Executive Summary

Stadium Academia, a senior design team from Calvin College, seeks to produce plans for a proposed athletic complex on Calvin’s campus. The complex would include two artificial turf fields, stands for spectators and other necessary site components for hosting athletic events. The goal of team Stadium Academia is to produce a set of preliminary drawings for the construction of such a complex and report the feasibility, cost and implementation process of the proposed design.

Calvin College is a liberal arts college in the Reformed tradition of Christianity. Calvin College is located in suburban Grand Rapids, Michigan. In February of 2011, the Football Feasibility Task Force was established to “examine the implications for the identity, mission and programming of Calvin College of initiating a co-curricular football program.” and seeks to report its findings to the college’s Planning and Priorities Committee.¹ Regardless of the outcome of the Football Feasibility Task Force’s findings or the College’s decision whether or not to add a football program, Stadium Academia saw an opportunity to propose a design for an athletic complex that would meet Calvin’s needs.

Stadium Academia’s design will be guided by the target cost established by GMB Architecture + Engineering in their preliminary study of the project. The goal of the design is to serve Calvin’s current needs and provide opportunity for future growth. The athletic complex will incorporate architectural elements from campus in order to integrate the design into the existing campus environment.

Based on a budget specified by the Calvin College Physical Plant, the estimated cost of the complex is $8,100,000. This cost includes the construction materials and labor, as well as a contingency for design and engineering fees.

¹ Calvin College Football Feasibility Task Force Mandate
http://www.calvin.edu/football/mandate.html
# Table of Contents

Executive Summary ........................................................................................................................ 3

List of Figures ................................................................................................................................. 6
  Figures ......................................................................................................................................... 6

List of Tables .................................................................................................................................. 7
  Tables .......................................................................................................................................... 7

Introduction ..................................................................................................................................... 8

Acknowledgements ......................................................................................................................... 8

Schedule .......................................................................................................................................... 8

Team Organization .......................................................................................................................... 9

Business Plan .................................................................................................................................. 9

Stadium Research ............................................................................................................................ 9
  Trine University .......................................................................................................................... 9
  Ohio Northern University .......................................................................................................... 10

Requirements ................................................................................................................................ 11
  Football ...................................................................................................................................... 11
  Soccer ........................................................................................................................................ 12
  Plaza .......................................................................................................................................... 12

Basis of Design ............................................................................................................................. 12
  Site Selection ............................................................................................................................ 12
  Site Planning ............................................................................................................................. 16

Utilities .......................................................................................................................................... 16
  Storm Sewer .......................................................................................................................... 19
  Sanitary Sewer ....................................................................................................................... 19
  Water Main ............................................................................................................................ 20

Home Stand Building .................................................................................................................... 20
  Building Architecture ............................................................................................................. 20
  First Level .............................................................................................................................. 21
  Second Level .......................................................................................................................... 23
  Third Level ............................................................................................................................ 27
## List of Figures

### Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fred Zollner Stadium at Trine University</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Dial-Roberts Stadium at Ohio Northern University</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>Current Layout of Campus</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>Proposed Changes to Campus</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>Site Layout</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>Utilities and Proposed Connections</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>Locker room schematics</td>
<td>22</td>
</tr>
<tr>
<td>8</td>
<td>First Floor Layout</td>
<td>23</td>
</tr>
<tr>
<td>9</td>
<td>ADAAG Public Restroom Requirements</td>
<td>24</td>
</tr>
<tr>
<td>10</td>
<td>South elevation view of home stands building</td>
<td>25</td>
</tr>
<tr>
<td>11</td>
<td>Second Floor Layout</td>
<td>25</td>
</tr>
<tr>
<td>12</td>
<td>Front Access Bleachers</td>
<td>26</td>
</tr>
<tr>
<td>13</td>
<td>Mid-level walkway</td>
<td>27</td>
</tr>
<tr>
<td>14</td>
<td>Press Box &amp; Upper Section of Stands</td>
<td>28</td>
</tr>
<tr>
<td>15</td>
<td>Open deck bleachers</td>
<td>31</td>
</tr>
<tr>
<td>16</td>
<td>John Jacobs’s Track and Field Complex University of Oklahoma, closed deck stands</td>
<td>32</td>
</tr>
<tr>
<td>17</td>
<td>Concrete Stadium</td>
<td>33</td>
</tr>
<tr>
<td>18</td>
<td>Precast concrete stadia installation process</td>
<td>34</td>
</tr>
<tr>
<td>19</td>
<td>Stadium stands live loading sections</td>
<td>38</td>
</tr>
<tr>
<td>20</td>
<td>Wind Directions for Each Case</td>
<td>39</td>
</tr>
<tr>
<td>21</td>
<td>Displays Figure 7-5 Balanced and unbalanced snow loading from ASCE 7-10</td>
<td>41</td>
</tr>
<tr>
<td>22</td>
<td>LRFD Load Combinations</td>
<td>42</td>
</tr>
<tr>
<td>23</td>
<td>Interaction Diagram for Column Design</td>
<td>44</td>
</tr>
<tr>
<td>24</td>
<td>Steel Reinforcement Design</td>
<td>45</td>
</tr>
<tr>
<td>25</td>
<td>Beam Diagram</td>
<td>46</td>
</tr>
<tr>
<td>26</td>
<td>Stirrup Spacing Design</td>
<td>47</td>
</tr>
<tr>
<td>27</td>
<td>Press Box Framing Plan</td>
<td>48</td>
</tr>
</tbody>
</table>
List of Tables

Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Designed seating capacities for each grandstand</td>
<td>29</td>
</tr>
<tr>
<td>Table 2</td>
<td>Decision Matrix for bleach construction material</td>
<td>30</td>
</tr>
<tr>
<td>Table 3</td>
<td>Snow loads calculated with ASCE 7-10</td>
<td>42</td>
</tr>
<tr>
<td>Table 4</td>
<td>Construction Costs</td>
<td>50</td>
</tr>
<tr>
<td>Table 5</td>
<td>Detailed Budget for Team 9</td>
<td>51</td>
</tr>
<tr>
<td>Table 6</td>
<td>Conceptual Budget - Football Stadium</td>
<td>53</td>
</tr>
<tr>
<td>Table 7</td>
<td>Conceptual Budget: Soccer Stadium</td>
<td>53</td>
</tr>
<tr>
<td>Table 8</td>
<td>Conceptual Budget: Connector</td>
<td>54</td>
</tr>
</tbody>
</table>
Introduction

Team 9 is designing a multipurpose sports stadium complex to support Calvin College’s growing athletics and intramurals. This design consists of two fields: 1) A football field that will also double as a lacrosse field and 2) a soccer field. Buildings are to be included in the design to house the necessary facilities for sustaining the proposed football team and other athletics at Calvin College. This project will involve architectural and structural design of the buildings and stands as well as hydrologic and traffic flow impacts on the campus. Team 9 is made up for four senior engineering majors in the civil and environmental concentration: Mark Kiemel, Elliot Spronk, Dan Van Slooten, and Reid Veenstra. This project is to be completed for Senior Design 339/340 as part of the engineering curriculum at Calvin College

Acknowledgements

Team 9 wishes to thank people who have helped us throughout the project. Our team advisors, Professor Leonard De Rooy and David Wunder, helped get this project from the clouds to the ground, and encouraged us in so many ways to pursue a project that interested us. Dr. Jim Timmer, Calvin College’s Athletic Director, for taking countless hours out of his schedule to keep in touch with a bunch of kids, and for being encouraging of our project. We’d also like to thank Mr. Jeffery Posendek of Trine University and Mr. Tom Simmons of Ohio Northern University for their incredible hospitality when giving us a tour of their respective stadium facilities.

Schedule

Scheduling was done using Microsoft Word document comprised of all the tasks that Team 9 needed to complete the project. These tasks are comprised of design decisions and issues that arose as the project developed. The schedule is updated whenever a new task arises, or when a task has fallen behind schedule and needs adjusting. The schedule is used as a tool to make sure that all members of the team are aware of what needs to be done so that the project is completed.
If a scheduling issue arises, the team will evaluate the situation with respect to the entire project and come to a mutual decision for the benefit of the project. The average time spent on the project per person each week is estimated to be around 10 to 15 hours.

**Team Organization**

Team 9 – Stadium Academia is comprised of four civil/environmental engineering students; Elliot Spronk, Reid Veenstra, Dan Van Slooten, and Mark Kiemel. The team advisor is Dr. David Wunder and team consultant is Mr. Roger Lamer. All these people play an important part in the preliminary design of a Calvin College football stadium complex. Team meetings were conducted every Thursday and Friday where work was divided between members, progress was checked, and goals needed to be accomplished by next meeting were planned. All documents for the project, including STAAD.Pro output file, can be found on the team website.

**Business Plan**

The stadium complex will be a site specific construction project and will not be marketed outside Calvin College. Because of this no business plan was implemented in the design of the structure, but an integrate budget will be created and refined throughout the project, starting with the approximate budget acquired from the Calvin College Physical Plant (Append 0). Note: the traditional 6% engineer and architect fee was not included) for a total of $7,122,500.

**Stadium Research**

**Trine University**

Trine University constructed a new football stadium in 2008 (Figure 1). We visited this stadium on October 11, 2011 to gather ideas for our design. Their stadium seats approximately 2500 – 2700 on steel I-beam bleachers. The building contains coaches’ offices, training room, home locker room, weight room, and a laundry room. This is similar to the types of rooms we will include in Calvin’s stadium design with the exception of the coaching offices. The field is artificial turf with only football lines sewn in. Mr. Posendek, the school’s athletic director,
explained to us that storage was the only thing missing from the stadium building. Storage is something easily overlooked and has been considered in our design of the stadium.

Figure 1: Fred Zollner Stadium at Trine University

Ohio Northern University
Ohio Northern University is still in the process of upgrading their athletic facilities. They currently have a stadium with home seating for 3500 on a steel I-beam platform stands and a natural grass field (see Figure 2). The unique features of this stadium are the elevated stands, sitting almost seven feet above the ground, and all the restrooms and concessions are located inside the building under the stands. Our design of Calvin’s stadium would like to incorporate the elements of the elevated stands and indoors spectator facilities. Again this stadium had a lack of space for the necessary storage.
Requirements

There are three primary aspects of the project: the football stadium, the soccer stadium, and a connecting plaza.

Football
The football stadium is the primary task of the project due to its importance and complexity. The stadium will include an artificial turf surface with football lines sewn in. Additional items that NCAA Football regulations require are two field goal posts as well as two play clocks on either end of the field. The field will also be used for men’s and women’s lacrosse, but to avoid surface clutter, those lines will be painted on during the spring season. The home stands will include bleachers for 3500 spectators, a press box with a hospitality suite, home and away coaches boxes, media/press room, announcing and board control room, and a film room, and a building underneath containing a first level for a home locker room, visiting locker room, training room, weight room, and laundry room, and a second level with fan restrooms, concessions,
merchandise store, and storage. There will also be stands on the away side with seating for 500 guests. Space underneath these stands will be used for storage.

**Soccer**
The soccer stadium will only service men’s and women’s soccer on a varsity sport basis, but may also be used for intramural sports. This will also require an artificial turf field, and will only have soccer lines sewn in. There will be only one set of stands, which will be located on the home side and seat 750 fans. There will also be a building attached to the soccer stands with the first level containing concessions, men’s and women’s public restrooms, and an officials locker room, and a second level press box for announcing and scoreboard control.

**Plaza**
Having two separate stadiums creates a problem for ticketing and entrances. To simplify the entrances, the project is to make the away football stands and soccer stands one complex. This will be accomplished by building a plaza in the space between the two stadiums that will house the away stands of the football stadium as well as a building connected to the soccer stands which would contain guest restrooms and concessions for football and soccer spectators. Ideally, a way to separate the two stadiums will be implemented in case of events being hosted at the same time need to be isolated from each other (for ticketing purposes.) A fence will be installed around the entire complex, and on the eastern most side (the east side of the soccer stadium,) the fence will also be covered with a wind-breaking sheet. A ticket booth will be included on the Southwest corner of the complex, with a small gate east of the away football stands where patrons already with football tickets can enter or for a soccer game can purchase tickets and enter.

**Basis of Design**

**Site Selection**
While Stadium Academia’s work focuses only on the football and soccer complex, the master plan of campus was a consideration in early site design and verification. The location chosen for the football and soccer complex is north side of Calvin College’s campus where the current outdoor track and soccer field reside, Figure 3 shows the current layout of campus. The athletic complex design is part of a master plan for the campus that includes relocation of the baseball
field and outdoor track as well as the insertion of the new complex. Figure 4 highlights these areas of change as they are anticipated: the baseball team will play at the Gainey Athletic Complex, a new outdoor track will be located where the baseball field currently is, and the football and soccer complex will be located just to the north of the Spoelhof Fieldhouse Complex.

This master plan was suggested by Dr. James Timmer, Athletic Director at Calvin College and illustrated by GMB Architecture + Engineering in their preliminary analysis of the project. This location on Calvin’s campus is the best choice for the football and soccer complex. The proximity to the Spoelhof Fieldhouse Complex is a benefit in a number of ways. The Fieldhouse is designed for over 5000 spectators, and parking lots 2-7 (Figure 4) are designed to handle these events. Therefore, this parking can also be allocated for hosting football and soccer games and no additional parking is necessary. Also, the Fieldhouse contains many of the other athletic facilities on campus, so this placement maintains the current organization of campus. The athletic complex is also close enough to the rest of campus, including student dorms, that students will be able to walk to athletic contests and other events held at the complex. Finally, the location is near the core of campus as opposed to the edge of the campus. This will help mitigate possible high levels of noise and light pollution into the surrounding residential neighborhoods.
Figure 3: Current Layout of Campus
Figure 4: Proposed Changes to Campus
Site Planning
A potential field layout was obtained from GMB and was analyzed to ensure the layout was workable. The soccer field was left at the location given by GMB and the football field layout was moved approximately 30 feet east, closer to the soccer field. This change leaves more room for the home stands, which we determined would need more space than suggested by GMB. Between the space needed for the fields and field sidelines, about 100 feet of room is available. This area will be utilized as a plaza connecting the two fields. The plaza will be approximately 100 feet wide by 150 feet long. The fields are oriented north-south so that players will not be looking directly into the sun at evening games. The athletic field complex will be edged by a fence on all sides for security and admittance purposes.

For the same reason, the stands for both fields are located on the west side of the field. This placement also works well for the football stadium because the majority of spectators will approach the athletic complex from the parking lots to the south and west. All three sets of stands (3500 home football, 500 visiting football, 750 home soccer) will be centered on the fields to provide the best view for the spectators (Figure 5). The home football stands will house public restrooms and a concessions booth. The soccer stands will be accommodated by a building with public restrooms and a concessions stand for the soccer spectators and visitor football spectators. The building will also include an official’s locker room; in accordance with the preference of many officials, this distances their locker rooms from the majority of the spectators as well as the team locker rooms.

The majority of spectators for a home football game will park in lots 2-6 (Figure 4) and will approach the stadium from the southwest. Therefore, a main entrance gate will be located in the southwest corner of the complex. Another entrance will be located between the two fields at the south end of the plaza. This entrance will be used mostly by students, however may serve spectators who wish to park in lot 8.

Utilities
Since our team is made up of civil and environmental engineering majors we will only focus on the connections of drinking water, sanitary sewage, and storm water utilities only. The proposed connects are shown in Figure 6.
Figure 5: Site Layout
Figure 6: Utilities and Proposed Connections
Storm Sewer

The proposed storm sewer was designed for a 24hr, 100 year storm event with 6.15 in of rainfall\(^2\). Precipitation on the synthetic turf fields does not create any runoff. Instead it will travel vertically through the infill and gravel. \(^3\) Some of the water will infiltrate into the ground while the rest will travel approximately 30 yards to the edges of the field where flat panel drains collect the water and outlet it into the proposed storm sewer drain. Pipes will be constructed out of smooth PVC pipe and sized according to the turf contractor’s policies. There are two storm sewer pipes in the vicinity; one leading to Lake Drive, the other leading to the detention pond in the basin by Calvin’s baseball field. It was decided that to make sure any increase in runoff could be dealt with in an environmentally conscious manner, the new storm sewer would tap into the 24” pipe leading to the detention pond through the baseball field. Therefore these pipes will be attached to the current storm sewer pipes that already exist beneath parking lot 7. A study was performed to calculate the amount of additional runoff that would be created as a result of the new complex, and it was found that the amount of runoff during a 25-year storm event would increase 13.4 cubic feet per second (cfs) from 30.7 cfs to 44.1 cfs. This was then modeled in EPA SWMM to see if the current drainage system could handle having the new storm sewer system being attached to the aforementioned 8 inch PVC pipe beneath the parking lot. It was found that the additional runoff would require the existing pipe beneath the parking lot to be replaced with 24” pipe at the connection to the existing 24” pipe until the northernmost entrance to parking lot 7. From here, new pipe installed will be 18” until the drain located the northeast corner of the football field in the plaza. The following lengths of pipe (which connect drains in the plaza between the two fields) will be 12”, and the remaining upstream lengths (connecting the soccer field drain to the plaza drain & the east entrance drain to the plaza drain) will be 8”.

Sanitary Sewer

The existing sanitary sewer is located on the North-East corner of the Track and Tennis building on Calvin’s campus. We proposed connecting to this existing pipe through pipes branching out from the home stand building and the concessions building. These pipes will be designed to

\(^2\) Drainage Rules.: Kent County Drain Commission, 2006 Table 1, Section 3
handle 14,000gpd from the home stand building and 5,000gpd from the plaza building based on 4 gallons per seat per day. Further details are considered outside of the scope of this project, therefore pipe sizes have not been determined.

**Water Main**

Because of the high volume of people, it is imperative that the current water distribution system for Calvin College can handle a large water load over a relatively short amount of time (3-6 hours.) A study on the water demands from a stadium by the University of Central Florida\(^4\) stated that a demand of 4 gallons per day (gpd) per seat (spectator) could be assumed with a peaking factor of 2. For approx. 4000 spectators, this would mean a demand of 32,000 gpd. The locker room would also require a large demand based on shower use by both teams as well as toilet/urinal and sink use. It was found\(^5\) that a shower head emits a maximum of 2.2 gallons per minute, a toilet uses 1.6 gallons per flush, a urinal uses 1 gallon per flush, and a sink uses 0.5 gallons per minute. Assuming a 20 minute shower per player and 200 total players (approx. 100 per team), the locker rooms would require 16,200 gpd. This means a grand total of 48,200 gpd for the stadium. The current water distribution system for Calvin College goes as far as the northern-most part of the Track and Tennis Center, and the northwestern-most part of Van Reken dormitory. For supplying the stadium, one option would be to tie in to the water main through the track and tennis center for the home stands restrooms and locker rooms, and have the plaza concessions building tie into the same line by following the sanitary sewer line that will run from the North-East corner of the Track and Tennis building.

**Home Stand Building**

The building is bound by, among other things, physical space requirements, projected construction cost limits, and adherence to a general set of architectural guidelines that create an aesthetically uniform campus.

**Building Architecture**

Aesthetically, it is important to keep the building within the architectural precedent set for Calvin’s campus, maintaining the architectural integrity of the campus. The prospect of set of


stands with the capacity to seat over 3000 people presents a significant challenge to the design. Calvin’s architecture is of a very distinct style, following from that of architect Frank Lloyd Wright. Original campus architect Bill Fyfe, a student of Wright, took a less formal approach to the layout and style of campus, taking into consideration natural land contours and creating harmony between the buildings and these landforms. Recent construction projects on campus have been received quite well by the student body and faculty, taking cues from the original designs while contributing new elements to the architectural palette of campus. Within our design, the home stands will be appropriately blended into the existing setting while expressing signs of a new direction for Calvin.

**First Level**

The home stands building must contain a number of rooms and spaces – both for teams, coaches and officials, and for the spectators. First, the building must include locker rooms for football and lacrosse teams. During football season in the fall, the ideal configuration is a home locker room for 130 users and a visiting locker room for 70 users. In the spring, during lacrosse season, there would preferably be two home locker rooms, one each for men’s and women’s teams, as well as a space for visiting teams to use as a locker room. Additionally, if the fields are ever used for high school competitions or other events, up to four locker rooms may be useful. Locker rooms are also required to have 50 gross square feet per occupant. This requirement means the locker rooms have a large footprint, for example when designing the home locker rooms to accommodate 130 players, coaches and trainers the room must be at least 6500 square feet. After evaluating all of these components, a general schematic was chosen (Figure 8). Our design choice consists of two large locker rooms, each with the ability to be closed off into two separate spaces, resulting in four available locker rooms (Figure 7). Each large locker room will have a restroom, sink and shower area that will be adjacent to each divided half, so that one set of amenities can serve both sides. The locker rooms will be accessible from the main tunnel onto the field and will also have emergency exits.

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7 International Building Code 1003.1.1
8 International Building Code, 2000
In addition to the locker rooms, the main floor of the building will have a weight room, trainer’s room, laundry room, custodial closet, a lobby with stairs leading to the second level, and storage capacity located beneath the stands. If a weight room is not included in the final design, athletes could use the expandable team weight room located in the Spoelhof Fieldhouse Complex. The option of a weight room at the stadium was recommended by the Athletic Directors of both Trine University and Ohio Northern University. The football team would require a rather unique weight set and arrangement, which wouldn’t be as compatible with other sports team’s necessities. Also, since the football locker room is located at the stadium, this would also be the ideal location for their weight room. Our design specifies a small weight room with ample room for necessary equipment.
After defining the needs for public restrooms, which will be designed according to ADAAG requirements\(^9\) (Figure 9), concessions and means of egress from the home stands, Team Stadium Academia decided to add a second level of rooms to the building. With a large set of stands, there is considerable space underneath the seating area to be taken advantage of. Since available space on site is limited, using the space efficiently is important. Making use of the space on the second level (Figure 10) not only offers more square footage, but also offers a unique experience for visitors to the stadium by making use of a concourse style approach that is found in many large stadiums. Spectator amenities (i.e. concessions and restrooms) as well as a fan merchandise store will be located on the second level of the structure (Figure 11).

Figure 9: ADAAG Public Restroom Requirements
Another aspect of the available space analysis takes into account the spectator experience when visiting the stadium. The approach and entry to the home stands must accommodate a large amount of people, (i.e. 3500). There must be appropriate means of egress, which consists of wide
enough stairways, ramps and exits. Team Stadium Academia laid out two different options for how visitors and fans would approach the home stands. First, all access points could be from the front, or the very lowest point of the stands (Figure 12). This leaves for a relatively simple layout, with stairways leading into the stands from the different access points. This design is utilized at the Fred Zollner Stadium at Trine University, shown in Figure 1. While it is a straightforward layout, the disadvantage of it is that spectators must pass directly adjacent to the sidelines of the field to find their seats or during the game to use the restroom and visit the concessions stand. The Athletic Director at Trine did identify this as a problem, saying that temporary barriers must be set up for each game to maintain a boundary between the spectators and the sideline of the field.

A second seating layout option places a horizontal walkway somewhere among the rows of seating (Figure 13). This type of design is utilized at the Dial-Roberts Stadium of Ohio Northern University. One advantage of this layout is that the distance from the furthest seat from the exit is generally less. Another factor is the interaction between the sidelines, where the teams and coaches will be standing during games, and the spectators entering and exiting the stands. Ideally, there would be appropriate separation between these two, and placing a walkway midway through the stands allows for this. With a mid-level walkway, spectators approach the

Figure 12: Front Access Bleachers

A second seating layout option places a horizontal walkway somewhere among the rows of seating (Figure 13). This type of design is utilized at the Dial-Roberts Stadium of Ohio Northern University. One advantage of this layout is that the distance from the furthest seat from the exit is generally less. Another factor is the interaction between the sidelines, where the teams and coaches will be standing during games, and the spectators entering and exiting the stands. Ideally, there would be appropriate separation between these two, and placing a walkway midway through the stands allows for this. With a mid-level walkway, spectators approach the

10 Gerber Leisure Products Inc.
stands from underneath, walk out towards the field in a tunnel beneath the stands, and come out onto the mid-level walkway.

![Figure 13: Mid-level walkway](image)

Team Stadium Academia has chosen to implement the second option, placing a walkway somewhere around one-third of the way up into the stands. The second level in our design would incorporate a concourse that would serve as the main access route for the spectators, with a number of tunnels leading out to the walkway in the stands. The interior of this level would include all of the public restrooms, the concessions stand, a spirit store, a mechanical/HVAC room, storage space, and staircase access to the first level as well as the press box.

**Third Level**

The third level of the home stands building will include a media/press room, an announcing/scoreboard room, a home and an away coach’s box, and a hospitality suite that also has a patio attached to the North (see Figure 14.) There will be elevator access to this floor as well as access from a stairwell. This level will sit above the home stands and overlook the field.

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11 Middle Tennessee State University
Figure 14: Press Box & Upper Section of Stands
Stands
The stands were designed with the following criteria in mind:

- Designed seating capacities for each grand stand are shown in Table 1.

Table 1: Designed seating capacities for each grandstand

<table>
<thead>
<tr>
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<th>Seating Capacity</th>
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<tr>
<td>Home Stands (Football)</td>
<td>3500 people</td>
</tr>
<tr>
<td>Away Stands (Football)</td>
<td>500 people</td>
</tr>
<tr>
<td>Soccer Stands</td>
<td>750 people</td>
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- The home stands were designed to allow for maximum usable area on the underside of the seats.
- The away and soccer stands were designed with usable space underneath the stands for storage purposes.

Alternatives

Four alternative designs were considered for the construction of the sports stadium stands.

Table 2 displays the design matrix for the selection of this material.
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<thead>
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<th>Maintenance cost</th>
<th>Life</th>
<th>Construction Time</th>
<th>Usable square footage underneath</th>
<th>Vibration Control</th>
<th>Customer Preference</th>
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</tr>
</thead>
<tbody>
<tr>
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<td>Cast in place Concrete</td>
<td>10</td>
<td>1</td>
<td>8</td>
<td>8</td>
<td>2</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>307</td>
</tr>
<tr>
<td>Precast Concrete</td>
<td>10</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>462</td>
</tr>
</tbody>
</table>
**Steel Open Deck Stands**

Steel open deck stands (Figure 15) are typically portable stands constructed out of aluminum with an open deck creating large gaps between the seat benches and the walkway floor. This design is the lowest cost yet does not provide the aesthetics, vibration and deflection control, or water seep resistance that is desired for this project.

![Open deck bleachers](image)

*Figure 15: Open deck bleachers*¹²

**Steel I-beam Closed Deck Grandstand**

This alternative is similar to steel open deck but has sheets of aluminum that seal the open gaps beneath the seat benches and the walkway floors. This alternative provides adequate aesthetics to the stands along with some vibration and deflection control and water proofing to below area. The steel design material is a lower cost than the concrete. This option was disregarded because of a higher maintenance cost and low amount of usable space underneath the stands. Figure 16 displays a picture of the closed decking system.

---

¹² [Front Row Seating Systems](http://www.frontrowseatingsystems.com/aluminum-bleacher.htm)
Figure 16: John Jacobs’s Track and Field Complex University of Oklahoma, closed deck stands\textsuperscript{13}

**Cast in Place Concrete**

This alternative uses forms built on the job site to construct a solid concrete grandstand. This design would provide adequate vibration and deflection control, be aesthetically pleasing, be water resistant and have a lower maintenance cost. This option was removed because of the high cost of form work needed for erecting the stands. Figure 17 shows a concrete stadium that was cast in place.

\textsuperscript{13} Dant Clayton Corporation, http://www.stadiumbleachers.com/project-portfolio/university-of-oklahoma-track#
Figure 17: Concrete Stadium

Precast Concrete

This method uses a single form to produce slabs of concrete, or stadia, in a specific concrete company’s warehouse. The environment is controlled allowing for higher quality concrete (increased strength) and faster production and construction times. This method has a much lower cost than cast in place with all the benefits of concrete as shown earlier. This method also means that the concrete is prestressed, which makes it more durable and cracking is less of an issue. Concrete also requires little or no maintenance to preserve original look. Figure 18 displays how a stadia piece is installed in the precast stadium. Kerkstra Precast was selected to create the stadia sections because of our contact information with them and availability to price/design for us.

---

Seating

The design specifies a 24-inch row spacing with a plastic seat cap. This provides adequate space while maximizing the number of rows for spectator seating. Also taken into consideration were spectator sight lines, including the line of sight from the press box above the stands. This resulted in a steep, but compact seating arrangement. This is necessary because of the small space for the building footprint, but also allows for very close proximity of the spectators to the field. The seating is recommended to be between 18 – 24 inches per person parallel to the seat way. The seating can be single seats or a bench system. The recommended amount would be to install aluminum bench system. This provides low cost and adequate space.

Floor Slabs

Hollow core plank floors from Kerkstra Precast have been specified for the home stands building. These floor planks have been pre-engineered to meet specified loads and are readily installed onto a framing structure. For the second and third levels of the home stands, 10-inch thick planks with 30 foot clear span were chosen. These planks come in 3-foot wide sections, are made of 7000 psi concrete and have a weight of 65 psf.

Construction Traffic
Construction of the athletic facilities is not likely to stress the current traffic system that Calvin College utilizes due to the location of the project site. The stretch of road from the entrance to the current baseball field to the Lake Drive entrance would have to be closed down, but cars still have access to the rest of campus. The project is to be staged in a parking lot sitting north of the Calvin College Track and Tennis Center. This will allow for construction to proceed without large traffic concerns.

Parking
Currently, the commuter parking lot adequately serves parking purposes for the largest of Calvin events such as Calvin-Hope Rivalry basketball games and commencement. It is therefore assumed that there will be enough parking for stadium events.

Detailed Design
Much of the integration and testing of the athletic facility design has been accomplished through the use of various software packages and computer modeling. Integrating the new systems into the existing utilities and amenities on campus will be an important part of the design. In coordination with the Physical Plant office, detailed information about the existing features of the site have been obtained in the form of various AutoCAD files.

Hydraulic analysis was completed with the ArcMap 10 GIS package. Modeling of stormwater handling was tested in EPA SWMM.

Structural components of the stadium were analyzed with STAAD.Pro computer program. This program calculated the forces and moments in the each of the beams and columns so that they could be individually designed using spreadsheets.

Revit Architecture was used to generate a building information model and visual representation of the stadium and surrounding site. Through the production of an accurate computer model, realistic renderings can be generated as well as walkthrough videos of the complex. These items will be useful for the final presentation of the project.
**Hydraulic Design**

The fields and surrounding plaza spaces will produce significant storm water runoff, which will need to be handled appropriately by the existing storm water network on campus. Additionally, the new water demands of the complex have been identified and quantified. They include the daily demands for showers and laundry, as well as the peak demands for water that will occur during and after games.

**Site Design**

The design of necessary site work was carried out based on existing topography, land cover and soil conditions. Site grading was planned to comply with current surface drainage patterns. The general layout is with the highest ground in the southeast corner of the site and the low point at the north edge of the site. According to the turf field installation guidelines, they require a prepared bed sloping from center to edge at 0.75% grade. Each building site was specified to be graded at 1’-0” below the desired finished floor elevation. This allows for 0’-6” of compacted fill and 0’-6” of concrete. Plaza and entrance landings require fill in some areas, as noted by the plans. From each field, an emergency access route was designed for an ambulance to get from the field onto campus road Knight Way to the northwest.

Along the east edge of the soccer field, a block retaining wall has been specified. Since the site has only been designed in terms of site grading and leveling, the structural design of this wall has not been completed. More detailed information about existing soils would be necessary for this analysis. Similar to the bearing capacity, this analysis and design must be completed were the project to move forward.

**Structural Design**

**Loading**

Loading weights and pressures used in the STAAD.Pro model were calculated in accordance with Michigan Building Code and ASCE 7-10. These loads were calculated over an area and distributed into the structural beam, column, and shear wall components.
Dead Loads

The dead loads for the second level (spectator area) and third level (press box) floors were based on:

**Floor Slabs**

Hollow core plank floors from Kerkstra Precast have been specified for the home stands building. These floor planks have been pre-engineered to meet specified loads and are readily installed onto a framing structure. For the second and third levels of the home stands, 10-inch thick planks with 30 foot clear span were chosen. These planks come in 3-foot wide sections, are made of 7000 psi concrete and have a weight of 65 psf.

**Stadia**

Stadia pieces were also selected from Kerkstra Precast to provide a lighter and stronger grandstand area. These stadia pieces span one direction similar to the hollowcore slabs with the weight forces transferring into the supporting raker beams.

**Roof**

Roof material was estimated at 30 psf and was used in the design. The final design of the roof included a Vulcraft 1.5B18 gauge steel decking, which was selected for its load-bearing capacity as well as its ability to absorb up to 60% of sound striking the deck, shingles, insulations, and 0.5in plywood. The total dead load calculated for the roof was estimated at 16psf including 5 psf for miscellaneous lights.

**Beams**

All beam weights were first estimated based on an estimate beam size and will be revised to match the actual weight of the beams after design.

**Live Loads**

**Stands Live Load**

Stadium stands live loading creates a difficult model to produce because fans can sit in any combination of scenario. For example all the fans could be located at the top, bottom, or middle at any given time and in any combination of the two. Figure 19 displays the three sections that were selected for the molding. These sections lay between columns and would create the greatest stress on the raker beams supporting the stadia. Fans also create a horizontal force the
acts parallel and perpendicular to the seating row. These factors combine to create 14 different live load cases imported into STAAD.Pro.

Wind Loads
In West Michigan, wind loading controls over seismic loading so only wind was analyzed in the model. Wind loading was based on exterior dimensions and 120 mph 3 second wind gust in accordance with ASCE 7-10 chapter 26 through 28.

First, velocity pressures were calculated based on an enclosed building, exposure category B, Risk Factor III, and a mean roof height of 55ft. These velocity pressures were calculated for windward wall (on 10 ft elevation intervals) leeward walls, roof (windward and leeward), and sides using Equation 27.3-1 as shown below.

\[ q_v = 0.00256K_vK_dK_w V^2 \text{ (lb/ft}^2) \] \hspace{1cm} (27.3-1)

Once this velocity pressure was calculated the external pressure for each case was calculated with a gust factor (0.85) and external pressure coefficient (Cp). The external pressure coefficient varies based on windward, leeward, roof, or side directions.

Wind was assumed to traverse from 8 separate directions as shown in Figure 20.
After the external pressures were calculated the net internal pressure was calculated based it being an enclosed building. Two cases were considered based on positive and negative internal pressure acting on the walls. Equation 27.4-1 was used to calculate the net pressure acting on the walls and roofs of the building.

To calculate the wind forces acting on the structural components, the pressure was multiplied by the affective area and distributed onto the columns of the framing plan. These pressures

\[ p = qGC_p - q(GC_p) \text{ (lb/ft}^2\text{)} \text{ (N/m}^2\text{)} \quad (27.4-1) \]

The sloped stands were assumed to act as a vertical and the pressures were distributed horizontally onto the supporting raker beams.

Each final net pressure was evaluated for positive and negative internal pressure along with toward and away pressure acting on the roof for a total of 4 load cases for each direction creating 32 wind pressure entries into the STAAD.Pro model.

**Snow Loads**

Snow live loads are also based on the shape of the building and will vary with drifting factors applied. These loads were established using ASCE 7-10 Chapter 7 and the calculations were done in Excel. The first step in calculating roof snow load was calculating the flat roof snow load with Equation 7.3-1

\[ p_f = 0.7C_eC_Ip_g \quad (7.3-1) \]
$C_e = \text{exposure factor}$

$C_t = \text{thermal factor}$

$I_s = \text{Importance factor}$

$p_g = \text{ground snow load}$

The exposure factor and thermal factor was found from Table 7-2 and Table 7-3 in ASCE 7-10 respectively. A Terrain Category B and a fully exposed roof was used for the exposure factor and a category of “All structures except as indicated below” was used for the thermal factor. The importance factor was based on a level III, buildings with high risk to human inhabitance.

Once the flat roof snow load was calculated the sloping factor ($C_s$) is added in as shown in Equation 7.4-1

$$p_s = C_s p_f \quad (7.4-1)$$

This slope factor was based on a roof of 20 degrees. Once this value was calculated the balanced and unbalanced roof snow loads were calculated according to Figure 21 for $W < 20$ft.
Figure 21: Displays Figure 7-5 Balanced and unbalanced snow loading from ASCE 7-10

This creates three different scenarios for snow loading: balanced, front of roof, and back of roof. The final snow loading values are summarized in Table 3.
Table 3: Snow loads calculated with ASCE 7-10

<table>
<thead>
<tr>
<th>Load Combination</th>
<th>Load (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balanced Load (Pf)</td>
<td>24.26</td>
</tr>
<tr>
<td>Sloped Roof Load (Ps)</td>
<td>22.56</td>
</tr>
<tr>
<td>Unbalanced Load (I*Pg)</td>
<td>38.5</td>
</tr>
</tbody>
</table>

It was assumed that if there is live load present on the stands (i.e. fans) the snow will be shoveled off, therefore snow loads on the seating area were not analyzed in the load combinations.

**Load Combinations**

The desire for the STAAD.Pro model was to simulate every possible scenario. There were 32 wind load cases, 14 stand load cases, and 3 snow load cases combined according to LRFD basic combinations found in ASCE 7-10 as shown in Figure 22. This created a model that ran through over 1,500 load cases.

Figure 22: LRFD Load Combinations

1. 1.4D
2. 1.2D + 1.6L + 0.5(L_r or S or R)
3. 1.2D + 1.6(L_r or S or R) + (L or 0.5W)
4. 1.2D + 1.0W + L + 0.5(L_r or S or R)
5. 1.2D + 1.0E + L + 0.2S
6. 0.9D + 1.0W
7. 0.9D + 1.0E
**Framing System**

The design of the framing system was created using STAAD.Pro software. This allowed the whole framing system to be built and analyzed in a single file with all load cases. Wind loads were first analyzed in STAAD.Pro on the structural members. The worst case was determined and all other loads were added into the model. Load combinations were created in accordance with ASCE 7-10. STAAD.Pro was used to calculated the moments of each beam and column were in excel was used to compute a minimum area of steel according to the standards in ACI 318-08.

**Columns**

There are two types of column supports that can be used with precast stadia slabs, steel I-beams and concrete columns. Concrete columns were selected because vibration control, aesthetics, and constancy of design. Ideally the concrete beams and columns supporting the structure would be constructed out of prestressed precast concrete to lower overall cost, but because of scope of project all members of the structure were designed as reinforced concrete with a density of 150psf and 5ksi compressive strength and 60ksi yield strength.

After the model was analyzed with STAAD.Pro compressive forces and moments were calculated for each column. These forces were added into an excel spreadsheet that created a column interaction diagram as shown in Figure 23. Calculations were done according to the textbook *Reinforced Concrete Mechanics and Design Third Edition* by James G. MacGregor. The interaction diagram relates axial load force to moments acting on the column. The P0 Max (blue) line represents the maximum axial load the column can handle. The moment interaction (orange) line represents the maximum moment the column can handle for a given axial load. For each load combination a point is created. When the point lies below the P0 Max line and to the left of the moment interaction line the column can handle the forces.
Individual interaction diagrams were created for each size column used in the design. The final selection consisted of 24 inch square columns with 6 #9 bars for the first level. The second and third levels are supported by 18 in columns with the varying reinforcing amounts as shown in the column schedule. A #3 stirrup bar will be placed horizontally along the column in accordance with Section 7.10.5 of ACI 318-11 building code requirements to help with shear reinforcement and lateral deformation of interior concrete.

Beams

Steel Reinforcement

The beam design for this project was done following Ultimate Strength Design and ACI codes. With the overall size of the beams being limited architecturally by the size of columns and floor slab widths, the main design element available to meet the required moments was the area of
steel reinforcing the beams. The beams will be designed with a base \( b \) of 24 inches at the first level of beams, and a base \( b \) of 18 inches for all beams on the following levels. The height of the beams will be 18 inches. An initial guess will be made for the area of steel by choosing the size and number of reinforcing steel bars. From the bar of steel chosen, the depth of steel \( d \) can be found by subtracting the width of the stirrup bar (#3 bar), 1.5 inches of cover and 0.5 of the chosen bar size from the total height of the beam. The strain graphs are then drawn by assuming the strain in the concrete of 0.003 and 0.005 in the steel reinforcing bars. On the Stress graphs, seen in Figure 21, \( C \) is the distance to the extreme compression fiber at the neutral axis, \( a \) is the depth of equivalent rectangular stress block. The width of the block is calculated by multiplying the compressive strength of the concrete. The calculations to find \( a \) and \( C \) can be found below in Figure 20, equations 2 and 3.

**Steel Reinforcement Design**

\[
T = A_y \cdot f_y \quad \text{Equation 1}
\]

\[
a = \frac{T}{(0.85 + f'_c + b)} \quad \text{Equation 2}
\]

\[
C = \frac{a}{0.85} \quad \text{Equation 3}
\]

\[
M_u = (\max(C, T)) \cdot (d - \frac{a}{2}) \quad \text{Equation 4}
\]

*Figure 24: Steel Reinforcement Design*

With these values it is possible to calculate the moment that the beam has been designed for with Equation 4 of Figure 20. This moment can be compared to the maximum moments for the beam being looked generated by STAAD.Pro. The steel will be placed in the bottom of the beam when the moment is positive, and at the top of the beam when the moment is negative.
This process was completed for every unique beam in the stadium design, allowing for similar beams to be designed for the worst case of the similar beams. Some checks done to ensure the design was correct included comparing the required and calculated moments, minimum steel requirements and flexure minimums.

**Stirrup Spacing**

The design surrounding the stirrup spacing is reliant upon the maximum shear forces generated from the STAAD.Pro model. The steps followed will be summarized initially then explained in greater detail. First the factored shear force diagram is computed, and then the stirrups are checked for necessity according to ACI sec. 11.5.5.1. Then a check for the anchorage of the stirrups and maximum spacing is done, following ACI code. Finally, the stirrup spacing required to resist the shear forces is calculated. This process is then repeated for each unique beam, allowing for similar beams to be designed for the worst case values. The equations\(^{19}\) to be used in their appropriate steps are shown below in Figure 22. The actual spacing requirements were done at intervals of 3, 5 and 7 inches for the first floor beams and 3, 6, and 9 inch spacing for all

\(\text{Figure 25: Beam Diagram}^{18}\)

---


beams designed above the first floor. The results of both the beam design and stirrup design can be found in the Concrete Beam Schedule submitted along with this report.

**Stirrup Spacing Design**

\[
V_n = \frac{V_u}{\phi} \quad \text{Equation 1}
\]

\[
V_n \leq \frac{V_c}{2} \quad \text{Equation 2}
\]

\[
V_c = 2 \times \sqrt{f'c \times b \times d} \quad \text{Equation 3}
\]

\[
A_{vmin} = \frac{50 \times b \times s}{f_y} \quad \text{Equation 4}
\]

\[
S_{max} = \frac{A_y \times f_y \times d}{50 \times b} \quad \text{Equation 5}
\]

\[
s = \frac{A_y \times f_y \times d}{V_u / \phi - V_c} \quad \text{Equation 6}
\]

\[
\frac{V_u}{\phi} = \frac{A_y \times f_y \times d}{s} + V_c \quad \text{Equation 7}
\]

**Figure 26: Stirrup Spacing Design**

**Roof Member Selection**

The design of the stadium press box includes steal wide flange beams to support the roof. The moments were calculated in STAAD.Pro. A worst case moment of 89.5 ft-kips was computed and W12x19 beams were selected to support the roof as shown in Figure 27. These beams can support a moment up to 92.6 ft-kips according to Table 3-2 in the AISC Steel Construction Manual.
Figure 27: Press Box Framing Plan
**Footing Design**

The foundations of the home stands building were designed to distribute the weight of the complex to 3500 psf, which is consistent with the bearing capacity of the soil on site.\(^\text{20}\) If the design were to move forward, the bearing capacity would need to be verified by soil borings and analysis done by a soils engineer. Column spread footing designs were carried out once the critical column loads and moments were obtained from the STAAD.Pro model. Following ACI 318-11 Chapter 15, footing depths were computed based on both one-way and two-way shear analysis of the footing. Next, the footings were analyzed for flexure and steel flexural reinforcement was specified accordingly for each footing. The footings are specified as square, ranging in size from 4 feet to 13 feet side length and range from 15 to 18 inches deep. Steel reinforcement is placed 3 inches from the base of each footing in a 1-foot spaced grid; the reinforcing calls for #7 and #8 bars.

**Other Specifications**

Artificial grass from FieldTurf Inc. has been specified for both artificial turf fields. This manufacturer was chosen based on quality of product, lifespan, and cost. Site conditions have been specified in order to be prepared for the installation of the FieldTurf product.

The field lighting systems were chosen from Musco Sports Lighting. Each field requires four lighting poles, two near each sideline of the field. Based on the manufacturer’s guidance and observation from other fields, this would provide adequate lighting.

**Project Cost**

The project has been designed first and foremost to meet the requirements of the College; the project has not been designed on a lowest-cost basis, however, cost was a major consideration in many of the design choices. It should be noted that the master plan accompanying this football and soccer complex includes the relocation of the outdoor running track as well as the plan for Calvin’s baseball games to be held at the Gainey Athletic Facilities. These items would come with additional costs which were not explored in Team 9’s analysis. Some factors that had significant impact on the final cost were the choice of reinforced concrete and the site location. Using reinforced concrete as the primary structural material increased the construction cost, but

\(^{20}\) Bearing capacity of the soil was provided by Professor De Rooy, no calculations were used to verify 3500psf
has other benefits, including lifespan and aesthetic appeal. The site location chosen helped keep the project cost relatively low in terms of site preparation since the specified site requires minimal demolition and grading.

Costs of materials and construction were estimated using RSMeans Building Construction Cost Data 2009 and RSMeans Square Foot Costs 2012, both taking into account location factors and yearly construction factors. Both of these resources provide detailed construction cost information and all costs include contractor/subcontractor fees, engineering/design fees, and a 5% contingency. Table 4 outlines the major categories and associated costs and the total estimated project cost.

Operations and Maintenance costs have not been calculated for this design. These costs would need to be assessed in terms of water usage, energy usage of the buildings, and site and landscaping maintenance. If the design process were to move forward, these assessments should be made by qualified professionals in each respective field. The lifespan of the structure was a design consideration when choosing materials, but has not been estimated for the proposed design.

Table 4: Construction Costs

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Site Demolition and Grading</td>
<td>800,000</td>
</tr>
<tr>
<td>Concrete Framing</td>
<td>1,800,000</td>
</tr>
<tr>
<td>Masonry and Concrete</td>
<td>1,300,000</td>
</tr>
<tr>
<td>Finishing, Plumbing, Electrical</td>
<td>2,500,000</td>
</tr>
<tr>
<td>Turf Field</td>
<td>1,700,000</td>
</tr>
<tr>
<td><strong>Total Project Cost</strong></td>
<td><strong>$8,100,000</strong></td>
</tr>
</tbody>
</table>

Team Budget

A stipend of $500 was given to each team at the beginning of the semester, with the potential for additional funding if absolutely necessary. A budget was discussed among group members, and it was decided that the funds would primarily go towards car rental and travel for visiting Fred
Zollner Athletic stadium at Trine University in Angola, Indiana, as well as the Dial-Roberson All-Events Stadium at Ohio Northern University in Ada, Ohio. Additional funds were requested by Team 9 from Dr. James Timmer, Calvin College Athletic Director, for travel expenses. The request was granted, and funds for all fuel expenses were covered. Additional needs for funds include a scale model of the complex, as well as any printing fees incurred. The budget was updated on a use by use basis, and a detailed budget can be seen in Table 5.

Table 5: Detailed Budget for Team 9

<table>
<thead>
<tr>
<th>Item</th>
<th>Additional Information</th>
<th>$</th>
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</thead>
<tbody>
<tr>
<td>Trine Visit:</td>
<td>Mid-size Budget Rental</td>
<td>(36.00)</td>
</tr>
<tr>
<td>Ohio Northern Visit:</td>
<td>Mid-size Budget Rental</td>
<td>(36.00)</td>
</tr>
<tr>
<td>Visits to Trine and Ohio Northern</td>
<td>Cost of gas paid for by Football Feasibility Task Force</td>
<td></td>
</tr>
<tr>
<td>Printing</td>
<td>Final posters for display Books through interlibrary loan</td>
<td>(20.00)</td>
</tr>
<tr>
<td>ILL late fees</td>
<td></td>
<td>(20.00)</td>
</tr>
</tbody>
</table>

Remaining Budget: $ 388.00
**Conclusion**

Currently, the future of Football at Calvin has not been decided for certain, but Team 9 believes that it has established and accomplished substantial goals over the course of this project. This was done by communicating with the many parties involved in the decision process as well as consulting informed professionals. The contents of this report meet and exceed the needs that Calvin College has expressed as well as providing a cost estimate and an idea of what is possible than initially should Calvin College decide to go forward with football. The set of drawings and schematics provided with this report detail Team 9’s designs of the layout, structural concrete beams, columns, footings, floor slabs, and architectural layout. If this structure is to be built, a licensed engineer will need to approve the structural designs, further design will also be required, in both the topics mentioned as well as other parts of the design that fell outside of the project scope.
Appendix

I. Athletic Fields Master Plan: Stadium

Conceptual Budget
3/20/2011

Table 6: Conceptual Budget - Football Stadium

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site work &amp; Utilities</td>
<td>$ 800,000.00</td>
</tr>
<tr>
<td>Stadium Building w/press box (seats for 3000)</td>
<td>$ 3,000,000.00</td>
</tr>
<tr>
<td>Concessions Building</td>
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</tr>
<tr>
<td>Artificial Turf Field</td>
<td>$ 750,000.00</td>
</tr>
<tr>
<td>Visitor Bleachers for 500</td>
<td>$ 100,000.00</td>
</tr>
<tr>
<td>Plaza &amp; Walkways</td>
<td>$ 75,000.00</td>
</tr>
<tr>
<td>Contingency</td>
<td>$ 512,500.00</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>$ 5,637,500.00</strong></td>
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</table>

Table 7: Conceptual Budget: Soccer Stadium

<table>
<thead>
<tr>
<th>Item</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Remove Current Track</td>
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</tr>
<tr>
<td>Soccer Field site work w/ Artificial Turf</td>
<td>$ 1,000,000.00</td>
</tr>
<tr>
<td>Soccer Bleachers</td>
<td>$ 150,000.00</td>
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</table>
Table 8: Conceptual Budget: Connector

<table>
<thead>
<tr>
<th>Item</th>
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<tbody>
<tr>
<td>Entry Connection/Structure</td>
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<tr>
<td>Landscaping</td>
<td>$50,000.00</td>
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<td><strong>Total:</strong></td>
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### SECTION PROPERTIES

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<th>S (in)</th>
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<tbody>
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<td>0.222</td>
<td>0.247</td>
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<tr>
<td>B18</td>
<td>0.2016</td>
<td>0.93</td>
<td>0.096</td>
<td>0.114</td>
<td>0.126</td>
<td>0.137</td>
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<tr>
<td>B16</td>
<td>0.2056</td>
<td>0.34</td>
<td>0.373</td>
<td>0.408</td>
<td>0.373</td>
<td>0.411</td>
</tr>
</tbody>
</table>

### ACOUSTICAL INFORMATION

- **Deck Type:** B24, B22, B29, B18, B16
- **Absorption Coefficient:** (105, 250, 500, 1000, 2000, 4000)
- **Noise Reduction Coefficient:** 53

1. Source: Rhoads Acoustical Laboratories. Text was conducted with 1.50-pf fiberglass bats and 2-inch polystyrene foam insulation for the SDL.

### VERTICAL LOADS FOR TYPE 1.5B

<table>
<thead>
<tr>
<th>No. of Spans</th>
<th>Deck Type</th>
<th>SUD (in)</th>
<th>Soa (in)</th>
<th>Spans</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B24</td>
<td>115/53</td>
<td>95.42</td>
<td>80/32</td>
</tr>
<tr>
<td>2</td>
<td>B22</td>
<td>94/1</td>
<td>69.73</td>
<td>86/48</td>
</tr>
<tr>
<td>3</td>
<td>B29</td>
<td>74/16</td>
<td>57.99</td>
<td>106/32</td>
</tr>
<tr>
<td>4</td>
<td>B18</td>
<td>65/10</td>
<td>52.16</td>
<td>80/32</td>
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<tr>
<td>5</td>
<td>B16</td>
<td>95/36</td>
<td>65.73</td>
<td>106/32</td>
</tr>
</tbody>
</table>

Notes:
1. Minimum interior bearing length required is 1.50 inches. Minimum interior bearing length required is 3.00 inches.
2. FM Global approved numbers and spans available on page 21.