trusses
	16	Choose a Computer Program for Analysis
	23	Decide Truss Layout
	30	Size Members Due To Gravity Loads
Feb	6	Lateral Load Analysis
	13	Connections, Foundation, Other Structural Topics
	20	Address Impacts on Other Breadths
	27	Cost Analysis
Mar	6-10	Spring Break
	13	Construction Schedules
	20	Compile All Calcs & Info
	22	Celebrate 23rd Birthday
	27	Finishing Touches
Apr	3	Finalize Report & Practice Presentation
	5	Report Due
	10	Thesis Presentations
	28	Classes End
May	1-5	Finals

Current Cantilever Structure

A shallow foundation system rests on the existing soil which has a bearing pressure of 3000 psf. The site of the Renick Building slopes from a height of 813 feet above sea level at the southwest corner down to an elevation of 790 feet on the northeast side. This necessitates a basement at the southwest corner of the building, which will have to be designed to withstand overturning moments and horizontal shear.

The shallow footings are made of 3000 psi, normal weight concrete and range in depth from 1'6" to 2'6". The soil samples showed that a shallow foundation system would work very well, especially if the depth does not go beyond a 24" thick footing for frost protection reasons. As listed in the subsurface exploration report, the allowable net bearing pressure can actually be designed for up to 5000 psf, if the footings rest on hard residual material below 790 feet. This happens to coincide very well with the positioning of the columns which support the huge cantilever loads at the northern end of the structure. There are seven cylinder shaped caissons underneath these columns, to help drive the extreme point loads from the cantilever trusses well below the surface to solid rock. The values of these vertical loads could reach as high as 1200 kips. The 6' diameter caissons are all assumed to be approximately 12' deep, depending on the depth of rock below ground level. There is an issue arising about differential settlements in the building's foundation due to the combination of deep caissons and shallow footings. However, the soil below an elevation of 790 feet was found to be a small layer of highly consistent residual soil on top of partially weathered rock, so settlements should be limited. In fact, the soil report insists that most of the settlement will occur during construction is estimated to be less than 1/2".

The 4" slab on grade will also consist of 3000 psi, normal weight concrete and contains 6x6-W2.1xW2.1 welded wire mesh reinforcement at 1/2" down from the top of the slab. It shall rest on top of a 4" thick layer of compacted NCDOT #57 stone.



The steel columns, A992 Grade 50 steel, are attached to concrete footings with base plates that range in size from a 1'2" square, at 1" thick, to 1'8"x1'10", 2" thick. The base plates are all bolted with four A36 or A307 anchor bolts, one at each corner, located at 2" in from the edges. The columns are mostly wide flange members, smallest being W8x24 and largest being W14x132. The lobby, with its glazed façade and open stairwell, is supported with 10" diameter, A53 Grade B structural pipes for aesthetic reasons.

The assortment of horizontal wide flanges can span up to a maximum distance of 42'6" and are as large as W24x55s. These girders and beams are attached to their respective columns more than often using just simple shear connections with ¾" diameter A325 bolts. It is mandatory that the bolts are snug-tight per AISC requirements. The southern wing contains a few full penetration welded moment connections, at the girders that span in the north-south direction.

The girders and beams on the second and third floors will support a 3¼" thick, 4000 psi lightweight concrete slab on 2" 20-gage composite metal deck with a total thickness of 5¼". The roof however consists of 2" lightweight cellular concrete on 20 gage metal deck. The northern wing has 3" Type NS deck and is still supported by the girders and beams. The southern wing, however has a 1½" metal deck carried by open web steel joists, the largest being 30K9s with a span of 42'6".

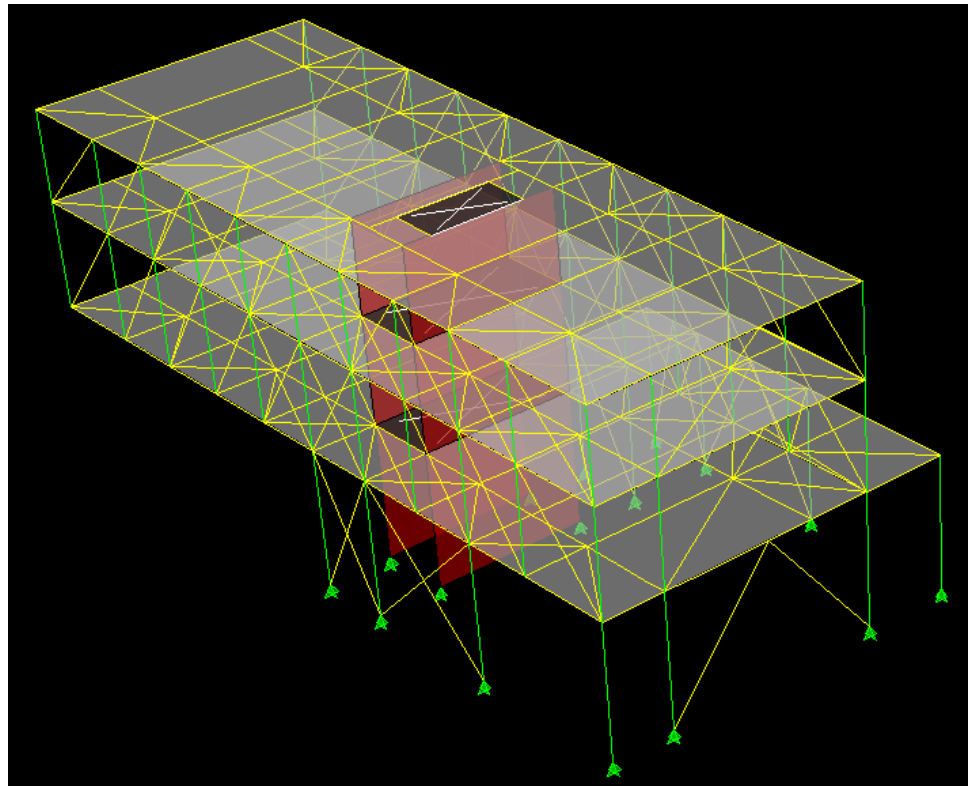
The cantilever in the northern wing of the building is supported by 8 columns and the 2 one foot thick concrete bearing/shear walls. The columns all ascend to a height of 42'8" above the top of the concrete footings. The horizontal girders in the truss that are fastened into these columns are W18x211s at the second floor level, W24x55s at the third floor level, and W14x211s at roof level. These girders see large spans of 43'6", and 52'6", the latter being the cantilever. The vertical and most of the diagonal members of the truss are W14x43s, with the remaining diagonal braces being W14x90. The isometric view, created with the use of ETABS, below shows the north building's structure.

Green lines represent columns.

Yellow lines are girders, beams, or diagonal braces.

The gray areas define the floor slabs.

The red surfaces show the location of the concrete shear walls.



Alternative Cantilever Structure



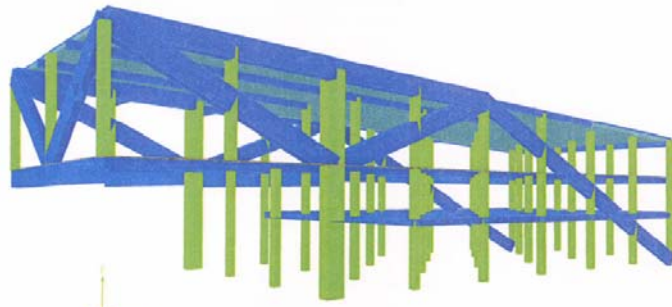
Chongqing Public Library – Rendering Provided by [Axis Design Group](#)

The major structural replacement consideration is a system of concrete columns, beams, and trusses such as the ones designed for the Chongqing Public Library located in Chongqing, China. This 540,000 square foot, six story building is U-shaped, to enclose an outdoor courtyard. The approximately 560 foot long west wing forms the locale for the library itself, while the opposite wing, containing classroom space, is only three stories tall and about 330 feet long. A large lecture hall connects the two wings together at the north end of the building. Due to the building's length, it requires an expansion joint to help protect the structure from excessive thermal expansion and compression. All in all, the building is designed with three divided structural arrangements. The typical bays of these systems are laid out in a $26\frac{1}{2}$ by $26\frac{1}{2}$ foot grid. Typical square column sizes are 2.62 feet, but were reduced where appropriate at upper floor levels and in the classroom wing to 2x2 feet. A few cylindrical concrete tree columns are located within the structure as well, ranging from 3.28 to 3.93 foot in diameters. The tree configuration at the top of the columns will consist of steel pipes laid out in a space frame. The floor construction is most efficiently designed as a .82 foot thick concrete flat slab with 6 inch drop panels located at the columns to help against punching shear. Exterior bays must have spandrel beams, sized at 1x2 feet, as required by Chinese building codes. This allows for a faster construction time, due to simplified formwork and reinforcing layouts.



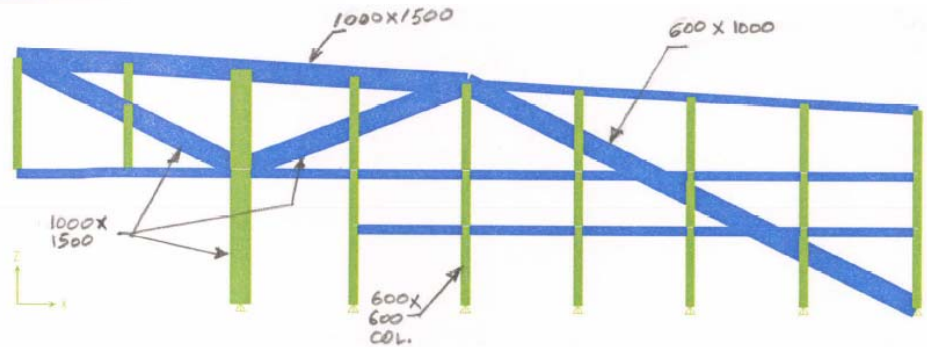
Cork Airport – Example of Tree Columns

One of the major elements of the structure, a 50 ft. x 80 ft. cantilever hanging over the courtyard level, is part of the classroom wing. Preliminary designs prepared by Axis Design Group show two possible structural arrangements for this cantilever. Reinforced concrete diagonal brace designs are commonly used in bridge construction, but two revised schemes were created to fit within the building's scope.

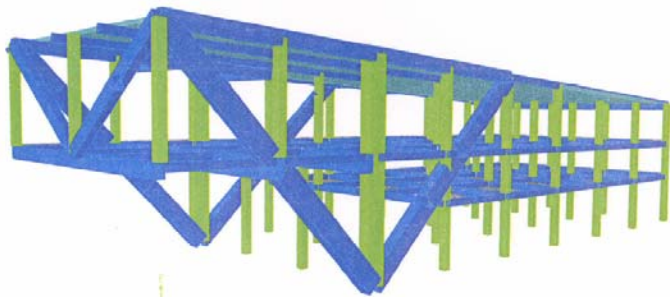


3-D VIEW OF STRUCTURAL FRAMING
 Scheme One

Scheme #1 follows the architect's intended cantilever design by placing diagonal braces above the second floor only. The rectangular concrete braces, with a 3.28x4.92 foot cross section, are able to support the cantilever, despite adding large amount of self weight to the building. There is additional tie bracing, 2x3.28 foot concrete struts, provided from the roof down to the ground.



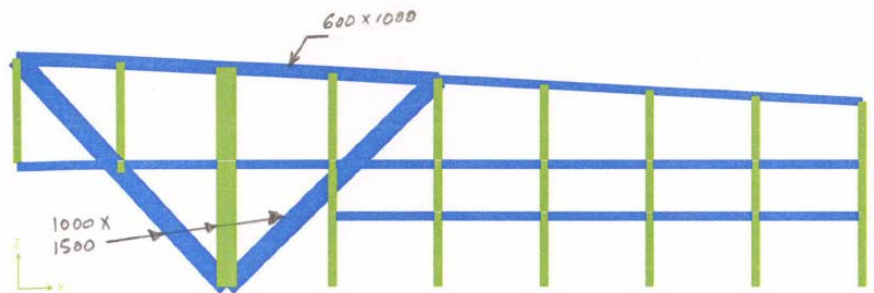
EXTERIOR FRAME ELEVATION
 Scheme One



EXTERIOR FRAME ELEVATION
 Scheme Two

Scheme #2 changes the architectural façade of the cantilever by introducing the concrete braces as ground to roof spanning struts. However, it removes the necessity of having additional ties throughout the rest of the building.

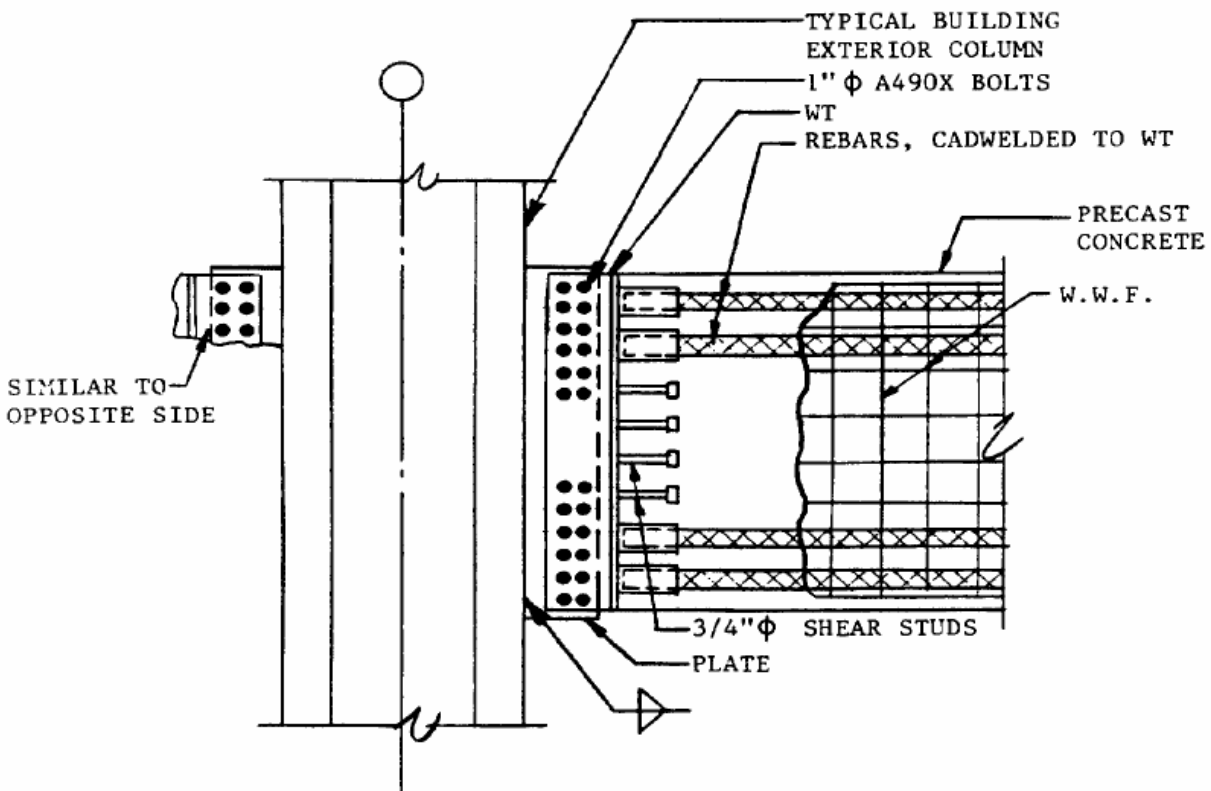
* Renderings supplied by Axis Design Group of Newark, NJ.



3-D VIEW OF STRUCTURAL FRAMING
 Scheme Two

Design Considerations

- Concrete works well in compression, but breaks easily in tension. Steel, however is equally strong in both tension and compression. So, to design a concrete truss, highly stressed tension members must be avoided at all cost.
- Architectural views can be changed greatly by the different sizes of concrete members. The large braces can decrease visibility for residents inside the building. However, there are only two braces that are required to support the entire cantilever.
- Deflections at the end of the cantilever must be kept to a reasonable minimum, as to not effect the façade.
- Floor vibrations are always a concern in cantilevers and can make building occupants very uncomfortable.
- Long term creep is a condition in which the cantilevered concrete can slowly sag over time.
- End connections in a concrete truss can be complicated, as shown below.



Example of a Pre-cast Concrete Connection

Additional Structures

Puente del Alamillo – Seville, Spain

This cable-stayed bridge substitutes the weight of an inclined pylon for one set of stay cables, and creates a dialogue of balance between pylon and deck



Heathrow Airport Hangar – London, England

A concrete-cable system such as this one looks similar to the riggings of a suspension bridge and works like a scale, requiring a balance of weight on either side of the main pillars for stability. This particular hangar uses a large concrete girder to provide the balancing weight opposite the cantilever span.

Philips Nederland – Eindhoven, the Netherlands

This is an example of a suspended building, made of concrete and steel cables. A suspended building is based on the idea of a central compression loaded core with a vertical cable grid hanging from it, supporting the floors around the perimeter of the façade. The cables can be much thinner than equivalent columns, which greatly decreases the building's self weight and enlarges floor and window space. The roof works supporting the cable grid can be difficult to design and expensive to build, but by adding the extra compression on the core ensures it will not be in tension on the windward side.



Conclusions

The Renick Education Building in Greensboro, North Carolina was designed as a combined braced frame steel structure with concrete shear walls. The north building, with its cantilever spanning over fifty feet, is supported by an assortment of wide flanges and steel rectangular tubes, as well as the shear walls. Two large trusses provide much of the strength in the cantilever, but also require braced frames in the perpendicular direction to settle complicated deflection issues. It incorporates a composite floor system which intertwines metal decking, shear studs, and poured on-site concrete with the grid of steel beams and girders. All of these assorted members rest on a shallow foundation system made out of normal weight concrete footings with a few deep concrete caissons directly below the cantilever supporting steel columns.

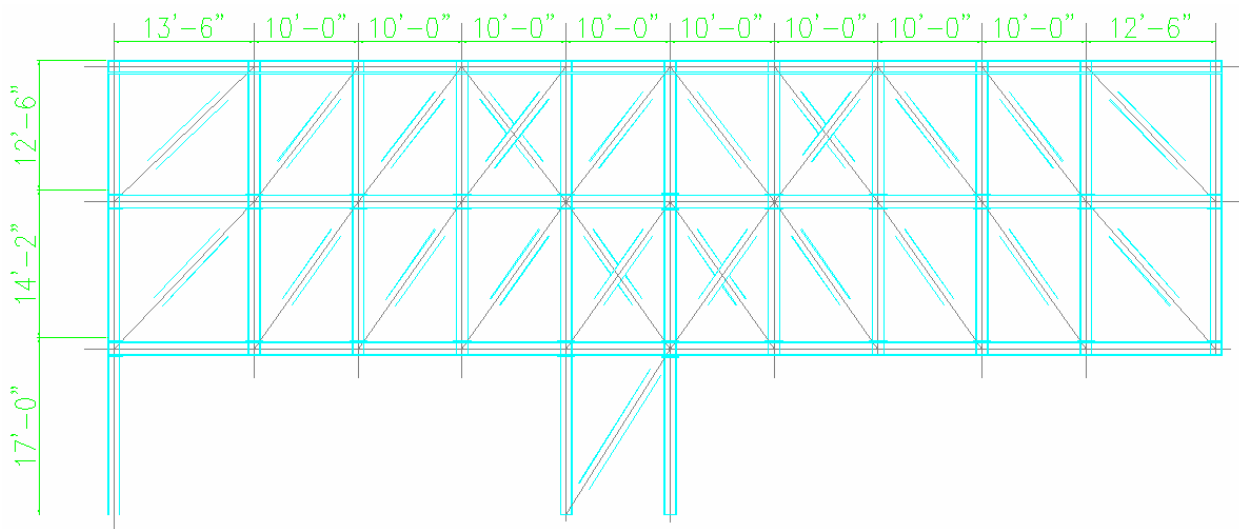
The structural system of the Renick Building calls for a wide variety of pieces that make for a complicated construction process. The goal of this proposal is to address possibilities of change within the structure that can affect the overall integrity of the building. Altering the existing structure into a concrete system and analyzing its full potential as an architecturally sound building with first-rate engineering could provide enough results to discuss which type of material would be best for the cantilever trusses of North Carolina A&T State University's newest, most inspiring structure.



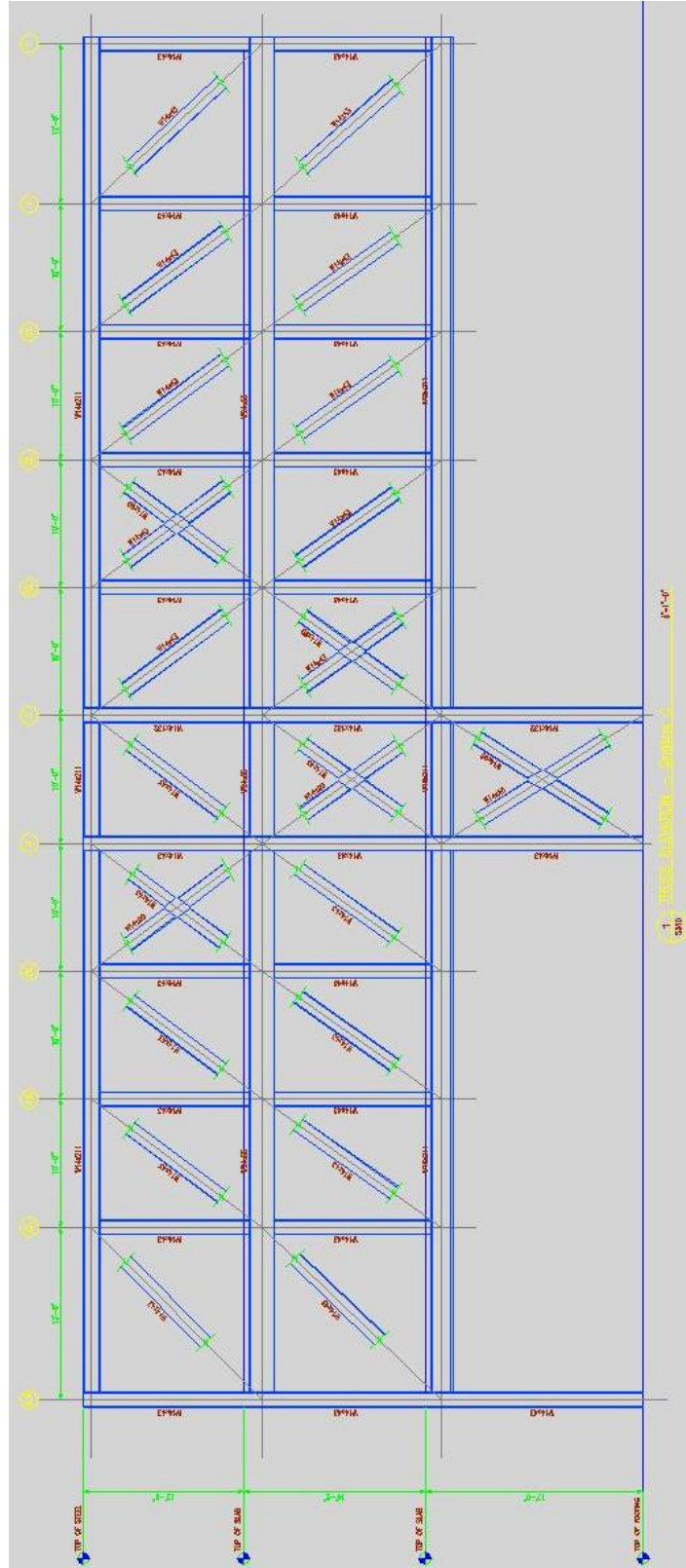
Appendix – Existing Structure



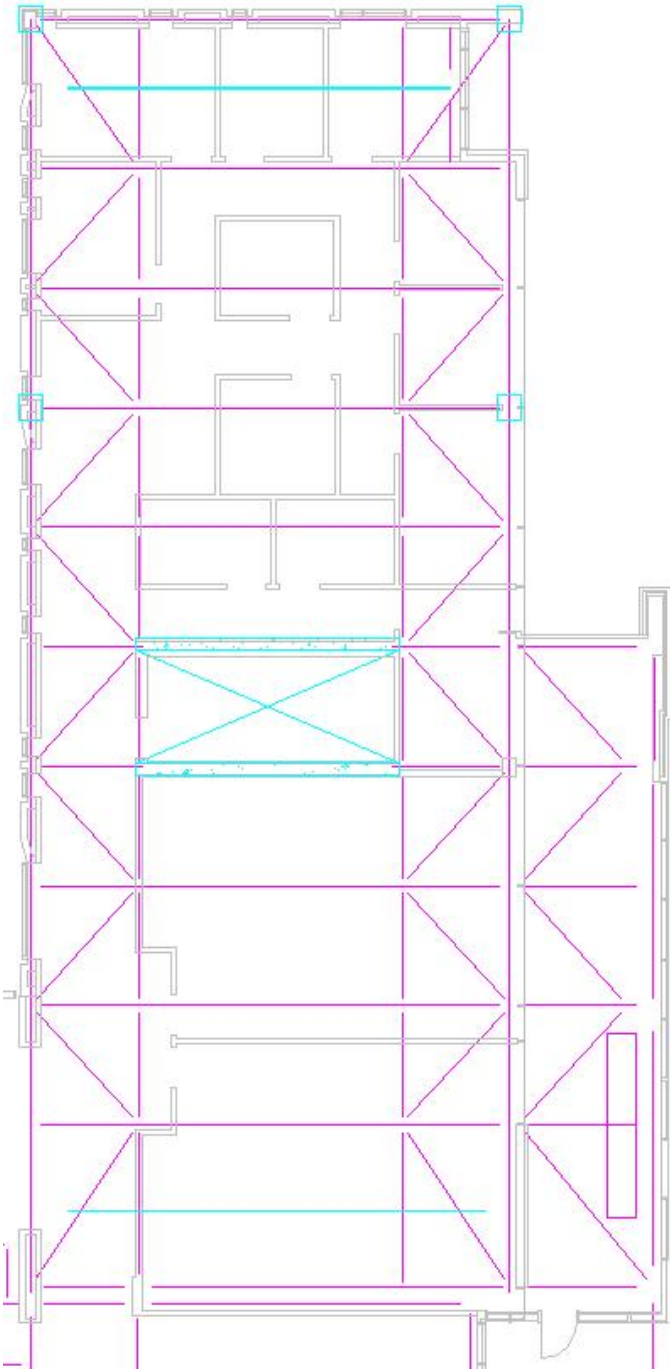
Floor Plan with North Building Defined



North Building Elevation



North Building Framing Elevation



North Building Framing Plan