Chris Shelow
Structural
Advisor: M. Kevin Parfitt
Koshland Integrated Natural Science Center
1/16/06
AE 481W

Senior Thesis Proposal

Executive Summary

The Koshland Integrated Natural Science Center is a four story science facility on the campus of Haverford College in Haverford, PA. This unique building is the new home to the departments of astronomy, biology, chemistry, computer science, mathematics, physics, and psychology at Haverford. The numerous state-of-the-art laboratories that consume the building are just one of the many innovative design features of this structure. The KINSC is also directly adjoined to two smaller existing science facilities, Sharpless and Hilles Halls. However, the KINSC acts independently as a structure from the two connected Halls due to several expansion joints found throughout the structure. The credit for this remarkable institution belongs to Ayers/Saint/Gross Architects and Planners, CUH2A Engineering, Skanska, and Earl Walls Laboratory Planners.

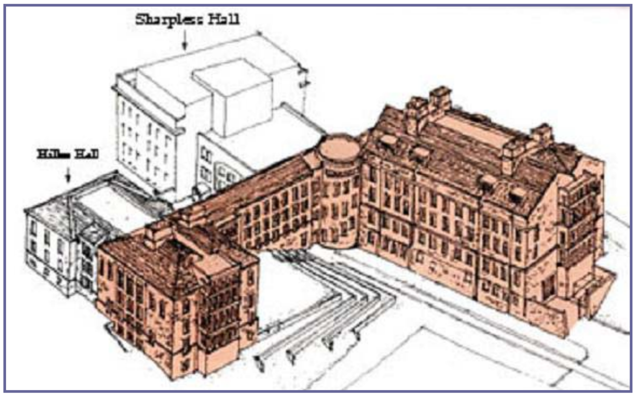
The focus of this proposal is to investigate an alternative structural system for the KINSC. Throughout this study, research will be done to compare the existing precast concrete structure to an alternative possibility of a steel framed structure. A composite floor system will be implemented as the alternate floor system to be compared to the existing precast hollow core plank flooring. In addition, the existing lateral force resisting system of precast concrete shear walls will be compared to a lateral system of steel braced frames. The software design program, RAM, will be utilized throughout this design process. A 3D model of the KINSC will be created in RAM and the proper gravity and lateral loads will be applied to the model. The program will aid in sizing the members to ensure that they will efficiently carry the loads. Several spot checks will be conducted to guarantee that the design output from RAM is accurate and useable. The resulting data from the new design will be calculated in order to be compared to the existing structural system.

In addition, breadth studies of CM issues, such as a cost estimate and construction schedule, and architecture of the structure will be conducted. These studies will also be compared to the existing conditions of the project. The comparisons of all the given categories will provide an answer as to which system is the more effective and more efficient system overall.

Building Introduction

The construction of the Koshland Integrated Natural Science Center, located on the Haverford College Campus in Haverford, PA, was completed in 2003. This four story structure is comprised of various spaces, such as offices, classrooms, and a multitude of laboratories. Each floor height of the building is approximately 13', resulting in a building height of 52'. The primary material used in the KINSC is precast concrete. Although the KINSC looks very similar to the Sharpless and Hilles Halls, to which it is directly adjoined, the appearance of the new science center is definitely a wonderful addition to the campus.

The total gross area of the entire building was calculated to be 185,423 square feet, with a total cost nearing $43 million. Laboratory space and lab support areas definitely account for the majority of the total area. The space breakdown of the KINSC indicates that the lab spaces accumulate nearly 66,000 square feet alone, which is about 73% of the total building space. Although the total gross are of the building is nearly 186,000 square feet, this does account for some of the spaces located in the Sharpless and Hilles Halls, which are joined with the newly constructed KINSC. The new construction of the KINSC claims approximately 120,000 square feet of this area, and about $38 million of the total cost. As seen in the spacial breakdown table below, the new science center houses a number of laboratories, classrooms, offices, communal spaces, and a library. The new facility is home to the departments of astronomy, biology, chemistry, computer science, mathematics, physics, as well as psychology. This explains why the KINSC was designed and constructed to be seen as a "laboratory for the 21st century." The innovative features of the labs as well as the aesthetics are meant to stand out as "state-of-the-art" (Case Study). The science center was designed with two main wings of the building, the East and West Wings, with a section of the building that serves as the connecting corridor between the Wings, known as the "Link". An additional design of the building involves the central core, which is a spiral stairwell, serving as the main entrance to the building. A remarkable display of engineering is present in this stairwell as the stairs cantilever out of the cylindrical exterior wall as they spiral upward.



KINSC Space Breakdown

Function	Size (ft^2)	% of Total Space
Labs/lab support	65,477	72.5
Classrooms	8,330	9.2
Communal/interactive spaces	8,963	9.9
Library	7,483	8.3
Total net sq. ft.	90,253	
Other	95,170	
Total gross sq. ft.	185,423	

The complete design of the KINSC is accredited to a number of very reputable firms, such as Ayers/Saint/Gross who were the architects on the project. CUH2A were the engineers for the science center with Skanska as the General Contractor/CM. Earl Walls Associates were the Laboratory planners for the building. This team of professionals worked together to produce an incredible science facility that will be considered state-of-the-art for some time.

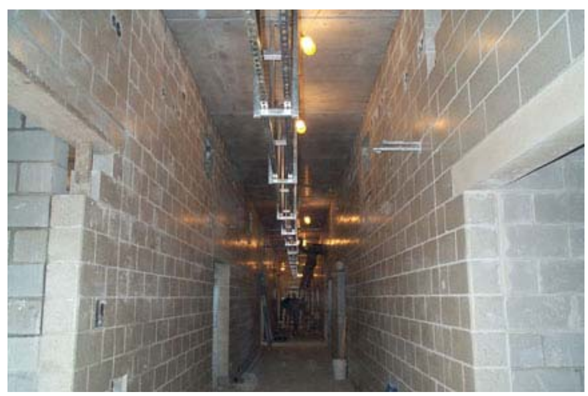
The Structure

The primary material chosen for the design of the KINSC was precast concrete. This material was utilized for the design of nearly all framing members as well as most lateral force resisting members. Throughout the typical floors of the building, precast columns and beams are used to frame the precast concrete hollow core plank floor system. In addition, the lateral system consists of precast concrete shear walls. However, the roof framing of the KINSC is comprised of steel w-shapes that form a trapezoidal bent-shape. Also, CMU block walls are located at several locations throughout the building, including bearing walls, foundation walls, and elevator shafts. An interesting and important feature of the KINSC is the existence of several expansion joints found among the building. There are expansion joints that separate each wing of the building from all other adjoining structures, thus allowing each wing to act as independent buildings. The first expansion joint separates the West Wing from the adjoining Hilles Hall and the Link. There is another that sets apart the Link from the connecting Sharpless Hall as well as the East Wing. And finally, there is an expansion joint that further separates the East Wing from the remaining portion of Sharpless Hall. Therefore, the KINSC is considered one simultaneous structure, but behaves otherwise as three smaller independent structures.

The floor framing is similar between the two wings of the building; however, the Link is framed considerably different. The floors of the East and West Wings of the building are framed typically with respect to each wing. In both wings, the floor system is made up of 10” deep precast hollow core planks with a 2” topping slab. The floor system is supported by precast beams that measure either 24”x12” or 12”x20” depending on location. Also in both wings, the precast beams frame into precast columns ranging in

sizes from 18”x26” to 22”x22” depending on location. The reinforcement of the floor system and framing members is unknown, but, as per Technical Assignment #1, the minimum reinforcement necessary for each member has been designed and assumed to be in place. The floor system for the Link remains as the 10” hollow core plank system with a 2” topping. However, the dimensions of this section of the building allow for the planks to span from the exterior walls. This being the case, the exterior walls of this portion of the building are CMU block bearing walls that range from 8”-14” in thickness.

The lateral resisting system in the KINSC is comprised solely of shear walls. Shear walls located in the East and West Wings of the building are 8” precast concrete walls. Steel reinforcement for these walls is also unknown. However, as per Technical Assignment #3, these walls were designed for necessary reinforcement and it was assumed to be present. In addition to these precast shear walls, the CMU walls that structure the elevator cores were also incorporated as lateral resisting elements. In the Link, the only lateral resisting member found is a 10” CMU shear wall. As confirmed in Technical Assignment #3, this was sufficient support against lateral loads for the building. All lateral resisting members are typical in layout on each floor.



Another location where the material used strays from the primary material of precast concrete is in the foundation. The foundation floor is constructed with cast-in-place slab on grade that is reinforced with WWF. Furthermore, the foundation walls are comprised of CMU block ranging in thickness from 8” to 10”. Some of the foundation walls are considered retaining walls and are reinforced in strength by the addition of CMU pilasters. The piers located in the foundation, that are responsible for supporting the first floor of the building, are all precast concrete piers. The piers are supported by square footings, while the exterior walls are supported by strip footings.

Problem Statement

From previous investigation, it became apparent that the existing design of the Koshland Integrated Natural Science Center is the most efficient design on several levels. The design expertise of the professionals who were involved in the KINSC is quite prevalent and was expected to be so. Referencing Technical Assignment #1, the design of the framing member, floor system, and lateral system all exceeded design requirements as per BOCA 93 and ASCE 07. As the comparisons of alternate floor system in Technical

Assignment #2 confirmed, the existing hollow core planking floor system proved to be the most efficient and effective of the five floor systems that were analyzed. Additionally, as proven in Technical Assignment #3, the lateral force resisting system in the KINSC proved to be quite sufficient to carry the controlling lateral loads that act upon the structure. Also, the design of the KINSC meets all code requirements concerning physical restrictions on the building by a considerable amount. Therefore, when considering an alternative design to this building, the final decision did not easily come about. However, I would like to further investigate some other options. I would like to consider redesigning the structural system of the existing KINSC at an attempt to find an equally effective or more efficient system.

To determine whether a different system is more efficient, it will be compared to the existing system in a number of categories. These categories will include, but are not limited to being the most cost effective, ease of constructability, most efficient construction schedule, material availability, better and longer performance, code limitations, and building standards. This proposal will research an alternative system that could possibly prove to be a more viable solution than the existing system in any of these categories.

Problem Solution

As a viable solution to an alternate structural system for the KINSC, the first modification to be considered is altering the framing of the typical floors to an entire steel frame. A transition from precast concrete to steel framing seems to be a logical comparison for this structure. This will consequently affect the footings, the foundation, as well as many other aspects such as CM issues like schedule and cost, and possibly architecture. In addition, since the controlling lateral load case is seismic, changing the building framing to steel may reduce those loads due to stiffness. A second adjustment will be to change the floor system from hollow core planks to a composite floor system while maintaining a similar floor depth and similar spans. As confirmed by Technical Assignment #2, a full composite floor system is a reasonable option for this building. Furthermore, I would like to change the lateral force resisting system to a braced frame system. The purpose of making these alterations to the structure is simply to investigate the overall affects they have on the project, whether the results be positive or negative.

All relative structural elements of the building will have to be considered throughout this alternate design. This includes, footings, the foundation, floor systems, beams, columns, fire protection, interior and exterior walls, and the roof. Obviously, since the redesign incorporates a different primary material for the building, in this case, steel, the sizes of basically every member will be altered. This, in return could give cause for the layout of the structural members to change as well. The floor spans and location of the floor framing members will remain unchanged where it is possible. However, should rearranging of the structural elements result in a more effective layout, this alteration will certainly be implemented. In addition, the expansion joints found throughout the building will remain a part of the redesign to maintain the independent behavior of the three sections of the building. When dealing with the lateral system, braced frames will take the place of shear walls to distribute the lateral loads that act on the structure.

Location of these steel braced frames will be carefully decided to possibly offer a more efficient lateral load resisting system. The design results of this alternative system will be thoroughly compared to the design of the existing system with hopes of proving to be a more viable solution.

Solution Method

In Technical Assignment #3, the design software package known as ETABS was used in the analysis of the lateral system of the KINSC. With the help of some short seminars and tutorials, the program proved to be quite user-friendly and easy to use, and it was a very good method for analysis at that point in my thesis study. ETABS served as a good analysis program for investigating the lateral system of the building, however a different design program may be used for the alternate design of the structural system. The use of RAM will most likely be the primary means of computer design for this study of an alternative system. A 3D model of the KINSC will be created in RAM and all steel structural members will be sized according to the calculated loads that will be applied to the structure. All aspects of the steel design will be based on the Manual of Steel Construction, Load and Resistance Factor Design, 3rd Edition. Also, all concrete design will be in accordance with the ACI-02 code, and all lateral loads will be based on the ASCE7-02 regulations. The IBC 2003 will be followed strictly throughout the design. The design and analysis performed through the use of RAM will include both gravity and lateral loads applied to the structure. While designing the floor system, alternate floor layouts, including member sizing, spacing, and direction, will be considered. Based on the results, the most effective floor system will be utilized.

Breadth Studies

As part of this thesis study, two breadth studies will be performed. The first study will be an involved investigation of some CM issues. The two primary issues that will be targeted are project cost and construction schedule. These two issues will be compared for both, the existing and alternative system. The cost estimate will be influenced by factors such as construction schedule, material availability, construction financing, as well as project deadline.

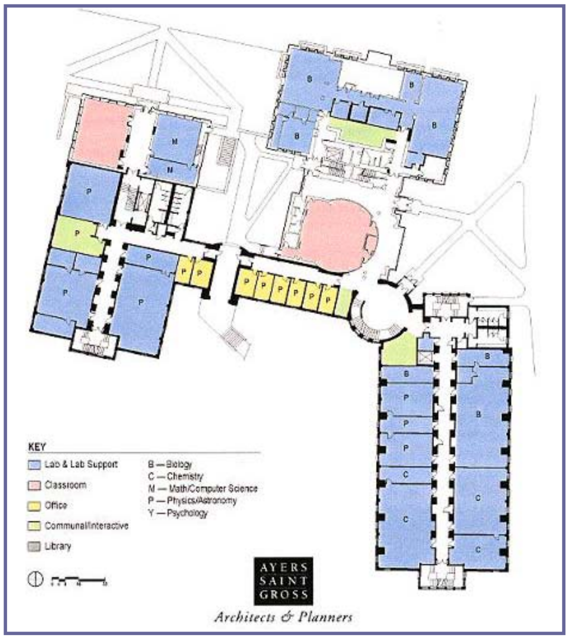
The second breadth study that will be performed is an investigation of the architecture of the alternate design. The use of steel as opposed to precast concrete may affect the layout of the structural elements. Should this be the case, the architecture of the KINSC could be altered. Another reason that the architecture of the building will be studied is the fact the existing adjoining buildings, Sharpless and Hilles Halls, have been constructed out of concrete. The current architecture of the KINSC coincides with the architecture of the two Halls. Therefore, with the alternate system changing the KINSC to a steel building directly adjoined to two concrete buildings with similar architecture, the architecture of the KINSC will need to somehow comply with the other two buildings.

Tasks and Tools

In designing an alternate system for the KINSC, the first step that needs to be taken is to define the gravity and lateral loads that are acting on the buildings. A majority of these loads will be referenced from the Technical Assignments. However, some loads will change due to the change in material and layout of the floor design. The second step in the process is to build an accurate 3D model of the KINSC in the design software to be used, which will be RAM. The correct spans and heights will be inputted with care according to the existing layout of the structure. Next the gravity and lateral loads that have been calculated will be applied to the 3D RAM model. From these loadings, RAM will output member sizes that have been designed to carry the applied loads. However, limitations such as certain member depths will be specified to ensure that the RAM output can be used effectively.

The next step will involve checking the layout of the building according to the member sizes. If all member sizes allow for the structural elements to remain as they were laid out in the existing structure, then rearranging of the structural framing will not be necessary. Also, the design of the floor system will be conducted simultaneously with the sizing of the members. This will be done both, with the use of RAM as well as by hand calculations. In addition, several spot checks of a typical bay will be conducted on several members of the building, including a column, beam, girder, slab, braced frame, footing, and a typical steel connection.

The final step will involve calculating the data for the required categories of comparison and ultimately comparing the alternate system to the existing structural system of the KINSC. Included in this final step of the study, the breadth studies will be carried out. As many of the comparison categories are carried out, the cost estimate and construction schedule will be investigated. In addition, once the layout of the building is concluded, the architecture study of the building can be carried out. This will involve making sure that the plan layout corresponds with the architectural layout of the building. Also, architectural decisions will be made based on the architecture found on the Haverford campus, including the two adjoining Halls.



Thesis Timetable

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Load definitions/calculations								
3D RAM model constructed								
Floor system designed by hand								
RAM model designed/analyzed								
Check layout of floor								
Architecture breadth study conducted								
Spot checks of structural elements								
Comparison criteria calculated								
CM breadth study conducted								
Alternate & Existing systems compared								
Prepare presentation								
Presentation								
Review								

	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
Load definitions/calculations	*S*						
3D RAM model constructed	*P*						
RAM model designed/analyzed	*R*						
Floor system designed by hand	*I*						
Check layout of floor	*N*						
Architecture breadth study conducted	*G*						
Spot checks of structural elements							
Comparison criteria calculated	*B*						
CM breadth study conducted	*R*						
Alternate & Existing systems compared	*E*						
Prepare presentation	*A*						
Presentation	*K*						
Review							