CE 490H

Structural Building Design Selection for Sukup Hall, Elings Hall, and the Advanced Teaching and Research Building

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Project Introduction

Building Overview

As an engineering student interested in the structural design of buildings, I decided to research Elings Hall, Sukup Hall, and the Advanced Teaching and Research Building (ATRB) and compare the different types of structural systems within these buildings. Elings Hall and Sukup Hall belong to the Agricultural and Biosystems Engineering (ABE) Department. The ATRB is currently under construction for the Biosciences Department. Thus, I felt it was worthwhile to understand how the function of these new facilities influenced the structural design decisions made for these structures.

First, Sukup Hall and Elings Hall serve the ABE Department at Iowa State. Since construction of these buildings began in 2012, the department has experienced significant growth. Even before then, the department needed more space and resources to better serve its students. Thus, it was ideal to construct new buildings to bring the entire department under one roof.

Sukup Hall is a research and laboratory facility that contains special laboratory equipment and machinery. It is designed as a reinforced concrete frame, which best suits this function. Elings Hall is an office building for the department's staff and faculty. This makes is well suited for a steel framed structure.

The ATRB for the Biosciences Department at Iowa State serves a very similar purpose to Sukup Hall. It is also a reinforced concrete structure that will provide research and laboratory space for students and faculty within this department. Similar to the ABE Department's need to provide more space and better resources for its students, the Biosciences Department faces the same challenge and seeks to achieve a solution to this problem with construction of the ATRB.

The following provides greater detail about the purpose of these buildings, their structural design, challenges encountered during design, and some of the owner's considerations for these structures. Thus, it is important to understand how the intended function of each building influenced the structural design.

Purpose of This Project

The purpose of my project is to share my interest in structural design with others who are not familiar with the structural design of buildings. My main goal is to help others understand how the function of Sukup Hall, Elings Hall, and the ATRB influenced the structural design decisions made by the structural engineers for these buildings.

Moreover, multiple criteria help people understand the function of these buildings. These include the different types of loads each building will experience. For example, Sukup Hall's first floor has four high-bay garages that contain heavy equipment and machinery and require a thickened concrete floor to help support these loads. Furthermore, it is important to understand the purposes of different spaces, the types of materials used to construct these buildings, architectural requirements, cost considerations, and how the overall function relates to the structural design. Each of these played an important role when structural engineers designed these structures.

Finally, with this knowledge, one learns how each structure fits a particular function when considering these criteria. This will help others not only understand how these three buildings were built, but also be able to apply it to other buildings as well. Overall, one has the opportunity to learn how to achieve the best structural solution for a building based on its purpose.

Sukup Hall

Purpose

Interviewing the chair of the ABE Department, Dr. Steve Mickelson, gave me insight into the purpose of Sukup Hall and its function. Interviewing Dr. Mickelson helped me understand how this function influenced the design of the structure. Sukup Hall is a teaching, research, and laboratory building. It provides many resources for the five focus areas within the ABE Department. These areas are Land and Water Resources Engineering, Biological and Process Engineering and Technology, Animal Production Systems Engineering, Advanced Machinery Engineering and Manufacturing Systems, and Occupational Safety Engineering (Mickelson).

The first and second floors of Sukup Hall primarily accommodate the Advanced Machinery Engineering and Manufacturing Systems focus area. These floors contain four high-bay garages used to store equipment and machinery. Specifically, this includes tractors, combines, diesel engines, off-road machinery, dynamometers, and even a water jet that cuts through any type of material (Building Floor Plans and Mickelson). Moreover, 26 miles of tubing within the 8-inch thick concrete floor heat and cool these bays when needed.

The third and fourth floors in Sukup Hall serve the Land and Water Resources and Biological and Process Engineering and Technology focus areas. These floors contain wet laboratory space with hoods that require additional ventilation compared to the lower levels of Sukup Hall (Mickelson). After walking through Sukup Hall, examples of these rooms include an Air Quality Mitigation Laboratory, Water Quality Microbiology Laboratory, and a Biomass Treatment Laboratory.

Additionally, Sukup Hall contains traditional classroom space found in any type of university building. These spaces include computer labs and a lecture hall located in the basement level. Dr. Mickelson informed me that any new campus building must contain a percentage of university space for anyone at Iowa State to use. This explains why there is a lecture hall in the basement level of Sukup Hall.

Furthermore, Sukup Hall is built to accommodate the rapid growth within the ABE Department which has experienced a 38% increase in student enrollment the past five years for a total of 900 students as of Fall 2016 (Mickelson). In particular, the department merged with Industrial Technology about 12 years ago to add an additional 175 students. (Mickelson). Moreover, the department added Agricultural Biosystems Engineering to its program 8 years ago (Mickelson). This growth shaped the need for new and better facilities, which is the reason for construction of Sukup Hall.

Finally, considering the function of Sukup Hall leads one to understand how this structure is designed. With this background information, one will understand the design of the building from a structural engineering perspective, which is the main goal of this project.

Structural Design

Loads

After understanding the function of Sukup Hall, one can learn how this influences the structural design of the building. Before exploring the reasons why Brad Stork, the structural engineer for this facility, made certain design decisions, it is important to understand the various loads the building will experience. Buildings are designed to resist a number of different loads. The typical loads a building is designed for include gravity loads such as dead loads, live loads, and snow loads, and lateral loads including wind loads, and earthquake loads. In Iowa, the first four loads are usually of primary concern.

Dead loads remain constant throughout the life of a structure and include the structure's own weight, superimposed loads such as mechanical equipment that hangs from the ceiling, wall partitions, and other objects that will not move over time. Live loads vary in intensity and location throughout the life of a structure. These may include people or moving equipment. Snow loads are due to snow accumulation on the structure. Wind loads and earthquake loads impart horizontal forces against structures in addition to vertical forces. Overall, building codes such as the International Building Code or ASCE 7-10 Minimum Design Loads for Buildings and Other Structures determine the magnitude of these loads so they are properly designed for.

Since Sukup Hall contains a large amount of laboratory equipment and heavy machinery, the typical room is designed to accommodate a live load of 100 pounds per square foot (psf). After interviewing Mr. Stork, he informed me that during the design stage, he knew Sukup Hall would contain laboratory equipment, and since the exact type and location of this equipment was unknown at that time, the laboratory spaces are conservatively designed for a live load of 100 psf. Similarly, he informed me that the mechanical spaces are designed to accommodate loads of 100 psf.

These design loads make sense because Sukup Hall currently contains heavy machinery and equipment within the building. Designing for these loads ensures the structure will adequately support them. Moreover, the structural plans give additional loads Sukup Hall is designed for. For example, corridors are designed for 100 psf and stairs are designed for 100 psf. Thus, by understanding the machinery and equipment that Sukup Hall holds, one understands why it is designed for a live load of 100 psf.

Structural Framing System

After understanding the loads Sukup Hall carries, one can study the structural system selected for this building. For this structure, Mr. Stork selected a reinforced concrete frame. This is ideal for a laboratory and research building because compared to a steel structure such as Elings Hall, reinforced concrete provides more mass that helps carry larger loads and resists vibration (Stork). Sensitive laboratory equipment and heavy machinery that impose considerable loads on the structure could be affected by vibration. A reinforced concrete frame is ideal due to its rigidity and stiffness. Thus, this is the main reason why Sukup Hall is a reinforced concrete frame.

The different components of this structural frame include a concrete floor slab, joists, beams, columns, shear walls, and a shallow foundation system. Each floor of Sukup Hall has a typical floor system that consists of 5-inch concrete slabs with 25-inch deep joists. This system utilizes the slab and joists to distribute loads to the concrete girders (beams) that transfer loads to the columns and eventually to the foundation.

Furthermore, the structural plans of Sukup Hall show the concrete beams are 25 inches deep and typically wider than this depth. Mr. Stork informed me the reason for this is based on economics to achieve a cost effective solution for concrete construction. Typically, the cost of formwork needed to pour concrete is a significant portion of concrete construction costs. Thus, it is efficient to form and pour all of the concrete beams and joists to a constant depth even if some of the beams need to be wider than their depth. This requires only one formwork system from floor to floor instead of multiple pieces of formwork for different depths that helps save money.

Additionally, the beams are slightly wider than the concrete columns. Mr. Stork informed me this spreads out the beam reinforcement to prevent congestion with the column reinforcement where the two intersect each other. Most of the columns are 20-inch square columns while a majority of the beams is 30 inches wide. This layout provides sufficient space for beam reinforcement to run past the column reinforcement.

Following the description of the slab, joist, and beam system in Sukup Hall, one can analyze the lateral load resisting system that resists forces due to horizontal wind or earthquake loads. Sukup Hall utilizes two separate lateral load-resisting systems. In the north-south direction, concrete moment frames resist lateral loads. Moment frames provide lateral resistance by moment connections between beams and columns.

In the east-west direction, 8-inch and 12-inch concrete shear walls resist lateral loads. These are located in the middle and ends of Sukup Hall. Mr. Stork informed me that moment frames would be used for the entire structure if there was not a corridor that runs down the middle of Sukup Hall. This prevents beams on either side of the corridor from connecting with each other and thus shear walls are used.

The foundation system in Sukup Hall consists of spread footings and wall footings. This type of system is used because the net allowable bearing capacity of the soil is adequate for this system. At elevations deeper than 950 feet, which is 4 feet below the lower level finished floor elevation of 946 feet, the soil bearing capacity is 7,000 psf for column footings and 5,000 psf for wall footings. Above this elevation, the soil bearing capacity reduces to 3,000 psf for both column and wall footings. Mr. Stork told me this change occurs because the soil becomes denser sand that is capable of supporting greater loads at an elevation of 950 feet or deeper. This reduces the need for a large foundation system and allows spread footings and wall footings to be used in the structure.

It is important to utilize the larger soil bearing capacity because spread footing and wall footing foundation systems (shallow foundations) are cheaper and more economical than deep foundation systems that might have been considered if the smaller bearing capacity was used in design. Opposed to shallow foundation systems, deep foundations such as piles are more difficult to install and much more expensive than spread footing systems. Thus, spread footings are the most economical foundation system for Sukup Hall.

Finally, at the top of Sukup Hall, the roof framing system uses open-web steel joists. Specifically, the KCS Series joists are selected because they allow for concentrated loads to be placed on top of the roof as opposed to K Series joists which are designed for uniformly distributed loads (Standard Specifications: Load Tables and Weight Tables for Steel Joists and Joist Girders 41 and Stork). Since mechanical equipment is placed on top of the roof structure, this gave the mechanical contractor greater flexibility when determining the location of his equipment. Thus, this is the reason this type of joist is used for Sukup Hall.

Challenges

The structural design of Sukup Hall did not come without some unique challenges. One of the first challenges Mr. Stork spoke about with me during our interview was the corridor that runs across the middle of Sukup Hall in the north-south direction of the building. As already discussed, this prevented a moment-frame from being constructed to resist lateral loads in the east-west direction and thus, shear walls are used to resist these loads.

Another challenge in design included details for control joints for the locations where Sukup Hall connects with Elings Hall (Stork). These are required to ensure the buildings operate independently of each other.

Lastly, special detailing is needed for the brick veneer that forms the exterior skin of the building. This detailing is needed to determine how the brick veneer was supported and how to prevent thermal bridging around the interior of the building. In addition, the atrium is a unique structure.

Cost Considerations

As previously mentioned, cost considerations that influenced the structural design of Sukup Hall included using a one-way joist system and spread footings for this building. Compared to other options, these are the most economical and efficient solutions for Sukup Hall's structure. Combined with the function of Sukup Hall as a laboratory and research building, these selections represent how both cost and building function determine the structural design of a building.

Owner Considerations

The last topic to cover about Sukup Hall is considerations of the owner that influenced the design of the building as well as the equipment it contains. The ABE Department required more space for its students to offer them the best education and experience possible. Even with a new building to house the entire department, space was still limited. One solution to this was an alternate basement plan selected for design, which added some extra space (Stork).

Also, Dr. Mickelson discussed with me some items left out of Sukup Hall due to space. First, his department considered putting animal facilities in the lower level and a grain quality initiative. However, there was not enough space and with a project budget $74,500,000, the department could not get everything it wanted.

Furthermore, the department was frugal with its money prior to constructing this building to ensure it would be equipped with the best laboratory equipment and machinery possible (Mickelson). This included saving money for brand new computers, using differential tuition strategically, and focusing on what types of equipment would enhance students' experiences within Sukup Hall. For example, the dynamometer lab contains brand new engines for students to work on and the Advanced Machinery and Manufacturing focus area has brand new mills and lugs to work with (Mickelson). Overall, it was essential to provide brand new equipment with a brand new building.

Likewise, Sukup Hall has helped market the department and recruit new students. Dr. Mickelson told me that rooms are still being named after people and this brings donations into the department. The atrium also draws people to the building because it is a good place for events and student tours.

Finally, Sukup Hall helped the ABE Department achieve the top ranking for both its undergraduate and graduate programs. In the Iowa State Daily, Dr. Mickelson spoke about the affect Sukup and Elings Hall have had on the ABE Department. "'It gave us world-class teaching and research. It made it easier to hire faculties when they know they are going to get the best facilities. It was easier for them to recruit graduate students as well'" (Jallow). Thus, Sukup Hall accommodates for the ABE's departments recent growth and provides the resources necessary for students to obtain a full educational experience.

Elings Hall

Purpose

Elings Hall is an office building for the ABE Department's faculty and staff. The primary spaces in this building include offices, conferences rooms, and classrooms (Building Floor Plans). Unlike Sukup Hall, Elings Hall does not contain any laboratory equipment or heavy machinery that impart heavy loads on the building. Thus, it is designed as a steel structure which is the most efficient and economical structural solution for this building.

Structural Design

Loads

Elings Hall is designed for dead loads, live loads, snow loads, wind loads, and earthquake loads just like Sukup Hall. The main difference between these two structures is the live load requirements. Instead of designing a typical room for 100 psf live load, the structural plans show the classroom spaces in Elings Hall are designed for 40 psf and the office spaces are designed for 50 psf. Thus, the building experiences much lighter loads compared to Sukup Hall. Additionally, the structure itself is much lighter than Sukup Hall because it is a steel framed building with concrete on metal deck.

Structural Framing System

After understanding the loads Elings Hall carries, one can understand why a steel framed structure is selected. Since the loads are lighter than Sukup Hall and Elings Hall does not contain any equipment or machinery that would be sensitive to vibration, a structural steel framing system is the most efficient and economical choice for this building (Stork). Furthermore, a steel framed structure is quicker to erect than a reinforced concrete frame because each concrete floor must cure and reach a specified strength before the next one can be poured whereas steel erection takes place at one time.

The steel framing system consists of wide-flange steel beams and columns and hollow structural steel (HSS) beams and columns. The structural floor is a composite system consisting of concrete on metal deck. Also, the lateral load resisting system utilizes braced frames. These are all typical components of a steel structure.

The structural floor is concrete on metal deck. This acts as a rigid diaphragm that ties the entire structure together. This system is typically a 7.5-inch normal weight concrete slab on top of 3-inch 18 gage (GA) metal deck. Similar to the concrete slab and joist system in Sukup Hall, this transfers loads on each floor to the steel beams.

The steel beams consist mostly of wide-flange beams spaced approximately 11 feet on each floor. Most floors use W18 x 35 beams. This means the nominal depth of the beam is 18 inches and the weight per linear foot of the beam is 35 pounds. Other sizes are used elsewhere in the building. The spacing layout and size of beams are determined from the loading requirements. For example, across the atrium floor adjacent to Elings Hall, the beams are W30 x 99 and spaced 5.5 feet from each other, which indicates the atrium floor experiences larger loads than the main levels of Elings Hall.

Following the description of the floor and beam system, one can analyze the lateral load resisting system. It is quite different from Sukup Hall. It consists of four braced frames to resist lateral loads. Two are oriented in the north-south direction and the other two are oriented in the east-west direction. Mr. Stork informed me this is the most efficient and cost-effective solution for Elings Hall because steel braced frame erection occurs simultaneously with the rest of the steel structure. If reinforced concrete shear walls are used, these need to be poured first before beginning steel erection.

Furthermore, it is important to understand how the structural systems interact with each other. The gravity load carrying system is connected to the lateral load carrying system by the composite structural floor. The gravity load carrying system consists of the beams and columns that are not part of the braced frames. They carry only vertical loads. Lateral loads are transmitted from this gravity load carrying system to the braced frames by the composite structural floor, which acts as a rigid diaphragm to transfer these loads to the braces.

The foundation system for Sukup Hall is the same for Elings Hall. Spread footings and wall footings are used below an elevation of 950 feet to utilize the greater soil bearing capacity that can be achieved at this depth. The lower level finished floor elevation is approximately 4 feet below 950 feet at an elevation of 946 feet. Thus, using a shallow foundation system eliminates the need for a deep foundation system, which would be much more expensive.

Lastly, the roof framing system is similar to Sukup Hall. KCS Series joists are used where mechanical equipment is placed. Since these are concentrated loads, KCS Series joists accommodate for this equipment since the exact location was unknown during design. K Series joists are also used for the roof framing system. These joists are used to support uniform loads (Standard Specifications: Load Tables and Weight Tables for Steel Joists and Joist Girders 41).

Challenges

The same challenges that Mr. Stork faced when designing Sukup Hall also applied to Elings Hall. For the foundation system, footings are below an elevation of 950 feet to ensure the greater soil bearing capacity of 7,000 psf for column footings and 5,000 psf for wall footings can be used. This allows for a shallow foundation system. Moreover, special control joints are needed where Elings Hall meets with Sukup Hall to ensure the buildings operate independently of one another.

Owner Considerations

Elings Hall is home to the ABE Department's faculty and staff. Dr. Mickelson informed me that his department should have constructed a larger building from the beginning because it is already at capacity.

Moreover, the same cost and budget concerns that Sukup Hall faced applied to Elings Hall. The ABE Department had to raise $14,500,000 to begin this project. This was initiated by a $5,000,000 gift from Virgil Elings, an alumnus of Iowa State. Also, having the governor and relevant legislators come to campus and recognize this department's need for more space helped start construction for both of these structures. Finally, Elings Hall provides sufficient space, at least in the meantime, for the growing ABE Department.

Advanced Teaching and Research Building (ATRB)

Purpose

Similar to Sukup Hall, the ATRB will contain laboratory and research space for the Biosciences at Iowa State. Specifically, it will be home to Plant Pathology and Microbiology, Entomology, and Genetics, Development, and Cell Biology (Grief). Like Sukup Hall, this is a reinforced concrete structure.

After interviewing Mark Grief, the Iowa State architect for this project, he informed me this building is under construction due to the shortage of research and laboratory space within these departments. This building will provide more opportunities to students and faculty within the Biosciences to explore their field of study. Furthermore, these departments are spread out over campus and much like Sukup and Elings Hall did for the ABE department, the ATRB will bring all these disciplines under one roof. Finally, this structure is under construction because an increasing number of students are enrolling in STEM (Science, Technology, Engineering, and Mathematics) related fields.

Structural Design

Loads

The loads this building will experience are very similar to Sukup Hall. In particular, Erik Raker, the structural engineer for this building, informed me that dead loads and live loads governed vertical loads and dead loads and wind loads governed the lateral loads. Additionally, each floor is designed for a live load of 100 psf to account for laboratory equipment within the building. Since the exact location of this equipment is not specifically known during design, each floor is designed for 100 psf just like Sukup Hall's laboratory spaces. Also, Mr. Raker pointed out the building will be standing for a long time and in the future, the function of the space may change so conservatively designing each floor for 100 psf ensures the structure will be strong enough to hold any loads it may experience.

Moreover, greenhouses will be installed on the sixth floor. These are designed for 100 psf, which is much larger than normal roof live loads that are typically 25-30 psf. To design for these loads, Mr. Raker told me he assumed dead, live, and wind loads for this level and once the greenhouse loading information was available, these design loads were checked against the greenhouse loads to ensure the design was adequate.

Structural Framing System

The ATRB is a reinforced concrete structure. This is ideal for a laboratory building because it provides more mass than other structural framing systems, which helps, resist vibration for sensitive spaces such as the rooms that will contain microscopes or zebra fish (Grief and Raker). Specifically, this is a pan-joist structure similar to Sukup Hall. Mr. Raker selected this system because it is relatively thin compared to a steel frame with composite decking or hollow core concrete planks on steel beams, two other options considered. Also, this framing system provides its own fire-resistance since concrete is resistant to fire (Raker). Thus, for this six-story structure, a reinforced concrete frame is most economical.

The different components of this structural frame include a concrete floor slab, joists, beams, columns, shear walls, and a shallow foundation system just like Sukup Hall. First, the concrete slab is typically 5 inches thick and the joists are 25 inches deep. This slab and joist system transfers forces to the concrete girders (beams) that transmit these loads to the columns and eventually the foundation system.

The concrete girders (beams) that transfer loads from the slab and joist system to the columns are wider than they are deep. Similar to Sukup Hall, this allows the slab, joists, and beams to be formed and poured simultaneously which is the most cost efficient method when constructing this building. The beams are 25 inches deep just like the joists but vary in width. In addition, Mr. Raker informed me that the beams are all poured to one depth to maximize the space between floors to meet architectural requirements for the building. If the beams are deeper than they are wide, this would limit the height of each floor and leave less space for the building's occupants.

Moreover, the beams are wider than the columns just like the beams in Sukup Hall. This allows the steel reinforcement in the beams to be spread out and run past the column reinforcement where the two intersect to prevent reinforcement congestion. Most of the beams are between 32 inches and 36 inches wide and the columns are typically 24 inches square.

Following this discussion for the slab, joists, beams, and columns, the lateral load resisting system can be analyzed. As Mr. Raker discussed with me, the primary loads this system must resist are wind loads and dead loads. In the north-south direction, this is accomplished by three sets of concrete shear walls, two on either end of the building at the stairwells and one in the middle of the structure. For wind loads in the east-west direction, these are resisted by moment connections between the beams and columns of the concrete frame. Thus, just like Sukup Hall, two separate systems resist lateral forces the building will experience.

The foundation system uses spread footings and wall footings just like Sukup Hall. This shallow foundation system did face a unique challenge. In particular, since the building is tall and has a significant amount of mass, the foundation system uses rammed aggregate piers to improve the soil capacity enough so a shallow foundation system can be used (Raker). Like Sukup Hall, the soil bearing capacity changes about 7 feet below grade. The top 7 feel of soil can support approximately 3,000 psf while below 7 feet, the soil can support 6,000-7,000 psf. Rammed aggregate piers are used because they are cheaper compared to auger cast piles and saved about $200,000 to $300,000 (Raker).

Finally, the roof framing system is quite different from Sukup Hall and Elings Hall. Instead of open-web steel joists, wide flange beams and HSS beams and columns with 1.5-inch 20 GA metal floor decking are used to support mechanical equipment. The greenhouses are also located on the roof. Both the greenhouses and mechanical equipment require an additional concrete slab over rigid insulation on top of the concrete roof slab to support these loads. This was one of the main challenges Mr. Raker faced when designing this structure and is described below.

Challenges

Mr. Raker expressed to me many of the challenges he faced during the design stages of the ATRB Building. This included keeping the floors as thin as possible to maximize the space between them, which required keeping the beams and joists at a constant depth. Additionally, he designed for a partial basement plan because originally, there was not going to be a basement but space requirements dictated the need for one.

Some other challenges Mr. Raker faced during the design stages included designing a concrete slab on top of concrete slab for the greenhouse floor system. The structural plans show a 6-inch or 4-inch topping slab on top of 2 inches of rigid insulation that is added to the 5-inch thick slab already in place. Moreover, on the east end of the building, it cantilevers out and this required coordination between the Architectural, MEP, and Structural disciplines since this area is beyond the building's thermal boundary. Finally, Mr. Raker had to coordinate with two architects on the project instead of just one.

Owner Considerations

From the owner's perspective, Mr. Grief told me that some notable features of this building included the building overhang on the east end that appeals to drivers at the intersection of Pammel Drive and Stange Road. Also, he informed me Iowa State wanted more space for this building but due to the project budget and scope, the total area had to be reduced. One way to compensate for this is the addition of a basement to the structure, which was not originally in the floor plans. Also, the fifth floor will be shell space that eventually will be used for research and office space.

Lastly, some challenges Mr. Grief discussed with me during the construction of this project included a limited labor market, the construction schedule, and the construction budget. Overall, this summarizes some of the owner considerations taken into account while this structure is being built.

Conclusion

Building Summary

Each building I studied for this project serves a unique purpose. Sukup Hall is a research, laboratory, and teaching building for the ABE Department. Since it contains special laboratory equipment and machinery, a reinforced concrete frame is the best structural design to serve this function.

On the other hand, Elings Hall is an office building that does not contain many large loads. Thus, a steel frame is the most economical structural design solution for this structure. Both of these buildings provide adequate space for the ABE Department.

Finally, the ATRB is also a research and laboratory building. Since it will contain heavy and sensitive equipment, a reinforced concrete frame is the best solution for this structure.

Building Comparison

The buildings that are most comparable are Sukup Hall and the ATRB. They are both research and laboratory facilities that offer students and faculty hands-on experiences within their respective departments. This makes them best suited for reinforced concrete. Additionally, they have many other similarities. Both use shear walls and moment frames to carry lateral loads. Both use a concrete slab and joist system. Lastly, both use spread footings and wall footings for their foundations.

Elings Hall differs from these two structures. It is an office building which makes it ideal for a steel structure. Since it does not carry large loads it is much lighter compared to a reinforced concrete structure. It does have some similarities such as spread and wall footings for its foundation system.

Project Insights

Each building I studied for this honors project serves a specific function, which influenced the design choices made for the buildings' structures. Also, each structure is unique. Sukup Hall and Elings Hall are specifically for the ABE Department at Iowa State. They provide many resources for students pursuing an education in this field. On the other hand, the ATRB building will serve the Biosciences and provide learning and research opportunities for students within these areas. Finally, all of these buildings serve Iowa State's mission to serve students and faculty and provide them with a quality education.

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Brad Stork, P.E., President, Saul Engineering

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Appendix

List of Contract Documents:

- Advanced Research and Teaching Building, Issued 2016, Construction Plans and Specifications by OPN Architects and the SLAM Collaborative

- Elings Hall, Issued 2012, Construction Plans and Specifications by OPN Architects and ZGF Architects

- Sukup Hall, Issued 2012, Construction Plans and Specifications by OPN Architects and ZGF Architects