LDA-0705

Renovating Alumni Gymnasium for Academic Purpose

A Major Qualifying Project Report

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

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Degree of Bachelor of Science

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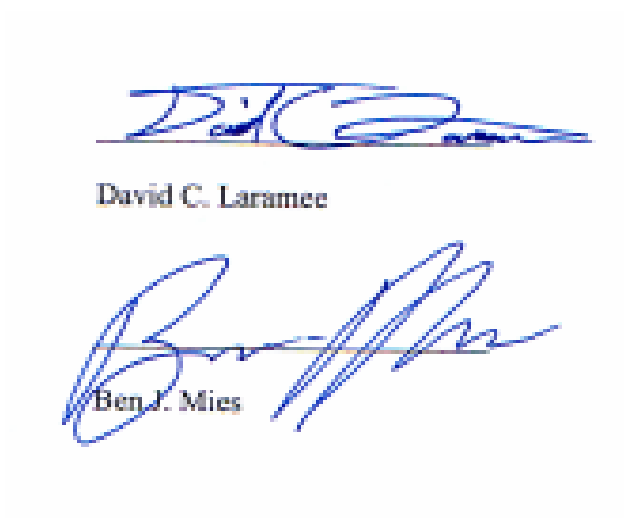
Abstract

Objective of this project was to develop alternative plans for Alumni Gymnasium such as classroom space to contribute to the WPI curriculum environment. This entailed design of additions to the existing wood and steel frame, calculations to ensure strength of the existing structure, and updates to the fire protection system to meet current requirements of the *Massachusetts State Building Code*. Along with the reconstruction and design of the gymnasium, an estimated budget was determined for remodeling and upgrading the building.

Authorship

For this project group members, David Laramee and Ben Mies have agreed that all work was divided evenly between them. For all sections of this project it should be known that it was a combined group effort. However, David focused on the fire protection and cost issues, while Ben focused on structural issues and code interpretations. In addition all members were present for all walk-throughs of Alumni Gymnasium, interviews, and provided input to the interview questions. All final corrections where review by both members and agreed upon.



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Nomenclature

NFPA – National Fire Protection Association

IBC – International Building Code

I.T Labs – A small type of conference room where there is computer hardware and projection capabilities. Elements include a plasma TV screen and computer network access to accommodate multiple users.

MSBC – Massachusetts State Building Code

S.L 104 – This is a lecture hall in Salisbury Labs designed to hold sixty to seventy students with stadium-type seating. The room has pull down screens and rolling chalk boards in the wall. The pull down screen is connected to the computer network so the instructor can use network facilities as a teaching tool.

psi – Pounds per square inch

psf - Pounds per square foot

plf – Pounds per linear foot

WPI – Worcester Polytechnic Institute

Executive Summary

This project stemmed from the idea to explore the renovation of older, historical buildings for a new and modern use. There are many parts to the re-design of a building; this report is focused on what it would take to alter the current use of a building to suit different needs.

Alumni Gymnasium is an important part of WPI's history and should be preserved for future generations of students. Alumni Gymnasium, as of now, is being used, in part, by the wrestling team. Wrestling has been hosting meets on the gym floor since the sport has been a part of the Institute. Two other varsity sports also use the gym as a training facility, the crew team, and the swim team. Furthermore, members of the ROTC program can often be seen using the indoor track. In addition, there are some offices located in the first and second floors.

Student population for the last couple of years has been slowly increasing. This trend of population growth has put a strain on the already limited number of classrooms available on the WPI campus. Since the space on campus is limited, renovating an existing, soon to be unused, building on campus makes sense. WPI is planning to construct a new field house sometime in the next ten years, and this project will free up the Alumni Gymnasium.

This practice of using old historical building is done often; it can be seen with the new gateway Project that WPI, Worcester Polytechnic Institute, is developing. The goal of the Gateway Project is to renovate and upgrade the systems in an old historical warehouse and connect a new structure. Keeping this idea in mind, this project will take an older, existing gymnasium and detail a renovation with an academic use as the

ultimate goal.

With a building chosen for our redesign, the design process began by taking a close look at what exists already. Examination of Alumni Gymnasium started with analyzing the existing structure and its load paths. Research for the old building plans along with research into how buildings were constructed in the early 1900s was performed in order to learn as much as possible about our building.

Historical building plans have a tendency to be crude and can sometimes be missing important information. The drawings that WPI had on file did not include structural plans; the Institute only had the elevation and floor plans of Alumni Gymnasium. In efforts to fill in this missing information, old building codes were examined. For example, building codes from 1911 made it possible to confirm measurements for the thickness of masonry walls on the outside of the building for example. Even with the help of the building codes and plans, information gathered on the structure in question was still not sufficient to prove its adequacy under potential loads. On a number of occasions, we found ourselves walking through the gym with a tape measure in order to get dimensions on girders, beams, columns, and other structural elements throughout the structure. During these walk-throughs, relatively careful measurements were taken of the exposed structural members. Such measurements were later used in strength analyses of the existing structure.

Combining all the information that had been collected on the Alumni Gymnasium, it was possible to ascertain how the applied loads flow through the structure. Knowing the load and how it flows through the gymnasium, coupled with assumed material properties and dimensions of members, made it possible to determine if the existing structure is safe. After basic analyses of the existing structure it was determined that the structure is most likely safe for continued use and may be used for renovation. Once it was established that the existing materials in the structure were useable for new construction, redesign of the building began.

Updated spatial designs and functional layouts of Alumni Gymnasium were done using AutoCAD 2007. Two-dimensional drawings were created with the help of this computer aided drafting program. These drawings made it possible to see how and where rooms could be placed within the scope of the space provided by the existing load bearings walls and other structural members of Alumni Gymnasium. With the help of the drawings, the building codes were then studied to determine what modifications are necessary for safe occupancy of the building. Spatial layouts and floor-plans were iterated accordingly.

The Massachusetts State Building Code (MSBC), elements of the International Building Code (IBC), and codes and standards established by the National Fire Protection Association (NFPA) provided guidance for the analyses. These code organizations help designers, architects, engineers and contractors check their designs and make the building safe for its occupants. The MSBC, and IBC when necessary, were used to check safety and durability as a structure. The NFPA codes were used to insure that the building will be safe during an emergency. Once the codes were checked, the final, proposed designs for the building were compiled.

A construction cost estimate was prepared following the completion of our design. General construction cost data was used to determine unit costs taking into account labor and materials only. Together, the cost estimate and the proposed benefits of the new design, the report provides a basis for WPI to take a closer look at the possible renovation and reuse of Alumni Gymnasium.

There are some recommendations for pre-construction activities. The firm in charge of the buildings renovation would need to investigate thoroughly the adequacy of the existing structure. Completion of this project required assumptions about the materials in the building, so there is potential for a significant variance in strength from the calculations found here. Along with the assumptions about materials, the locations of columns and other structural members were also interpreted from the original drawings and the limited information that could be seen in the walk-through. Demolition or minor removal of cosmetic coverings can prove or disprove assumptions concerning the locations and sizes of structural elements. Following these investigations and the new calculations based on any differences that might be seen, if the structure still proves to be sufficient, and then the firm could continue with the design and construction of the renovated Alumni Gymnasium.

1 Introduction

In 2015, on its 150th anniversary, Worcester Polytechnic Institute plans on having a new athletic facility built for its growing athletic community. The current facilities are not up to date, and there is a need for more space available. With the introduction of the newer athletic building, the Alumni Gymnasium will be left open [13].

This open space could be used to fill a number of the University's needs; it could be turned into classrooms, offices, or even as another center for student life. As such a large, soon to be unused structure, the space available should not go to waste. According to the thoughts of some on campus, WPI would like to see the space be used as classrooms to reduce the demand on the current classroom space [12]. These extra classrooms would lessen conflicts with scheduling. Furthermore, extra offices, a computer lab, and a project lab would ease demands on other areas of the campus especially with the addition of two new majors and no new academic buildings.

This project details our proposed plan for the structure and examines the feasibility of further examination into the idea of altering Alumni Gymnasium for academic use. Areas included in the report are structural, fire, construction, and cost analyses. There have been a number of difficulties encountered in this project, and such struggles are common to endeavors of this nature. Realistic constraints, a lack of information regarding the original structure, and both the advantages and disadvantages in interpretation of building codes are just a few of the issues encountered throughout this realistic project.

2 Background

Worcester Polytechnic Institute (WPI) has a long athletic history in the New England area, but development of the program really began with the construction of one of the oldest and now one of the busiest buildings on campus. Nearly every student, at some point in his or her academic career, has stepped into this center for physical education and athletics. This building is known to the WPI community as the Alumni Gymnasium.

2.1 The gym

Alumni Gymnasium opened in 1915. It was the first gym to be built for the WPI community. The facility was built at the same time as Alumni Field, and was erected to provide for the growing need for physical training. It was placed near what is now the center of campus and, at the time of its construction, was a top of the line facility. The five-story gymnasium supported all the needs of the growing WPI student community. Three of the five stories are above ground; with the other two stories, including a pool, underground.

There was a wide range of amenities designed into the Alumni Gymnasium. On the top floor of the gym, the third floor, resides the indoor track. This track overlooks the floor below, where the basketball court is located. This second floor also has two racquetball courts, one on each side of the main stairwells. Below, on the first floor, is the main entrance as well as the locker rooms and administrative offices for the physical education department. The basement floor has the school's fitness center and weight room as well as a balcony overlooking the pool on the sub-basement floor.

Since the completion of the Alumni Gymnasium, the WPI community has kept this facility in the forefront of WPI's physical training program. In 1965, after fifty years of using Alumni, the community decided that it needed to update the athletic facilities again. The school started and constructed Harrington Auditorium, which was connected to the older Alumni Gymnasium. When Harrington was connected to Alumni there were many renovations performed within the older gym [13].

2.2 Building codes

Building codes set the minimum standards for new construction and any renovation done to a building. There are many organizations that provide the standards for how to design and construct a building; however, we have chosen to use those from the MSBC, the NFPA, and the IBC. These codes provide a series of guidelines and parameters for engineering a building. The codes are not only used as an aid to design of the building but they also act as legal documents for accepted standards. This means the courts may ask a designer if the building was safe, and the designer can say it was designed to code and therefore was believed to be safe. Over the last hundred years the codes have changed drastically. There are two types of codes, performance-based and prescriptive. A performance-based code describes a level of acceptable performance to which a designer must conform. A prescriptive code specifies in detail exactly what materials must be used and where. There is little to no room for freedom in construction, and it is difficult to adapt to new materials. A performance-based code is made to design more on the idea of calculating the loads and member sizes, whereas a prescriptive code builds on the idea of what has worked in the past.

2.2.1 1911 Building Codes

The design and construction of the Alumni Gymnasium was done under the guidelines of the 1911 Laws and Ordinances of the City of Worcester. During this era, design and construction was performed by a "rule of thumb": building codes were a collection of good practices. They guided the designer as to what material and member proportions to use for a certain situation. For example, buildings three stories tall, like Alumni Gymnasium, would be required to have brick walls 16 inches thick for the basement (and sub-basement) and 12 inches thick for the first through third floors. This prescriptive method is found throughout the code. The floors were the only areas on our building that may have been designed in an engineering sense based on load values. In Section 31, lines twenty-eight through thirty, the regulations state that when designing for a public assembly, the floor must support not less than 100 pounds per square foot [10].

This lack of a performance-based approach with reliance on engineering calculations and judgment to determine the maximum loads for a building may have caused many buildings to be over built. This is seen in the Alumni Gymnasium framework. Depending on how one interprets the provisions of these regulations, the-first floor walls of the five-story (total) building with three floors above ground, should have a wall thickness of between 16 and 24 inches. From visual inspection of the walls for Alumni Gymnasium it was determined that they have a thickness of well over 24 inches; the true dimensions of the walls are about thirty inches [10].

2.2.2 Modern Building Codes

Modern building codes are less prescriptive in terms of structural provisions and rely primarily on the designer to follow a performance-based approach that makes use of analytical methods and industry standards in the building design. There are many equations, load variations, and factors for the designer to follow. The International Building Code (IBC) 2006 Edition, Massachusetts State Building Code (MSBC), and the codes and standards published by the National Fire Protection Association (NFPA), which were all followed in this design, allow the designer to interpret and perform the required calculations for structural engineering. The designer must calculate the size of structural elements depending on the loads applied to the structure and the engineering properties of available materials, rather than simply following a guideline based on the building's use and overall dimensions.

2.3 WPI Needs

As the years progressed, there became an increasing need for WPI to create a larger, more up to date athletic facility, and the WPI Administration has recently responded to this need. WPI has plans for the construction of a new, modern athletic recreational center to compliment Harrington Auditorium. Once this new athletic center is in place, there will be no need for the old Alumni Gymnasium. In fact, there are no plans for the subsequent use of this space.

The WPI academic community and campus has a problem with classroom space. Charles J. Kornik, the Administrator of Academic Programs, is in control of the scheduling for all of the classrooms on WPI's campus. Mr. Kornik would like to see more classrooms on the campus; however, with the commitment of existing open space to the new athletic building, there is very little space available on campus for the construction of a new building. He would like to see the renovation of the old Alumni Gymnasium include a number of much needed classrooms. The classrooms as of now are over-filled with students, and there are often issues of overbooked space. More classroom space would certainly help to alleviate these problems [12].

Mr. Kornik has kept detailed records of which classrooms are most used and which classrooms are the most desirable for use by professors, organizations, and meetings. With this information (reference in appendix), it was determined that classroom sizes most used and most desirable range from sixty to eighty students. Furthermore, he stated that another classroom similar to Salisbury Labs Room 104 would be a great addition to the campus. SL104 holds 76 students and is equipped with fixed tables, movable chairs, and has tiered levels for better viewing of the instructor and teaching materials at the front of the classroom [12].

In addition, personal experience has shown that there is a need for lab areas and offices for professors, teaching assistants, and student organizations. Many laboratories, especially those used for Major Qualifying Projects, are simply over crowded. An addition to the amount of space available to support these required projects could provide better overall results as frustrations over lab space can become overwhelming. Furthermore, with the addition of the new Robotics Engineering program, the addition of a significant number of new offices, lab space, and computer labs, all within a few steps of the Mechanical Engineering Department, would certainly prove to be beneficial.

With this information, the scope of the project was defined: a proposal to transform Alumni Gymnasium into much needed classroom, office, and lab space.

3 Existing Structure

Beginning a project like this one, it is imperative that the original structure be understood. How could one effectively change the use and design of a large structure without first understanding how this structure supports itself and the loads it must carry? Well, one might be able to, but it would almost certainly not take full advantage of the existing materials and thus would probably not be as cost effective as a more integrated solution. So, before creating a new plan, preparing calculations to support the plan, or detailing the proposed changes, the original structure must be understood.

3.1 Construction and Load Path

From the outside, looking at Alumni Gym is visually impressive in a simple but large sense. The robust, boxy structure is a prominent piece of the campus. Upon entering the building one gets an immediate sense of its character as an important part of the WPI history and community. Upon pulling open the heavy wooden doors of its front entrance, an informed observer can get a sense of the structural workings of the building itself.

From the peak of the roof down, the load paths within the building are visible and relatively simple. The roof load is supported by a grid of steel trusses, which span between the thick brick masonry exterior walls. The entire ninety-foot roof span is supported by the one hundred and thirty-foot front and rear exterior walls. This system leaves the upper two floors without columns. This column-free space is required for the second-floor open gym-floor and will suit the application of large classroom spaces. Immediately below the roof lies the building’s third floor which currently has a track partially supported from the roof trusses and thus nearly its entire load is ultimately supported by the exterior walls. A portion is supported by the load bearing main stairway walls. A section of the third floor also is supported by a standard girder and beam system. There do not appear to be any columns in this area, and it was assumed that the load-bearing exterior walls and staircase walls support the beams and girders.

As previously mentioned, an open gym floor occupies a great majority of the second-floor area. This floor is supported by timber beams, transferring their load to the exterior walls as well as four interior steel girders running lengthwise in the structure. The girders are supported by a grid of steel columns, many of which extend all the way to the foundation level and are supported by footings. The framing schemes for the first-floor, the basement, and the sub-basement, are all constructed in a similar manner with girders, beams, and columns.

As well as materials and geometry can be determined, the exterior walls are brick construction and are roughly 30" thick at the first floor level. The 1911 Laws and Ordinances of the City of Worcester allow the wall thickness to decrease on the second and third floors; however, it appears that this thickness remains roughly constant [10]. From our measurements, the timber floor beams are about 12" by 12". Southern Yellow Pine was the assumed species based on materials calculations outlined later in the text. The steel girders are of an I shape, roughly 24" tall, 12" wide, and 1" thick throughout both the flange and web. The only exposed columns available for examination are 9" in diameter and appear to be made of steel. An assumption was made for the wall thickness of this column to be ¼" for no other reason than it seemed reasonable given experience with structural materials. Notes on the walk-throughs can be seen in 11.4 Walk-Through.

3.2 Materials Assumptions

There are inherent issues with analyzing an old structure for re-use. In our case, there are significant issues as the building in question is nearly one hundred years old. This has presented a number of problems. First, there are no structural plans available. Several resources have been contacted to no avail. Furthermore, building codes from the early 1900s are severely limited in their depth. Codes of this era, and for the city of Worcester, were based on a prescriptive description of a structure, meaning, very little is said about specific materials and their engineering properties. In addition, the building is currently in use, so no destructive sample collection was performed. No testing of the materials used can be made, and no removal of aesthetic coverings was permitted.

With all of this in mind, beyond the visible structure, basic dimensions achieved through measurements, and the very limited building code provisions, assumptions were necessary to define the structural materials that are in use. For the steel beams and columns, dimensions of exposed members were taken and assumed to be consistent throughout. As the quality of structural steel and steel members have advanced tremendously over the past century, and research into material properties of that era did not return any definitive data, an envelope for the properties and dimensions of our steel members was assumed. For instance, the yield strength was assumed to be within a range of 24 to 36 kips per square inch. Through our initial calculations of the proposed loads and this range of strength values, the existing members were shown to be acceptable with the worst case scenario of unsupported beam length and column placement.

Timber floor beams are exposed underneath the gym floor looking up from the first. These beams run between the steel girders at a span of 17.1 feet. They are spaced roughly 6 feet on center at the widest point, and the cross section of the smallest of these are approximately 12” by 12” square. However, without taking a sample of the material, the selection of a species and grade of wood to use for design calculations required making assumptions. An interesting method can be used to assume an envelope of possible woods used and will be illustrated in the following section.

3.2.1 Timber Species

An accurate reverse engineering process for the required material strength through assumptions of the original design dead loads and live loads would likely give workable results. However, the addition of new loads, given the building’s intended new use, may prove these assumed material properties unacceptable, and the result would be to look at a table of properties for potential materials and iterate the calculations accordingly. By starting at the beginning of the material choice process and limiting our result to the possible materials present, an accurate envelope of materials used can be developed.

If we are to use as much of the existing structure as possible, the assumed geometry of this structure offers constraints as to the likely material possibilities. For example, by beginning with the objective of the structural member, stiffness and strength equations for a given cross section can be expressed as a series of material indexes. As for strength limitations, a timber floor beam must perform in two major ways. It must not buckle under compressive stresses from the girders that support it, but it also cannot fail under the bending load applied from the floor above. Furthermore, the member must satisfy stiffness limitations. Deflection of the member under both compression and bending must be kept below a maximum value given the initial design. In addition to these compression and bending loads, a certain amount of torsion is applied to the member through the angular deflection of its wall and girder connections, treated as pin connections, as they deform differently under load. However, the coupled material index for this applied torsion was seen to have a minimal effect on the ultimate range of materials in question. Furthermore, weight and cost are always a consideration in structural design; as such, these parameters were included in the indexes listed in Tables 1 and 2 below that are to be maximized in the materials choice.

Table 1 Strength Indexes

Bending	$(\text{Yield Strength})^{2/3}$/Density/Price
Buckling (from lateral loads)	(Yield Strength)/Density/Price

Table 2 Stiffness Indexes

Bending	(Young's Modulus)/Density/Price
Buckling (from lateral loads)	$(\text{Young's Modulus})^{1/2}$/Density/Price

This method is proven applicable through a powerful computer program. The Granta Material Intelligence program is based on the Cambridge Engineering Selector technology or CES [15]. The program offers an up to date and in-depth materials library with the availability to select a range of suitable materials through a series of limit stages. This includes the ability to graph materials based on a wide variety of materials indices. Using the program, the first step was to limit the material choices to types of commercially available wood. Both longitudinal and transverse properties were examined. Low-grade steel was left as an option for comparison reasons only. Figure 1

“Strength Materials Indeces” shows the initial graph of all available materials given the strength indexes. Labeled in the graph are both a type of wood and steel to show how well suited these two materials are to their common application in building structures. This graph shows nearly every available material from polymers and concretes to magnesium alloys and all but unavailable composites. Materials in the upper right hand corner are best suited to “beam type” applications as they maximize both the buckling and bending indices in Table 1 Strength Indexes and Table 2 Stiffness Indexes.

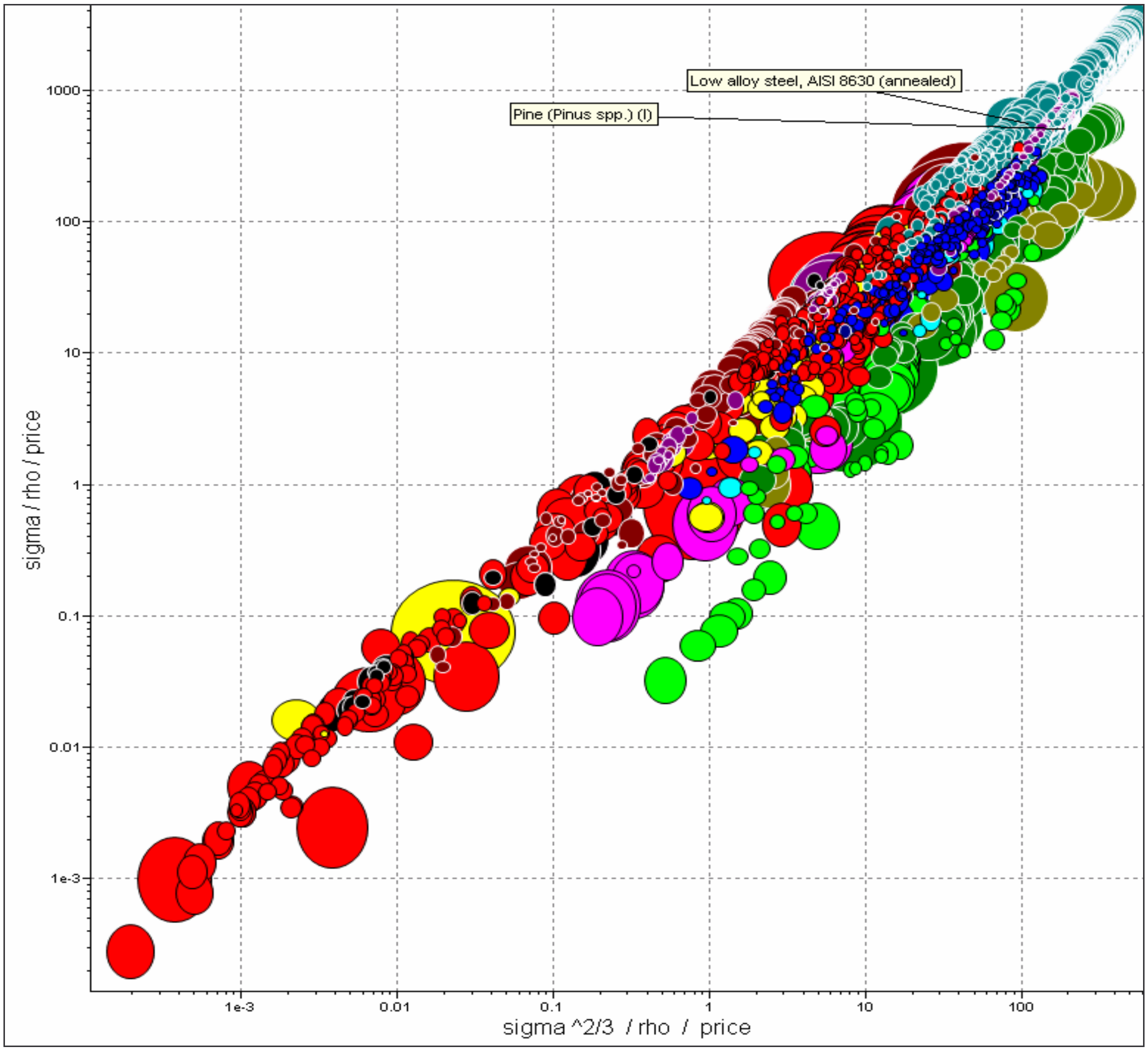


Figure 1 "Strength Materials Indeces"

Shown below in

Figure 2 “Stiffness vs. Price” and Figure 3 “Strength vs. Price” are the variety of strength and stiffness properties available in the array of wood types. For example, in Figure 2, the most effective species of wood considering price, and used in the longitudinal direction, for limiting deflection under a bending moment would be those found above a sloped line derived from the indices listed in Table 2, row 1.

Figure 2 "Stiffness vs. Price"

Figure 3 "Strength vs. Price"

To further narrow down the material choices, three more iterations of these limiting graph stages were made to reduce the set of all available wood species to a suitable envelope of plausible wood species. Birch, Douglas Fir, Maple, Pine, and Spruce were chosen as likely options given their performance throughout the limiting stages of material selection. Calculations were then made for the ultimate strength of members, given our measured dimensions of the beams in use, to create an envelope of realistic strengths for the existing beams. Of course, a safety factor must be applied to this envelope to account for various factors, such as the probability of damaged members, grades outside the allowance of the measured properties, and so forth. However, this material range, coupled with the safety factors, allowed us to pursue design calculations for assessing the impact imposed by the alteration of the loads on the structure.

In fact, the findings through this short material selection study proved the use of materials similar to those that exist in tables for the design of wood structures. However, the process gone through here is extraordinarily simple and time effective compared to the process that developed those tables that we use as a benchmark for structural wood design. Furthermore, this is very unlike the process that was probably used for the selection of material for the timber beams that we are analyzing. With a lack of availability of measured materials property values for design, the girders were likely chosen based on experience alone. The choice made was probably one of the types that have been chosen here.

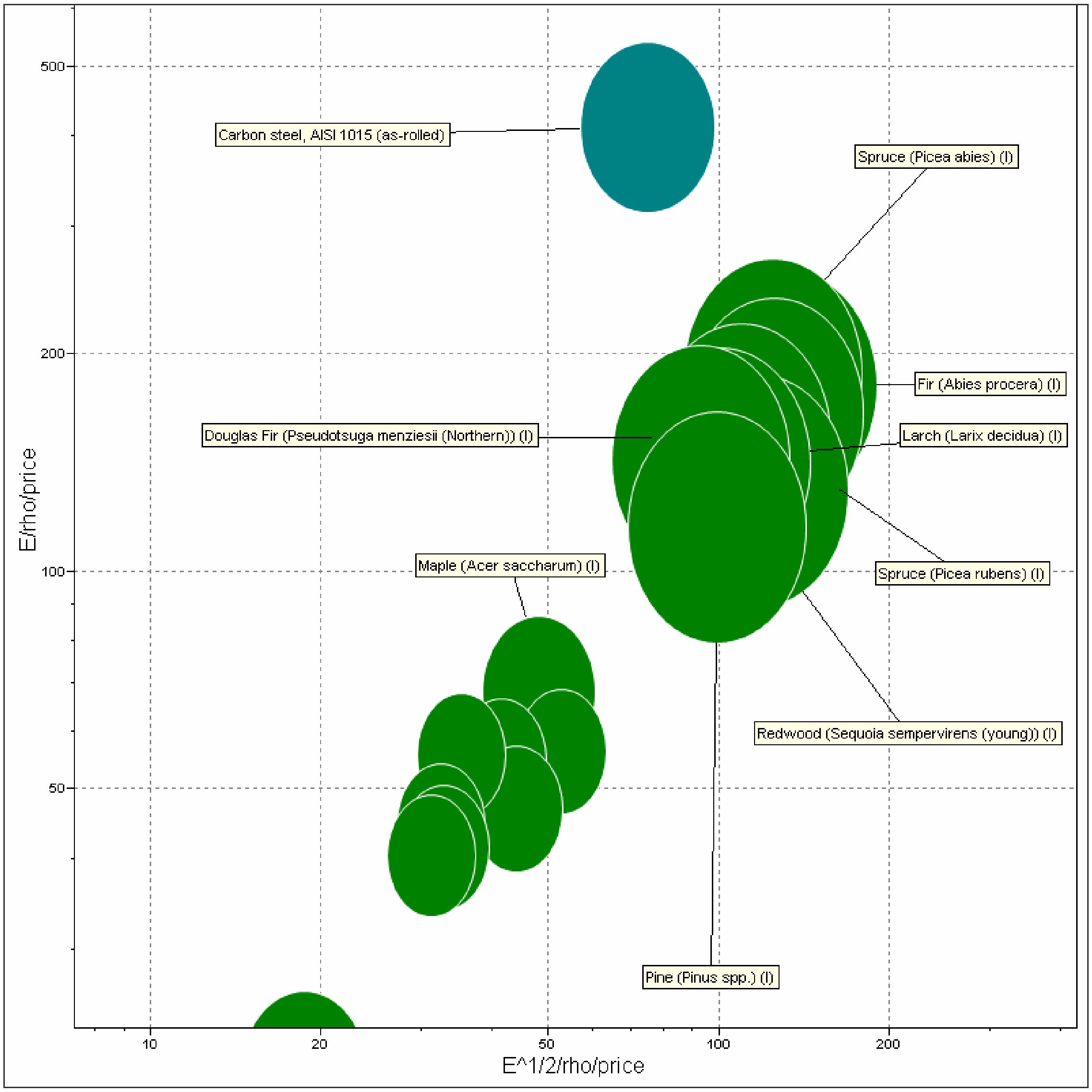


Figure 4 Wood stiffness

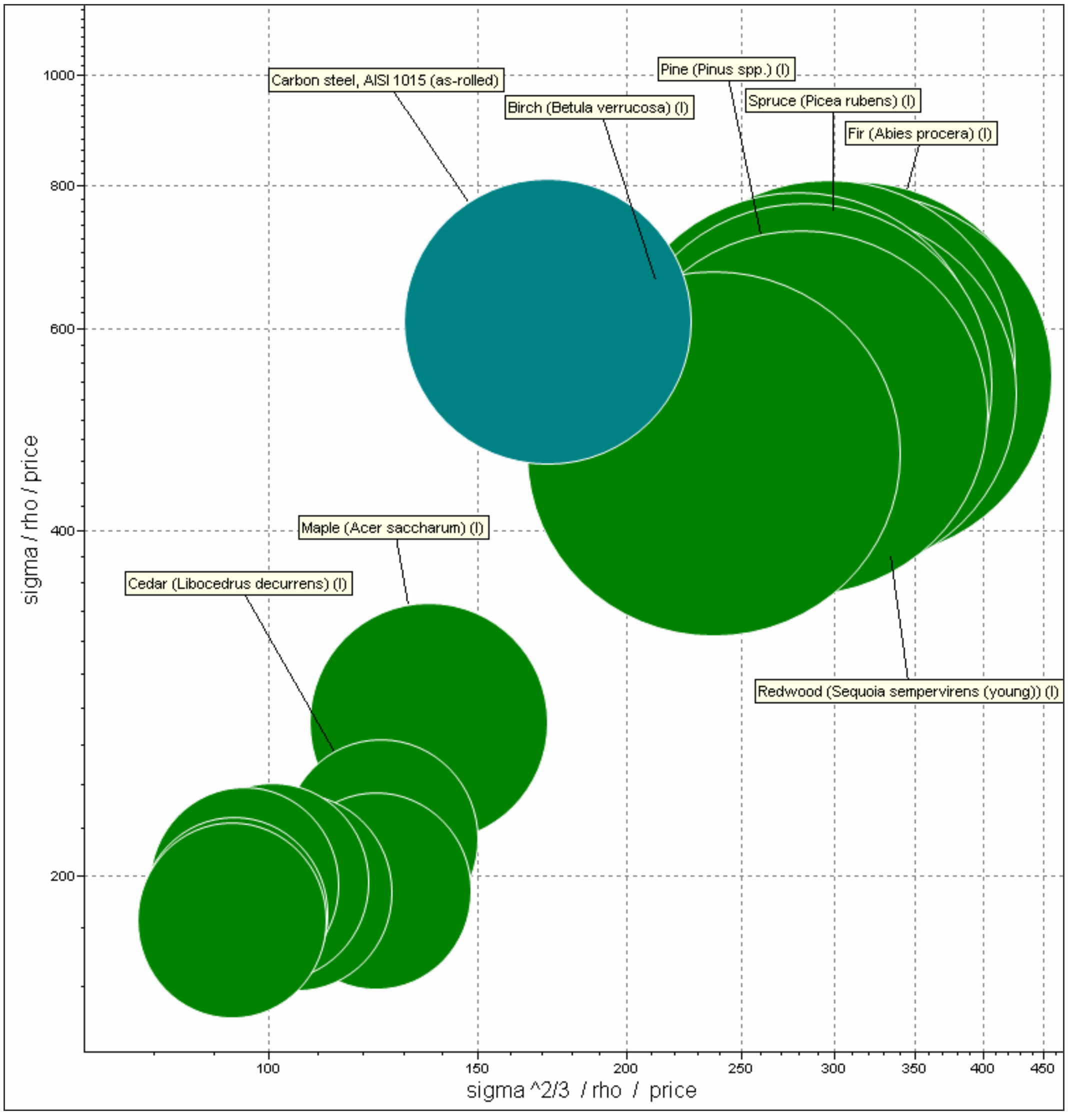


Figure 5 Wood strength

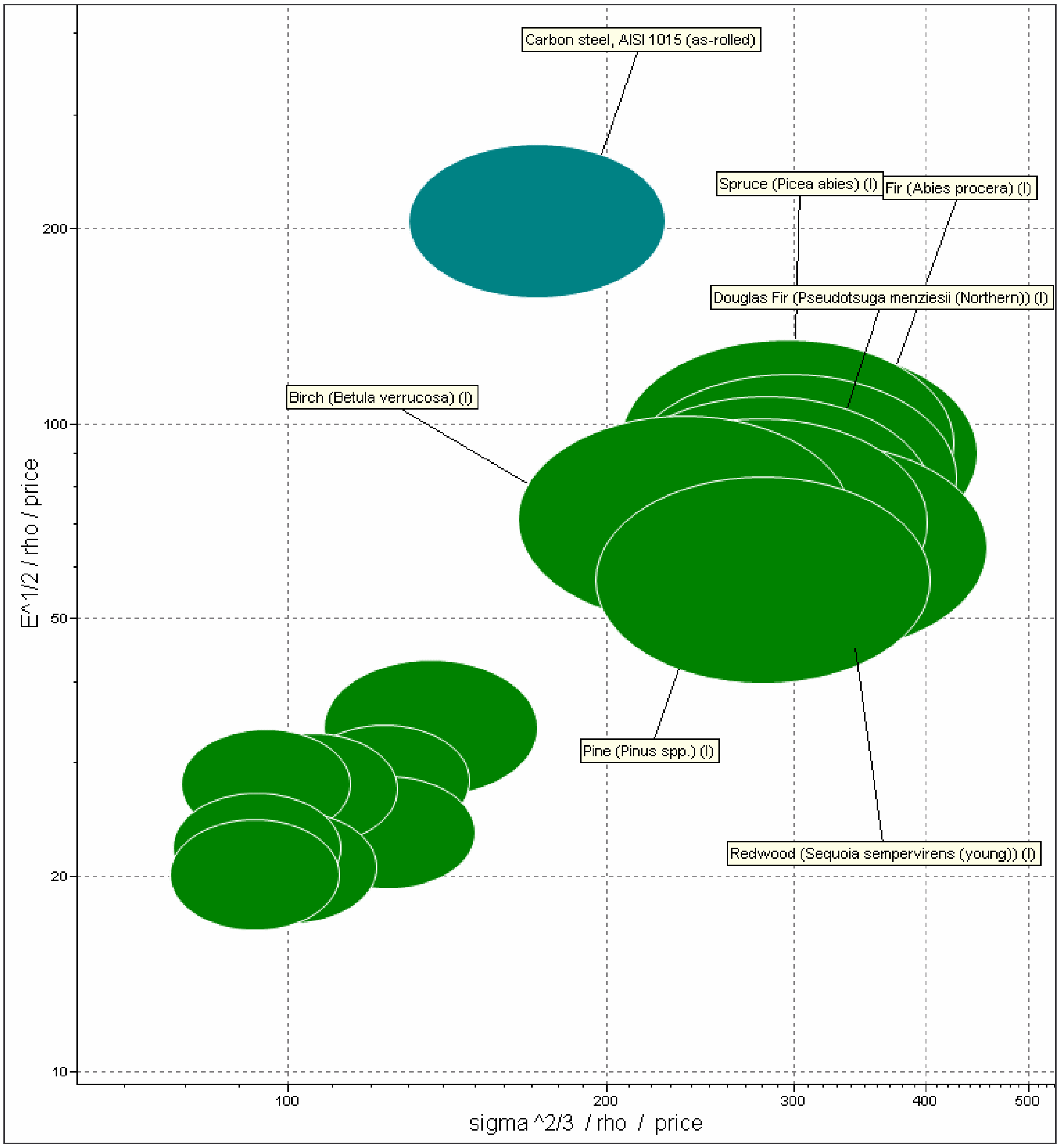


Figure 6 Stiffness vs. Strength

Figures 4, 5, and 6 display the species of wood chosen for comparison in our calculations found later in the text. A mild-steel is also included as a reference to how well wood performs given the constraints imposed by the indices. In these graphs, the best performing material is located in the upper right hand corner of the table with the maximum x and y value.

3.2.2 Masonry Strength

Alumni Gymnasium has brick and mortar exterior walls. There is a wide range of accepted strengths for brick masonry as a number of different factors are involved. Through research into old texts from around 1900, a range of possible strengths and acceptable factors of safety was developed.

The weakest part of brick masonry construction is the mortar. Mortars have different material properties and can be placed in different qualities and thicknesses; both of these parameters affect the overall strength. The purpose of mortar is two fold. It forms an adhesive bond between the bricks to hold them together. But, the thin layers of mortar also provide a cushion and an even surface to help distribute load uniformly amongst the bricks in the wall. As mortar is weaker than brick in most cases, the strength of the wall is dependant on the strength of the mortar.

Further challenges in determining the strength of masonry walls are the condition of the materials in question and the purity of these materials. Even in lab testing, with near perfect conditions, the results can vary a great deal due to the purity of the materials used. With all of this, the most reasonable method that we could determine, without taking samples of the actual mortar from the walls, was to create a broad range of values and impose a significant safety factor. The practice of using brick masonry in the early 1900s was very conservative with recommended safety factors above 10. This is evident in our building with the thirty-inch thick exterior walls. A base compressive strength of 530 psi and a maximum compressive strength of 3410 psi were taken from Baker's book A Treatise on Masonry Construction and used in conjunction with a large safety factor. These calculations and results can be seen in section 6.4 of this text [2].

3.3 Constraints and Plans

Through initial examination of the existing structure, a number of constraints as well as advantages are evident if the goal is to make minimal changes to the load-bearing elements of the building. For example, removal of the track on the top floor will be advantageous as the roof structure will then support less load. Below, at the gym floor level, the open area is extremely conducive to providing large classroom spaces. On subsequent floors, the columns that are in place outline potential functional spaces quite well and thus none are recommended for removal. Of course, all of this is on the basis that these structural elements are in adequate condition for the loads we intend to propose.

Following our series of assumptions, preliminary calculations were made as to the adequacy of the worst-case scenario members of the structure. In fact, it was found that the columns are well within the acceptance range under strictly compressive load given our proposed loading cases on the overlying floors. The steel beams are also adequate for bending, given a maximum unsupported length of 32.5 feet and an assumed minimum yield strength of 30ksi. In addition, the timber beams are adequate for bending for all materials in question and a proposed safety factor of 1.6 given possible damage to these members. Further, more detailed calculations are included following a discussion of the MSBC regulations in section 5.3.

In short, the constraints as to what can be done with the structure are welcome and relatively non-detrimental to the successful application of a new use for this building. Of course, some modifications will need to be made to accommodate proper classroom space; however, these modifications could be limited to these options with the lower overall cost while still providing adequate space for the intended new use. With this, a series of plans were prepared indicating our proposed use for the structure and the suggested structural modifications.

3.4 Fire Protection of Existing Building

When a building is being designed, a designer takes into consideration that the building must meet the previsions defined by the governing fire codes. The designer will create a building so that it is functional and safe for the occupants. Architects can design the building, but when it comes to the fire safety, a specialist is used. One type of specialist that would be used is a Fire Protection Engineer may become involved later to address compliance issues and part of the substructure for system design and installation. Another job of the fire protection engineer is to provide a safe means of egress from the building during a fire. The fire protection system will include fire barrier walls and egress from the building. In the renovations of Alumni Gymnasium the building code provisions for fire safety will need to be consulted. If need be, the facility maybe upgraded to meet present day criteria. The Fire Protection code systems that an Engineer used are the local codes, which based on one of the two national fire codes systems. The National Fire Protection Association (NFPA) and the other is the International Building Codes (IBC) is two types of the national fire protection codes that are used. This report will forces on the guide lines of the NFPA codes for the analysis of Alumni Gymnasium.

3.4.1 Pre-Renovation

Alumni Gymnasium is used as offices and as an athletic building. When Worcester Polytechnic Institute (WPI) constructs the new recreational center on the campus, the older, Alumni Gym will no longer be used for college athletics. The egress of the building and the fire barrier need to be investigating to see what exists in the building. As the building is now it is connected to Harrington Gym.

In order for an occupant to evacuate safely from the building in the time of a fire, a safe means of egress must be provided. The means of egress consists of the exits, corridors, stairways, and the fire barriers. When these elements act together and comply with the building code provisions, it is assumed that the building has a safe means of egress [6].

There are five exits from the first floor, and each floor has more than two exits. NFPA 5000 prescribes a standard for the number of exists that must be provide for the building occupancy load. Alumni Gym has occupancy load of 300, for that load two doors must be provided according to the provision of the NFPA 5000. The exits from the building are essential but not sufficient; the exits from each room are also important. For the small office-type rooms there only need to be one exit. Larger assembly-type rooms such as, the pool and the weight room must have at least two exits. The gym floor must have more than two exits due to its high occupant load [6].

Alumni Gym is a historical building according to the National Historical Building department, which means that its outer shell can't be changed, per section *780 CMR 3409.0 of the MSBC* [16]. Since the building has five different exits the occupancy load of the proposed redesign can't exceed the capacity of the current number of doors. According to *11.4.1.2*, the five exits with the current width of doors for the main floor allows for more than one thousand occupants to be considered.

Firer barriers are structural objects that are in place, to slow down the progress of fire in the building. Fire barriers are made up of the walls and the fire rating of the walls, doors, windows, ceiling, and floors. Alumni's outer shall is constructed from brick which was typical of that type of building during 1915. The inner construction material ranges from steel to wood. The steel and wood structural supports don't have any fire protection or insulation applied to them. The interior walls in the building have gypsum board on both sides, which provides the necessary two hours fire resistant rating needed. This style of construction is consistent with the type two construction of the building. Each wall has a door which is a D-bar failure in the walls fire rating. A D-bar failure is a whole in the fire barrier that is over 400 in^2 in size. When the door has a fire rating of one and half hours that's allows the wall it is part of to keep the two hour necessary fire rating; which only counts when the fire rated door is closed in the presents of the fire [3].

3.4.2 Conclusion

Now that the existing condition and the main constraints of the building are defined, there is a base for conceiving and developing the floor plan for the renovation of Alumni Gymnasium. The exterior masonry walls and their exit doors are significant constraints they can't be changed or modified due to historical reason. There are also columns throughout the building that must be considered in the space planning for the renovation.

4 Facility Planning

4.1 General

Once the designer knows the type of building for which they are designing, in terms of spaces attributed to occupant function, circulation, and building services. The floor plan is the design of each floor. The proposed redesign and conversion Alumni Gymnasium to classrooms would involve no change in occupancy classification, because WPI is a privately held business and of all its academic and administration buildings have a business classification. Alumni Gym is a five-story building that has two stories underground and the remaining three-stories above the ground. It has a total available space of 39,103 square feet that the designer can use; this square footage is the available space in the outer walls. When we were designing this building there were a couple of problems that made it hard to design each floor of the building.

The first problem the limited records and overall lack of good records for the existing structure. John Miller, Director of Physical Plant, did have a basic drawing of what was in the building at the time for space [13]. The crude CAD drawings be all that was found for the building; some assumptions were made, these CAD drawings can be seen in 11.2.2.1 Existing Floor Plan. If you look at these drawings one can see that there is an addition to the main structure to the left of the drawings. This addition is known as the connector piece to Harrington Auditorium. Once the renovation of Alumni Gym starts, the plan is to disconnect this building from Harrington Auditorium and have Alumni Gym stand on its own. The CAD drawing provided a scale on with it, which made it possible to make a good estimate of what the length and width of the building and where the immovable objects in the building are located. An immovable object would be the brick walls, columns, and stairwells that are located in the building.

It was noticed that the drawings seem to be incomplete and were missing some immovable objects like columns. With the help of many walk-throughs of the structure and the application of some engineering reasoning a more in-depth layout of the floor plan were developed. An example of when this had to be done was with column B-3 on the first floor, which can be seen in Figure 7 Missing Column. This column was not recorded on the existing floor plans but identified during a walk through. Another assumption that was made from the existing drawings concerns the layout of the given infrastructure of the building. The columns and beams did not line up or coincide from floor to floor. It was assumed by us to align all the columns and have the beam lines coincide above each other. This is a reasonable assumption because structural practice would have fought to maintain the columns in stacks and to use a repetitive beam and girder layout.

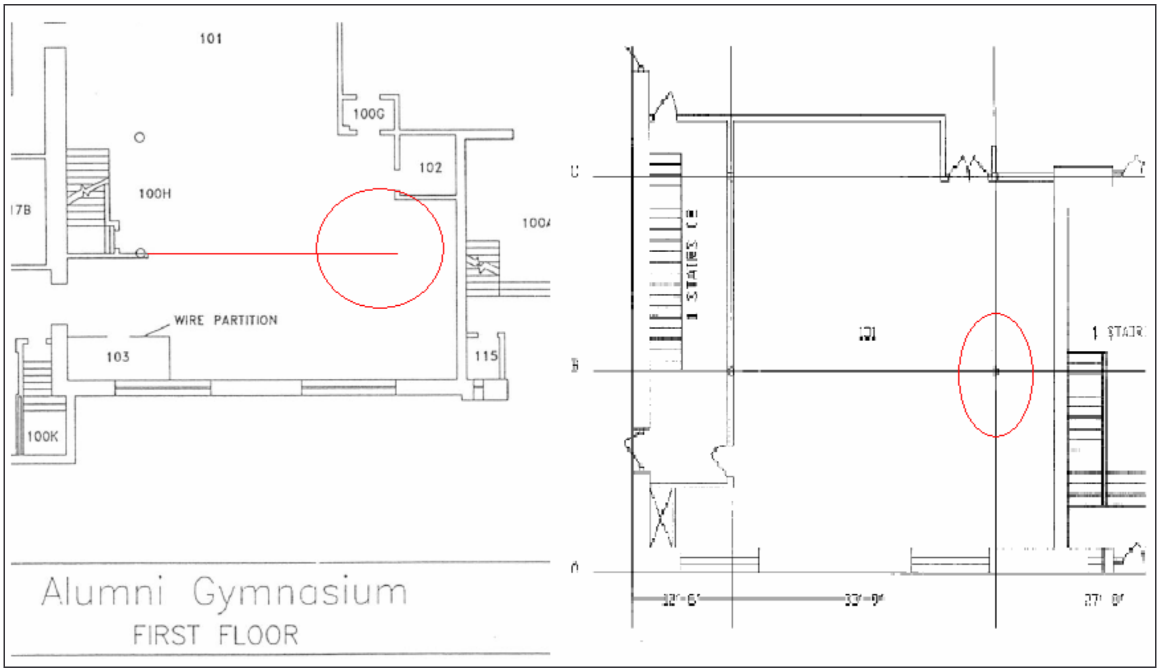


Figure 7 Missing Column

Not all the design challenges associated with the proposed renovation of this building were due to structural mistakes on the existing drawings. The building itself proved to be a challenging for integrating a new floor plan. The Gymnasium status as an historical building prevents any alteration to the outer shell. Consequently the designer not only needs to plan around interior elements like columns but the conversion of the interior space must also work with the location of the existing doors and windows. Before a redesign of the Gymnasium is possible the architect need to know what the owner wants to put into the building. When talking Charles J. Kornik, Administrator Academic Programs, he was able to lead what would be a wish list of what the WPI would want in the building. The list asked for more classroom space and more offices, and this data can be found in 11.2.1.1 Classroom Charts [12]. With the data that Mr. Kornik provided the project and knowing which types of classrooms room are the most in demand, the following functional spaces were targeted. Once all this was done a designer can than go ahead and design each floor of the building with knowledge of the existing condition and the foals for the future of the building.

4.2 Elevator

The elevator is a fixed component of the building that spans vertically through four of the five floors. The floors that will have stops on the elevator are the sub-basement through the second floor of the building. The gymnasium does not currently have an elevator located in the floor plan; this would be a new addition to the building. Installation of the elevator will allow for the building to be handicap accessible. With the location of the elevator being near the center of each floor it will allow for easy access and could be widely used by all occupants. The elevator will also allow for lab material to be easily moved out of the sub-basement.

4.3 Redesign Floor Plans

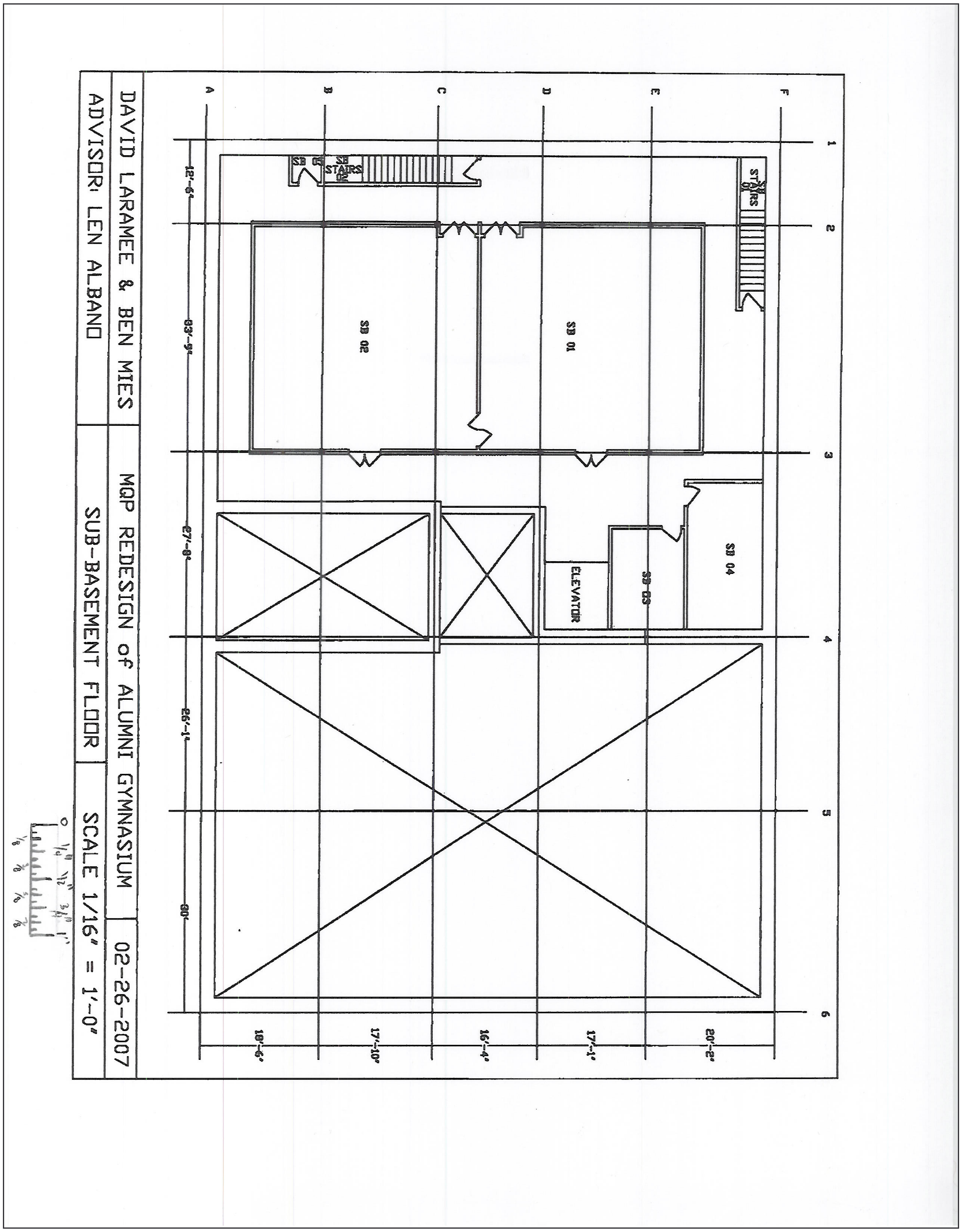


Figure 8 Sub-Basement Floor plan

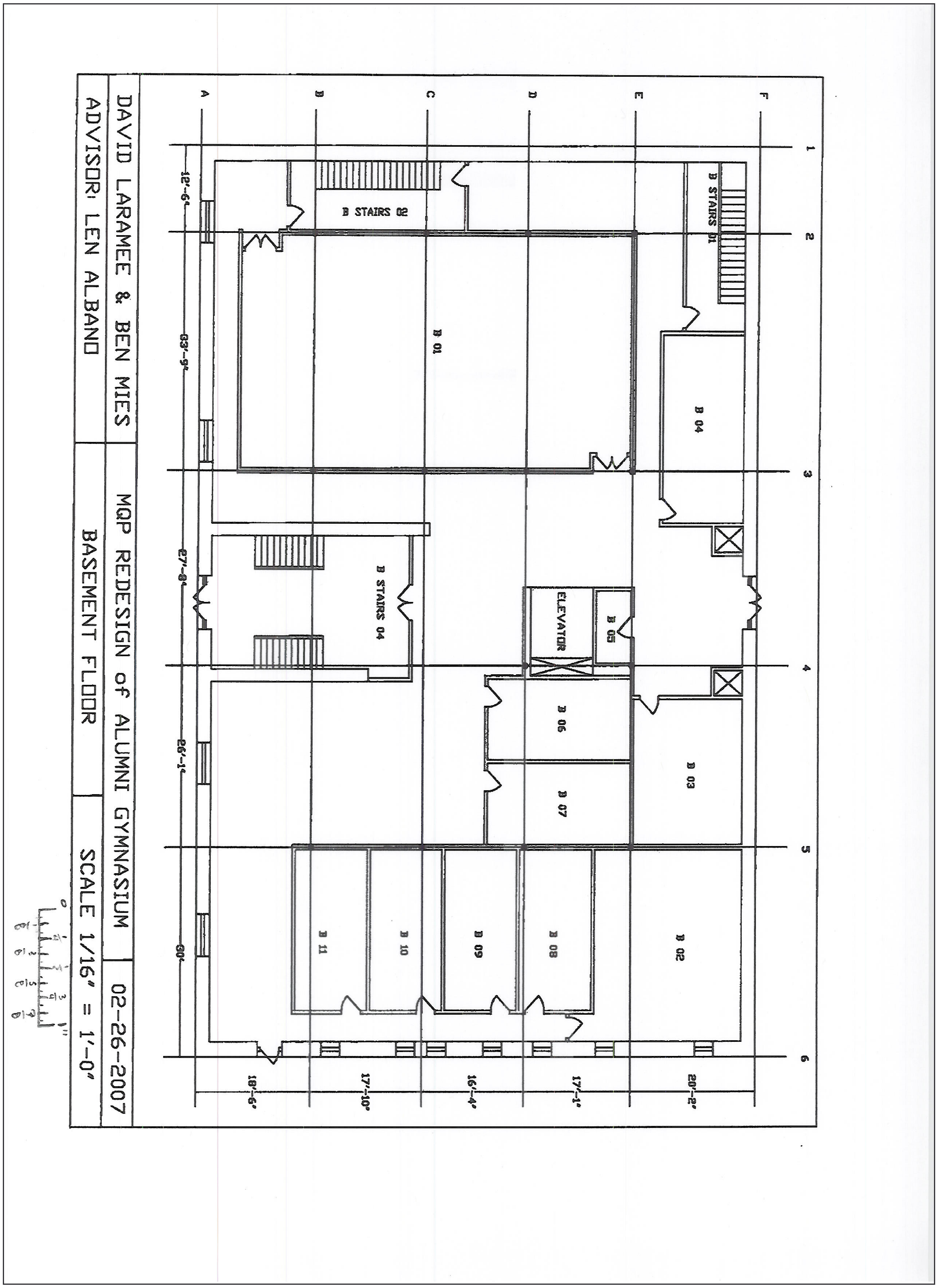


Figure 9 Basement Floor Plan

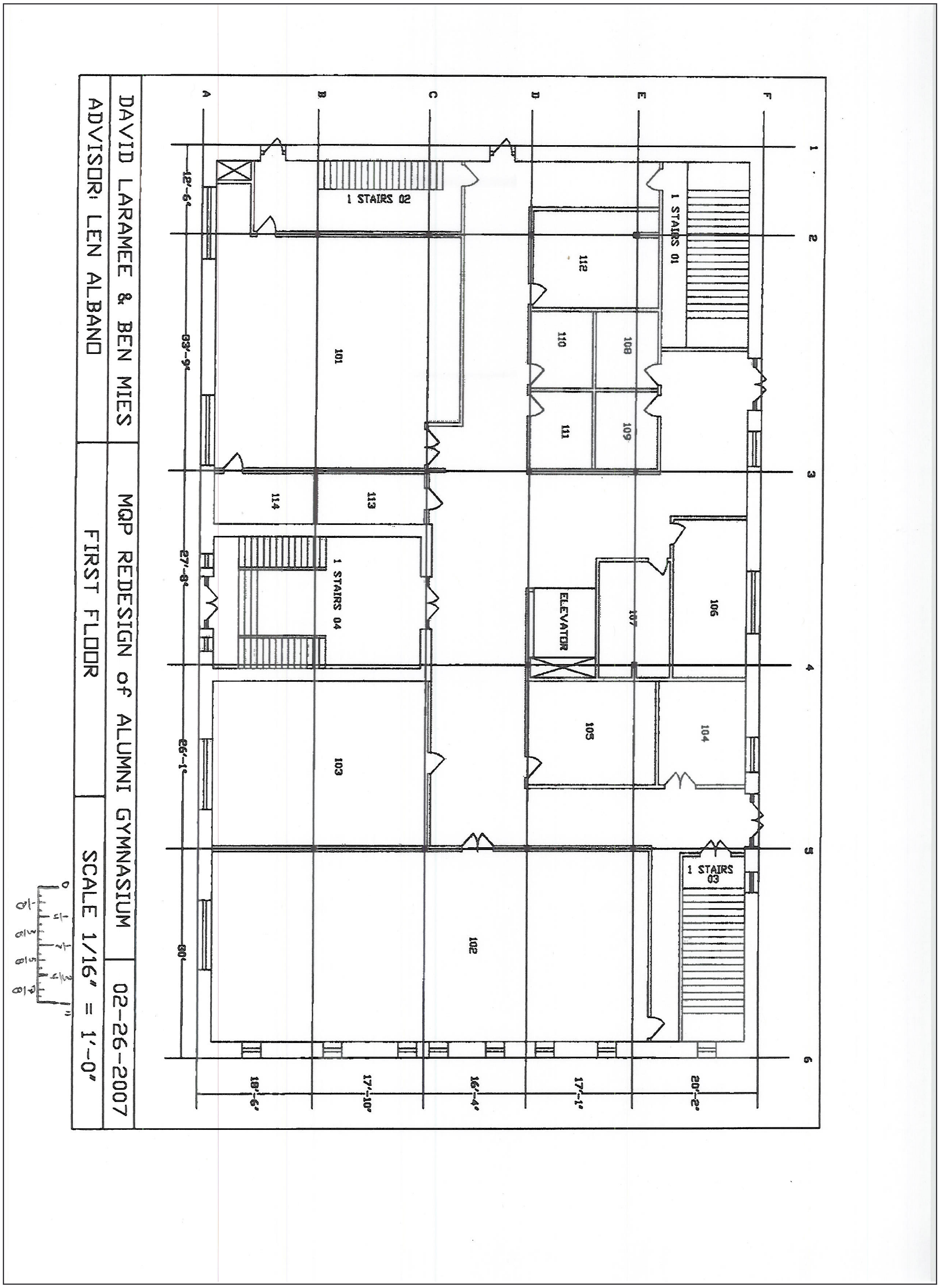


Figure 10 First Floor - Floor Plan

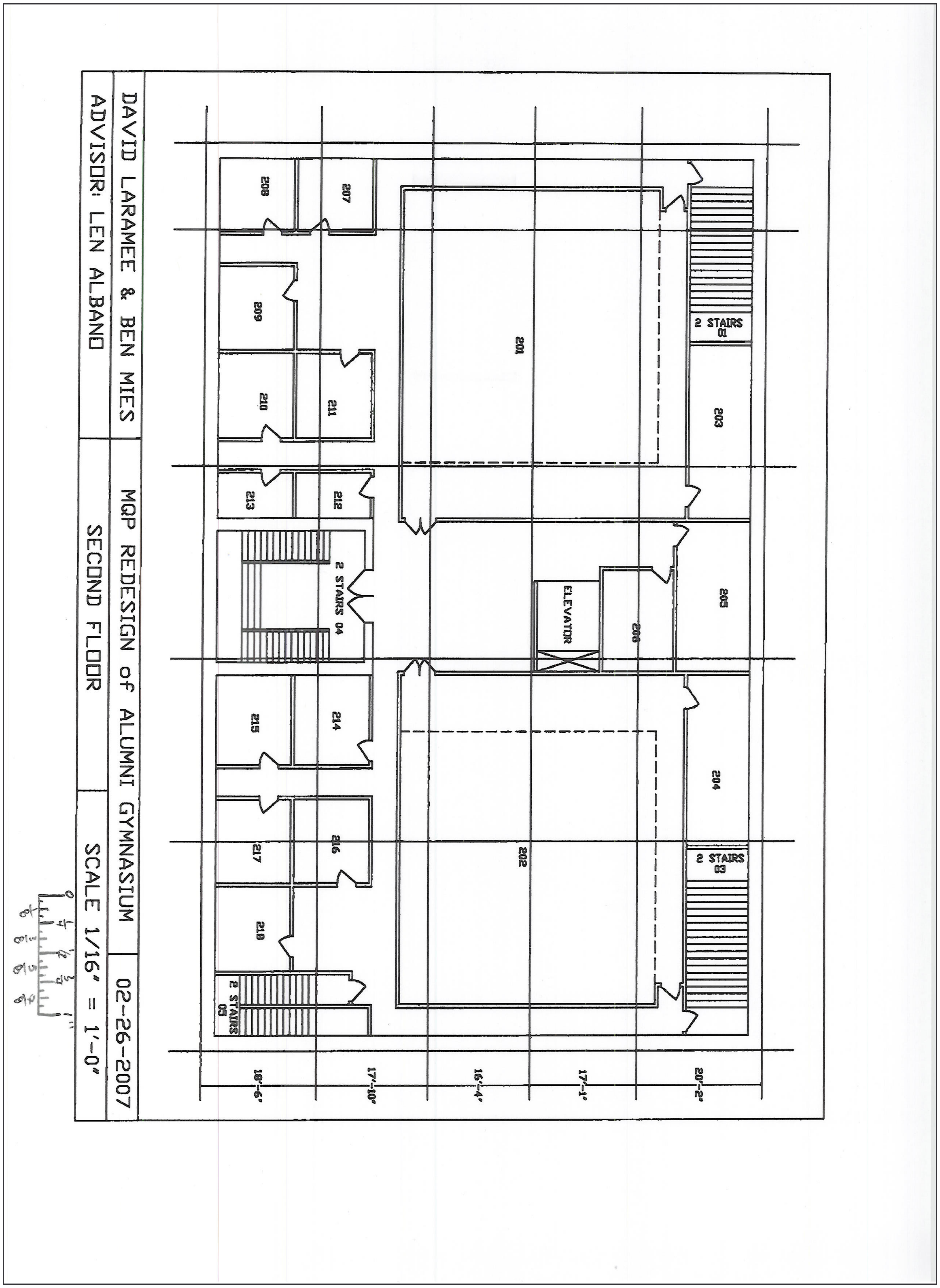


Figure 11 Second Floor- Floor Plan

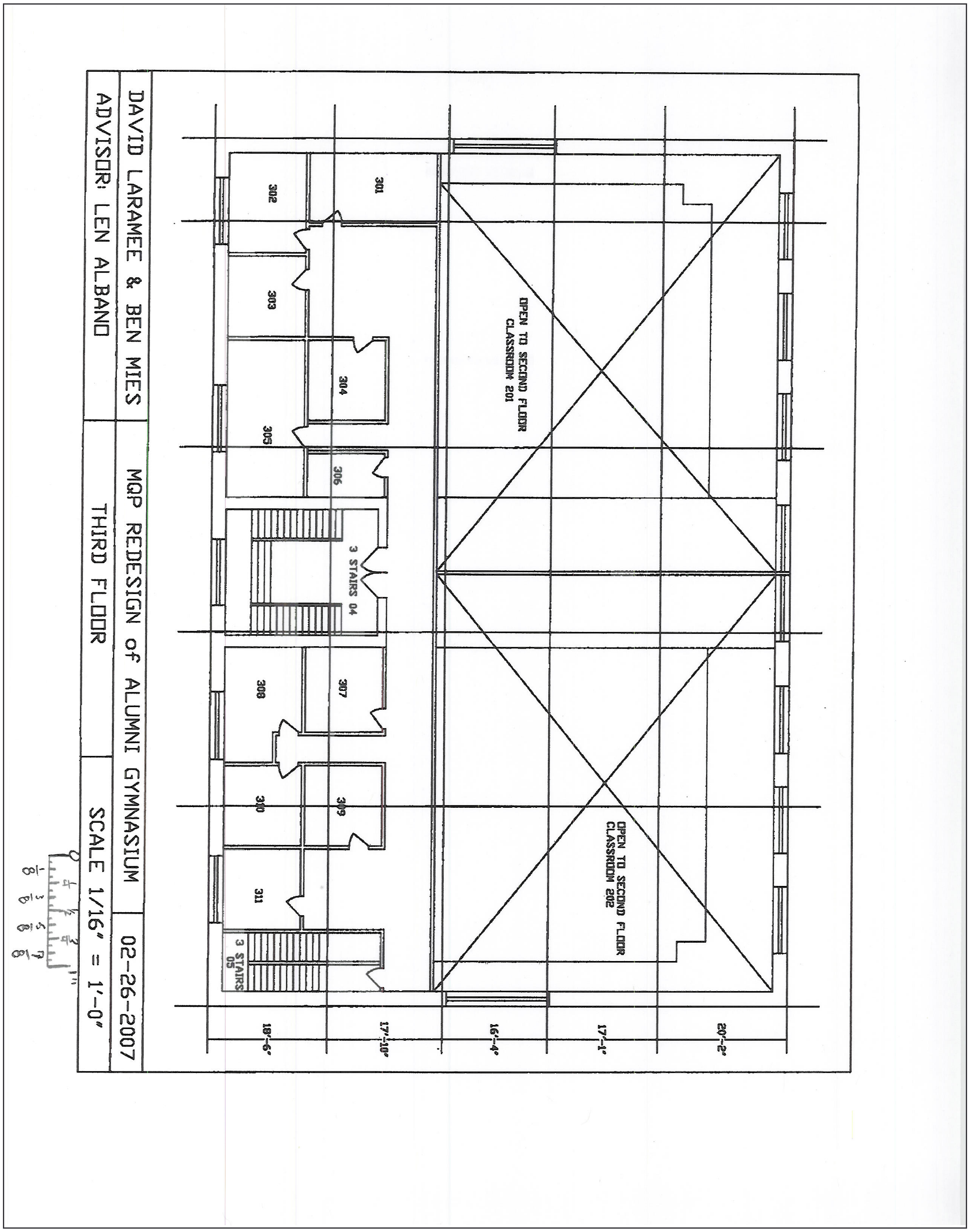


Figure 12 Third Floor - Floor Plan

Our floor plans for the redesign of Alumni Gymnasium to classrooms and office precede this paragraph as seen in figures 8 through figure 12. The drawings are showed with a scale of one inch is equals to twenty feet. Subsections 4.3.1 through 4.3.5 of this chapter provide a detailed description of the floor plan layout for each level.

4.3.1 Sub-Basement

Table 3 Sub-Basement Floor Summary

Sub-Basement Summary	
Room	**Number of Rooms**
Classrooms	0
Conference/I.T Lab	0
Labs	2
Offices	0
Restrooms	2
Closets	1

This floor is the bottom most floor of the existing Alumni Gymnasium. The existing use of this floor is the WPI's Athletic pool. This pool is a small pool according to intercollegiate standards. As a result it is mostly used for practices and not for competitions. The existing layout of the sub-basement allows for the redesign of 5,072.25 square footage of space. Two laboratories, which can be seen in Figure 8 Sub-Basement Floor plan, will be located in the current area of the pool. The pool is found between dimension lines one through three. Construction of the lab space will require filling in the existing pool and topping it off with a four inch reinforced concrete slab to create a floor. Along with two labs there are also two restrooms planned. The sub-basement only has two stairways that are used as the means of egress. These stairs are existing stairs that only need to be enclosed properly to meet code.

4.3.2 Basement

Table 4 Basement Floor Summary

Basement Summary	
Room	**Number of Rooms**
Classrooms	1
Conference/I.T Lab	7
Labs	0
Offices	0
Restrooms	2
Closets	1

The basement floor was the most complicated floor to convert from the existing athletic function to classrooms or laboratories. The open balcony overlooking the pool floor was the first issue; this involved was 2,270 square feet of unused space. Redesign proposes the construction of a steel frame and concrete floor slab to allow for one continuous floor with a total area of 10,730.25 square feet. With the floor in place the newly created spaces will allow for a large computer lab to be located there, which can be seen in Figure 9 Basement Floor Plan. The addition of closing off the balcony with a solid floor will increase the total floor space for Alumni Gym to 41,373 square feet. The floor also has two bathrooms and one closet designed into the layout.

Dead end corridor, which are limited by the fire safety provision of the building code were another problem for the redesign. More in-depth understanding is found in section 7.3.2 Dead Ends. The affect area is found between dimension lines four through six in Figure 9 Basement Floor Plan. As of now that area is used as workout room with weight lifting equipment. The proposed reuse of this area is redesign for conference rooms and I.T. labs. These usages were selected because their spaces do not need to have a window on it and so it is easy to place these types of rooms in the basement where window spaces are limited.

4.3.3 First

Table 5 First Floor Summary

First Floor Summary	
Room	**Number of Rooms**
Classrooms	2
Conference/I.T Lab	1
Labs	0
Offices	5
Restrooms	2
Lodge	2
Closets	2

The first floor has the most rooms designed into the limited square footages of 10,730.25. This floor is the main floor the occupants will enter, so there is a large range of rooms located on this floor. Currently the floor only houses office spaces for a number of the sports teams. The redesign will still have offices but two classrooms will also be incorporated into the floor plan as seen in Figure 10 First Floor - Floor Plan. In addition the floor has one conference room, two restrooms, and also two closets designed into the floor plan.

The one issue that caused a small problem in the redesign of the floor plan was column B-3. The location of this column caused a problem because the first plan was to remove it column and have a large classroom, with 3189.75 square feet. However, initial cost estimates for the structural framing needed to replace the column suggested that the cost to remove column B-3 would not be cost effective for the redesign. The second option was to place the column with in a wall that will create two closets for that floor. One closet will be used for the floor, and the other closet will be used for the classroom only. Placement of these two closets will reduce the area of the classroom to 1,916.25 square feet, which is sufficient to accommodate the desired capacity of eighty occupants seen in Figure 13 Room 101 Alterations.

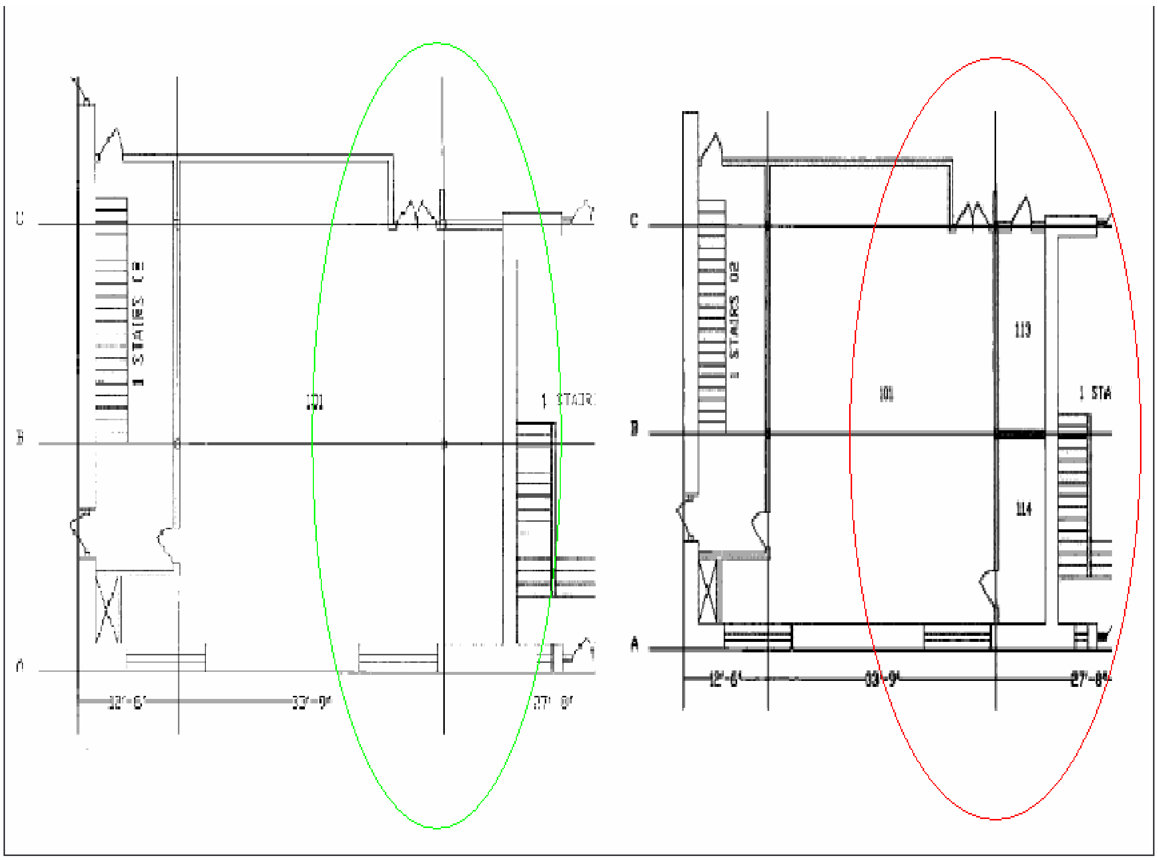


Figure 13 Room 101 Alterations

4.3.4 Second

Table 6 Second Floor Summary

Second Floor Summary	
Room	**Number of Rooms**
Classrooms	2
Conference/I.T Lab	0
Labs	0
Offices	10
Restrooms	2
Closets	4

The second floor of Alumni Gymnasium is a basketball court, with a square footage of 10,730.25. The proposed redesign for this floor would contain two large lecture halls and ten different offices. Figure 11 Second Floor- Floor Plan shows the proposed layout of this second floor. The lecture halls are rooms 201 and 202, which will hold eighty occupants with a stadium style seating arrangement. Each lecture hall also has it own closet for storage of class materials so instructors can leave class experiments and other supplies. The front wall of the gymnasium, between dimension lines A through C, is where the offices are designed. These would be large office to support various facilities of the school with an average square footage of 150. The expected use of these offices would be for instructors and teaching assistant offices.

4.3.5 Third

Table 7 Third Floor Summary

Third Floor Summary	
Room	**Number of Rooms**
Classrooms	0
Conference/I.T Lab	0
Labs	0
Offices	10
Restrooms	0
Closets	1

The third floor of Alumni Gymnasium was the easiest floor for the redesign efforts. This is because there were not a lot of options to investigate because an available space is limited. The main purpose of the area now is to gain access to the indoor track. This track, which is supported by the roof for the most part, would be removed for the redesign of the floor. The redesign also calls for a wall to extend all the way to the ceiling truss system just in front of dimension line C toward dimension line B. The third floor has a square footage around 6,110; but the new design will be for a square footage of 4,110. There will also be a wall that splits the floor in half which is a cause from the second floor lecture halls constructed between dimension lines 3 and 4; this can be seen in Figure 12 Third Floor - Floor Plan. The floor will still have offices in the design just like the second floor has the offices in the front of the building.

This wall has a unique role in the role of the third floor as well as for the second floor. Since the second floor has no windows in it and the third floor has windows in all four walls, an open third floor area would be a good way to get natural sun light into the classrooms below. Thus walls 1, F, and 6 have their windows open to the second floor classrooms below. This dividing wall also provides sound reduction to classrooms 201 and 202. This wall isn't all for cosmetic reason, since it extends all the way to the roof, which is the ceiling to the classrooms, also will keep the two hour fire rating for the barriers as it is called for in the code.

4.4 Conclusion

The redesign of Alumni Gymnasium required the preparation of five different floor plans. The redesign will add 2,270 square feet to the basement floor plan, by extending and enclosing the existing balcony. Overall the new design only gains a total of 370 square feet for the entire building because there will be a lost in space when the indoor track is removed. The overall square footage of the proposed redesign for the Alumni Gymnasium is for 41,373, as seen in Table 8 Square Footage of Alumni Gymnasium. The proposal adds twenty-five new offices and five classrooms, two of which are lecture halls. The design also will allow for two labs in the sub-basement, six new I.T laboratories, and two conference rooms. These renovations to the Gymnasium will meet the needs that was suggested by Mr. Kornik and observed from the emergency of new academic programs, the increase enrollments, and the new technologies that are available to support learning and collaboration for the institute.

Table 8 Square Footage of Alumni Gymnasium

FLOOR	TOTAL SQARE FOOTAGE	TOTAL PERIMETER
SUB BASEMENT	5,072.25	1,037.34
BASEMENT	10,730.25	2,230.09
FIRST	10,730.25	2,226.14
SECOND	10,730.25	2,164.42
THIRD	4,110.00	1,233.08
ALL FLOORS	41,373.00	8,891.07

5 Building Codes Provisions for the Redesign

As the proposed modifications to this building were substantial, compliance with the Massachusetts State Building Code (MSBC) was essential [10]. These codes ensure the safety of a building's occupants. Furthermore, they offer both prescriptive and performance-based provisions for a designer to follow. In application to a new building, the MSBC provides a framework for the design of each system within the building. In this case, the procedure began with Chapter 34, Repair, Alteration, Addition, and Change of Use of Existing Buildings. From this section, the necessary areas of compliance with the remainder of the code were determined.

5.1 General Requirements

780 CMR 3400.0 SCOPE

3400.1 General: The provisions of 780 CMR 34 are intended to maintain or increase public safety, health, and general welfare in existing buildings by permitting repair, alteration, addition, and/or change of use without requiring full compliance with the code for new construction except where otherwise specified in 780 CMR 34.

Figure 14 General Requirements

Alumni Gymnasium, along with other buildings on campus, was added to the National Register of Historic Places in 1979 (district - #79003913). As such, the gym is legally designated as a historic building, and, therefore, the provisions of *780 CMR 3409.0* govern alterations to the building. In this section buildings are further classified as either partially preserved buildings or totally preserved buildings. Since the building is listed on the National Register of Historic Places and its principal use is not as an exhibit of the structure itself, it falls under the partially preserved category [16]. With this classification, section *3409.3 Partially Preserved Buildings* governs all further requirements for code compliance. As the use and occupancy of the building will not change from its current status as a business use group, section *3409.3.4* adds that "the provisions of 780 CMR 3409.2 shall be required for Historic buildings accessible to the public on more than 50 days per year". So, the building must comply with section *3409.2 Totally Preserved Buildings*. While not a totally preserved building according to the definition outlined in the MSBC, the condition in 3409.3.4, referring compliance to the requirements of 3409.2, proves helpful in later code interpretations.

The implications of these sections refer primarily to the replacement of building materials such that the historic character of the building is not lost. The proposed changes would not alter the exterior of the building and are intended to preserve as much of the building's internal character as possible. For example, the large classrooms on the 2nd floor will be left open above to the existing roof truss system and will have natural lighting from the existing windows at the ends of the building.

Going back to section *3400.3 Applicability*, the changes to the building allow the continuation of the same use group and do not change the hazard index as determined by section *3403* and therefore alterations shall comply with section *3404.0*. Furthermore, as this is a partially preserved historic building, it need not comply with the seismic load requirements of section *3408*. In addition, it can be argued that the building does not need to comply with wind load requirements of *3408* as, per section *3409.3.4*, the building must comply with these requirements for a totally preserved building. These assumptions in the interpretation of MSBC should be reviewed with an official prior to further progress in the event that the interpretation is incorrect.

Figure 15 Hazard Index, below, is an excerpt from *Table 3403* and identifies the hazard index of each use group. The concept of use groups and hazard ratings were not present in early building regulations. It has been assumed that as WPI is a business, its academic and administrative buildings are classified under the business use group, and therefore the current use classification of Alumni Gym has been deemed business. As the building will be classified as a business use group with this refurbish, the hazard index would remain the same.

Table 3403
HAZARD INDEX

USE GROUP(1)	DESCRIPTION	HAZARD INDEX NO.(2)
A-1	Theater with stage	6
A-2	Night Club	7
A-3	Theater without stage	5
A-3	Restaurant	5
A-3	Lecture halls, recreations centers, museums, libraries. similar assembly buildings	4
A-4	Churches	4
B	Business	2
E	Educational (K through 12)	4
F	Factory and industrial	3
H	High hazard	8
I-1, I-3	Institutional restrained	5
I-2	Institutional incapacitated	4
M	Mercantile	3
R-1	Hotels, motels	2
R-2	Multi-family	2
R-3	One and two family	2
S-1	Storage, moderate hazard	3
S-2	Storage, low hazard	1

Figure 15 Hazard Index

Section *3404* of the code outlines the requirements for a continuation of the same use group or change to a use group resulting in a change in hazard index of one or less. The proposed changes fall under this category. *3404.3 New building systems* states that any new system, including structural, "shall conform to 780 CMR for new construction to the fullest extent practical". For example, this means that the one area of structural changes over the existing pool must comply with the requirements for new construction. The section *3404.4 Alterations and repairs* allows materials to be replaced or repaired with like materials unless otherwise stated in section *3408.* Likewise, the number of means of egress must comply with section *3400.4* and the capacity of the exits must meet the requirements in section *1009.0*.

5.2 Structural Requirements

There are requirements listed in the code for every system of a building; however, in the interest of this project, the focus is primarily on the structural requirements for the design and alteration of an existing building. Section *3408* focuses on the structural requirements for existing buildings. Provisions under this section govern over the building code provisions that were in place at the time the building was built. Thus, the Worcester building code of 1911 holds no weight against compliance with this modern code and, therefore, is only used as a reference to help ascertain assumptions of existing building materials and design attributes.

5.3 Evaluation of the Existing Structure

5.3.1 Acquiring Information about the Structure

Section *3408* begins with defining the requirements for the evaluation of existing buildings. Prior to proceeding with the structural design of the alterations to a building, a "structural engineer should make a structural evaluation of the existing building to determine the adequacy of all structural systems that are effected by alteration, addition, change in use, or damage to be repaired" as per section *3408.2*. A field investigation should be performed to determine the location, size, details, and conditions of existing structural elements. This was done to a degree in our case.

After acquiring drawings of the building's floor plan, we performed a walk-through noting sizes and locations of visible structural members to determine weather they were consistent with the drawings and to update these drawings as necessary. Sizes, materials, and styles of design similar to those visible in the walk-though were assumed to be in place throughout the building for the purpose of proceeding with a structural analysis. This is a step that we were unable to perform to a satisfactory level. We were unable to remove cosmetic coverings of structural members or do any tests on those exposed to viewing. In fact, there are few areas where structural materials are actually visible in most buildings. This includes Alumni Gymnasium. The importance of this process cannot be downplayed. Any calculations of existing materials in this report are based on assumptions made from a visual inspection of the existing structure.

5.3.2 Analysis of the Structure in Place

A structural analysis of all structural systems affected by the alterations was performed per section *3408.2.2*. For example, a structural analysis of the visible materials in the existing first floor hallway supporting the gym floor was performed using the modern calculations outlined elsewhere in the code. The heaviest possible distributed floor loads proposed for the building, through examination of the code-specified design loads were applied through the calculations to the existing structure to ensure its performance against the new alterations. These preliminary calculations must be updated once cosmetic coverings are removed to uncover connections and other specific data on the existing construction.

The structural engineer should make periodic visits to the construction site during demolition as well as structural construction to ensure that prior calculations are valid as more of the building is uncovered. Section *3408.2.3* expands upon this point. To comply with these provisions, assumed conditions, materials, and design of the existing structure must be verified, and, if they differ, the building official must be notified of any required changes in design.

As previously stated, all new structural members and systems must comply with code requirements for new construction as specified in *780 CMR 3408.0*. The strength of existing structural elements, systems, and connections must be determined using current, accepted engineering practices and using the actual strength and physical properties of the materials. This does permit use of the design codes from the time of original construction can if they prove to be acceptable with public safety. We chose to disregard the older building codes and check the existing structure against modern regulations as the older codes seemed unacceptable against modern standards. According to section *3408.3.2.1*, "the strength of existing materials shall be determined by tests or from generally accepted historical records". As such tests could not be performed nor could acceptable historic records be found, we relied on library research as a basis for reasonable assumptions in order to proceed with calculations. Section *3408.3.2* permits the continued use of existing structural elements if analysis demonstrates adequate capacity to support the loads required by *3408.0* and they are in sound structural condition.

The sections of the code regarding wind loads (*3408.4.2*) were not taken into account given our interpretation of section *3404.0.* Furthermore, the proposed design would not alter those members and elements contributing to lateral load resistance. It has been assumed through examination of the building's construction that the masonry exterior walls are sufficient to support lateral loads on the building. Even though seismic and wind load analyzes are not required to comply with the MSBC given our interpretation, it is advised that calculations, beyond the simplified calculations included for stresses due to gravity load, should be made to prove this assumption based on proper testing of the mortar and brick materials used in the exterior walls.

The loads used in calculations proving adequacy of structural members in the alteration of Alumni Gymnasium are from section *3408.5 Alterations, Repairs and Changes of Use*. From this section, it has been determined that the load capacity of all floors affected by alterations must be adequate to support the design loads defined in sections *1605.0* through *1608.0*, *1613.0*, and *1614.0*. These loads are to be combined in accordance with section *1616.0*. Furthermore, live loads may be reduced as specified in section *1608.0*.

5.4 Loads and Load Combinations

Section *1605.1* states that the actual weights of materials should be considered in estimating dead loads; however, these values must not be less than those listed in *Appendix G* of the MSBC. Fixed service equipment must also be included in estimating dead loads in accordance with section *1605.2*. Without proper weights of the actual materials, our dead load values were estimated using the unit dead loads listed in Appendix G. *Table 1606.1* of the code lists minimum uniformly distributed live loads to be used for those occupancies listed. Furthermore, according to *1605.3* office areas with partitions assume an additional 20lbs per square foot (psf) of floor area unless the live load is 80psf or above. Table 9 Loads summarizes the design values for dead and live loads gathered from *Appendix G* and *Table 1606.1.*

Table 9 Loads

Dead Loads		
Material	**(psf)**	**(pcf)**
hardwood flooring per Inch of depth	4	
2x8 wood joist floors (12inch spacing)	6	
southern pine (short leaf)		39
slate (3/16" thick)	10	
suspended metal and gypsum ceiling	10	
medium absorption clay brick	about 9 psf per inch thick	
Live Loads		
Type	**(psf)**	
fixed seat assembly	60	
corridors	100	
offices	50	
lobbies	100	
classrooms	50	

Section *1607.1*stipulates that "the live loads used in the design of buildings and structures shall be the greatest load produced by the intended occupancy, but not less than the minimum uniformly distributed unit loads required in *780 CMR 1606.0* for specific use groups". Therefore, the live loads used in this design are those from the Table 9 Loads. Furthermore, live loads may be reduced according to the provisions of section *1608.2 Design live loads of 100 psf or less.* These provisions are included in Figure 16 Live Load Reduction. Live loads used in the design of new structural members, as well as the strength verification of existing structural members, were reduced according to section *1608.2*.

N = the largest of the following:

1. 1 - 0.0008 (A_T - A_B)
2. 0.75 - 0.20 (D_o/L_o)
3. 0.50 for members supporting load from more than one floor, or 0.60 for members supporting load from one floor only, in which:

L = reduced design live load for the member

L_o = basic design live load

D_o = dead load on the member

A_T = loaded area tributary to the member, square feet

A_B = basic tributary area, square feet, defined as follows:

A_B = 100 square feet for members supporting load from more than one floor

A_B = 250 square feet for members supporting load from one floor only

Figure 16 Live Load Reduction

Loads are to be combined in accordance with section *1616* as per section *3408.5*. According to this section of the MSBC the structural designer may use either the allowable stress or strength design methods: both of which can be seen below in Figure 17 Load Combinations. The result of the most unfavorable effect of the combinations is to be used in design. However, there is an exception listed in section

1616.2 Load Combinations Using Allowable Stress Design

1616.2.1 Basic Combinations. All *loads* listed herein shall be considered to act in the following combinations, whichever produces the most unfavorable effect in the building, foundation or structural member being considered. The most unfavorable effect may occur when one or more of the contributing *loads* is not acting.

1. Dead
2. Dead + floor live + roof live (or snow)
3. Dead + floor live + 0.5 roof live (or 0.5 snow) + wind
4. Dead + floor live + roof live (or snow) + 0.5 wind
5. 0.67 Dead - wind
6. 0.67 Dead - 0.8 seismic
7. Dead + 0.9 floor live + 0.6 snow + 0.8 seismic

1616.3 Load Combinations Using Strength Design

1616.3.1 Basic Combinations. All *loads* listed herein shall be considered to act in the following factored load combinations, whichever produces the most unfavorable effect in the building, foundation or structural member being considered. The most unfavorable effect may occur when one or more of the contributing *loads* is not acting.

1. 1.4 Dead
2. 1.3 Dead + 1.6 floor live + 0.5 roof live (or 0.5 snow)
3. 1.3 Dead + 0.5 floor live + 1.6 roof live (or 1.6 snow)
4. 1.3 Dead + 0.5 floor live + 0.5 roof live (or 0.5 snow) + 1.3 wind
5. 1.3 Dead + 1.6 roof live (or 1.6 snow) + 0.8 wind
6. 0.9 Dead - 1.3 wind

Figure 17 Load Combinations

1616.1.1; the use of load combinations from acceptable design standards listed in *Appendix A* can be used in the absence of wind or snow loads. As the roof of the Alumni Gymnasium is supported entirely by the exterior walls and it has been assumed that these walls also support the wind load, structural members in the interior of the building are designed and verified in accordance with load combinations found in design standards listed in *Appendix A*. Thus, the loads and load combinations gathered by examination of the code have been used to determine the adequacy of structural members in Alumni Gymnasium.

5.5 Application of Updated Loads on Existing Structural Members

5.5.1 Steel Girders

The adequacy of the existing steel girders was assessed based on the worst-case scenario. As stated previously, the size and assumed material properties of the visible structural members were assumed to be applicable to other areas of the building. Given the new loads, the worst-case for the existing steel girders was determined to be underneath classroom 201 on the second floor between columns D2 and D3. The results are shown below in

Table 10 Steel Girders.

Table 10 Steel Girders

Dead Load

Weight of Girder	157.0	plf	according to steel girder size and density of steel
Materials Weight	10.0	psf	2x8 wood joist floors 12" spacing / hardwood flooring
Wood Beam	33.7	plf	according to wood beam size and density of Pine

Live Load

Partition	20.0	psf	assumed for worst case loading
Assembly(fixed seats)	60.0	psf	intent of classroom space
Tributary Width	17.3	feet	1/2 of distance between girders
Span of Girder	33.8	feet	from column center to column center

Reduced Live Load

Live Load	1381.3	plf	At=	582.8	N1=	0.7
N factor	0.7338		Do=	3239.1	N2=	0.3
Reduced Live Load	1013.6	plf	Lo=	1381.3	N3=	0.6
			Ab=	250.0	N=	0.7

Load Cases

1.4(DL)	4534.7	plf	
1.2(DL) + 1.6(LL)	5508.7	plf	Governs
M_u	784.3	ft-k	

Required Zx vs Zx of Girder

Z_x for 36 ksi	261.4	in^3	acceptable	261.4<397
Z_x for 30 ksi	348.6	in^3	acceptable	348.6<397
Z_x for 24 ksi	435.7	in^3	not acceptable	435.7>397

The results show that, given the proposed loads and assumptions in geometry, a girder of this size, and a steel yield strength of 30ksi grade of steel or higher, will perform safely under the proposed loads with proper connections to the columns and beams. The plastic moment capacity of the girder was the critical design criteria. The type of steel used in the girder should be determined with adequate testing. Furthermore, connections to columns, beams, and load bearing walls must be examined for proper resistance to shear and moment forces as fixed end conditions were assumed. However, as this is the worst-case loading scenario in the building, there is great potential for the use of these structural elements under the proposed load cases.

5.5.2 Wood Beams

Similar to the steel girders, only approximate dimensions of the timber beams spanning between the girders could be gathered. Earlier in this text, an effort to ascertain the likely properties and species of the beam's material was discussed. These findings, coupled with the loading cases taken from the building code, were used to determine the flexural performance of these wooden members under the proposed load cases. Again, the worst-case scenario of the building was evaluated. The results are shown below in Table 11 Timber Beams.

Table 11 Timber Beams

Geometry						
	Birch	**Douglas Fir**	**Maple**	**Pine**	**Spruce**	
Length(in)	214.0	214.0	214.0	214.0	214.0	
Side(in) (square)	12.0	12.0	12.0	12.0	12.0	
Cross Section Area (in^2)	144.0	144.0	144.0	144.0	144.0	
Volume Of Girder (in^3)	30816.0	30816.0	30816.0	30816.0	30816.0	
Tributary Width (in)	72.0	72.0	72.0	72.0	72.0	
Tributary Area (in^2)	15408.0	15408.0	15408.0	15408.0	15408.0	
Moment I (in^4)	1728.0	1728.0	1728.0	1728.0	1728.0	
Moment K (in^4)	2903.0	2903.0	2903.0	2903.0	2903.0	
Moment Z (in^4)	288.0	288.0	288.0	288.0	288.0	
Dead Loads						
weight of girder (plf)	47.5	36.8	48.7	33.7	35.0	
materials weight (psf)	10.0	10.0	10.0	10.0	10.0	
Live Loads						
Partition (psf)	20.0	20.0	20.0	20.0	20.0	
Assembly(fixed seats)(psf)	60.0	60.0	60.0	60.0	60.0	
Reduced Live Loads						
Live Load (plf)	1426.7		At=	1284.0	N1=	0.2
N factor	0.7		Do=	225.8	N2=	0.7
Reduced Live Load (plf)	1024.8		Lo=	1426.7	N3=	0.6
			Ab=	250.0	N=	0.7
Load Cases						
1.4 DL	316.1	301.2	317.8	296.9	298.6	
1.2 DL + 1.6 LL	1910.7	1897.9	1912.2	1894.2	1895.7	governs
Mu	76.0	75.4	76.0	75.3	75.4	
Required Zx Value for the Beam to be Sufficient						
required Zx	107.1	119.4	102.9	137.5	119.4	
required Zx with a 1.6 safety factor	171.4	191.0	164.7	220.1	191.1	
	ok	ok	ok	ok	ok	

The results show that, given the proposed loads and assumptions in geometry, a timber beam, made of one of the five species listed above, and in proper condition, will perform safely under the proposed loads with proper connections to the columns and beams. An arbitrary "safety factor" of 1.6 was added to show that the design capacity is much greater than the load applied. The design capacity to load ratio, in this case shown as a "safety factor" is greater than 1.6. The species of wood should be determined with adequate testing. Furthermore, connections to girders and load bearing walls must be examined for proper resistance to shear and moment forces as fixed end conditions were assumed. However, as this is the worst-case loading scenario in the building, there is great potential for the use of these structural elements under the proposed load cases.

5.5.3 Columns

Compressive strength of the columns in the building was investigated to ensure their performance under the design loads due to the proposed renovation. Here, significant assumptions were required to proceed with calculations. The diameter of these cylindrical columns and the basic material type were the only properties that could be determined through visual inspection. It was assumed that each column is a hollow cylinder with a wall thickness of a ¼ of an inch for no other reason than it seemed reasonable. The results of our calculations can be found below in Table 12 Columns.

Table 12 Columns

	Loads	**Floors**
At	571.20	2
steel beam	4821.47	2
wood beams	3137.47	2
live loads	45696.00	2
dead loads	5712.00	2
Total Load	**107309.88**	**lbs**
t	0.25	
L_r	102.00	
f_y	36000.00	
E	29000000.00	
I	71.53	
P	**1965912.34**	**lbs**
1,970,000 lbs > 107,309lbs		
tributary area	**length of steel**	**length of wood**
571.92	30.71	18.6235
	1 girder	5 beams

The worst-case scenario column was found to be under classroom 201, supporting the load of two floors. The design capacity-to-load ratio for the assumed column is over 18, which is more than sufficient to support the compressive loads. As with the other structural members, the connections to the column, dimensions, material, condition, and footings should all be checked prior to construction and final design.

5.5.4 Masonry Load Bearing Walls

The exterior masonry walls support tremendous loads. These walls support the entire roof structure, as well as a portion of each floor. Without knowledge of the actual brick, mortar, or possible internal reinforcement used in these walls, efforts to assess its strength were limited by assumptions. Beginning with the roof structure, where a number of different element sizes were used to construct four major steel truss systems connected with steel beams, the total weight was estimated by way of approximate dimensions obtained from our walk-through of the building. Without access to the actual roof, assumptions of roofing materials were made with guidance from the MSBC.

Following calculations of the material weight of the roof, a worst-case scenario was established regarding the supported tributary area of each floor that the wall supports. Design values for dead and live loads used defined in Table 9 Loads were used to calculate the floor loads that the wall may support. Furthermore, the weight of wall material above the bottom most brick was found using a materials weight calculated from the MSBC. These values and the results can be found in Table 13 Masonry Walls below.

Table 13 Masonry Walls

Compressive Strength Assumptions		
material	**fc (psi)**	**source**
lime mortar	1000-2000	Webb
cement	1500-3000	Webb
varied	1508-2375	Baker
varied	530-3410	Baker
Loads		
type	**load**	**source**
masonry	108 pcf	MSBC
dead load	10 psf	MSBC
live load	80 psf	MSBC
wood beam	33.7 plf	calculations
steel	495 pcf	calculations
Load from Floors Supported		
trib area	**weight (lbs)**	**number**
1310.4 sqft	122,317	4
Roof Load -steel		
steel	**length (ft)**	**weight (lbs)**
I beam	1950	377051
Large Angle	1552	552173
Small Angle	1392	100485
Roof Load - Other Materials		
slate	10psf	
wood	6psf	
area (sqft)	**weight (lbs)**	
13520	216320	
Wall Load -Masonry		
height	**thickness**	**weight**
40 ft	30 in	1,404,000 lbs
Compressive Stress		
total load	**area**	**stress**
2,516,268 lbs	46,800 sqin	53.77 psi

The result of these calculations is that the one hundred and thirty foot walls support a load on the order of 2.5 million pounds. With its thickness of 30 inches, the compressive stress at the bottom of the wall is about 54 pounds per square inch. According to references found from the time period of the building's original construction, mortar construction can support between 530 and 3410 pounds per square inch in compression. This wide variance in allowable compressive stress is due to the dependency on the types of mortar and brick as well as the abilities of the bricklayer [2 and 9]. However, the design capacity-to-load ratio of even the worst case allowable stress, 530psi, is about ten; therefore, the calculated stress is consistent with the suggested safety factor of the time, ten.

6 New Structural Elements and Modifications

The analyses in the previous chapter indicate that our proposed plans for alteration require very few modifications to the structural system of the building. In an effort to keep cost and time spent during construction to a minimum, the classroom, office, lab, and other functional spaces were designed to use as much of the original structure as possible. Beginning with the exterior of the structure, the necessary modifications are outlined in the following sections.

6.1 Roof

The roof of the building will only be upgraded as necessary for maintenance. The supporting structure of the roof has held for almost a century and appears to still be in satisfactory condition. There are no signs of damage to the steel truss system, wood supporting structure, or roof covering. However, all roof coverings and its secondary supporting structure should be checked thoroughly as it could need maintenance.

6.2 Exterior Walls

This is a historic building, and, as such, the exterior walls should not be modified. In terms of this new use for the building, no modification is necessary. Re-pointing and cleaning of the masonry is advised and included in the cost estimate. All means of egress leading through these exterior walls to outside the building have proven sufficient in size, and, thus, no modification to the structure would be necessary to enlarge or add doors.

6.3 3rd Floor

The modifications to the third floor entail the removal of the existing track. This track is supported in part from tension members connected to the truss system supporting the roof. Removal of the track will decrease the design values for the dead and live loads on the roof. As the existing columns and walls are capable of supporting the proposed design loads, the 3,167 square feet of office space will pose no problems to the existing structural members. There are no new load-bearing structural members added here.

6.4 2nd Floor

The gym floor is supported from underneath by a substantial structural system. The second floor is supported with beams from the exterior walls and the load-bearing wells of the stairwell; there are no columns. The proposed renovation would not add or remove any load-bearing structural members in this area. However, a tall, partitioning wall would be constructed between the two, large classroom spaces. This wall must be sufficient in strength to support its own weight. Furthermore, the supporting floor below could need attention given the uncommon load of this supporting wall as it would likely impose more load than the design loads account for.

6.5 1st Floor

A potential structural modification was explored on the first floor. Classroom 101, as seen in Figure 18 Potential Girder, could be larger with removal of the column at the corner of classroom 101 and closets 103 and 104. There is currently a 24-inch tall girder spanning between these two columns and the load bearing walls. In order to support the loads from above, a new steel beam section would need to be added as the current section would be insufficient.

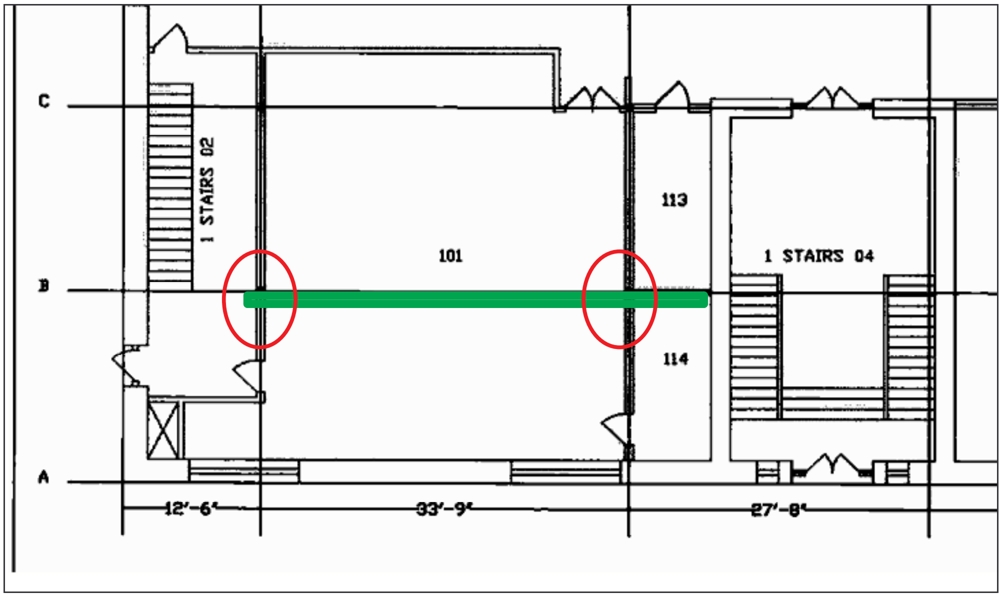


Figure 18 Potential Girder

Table 14 Potential Girder

Loads			
Dead			
Weight of Girder	162.0	plf	
Materials Weight	10.0	psf	
Weight of Beam	33.7	plf	
Live			
Partition	20.0	psf	
Assembly(fixed seats)	60.0	psf	
Trib Width	17.1	feet	
Span of beam	41.3	feet	Non-Reduced Live Loads
Load Cases			
1.4(DL)	6012.8		
1.2(DL) + 1.6(LL)	7342.6	Governs	
M_u	1735.3	ft-k	
Zx for 50ksi	462.7	in^3	
W24x146 Steel Girder			
Zx	468.0	in3	
Mp	1760.0	ft-k	
Weight (lbs)	6022.5	difficult to manage	

To keep structural alterations to a minimum, and to facilitate construction, it was decided that the proposed girder for this section should be the same depth as the existing member. The resultant calculations, summarized in Table 14 Potential Girder, show that a W24x146 beam [1] would be required to accommodate the removal of that column. At a cost of 145.2 dollars per linear foot of beam, this modification would cost about six thousand dollars in materials and basic construction costs alone. In addition, provisions would have to be made to erect a 41-foot, 6000 pound beam into an enclosed structure. The existing girder would have to be removed and the dependent structure temporarily supported. Only about 240 square feet would be added to the room; however, the resultant cost and safety concerns seem unnecessary for such a relatively small gain in floor area. Therefore, it is recommended that the column and girder remain in place and that the floor plan be designed to fit. The proposed plan shown in Figure 18 Potential Girder would use the space effectively.

6.6 Basement

The basement area would require significant structural modifications in order to use the potential floor space above the pool. Currently, there is an opening looking down on the sub-basement pool from the balcony on the basement floor. The dimensions of this opening, its perimeter created by structural columns, would suit an open lab space. However, a support structure to support the floor loads of this lab must be built within the existing structure.

A simple steel girder and beam structural system could be used here. Steel girders would span between the existing columns. These columns are currently covered in what appears to be a cosmetic plaster. It was assumed that these columns, supporting the load of the first floor and sub-basement, are the same size as the other columns in the building and thus are sufficient in strength to support the added loads. However, as a dimension or shape cannot be determined, connections to the columns cannot be designed. The span between the columns is approximately 34 feet as seen below in Figure 19 Basement Lab.

6.6.1 Girders

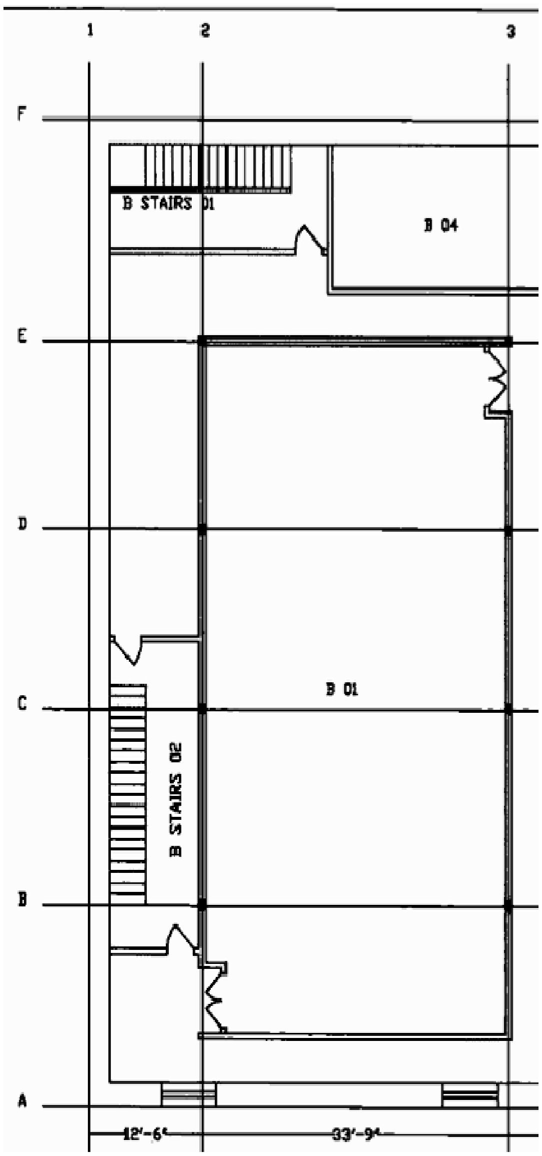


Figure 19 Basement Lab

The four new girders spanning between columns B2 and B3, C2 and C3, D2 and D3, and E2 and E3 would all be of the same size and shape to simplify design and construction. The worst-case scenario for design of these girders is between columns C2 and C3 with a tributary area of 578 square feet. These girders must support the weight of the beams between them, the deadweight of the flooring above, and the live loads from the lab above. Live load reduction was not used in the calculations; however, it is allowed in the code. A summary of these calculations and results can be seen below in Table 15 New Girder.

Table 15 New Girder

Loads			
Dead			
Weight of Girder	68.0	plf	Non-Reduced Live Load
Materials Weight	23.0	psf	
Weight of Beam	15.0	plf	
Live			
Partition	20.0	psf	
Classroom	50.0	psf	
Corridor	80.0	psf	
Span of beam	17.1	feet	
Span of girders	33.8	feet	
Load Cases			
1.4(DL)	2080.3		
1.2(DL) + 1.6(LL)	4516.4	Governs	
M_u	643.1	ft-k	
Zx for 50ksi	171.5	in^3	
W24x68 Steel Girder			
Zx	177.0	in3	
Mp	664.0	ft-k	
Weight (lbs)	2295.0	relatively easy to handle	

A W24x68 steel girder was suggested for use [1]. With an unsupported length of 33.8 feet and a laterally unbraced length of 6.75 feet, the maximum design moment capacity of the section is 664 foot kips, which is sufficient for the design moment of 643 foot kips. Furthermore, at 2300 pounds in weight, while long, the beam can be handled in construction. Constructability was a concern in the design of new structural elements for the building, as it will be difficult to get a large, heavy beam into the enclosed structure. This girder could be transported into the building through a window or doorway using rollers and a lift from outside. The structural member could then be lowered into place using the roof truss system as support with only minor removal of flooring necessary. The four new girders would be manageable.

6.6.2 Beams

Beams must be connected between the four girders to gather and transfer the floor loads as well as provide adequate lateral support against buckling. Four beams shall be placed at 6.75 feet on center between each set of new girders as well as the span between the new girders and the existing structure at the shorter ends of the existing opening to below. The four beams at each end will be shorter than the others and carry less load; however, they will be assumed to be the same size as the others calculated through the worst-case scenario. Again, this is for ease of design, construction, and ultimate cost.

The beams will support the material weight from the floor above in the form of dead load and the live loads due to the lab above. As in the girder calculations, live loads were not reduced in the beam design. A worst-case scenario was found using the longest span between girders, 17.8 feet. A tributary width of 6.75 feet is used. Dead and live loads are taken from the MSBC. As the wooden floor above shall offer lateral buckling support to the beam, the maximum moment that the beam can handle is above the design moment. Table 16 New Beam below summarizes the calculations and results.

Table 16 New Beam

Loads			
Dead			
Weight of Beam	15.0	plf	
Materials Weight	23.0	psf	
Live			
Partition	20.0	psf	
Classroom	50.0	psf	
Corridor	80.0	psf	
Trib Width	6.8	feet	
Span of Beam	17.8	feet	Non-Reduced Live Load
Load Cases			
1.4(DL)	238.4		
1.2(DL) + 1.6(LL)	1284.3	Governs	
M_u	51.1	ft-k	
Zx for 50ksi	13.6	in^3	
W10x15 Steel Beam			
Zx	16.0	in3	
Mp	60.0	ft-k	
Weight (lbs)	267.5	relatively easy to handle	

The W10x15 steel beam used here is lightweight at 15 pounds per foot [1]. An 18-foot beam would only weigh 270 pounds, and this is the longest of the beams used. Handling this beam during construction would be easy and cost effective. The beam could be brought in by hand, through the front door. This size of beam would be a good choice in the new structural system for supporting this lab on the basement level.

6.7 Sub Basement

The bottom floor of the building, the sub basement level, will only require one major modification. The pool that is in place now must be filled and covered in an adequate floor material to facilitate the lab spaces above. A four-inch concrete floor could work here. The existing columns, supporting the new beams and girders above, offer good boundaries for lab space. Furthermore, as the floor in this area is likely heavy concrete, heavier loads imposed by lab equipment should be supported well.

6.8 Foundation

With no access to the foundation of Alumni Gymnasium, it is difficult to determine whether any modifications to the foundation should be considered. If the foundation is still in adequate condition according to a detailed structural examination of the building, then it most likely could be left alone. There would be little additional compressive stress imposed on the pillars from the existing columns, and the exterior wall foundations would support less load than current conditions with the removal of the track. The addition of an elevator would require additional foundation work underneath the shaft. As always, the condition of the foundation should be thoroughly reviewed prior to any level of construction.

6.9 Summary and Additional Comments

Table 17 Structural Summary

Material	Use	Number	Length	Where
Elevator	Required Structure			2nd floor and Below
Partitioning Walls and Flooring	As Necessary for the Type of Room			All Floors
W24x68 Steel	Girder	4	33'-9"	Basement
W10x15 Steel	Beam	4	8'	Basement
W10x15 Steel	Beam	4	17'-10"	Basement
W10x15 Steel	Beam	4	16'4"	Basement
W10x15 Steel	Beam	4	17'-1"	Basement
W10x15 Steel	Beam	4	8'	Basement
Connections	As Necessary Given Existing Mtrls.			Basement
4" Concrete Slab	Over Pool			Sub-Basement
Fill	Fill in Pool			Sub-Basement

The known structural modifications necessary for the proposed modifications to Alumni Gymnasium are summarized above in Table 17 Structural Summary. These are the modifications that must be made to meet the proposed floor plan and intended use if the remainder of the structure is deemed adequate for carrying the altered loads. Structural changes and the sizes of new structural members have been limited in order to keep costs as low as possible and construction time reasonable. With the planned completion of the new athletic facilities in 2015, it seems as though, a swift implementation of a re-use plan for Alumni Gymnasium would be important to avoid the presence of an unused building on campus.

Construction of the proposed structure seems relatively straightforward. The roof is supported entirely by the exterior walls allowing the internal structure to be altered piece by piece with fairly minimal temporary supports necessary. Following the demolition phase, large structural members, such as the proposed girders for the basement floor, can be brought in with relative ease because the building already has an open space in this area. The process of filling the pool may prove difficult as earth and concrete would need to be brought in from above. Perhaps a system of smaller girders, beams, and short columns could be employed instead to ease the construction process.

The historical nature of the building has also been kept in mind. In terms of constraints, by not altering the exterior of the building, these masonry walls can be used to support an entirely new use for the interior of the building with minimal structural changes. In addition, by retaining features such as the large windows, the substantial main stairwell, and the roof truss system, a definite historic nature can be kept throughout the building.

7 Fire Protection of the New Design

After completing the floor plans, an architect may engage a Fire Protection Engineer (FPE) to ensure that the building is safe for the occupants to exit the building during a fire. The plans are viewed by the FPE to make sure that the means of egress comply with the local building code requirements. Along with ensuring that the codes provisions are met, the FPE should assess the risk that may be inherent to because it is possible to design a building that complies with the governing code but poses a danger to the occupants. As earlier stated the codes that are being used to analysis the newly designed building will be NFPA [6]. One critical assumption is that the building will be fully sprinklered. When a building is fully sprinklered there are some code easements for the designer to take into consideration. To assume that the building will be fully sprinklered is justified per *NFPA 5000 Code 15.10.4.12* for automatic sprinkler system in a historical building, which Alumni Gym must conform to the new codes for fire sprinkler system.

7.1 Elements of a Means of Egress

There are three main parts to a means of egress system: Exit Access, Exits and Exit Discharge. The components that combine to form these individual sub-systems all need to be analyzed for code compliance as part of the regulatory approach to ensuring safe egress from a building in a fire emergency. According to provision *3.3.391*, well-designed egress system needs to include multiple exit locations, adequate capacity for building occupants, easily accessible exit locations, barriers or enclosures to protect occupants from products of fire, as well as marking of the exit route [6].

7.2 Occupant Load

Occupant loads within a building depend on the uses of each room, as long as there is the proper two-hour fire rating for the barrier. More specifically, occupant loads are separated by floor and calculated according to use in relation to an occupant load factor. Table 18 Occupant Load Factors is a summary of the type of factors used to determine the occupant load fact, from the 2006 edition of *NFPA 5000* and look at *Table 11.3.1.2*.

Table 18 Occupant Load Factors

Occupancy Classification	Occupancy factor
Business	100 Gross Sq. Ft. per person
Classrooms (Assembly)	15 Net Sq. Ft. per person
Shops and Lab Areas	50 Net Sq. Ft. per person
Accessory Storage and Mech. Room	300 Gross Sq. Ft. per person

It should be noted for the analysis net square feet is the area of the room minus the area of any obstruction in the room; and the gross square footage in just the area of the room plus any obstruction. Once the appropriate square footage for each space was calculated it was then divided by the occupancy load factor, as shown in Equation 1 Door Width. The quotient was rounded up to the next whole number to the highest possible occupant load. Table 19 Summary of Calculated Occupant Design Loads per Floor displays a detailed summary of the breakdown of space per floor and the corresponding occupant loads. Table 19 square footage doesn’t match the square footage of Table 8 Square Footage of Alumni Gymnasium, because it doesn’t include the walls unlike Table 8 which is all the usable space in Alumni Gymnasium. The egress and fire protection systems are designed with the worst case in mind for safety reasons, but there are some areas where there is a smaller number than what a space could actually hold, which is seen in 11.5 Floor and Fire Summary Charts.

Table 19 Summary of Calculated Occupant Design Loads per Floor

Floor	Use	Square Footage (ft^2)	Number of Persons
Sub-Basement	Accessory Storage/Mech. Room	18.00	1
	Shops and Labs	2,290.50	46
	Business	2,009.86	21
	Restrooms	430.50	10
	TOTAL	***4,748.86***	***78***
Basement	Business	5,375.60	49
	Accessory Storage/Mech. Room	56.70	1
	Shops and Labs	1,345.00	36
	Classrooms	2,039.00	184
	Restrooms	718.30	16
	TOTAL	***9,534.60***	***286***
First	Business	6,052.45	92
	Accessory Storage/Mech. Room	236.75	2
	Classrooms	3,216.25	224
	Restrooms	455.91	10
	TOTAL	***9,961.36***	***328***
Second	Business	4,751.75	53
	Accessory Storage/Mech. Room	647.30	4
	Classrooms	4,249.80	284
	Restrooms	419.25	10
	TOTAL	***10,068.10***	***351***
Third	Business	3,088.80	38
	Accessory Storage/Mech. Room	78.00	1
	TOTAL	***3,166.80***	***39***
Building Total Occupancy		***37,479.72***	***1082***

7.3 Egress

7.3.1 Number of Exits

The required number of exits are in accordance with *11.4.1.2*. This code provision requires story to have at least two exits as long as its occupant load is less than 500. If the occupant loads is between 500 and a 1000, the requirement is three exits; and no less than four exits are required for more than a 1000, breakdown of number of exits per floor can be seen in Table 20 Compliance in the Number of Exits. Any room in the building with occupancy of less than one hundred people and is fully sprinklered than on door may be allowed according to *28.2.4.3*. For safety reason it is best to have at lest two exit in high by used rooms like classrooms. The building code requires that each door exiting from a room must have a UL Fire Resistance Rating of one and one-half hours a summary of the number of doors used throughout the renovation can be seen in Table 21 Total Fire Doors for Redesign.

Table 20 Compliance in the Number of Exits

Floor	Need for floor	Have for floor	Compliance
Sub-Basement	**2**	**2**	In Compliance
Basement	**2**	**5**	In Compliance
First	**4**	**5**	In Compliance
Second	**2**	**3**	In Compliance
Third	**2**	**2**	In Compliance

Table 21 Total Fire Doors for Redesign

DOORS				
FLOOR	INTERIOR		EXTERIOR	
	SINGLE 36"	DOUBLE 60"	SINGLE 36"	DOUBLE 60"
SUBBASEMENT	5	5	0	0
BASEMENT	13	3	2	2
FIRST	15	5	3	3
SECOND	21	3	0	0
THIRD	13	1	0	0
TOTAL	**67**	**17**	**5**	**5**

7.3.2 Dead Ends

A dead end is a corridor that leads to a wall and provides no other means of egress assuming that the new Alumni Gymnasium is fully sprinklered allows for the maximum dead end length per *28.2.5.2* to be fifty feet. If a corridor is to long an occupant may use the corridor when trying to egress the building may get lost and worst hurt.

The basement is the only floor level for which there is a dead end; the four other floors don’t have any dead ends. Basement provided difficulty to design that was a dead end; this can be seen in Figure 20 Dead end Design Issue. The original design of the basement had a dead end corridor with a length of seventy feet and three inches, which is shown with the green ellipse. That length is too long for code compliance. In response, corridor was redesigned to have a dead end length of forty seven feet and six inches; new design may be seen in with the red ellipse.

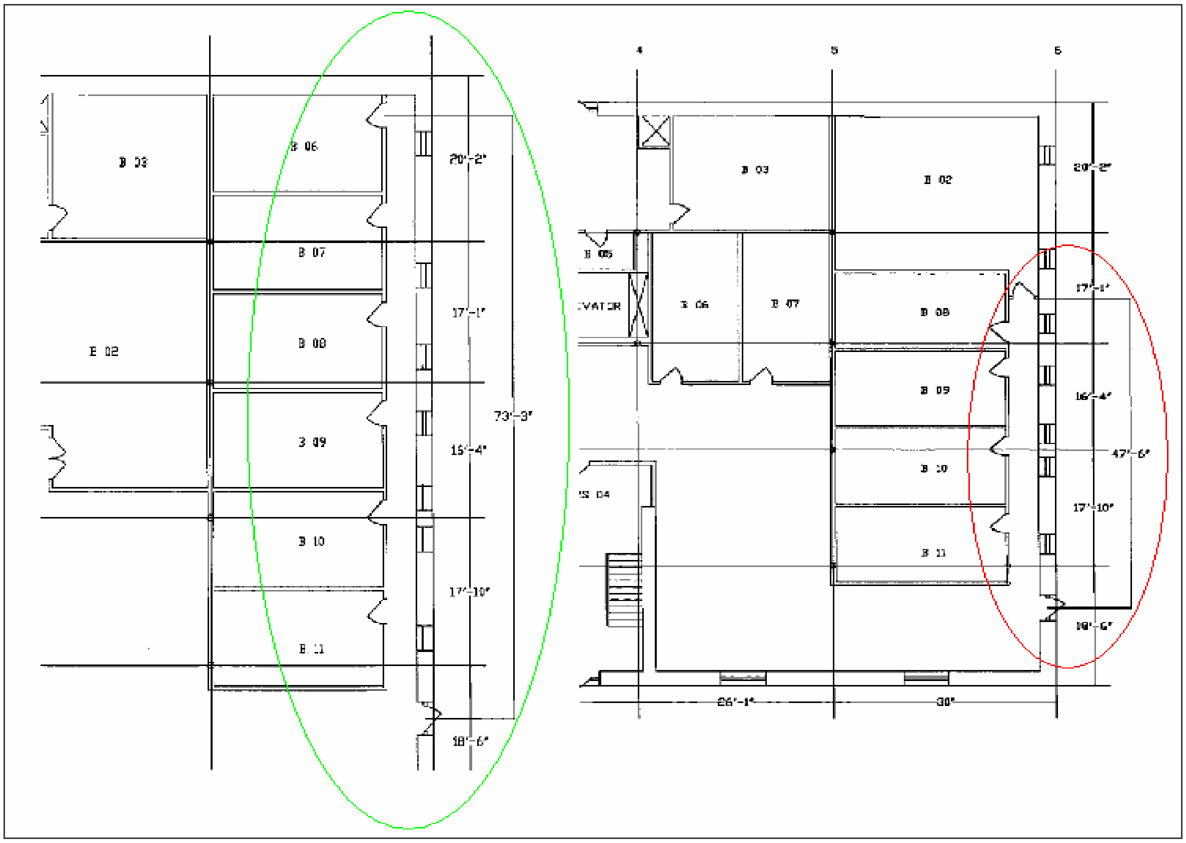


Figure 20 Dead end Design Issue

7.3.3 Travel Distance

The proposed design for Alumni Gymnasium in which classroom and offices are placed throughout the floor space, a designer has to be aware of the travel distance of the occupant. The travel distance is the total travel length from the furthest point from any occupied point to the entrance to an exit, as see in Figure 21 Travel Length. Paragraph *28.2.6.1* specifies the maximum travel distance for a fully sprinklered design is to be no more than 300 feet. In figured 21, if a fire, represented by the red circle, took place on the third floor in room 301, an occupant of room 301 would have the greatest travel distance, represented by the green line, of ninety three feet, which is an acceptable distance.

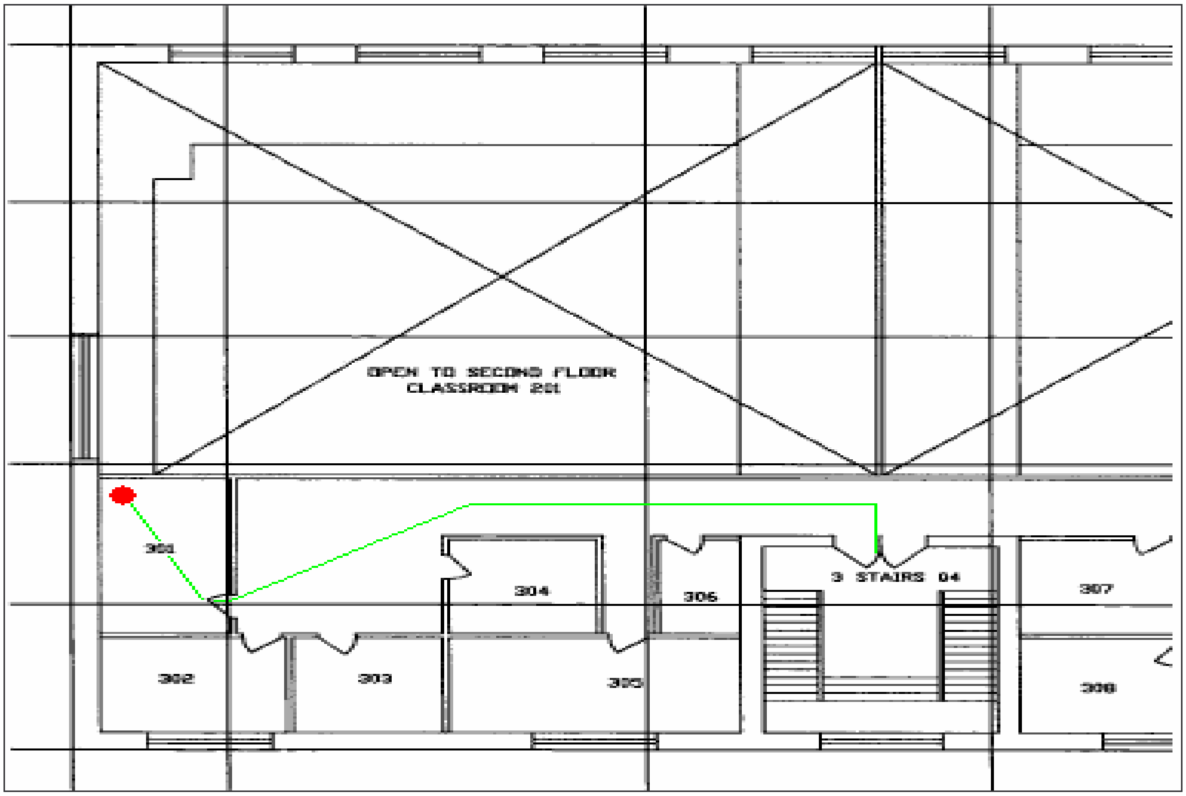


Figure 21 Travel Length

7.4 Capacity

The capacity of a building depends on the size of the building by square footage and type of building it is classified as. Using the square footage the designer can determine the occupancy load, which has an impact on the building design. The capacity of the building will affect the size of the doors and corridors width.

7.4.1 Exit Access Doors

Door width requirements were calculated using the inches per occupant factors given in *Table 11.3.3.1.* All egress components are required to have a total width of either 0.3 inches per person for stairways and 0.2 inches per person for corridor. For NFPA it doesn't matter if the building has sprinkler system or not when calculating the width but in the IBC an easement in width is allowed for the buildings with automatic sprinklers [4]. Based on the occupancy load calculations, each exit access doorway has two satisfy the more stringent of two criteria: one is to meet the needed width, and the second is to be at least 32 inches wide.

Equation 1 Door Width

$$TotalExitAccessDoorWidth = OccupantLoadFloor(.2) \geq 32inches$$

Equation 1 yields the total door width necessary for a floor. The total number of doors provided depends on the required door width and the required number of exits. For example, a floor that requires both 60 inches of total exit access door width and two exits could have two 32-inch doors; or, it could be over-designed with two, 36-inch doors. It is also important to note that these calculations must be completed for classrooms and other areas within all floors of the buildings.

Chapter 11 of the *NFPA 5000* indicates that stairwells are required to have a total width of 0.3 inches per occupant, with the minimum width for each set of stairs to be no less than 44-inches.

Equation 2 Stairwell width

$$TotalStairwellWidth = FloorOccupancyLoad * (.3) \geq 44inches$$

Equation 2 expresses the total required width for the stairwells, and it is similar to Equation 1. For example, a floor that requires 2 exits based on occupancy and 100 inches of stairwell width could have 2 stairwells that are 50 inches wide, or, 3 stairwells that are 44 inches wide. For the redesigned Alumni Gymnasium, the total existing stairwell width is often substantially greater than that which is required for the anticipated occupancy loads. Specifically, it should be recognized that the stairwells are sized for the maximum amount of occupants seen on any floor, because the stairs are not allowed to decrease in the direction of egress. Additionally, it has been assumed on the plans, for illustrative purposes, that all exits are used equally in an emergency. Although this is not likely, it allows visualization of the conservative values seen throughout the building.

7.4.2 Corridor Width

Corridors are required to have a total width of 0.2 inches per occupant, and for occupancy loads of more than fifty are required to have a clear width of at least 44 inches as stated in *28.2.3.2*. The calculations follow a similar process to those shown is Equation 1 and 2. The corridors of the redesigned Alumni Gymnasium are generous in size relative to these criteria. In most cases they accommodate allowing for an occupant load equal to that of the entire load of the floor. It would be safe to say that from an egress point of view the corridors are grossly over-designed. However, there are many reasons to design wide corridors. Fire protection is certainly not the driving factor in very wide corridor widths, but for moving furniture and lab equipment is easier with the wider corridors.

7.4.3 Exit Discharge

The exit discharge must flow directly out of the building according to paragraph *11.7*, which calls for the exit discharge to flow into a public area. For Alumni Gymnasium, there are five separate existing exit discharges which discharge in a public area for safety from the building and the fire. The building is well above the required amount of discharges.

7.5 Structural Fire Protection

The fire protection of a building doesn't stop with the active for suppression systems such as sprinklers. The fire suppression of a building depends also on the passive fire protection system such as the walls of the building to have so type of protection. The structure of a building needs to have a fire protection provided through two types: one type is fire barriers and the other is fire retardant materials. With these in place and working properly the fire is slowed down from progressing to adjacent rooms.

7.5.1 Fire Barriers

Fire Barriers are important part of the design of the fire protection system of a building. A fire barrier is a system that is in place to slow down or even stop the progression of a fire and the products of a fire from room to room. Fire barriers are defined as passive fire defense systems; it is not an active fire defense system like sprinkler systems. A passive fire defense system is a system that is in place and doesn't change its operation or mode after a fire has happen. Stairwells and walls are examples of two different types of fire barriers. A fire barrier only needs to resist the fire for a two-hour period, so that the occupants can escape the building safely. Gypsum board on both sides of a wall is a cost effective strategy for providing the required fire barrier and fire resistance [3].

7.5.2 Fire Retardant Materials

Even though there will be Gypsum board covering up ninety percent of the steel structure. For that percent not covered by the Gypsum board other fire protection is need, such as a spray coating the steel with fire retardant materials. During the construction of the building all of the existing steel structure will be exposed, and at this time it would be a good idea to further the protection of the building and its occupants by applying a fire retardant material to the steel and wood structure. A typical fire retardant is a concrete based spray covers up the steel or wood and when it comes in contact with the air it binds to the objects providing a fire resistant that is need for the object. This material is one of inexpensive materials to work with but it is not an aesthetic solution. It would be best to limit the use of this material to those areas of the structure that will be covered by finish work [6].

In the redesign of Alumni Gymnasium the steel truss system that supports the roof decking remain exposed when construction is finished. This would make the truss part of the architect's design for the floor. Even though it contributes to the interior aesthetics of the building, the truss still needs to have a fire retardant material in place. A cement-based, spray applied insulate would be bulky and would not have a nice look that the designer is trying to accomplish in their design. Intumescent spray material was developed to have the two hour fire rating that the steel requires but it is as thin as paint. This material would retain the overall look and aesthetic feature of the truss, and one would not notice the fire retardant material since it will look just like a painted material [6].

7.6 Conclusion

The redesign of Alumni Gymnasium follows the fire provisions defined in NFPA 5000. The width of corridors, stairwells, and doors were all determined by the occupancy load. In fact, the existing structure and our proposed design provides more than what is required by codes for any of the widths. During the double checking to see if the new design complied with this document, one trouble spot came up. This was the dead end corridor in the basement. A minor adjustment to the floor plan was needed for code compliance. After fixing the dead end problem the rest of the design was complaint with the codes. According to the building code philosophy, the proposed design to be a safe design from a fire protection perspective, as seen in Table 22 Compliance Width.

Table 22 Compliance Width

FLOOR	Width		
sub-basement	Floor Total Occupancy	78	
	Required Number of Stairs	2	
	Number of Stairs Provide	2	in compliance
	Exit doors		
	need	11 inches	
	provide	72 inches	in compliance
	Exit stairs		
	need	15 inches	
	provides	84 inches	in compliance
basement	Floor Total Occupancy	286	
	Cumulative Occupancy	364	
	Required Number of Stairs	2	
	Number of Stairs Provide	5	in compliance
	Exit doors		
	need	55 inches	
	provide	228 inches	in compliance
	Exit stairs		
	need	73 inches	
	provides	192 inches	in compliance
First	Floor Total Occupancy	328	
	Cumulative Occupancy	1082	
	Required Number of Stairs	4	
	Number of Stairs Provide	5	in compliance
	Exit doors		
	need	163 inches	
	provide	252 inches	in compliance
	Exit stairs		
	need	217 inches	
	provides	360 inches	in compliance
second	Floor Total Occupancy	351	
	Cumulative Occupancy	390	
	Required Number of Stairs	2	
	Number of Stairs Provide	3	in compliance
	Exit doors		
	need	59 inches	
	provide	132 inches	in compliance
	Exit stairs		
	need	78 inches	
	provides	264 inches	in compliance
third	Floor Total Occupancy	39	
	Required Number of Stairs	2	
	Number of Stairs Provide	2	in compliance
	Exit doors		
	need	6 inches	
	provide	72 inches	in compliance
	Exit stairs		
	need	8 inches	
	provides	96 inches	in compliance

8 Cost

Once the scope of the design is done, the firm may come up with the cost for the project. The report has focused on the cost of the project in the area of materials and labor. Determining the cost for the materials and labor is known as the bare cost of the project. Since the goal of this project is to see if it is a realistic choice to turn the existing Alumni Gymnasium into classroom and office space, a rough bare cost was need to complete the requirements. Cost for demolition, fire protection coating of steel, and construction of classrooms and offices most be examined.

Determination of an estimate for the project was made easier with the use of the *RS Means Building Construction Cost Data* book [8]. The 2005 edition of this book was used and adjusted to represent current cost by assuming an annual with a three percent. In addition to this book, some of WPI administrators' advice was also used in the cost estimate of the project.

Chris Salter, Associate Director of Plant Services, provided some insight on developing a cost estimate for college classroom spaces. He was able to provide cost estimates that WPI has been using for its remodeling projects for the last couple of years. The cost numbers were expressed in dollars per square footage for a couple types of rooms. According to data provided by Salter, state-of-the-art lecture hall is usually 200 dollars per square foot, and the smaller classrooms cost about 100 dollars per square foot. Offices are usually figured to cost 75 dollars per square foot while bath rooms are 150 dollars per square footage, and lab space would be 150 dollars per square foot [14].

Director of Academic Technology Center, Mary Beth Harrity, provided cost data for installing computer technologies with in academic building. For instance, an I.T Lab

(Tech Suite) has a price tag of about 15, 000 dollars per room. The cost of a computer lab is based on an assumption of about 1,500 dollars per computer plus construction of the room. For a complete break down of what the rooms included in the cost estimate figures looked at section Breakdown. With the data gathered for each source it can be determined what a project of this scope could cost the Institute [11].

8.1 Breakdown of Fit-out Needs by Room Type

Preparation of a construction cost estimate for the proposed redesign of Alumni Gymnasium requires a space plan and an inventory of the furnishings for each of the different rooms. The list below outlines the furnishings anticipated for each room.

8.1.1 Lecture Halls (2 Rooms in Proposed design)

- Stadium Seating
- Stud wood walls, drywall, paint, and wood molding
- Desks and chairs
- Audio and video equipment to teach with, multiple pull down screens
- Computer network
- In wall rolling choke boards

8.1.2 Small Classrooms (2 rooms)

- Moveable desks
- White board on the wall
- Stud wood walls, drywall, paint
- Computer network with pull down screen

8.1.3 Restrooms (8 restrooms)

- Sink
- Toilets
- Stud wood walls, drywall, paint

8.1.4 Office/ Conference Rooms (25 offices and 2 conferences rooms)

- Stud wood walls, drywall, paint
- Desk plus chair
- Computer

8.1.5 Research Labs (2 labs)

- Stud wood walls, drywall, paint
- Lab equipment

8.1.6 I.T Labs (6 Rooms)

- Plasma Screen TV
- Computer with multiple network hook ups
- Desk plus chairs
- Phone

8.1.7 Computer Labs (1 computer room)

- Multiple computers
- Teaching computer complete with A.V
- Desk plus chairs

8.2 Cost Breakdown

This section provides a complete break down of what the project would cost if the redesign of our plan had been followed. The cost for this project can be seen in Table 23 Cost Break Down of Project. This table gives a detail look at what goes into a project of this size and magnitude of cost in 2005. There was a twenty percent increase in the final cost for a factor of error. This increase will cover any of the things that may have been missed or forgotten, plus it also covers for the factor of the area the project is being constructed in, Massachusetts. Figure 22 Bar Graph of the Cost of the Project in 2005 shows that the majority of the cost is due the cost of the rooms. This cost estimate doesn't include the cost of the utilities [7].

Table 23 Cost Break Down of Project

Bare Cost Analysis of Redesign for 2005							
Category	**Area**		**Price**	**Quantity**	**unit**	**total cost**	**source**
Demolition	**pool**	concrete floor	1.22	2,000.00	sq-ft	2,440.00	RS Means Value

	floors	woods	0.84	7,210.00	sq-ft	6,056.40	RS Means Value
			0.52	7,210.00	sq-ft	3,749.20	RS Means Value
		tile	0.68	28,946.00	sq-ft	19,683.28	RS Means Value
	walls	wood with studs + drywall on both side	2.53	8,830.00	sq-ft	22,339.90	RS Means Value
	ceiling	drywall ceiling	0.83	24,022.25	sq-ft	19,938.47	RS Means Value
Fill	**pool**	heavy soil	19.40	600.00	L.C.Y	11,640.00	RS Means Value
						0.00	
Concrete	**floor over existing pool**	4" slab of concrete	1.65	2,000.00	sq-ft	3,300.00	RS Means Value
		reinforcing	78.50	2,000.00	C.S.F	157,000.00	RS Means Value
Masonary	**Brick**	repointing (soft old)	3.21	15,080.00	sq-ft	48,406.80	RS Means Value
		power washing	1.35	15,080.00	sq-ft	20,358.00	RS Means Value
Steel	**I-Beams**	W 24 x 68	69.47	135.20	L.F	9,392.34	RS Means Value
		W 10 x 15	20.11	268.00	L.F	5,389.48	RS Means Value
Fire Protection	**Beams**	fire proofing spray	1.24	3,106.21	sq-ft	3,851.69	RS Means Value
	Truss	intumescent spraying	0.37	1,177.60	sq-ft	435.71	RS Means Value
	columns	fire proofing spray	1.57	2,374.00	sq-ft	3,727.18	RS Means Value
Flooring	**Tile**	8" x 8"	5.00	41,373.00	sq-ft	206,865.00	RS Means Value
Rooms	**Lecture Hall**		200.00	4,250.00	sq-ft	850,000.00	Chris Salter
	classroom		100.00	6,128.25	sq-ft	612,825.00	Chris Salter
	I.T lab		15,000.00	6.00	e.a	90,000.00	Mary Beth Harrity
	Computer lab	computer cost	1,500.00	48.00	e.a	72,000.00	Mary Beth Harrity
		teach computer	20,000.00	1.00	e.a	20,000.00	Mary Beth Harrity
	offices		75.00	4,779.10	sq-ft	358,432.50	Chris Salter
	bathroom		125.00	1,993.46	sq-ft	249,182.50	Chris Salter

	labs		150.00	2,290.50	sq-ft	343,575.00	Chris Salter
Elevator	**5000 lbs capacity**		5,625.00	4.00	e.a	22,500.00	RS Means Value
Doors		3' x 7'	250.00	72.00	e.a	18,000.00	RS Means Value
		5' x 7'	480.50	22.00	e.a	10,571.00	RS Means Value
		handicap equipment	350.00	2.00	e.a	700.00	RS Means Value
		panic touch bar	450.50	94.00	e.a	42,347.00	RS Means Value

2005		
total cost of project	3,191,659.46	Dollars
20% increase to total cost	3,829,991.35	
cost per square foot	92.57	

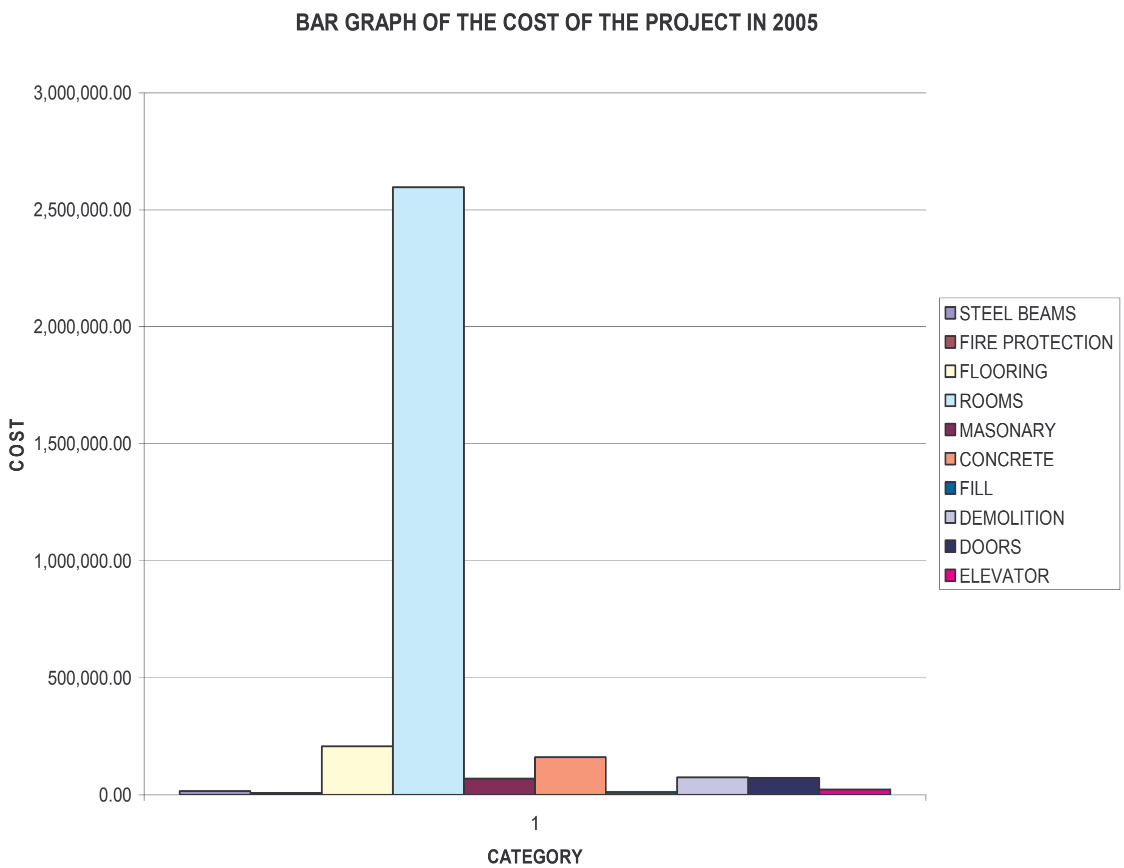


Figure 22 Bar Graph of the Cost of the Project in 2005

The project in 2005 would have cost in the range of $3.83 million which is a cost of $92.57 per square foot. Table 24 Cost of Construction for Different Years shows what the project will cost for future dates, by using a three percent increase per year for inflation [7]. If the Alumni Gymnasium was to be renovated this year it would cost the Institute around $4.1 million which is a cost of about $98.21 square foot. When talking to John Miller, he said that there are plans to build the new recreational center by the year 2015. That is most likely when the redesign of Alumni Gymnasium will be considered, and the associated future cost will be about $5.2 million, or $124.41 per square foot.

Table 24 Cost of Construction for Different Years

Cost of Construction for years other than 2005		
2006		
total cost of project	3,287,409.24	Dollars
20% increase to total cost	3,944,891.09	
cost per square foot	95.35	
2007		
total cost of project	3,386,031.52	Dollars
20% increase to total cost	4,063,237.82	
cost per square foot	98.21	
2010		
total cost of project	3,700,008.06	Dollars
20% increase to total cost	4,440,009.68	
cost per square foot	107.32	
2015		
total cost of project	4,289,323.42	Dollars
20% increase to total cost	5,147,188.11	
cost per square foot	124.41	

The cost of some of the utilities can significantly increase the cost of the project cost up. Examples include the sprinkler system, HVAC system, telephone, and electric. This being a 2005 book cost estimate the same three percent needs to calculate into the estimate, as seen in Table 25 Utilities Cost [8]. The cost of the utilities may cost in 2007 around $1.3 million with a square foot cost of $31.25. These costs are just rough estimates. Some design development and industry are needed for more accurate costs. This gives an idea of what kinds of cost it will take to build the new design for Alumni Gymnasium. Combining the cost of labor and materials with the rough estimate for utilities it will cost $5, 614,617.91 which is $135.71 a square foot.

Table 25 Utilities Cost

Utility Cost According to 2005				
Category	**Price**	**Quantity**	**Unit**	**Cost**
Heating	5.03	41,373.00	sq-ft	$ 208,106.19
Air Cooling	7.2	41,373.00	sq-ft	$ 297,885.60
Sprinklers	3.26	41,373.00	sq-ft	$ 134,875.98
Electrical Wire 600V	4.8	107,904.00	C.L.F	$ 517,939.20
Telephone	6.65	8,992.00	L.F	$ 59,796.80
Total Cost				$ 1,218,603.77
Total Cost For 2006				$ 1,255,161.88
Total Cost For 2007				$ 1,292,816.74
Cost Per Square Foot				$ 31.25

Table 26 Total Cost Project with Utilities for Years other than 2005

Cost of Construction for years other than 2005		
2006		
Material and Labor cost of project	3,287,409.24	Dollars
Utilities cost	1,255,161.88	
20% increase to total cost	5,451,085.35	
cost per square foot	131.75	
2007		
Material and Labor cost of project	3,386,031.52	Dollars
Utilities cost	1,292,816.74	
20% increase to total cost	5,614,617.91	
cost per square foot	135.71	
2010		
Material and Labor cost of project	3,700,008.06	Dollars
Utilities cost	1,412,695.75	
20% increase to total cost	6,135,244.58	
cost per square foot	148.29	
2015		
Material and Labor cost of project	4,289,323.42	Dollars
Utilities cost	1,637,701.56	
20% increase to total cost	7,112,429.98	
cost per square foot	171.91	

8.3 Cost Conclusion

Renovating the existing Alumni Gymnasium will cost WPI around $4.1 million, which is $98.21 square foot; not including the utilities and services that need to go into the building. The cost of utilities with the material and labor is $5.62 million, which bring the total cost and $135.7 square foot. The final cost doesn't include the overhead cost for design, engineering fees, plumbing, and construction bonds. When these costs are included the project could exceed six million dollars. For the alteration of Alumni Gymnasium for academic proposes it can be estimated to cost between five and ten million dollars from start to finish of the renovation. This big variation in cost of the project is because there may be unexpected cost for the project. For example, the cost of a project management and the utilities are rough estimates. When a HVAC firm goes the construction the cost could be more for an old build and there are unexpected implications for the installation.

9 Conclusion

As we all know, projects evolve, ideas bend, and plans change as time passes and new perspectives are gained and new information is uncovered. This is rarely a bad thing, and in most cases, the changes are simply necessary, or more reasonable, or more in-line with the end goal. Our changes brought to light interesting problems, benefits, and challenges. This project was begun with some expectations that were simply not met: plans changed accordingly. First, to execute the project, we initially thought that old structural drawings, itemized lists of materials, or any reference material in some level of detail on Alumni Gym existed. Nearly nothing was found beyond some simple and incorrect floor plans. Second, to define the project, we thought it would be interesting, and in the interest of the student body, to offer a plan that would convert the gym to a multi-use social center, study lounge, and student activities office area. Further insight into the needs of the school exposed the demand on classrooms, labs, and offices, those unexciting but very necessary requirements of an academic institution. So, with some of the drive and excitement towards the initial project dropped down a notch, very little reference as to how the building was built, and next to no information that could be interpolated from older building codes, we set out to offer a reasonable proposal for the alteration and restoration of Alumni Gymnasium into classrooms, offices, and lab space.

A thorough proposal should include an examination of every anticipated aspect of the design and construction schemes for the renovation. It should be evident through the pages of text, figures, and tables presented herein that we tried to touch on every perceivable aspect of this building upgrade. The result is a series of proposed areas, structural dimensions, cost estimates, and all of the respective calculations. But this is also a report that leads the reader through the process of first identifying the goals of a project then defining the constraints via a set of codes and an existing structure. It goes on to give an idea of many things that get in the way of such goals. This includes safety.

It is important to note that not all things that get in the way are bad. Placing safety as the highest concern is important and should be welcomed as one of these things that causes iteration after iteration of a design. Provisions are set in place to protect the well being of everyone involved: from the occupants to the engineer. The discussion proceeds with calculations and a resultant plan. Without a projective cost, this plan means little to those considering it. As a proposal, having a reasonable cost estimate is essential for giving a sound impression of the depth of the project. Cost of materials and labor are important considerations, but these numbers could be estimated based on construction of a new building, where, in comparison to the renovation of an existing building, the potential to optimize construction is fairly unlimited as there are fewer initial conditions to consider. With renovation and alteration, construction difficulties can prove very costly, as time is money. For example, placing large structural members within a structure can prove difficult with existing walls and roof structure. An effort was made to limit potential difficulties in construction. The result of this entire process is a relatively cost effective, reasonable to construct structure, which would lessen the demands on current academic spaces as well as provide substantial room for growth.

9.1 Project Outline and Results

The renovation of Alumni Gymnasium would begin with demolition of the existing, non load bearing, and interior walls. The track on the 3rd floor would then be removed as the space is now open for removal of the larger debris from this structure. The pool area should then be filled and temporary supporting members included for installation of the new beams and girders above. As the building is relatively free of walls at this point, the new structural members would be brought in and installed on the basement level. The elevator should be installed at this time. Interior masonry cleaning and fire proofing of steel members should then be performed. Following this step, new flooring and partitioning walls can be added from the bottom floor up. Finishing work can then be completed, and new equipment and furniture brought in.

The renovation would provide a great deal of added academic space to the campus. This proposal would provide two classrooms with seating for 80 students each, two lecture halls with stadium seating for 80 students each, twenty five offices, six tech rooms, two conference rooms, two research labs, and two computer labs. The building would cost approximately 5.6 million dollars to renovate at about 136 dollars per square foot of floor space. The addition of this space would improve the quality of the WPI campus as a whole while retaining the historic nature of the building itself.

9.2 Capstone Design

Well-developed cities, where land use is limited, but existing structures are plentiful, provide plenty of opportunity for building reclamation. This can be seen as a common trend in modern construction. One such example is the WPI project at Gateway Park where an older building was salvaged in order to save money and keep the feel of the surrounding community. The development of a plan for an alternative use of Alumni Gym follows this trend as a realistic project with many practical constraints. Ethics, safety, construction, practicality, politics, and cost are all parameters common to the workplace of a civil engineer.

Efforts to uphold the engineer's code of ethics have been taken by strictly conforming to the most stringent of codes while making the building as safe as is feasible. Widely accepted codes have been followed, and in many cases exceeded in an effort to ensure a safe structure. Furthermore, a deep emphasis on fire safety in the means of egress has been a significant portion of our design. By following the provisions of the IBC, NFPA, and local regulations for the building's structure, the proposed structure should remain standing for many years to come. Additionally, the construction process of the building has been emphasized to ensure feasibility.

Practicality of the design itself is not the only concern with a project like this. The proposed structure must also appeal to both those funding the project and the people who use it. With this in mind, the project has included significant interaction with members of the WPI faculty and staff regarding the most efficient use of the space. Politically, the ideas expressed in the project must appeal to the governing body, WPI. Finally, cost is always a substantial concern, and therefore efforts to estimate the cost of rehabilitating Alumni Gym have been taken. These cost estimates seem reasonable and are in line with those of other WPI projects.

9.3 Final Thoughts

This MQP experience offered a unique look into a “real world” project. We encountered difficulties in gathering information from a number of source types. Text resources were used to find information on modern materials used. Information on building materials from the early 1900s, currently in use in Alumni Gym, were found in the literature or estimated reasonably. Up to date, regulating codes were followed with the safety of the building’s occupants in mind. Construction and cost were concerns from the beginning of the project. The resultant use of space and proposed alterations will offer a great deal to the quality of the academic environment on the WPI campus by providing additional classroom, office, and lab space to the student body and faculty. In the end, we have learned a great deal about the struggles and rewards present in the development of a successful building alteration project.

This project has certainly given us a unique look into the civil engineering field. Other major qualifying projects, similar to this one, could provide students with valuable experience in areas which they will likely encounter as a civil engineer. Gathering information, interpreting provisions of accepted building codes, calculating the potential strength of existing structures, creating a layout which will provide the proper means of egress, and estimating a reasonable cost for construction: these are all important practices that students don’t often get the chance to perform together in the classroom. Worcester is full of buildings that have great potential but need renovation. Furthermore, the WPI student body is a good resource for providing the city with proposals for these buildings.

More MQPs like this one, in conjunction with the city, would provide students with the necessary practice in engineering while giving back to the city and assisting to create a better environment for the WPI community.

10 Reference

1. American Institute of Steel Construction Incorporated. Steel Construction Manual. 13th ed. USA: American Institute of Steel Construction, 2005.

2. Baker, Ira. A Treatise on Masonry Construction. New York: John Wiley and Sons, 1899.

3. Fitzgerald, Robert W. Building Fire Performance Analysis. Chichester, England: Wiley, 2004.

4. International Code Council. International Building Code, 2006. International Code Council; Illinois, 2006.

5. Massachusetts State Executive Office of Public Safety, Massachusetts State Building Code. 6th ed. Commonwealth of Massachusetts, 2006.

6. National Fire Protection Association. NFPA 5000: Building Construction and Safety Code. Quincy, MA: National fire protection agency, 2006.

7. Oberlender, Garold D. Project Management for Engineering and Construction. 2nd ed. Boston: McGraw Hill, 2000.

8. RS Means. Building Construction cost Data. 63rd ed. Kingston, MA: RS Means Construction Publishers & Consultants, 2005.

9. Webb, Walter and Herbert Gibson. Masonry and Reinforced Concrete. Chicago: American School of Correspondence, 1909.

10. Worcester, Ma. Charter, Laws and Ordinances of the City of Worcester, 1911. Worcester, Ma: The Blanchard Press, 1911.

11. Harrity, Mary Beth. Personal Interview. 22 February, 2007.

12. Kornik, Charles J. Personal Interview. 04 October, 2006.

13. Miller, John E. Personal Interview. 09 September, 2006.

14. Salter, Chris. Personal Interview. 22 February, 2007.

15. Cambridge Engineering Selector. EduPak 14 Dec. 2006. <http://www.grantadesign.com/>.

16. National Register of Historic Places. National Register. Oct. 9, 2006 <http://www.nationalregisterofhistoricplaces.com/ma/Worcester/state13.html>.

11 Appendix

11.1 Proposal

Proposal:

Renovating Alumni Gymnasium 2006

By:

David Laramee

Ben Mies

Advisor:

Prof. Leonard D. Albano

Table of Contents

1. Introduction

Worcester Polytechnic Institute's first athletic building, the Alumni Gymnasium was finished in 1915 but will soon be replaced by a proposed larger and more suitable facility. Its location bordering the quadrangle, near the center of campus, as well as the stature of the structure make it one of the more prominent buildings at the Institute. Most all of the freshman class and a great majority of the student body walk by this building each day. To many, this area is the heart of the WPI campus. The transformation from a gymnasium to class rooms would allow the building to sustain many more generations of enthusiastic students.

The Alumni Field and Gymnasium were built to satisfy the demands of a growing physical training and athletic conditioning program at WPI. The Alumni Association succeeded in completing the facilities just in time for the 50^{th} anniversary of the Institute in 1915. Just over fifty years later, Harrington Auditorium was completed and connected to the existing Alumni Gymnasium. Today, Alumni Gym is used primarily for club sports with only one varsity team using it as its home facility. Faculty and students use the gym as a place to relieve stress outside the classroom through physical activity.

Coming up on the 150^{th} Anniversary of the school, WPI plans to yet again introduce a new field house as the primary site for both competitive sporting events and athletic conditioning. With this, Alumni Gymnasium becomes obsolete as a training center. One of the primary concerns on campus is a lack of classroom space. With this classroom shortage and the upcoming availability of Alumni Gymnasium, creating a variety of classrooms, student meeting space, and offices through reclamation of the structure will likely be considered. This project will be an exploration into the renovation of the existing Alumni Gymnasium into a mix of classroom, office, and other areas to support WPI's growth.

2. Objectives

This MQP offers us experience in real-world reclamation of an existing structure. The areas where we expect to expand our knowledge and understanding are as follows:

- history of construction and WPI
- structural design
- renovations
- cost analysis
- fire protection systems
- building codes such as NFPA, IBC, local and state
- client communication
- technical report writing
- management of our project

3. Scope

By taking on this project, we plan to develop an approach for transforming Alumni Gymnasium into an area that embodies the interests of both the student and faculty populous. Secondary to these needs, our goal is to retain the history and atmosphere of the historic structure. Alumni Gymnasium was founded on the principles of the student's livelihood and this idea should be kept alive in a reclaimed structure. In developing a tactic for renovating the student's historical gym for new uses, we will complete these tasks:

- Gather historical information on Alumni Gym
    - 1915 Worcester building codes
    - intent of use and actual use
    - major modifications
        - additions
        - incidents
- Investigation of Current Use
    - structural status
        - load paths
        - load resisting systems
    - detailed structural drawings
    - occupancy
    - interview with John Miller
    - walk-through to investigate structure personally
    - current fire protection system
- Future Plans
    - Choosing alternative uses
        - our own ideas
        - WPI's needs
        - blending ideas into one that serves the purpose
        - analyzing and defining an appropriate solution
- Developing Our Plans
    - creating an overlaying floor plan of alterations to the structure
    - new floor plans and structural drawings in accordance with building codes
        - research into current building codes and governing codes
            - using National Fire Protection Association (NFPA) codes
            - using International Building Codes 2006 Edition
            - using local and state building codes

David Laramee and Ben Mies 4

            - choosing the governing specifications
        - structural alternatives and analysis
    - upgrading current fire protection systems to suit our needs and satisfy building code requirements
    - estimated cost of renovation
        - cost of labor
            - demolition and construction
        - cost materials

4. Capstone Design

Well developed cities, where land use is limited but existing structures are plentiful, provide plenty of opportunity for building reclamation. This can be seen as a common trend in modern construction. Developing a plan for an alternate use of the Alumni Gym follows this trend as a realistic project with many practical constraints. These parameters are common to the workplace for a civil engineer. For example, the WPI project at Gateway Park involves salvaging an older building in order to save money and keep the feel of the surrounding community.

Efforts to uphold the engineer's code of ethics will be taken by strictly conforming to the most stringent of codes while making the building as safe as is feasible. Furthermore, a deep emphasis on fire safety in the means of egress and suppression systems will be a significant portion of our final report. By following the provisions of IBC, NFPA, and local building regulations, our design should be safe for the occupants. Additionally, detailed structural drawings of connections will be a confirmation that building (manufacturing) the structure is feasible.

Practicality of the design itself is not the only concern with a project like this. The proposed structure must also appeal to both those funding the project and the people that use it. With this in mind, the scope of the project includes interaction with both students and faculty regarding most efficient use of the space. Politically, the ideas expressed in the project must appeal to the governing body, WPI. In addition, cost is always of concern, and therefore efforts to estimate the cost of rehabilitating Alumni Gym will be taken.

5. Schedule

This MQP project will follow a schedule closely in accordance with the dates listed below.

- A Term
  - Proposal – 9/27/2006
  - Meeting With John Miller- 9/29/2006
  - Meeting with Charles Kornik – 10/04/2006
    - Defind what the new use for the building will be
  - Walk through
  - Investigate building codes and the discrepancies of 1915
  - Research history-WPI achieves
- B Term
  - Continue
    - History research
    - Building code investigation and existing compliance
  - Choose an appropriate alternative use – being of B term
  - Develop and gather structural drawings of existing structure – mid of B term
  - Put the drawings into a digital format, simple drawings
  - Determine:
    - Space available

- how does the structure work
- fire safety evaluation

- C Term
  - Continue studying building codes
  - Develop floor plan for new idea- first week
    - Overlay this new plans on the simple computer drawings
    - While keeping in mine the hard unmovable features (doors, windows, bath rooms, and corridors)
  - Develop structural drawings of the alternative use – entire term
    - Satisfying building codes and complying with standards
    - Define what can stay from the old building and what needs to be added to the structure.
  - Building code compliance
  - Cost estimation – as if we are developing the structure
    - Figure out cost of labor
    - Figure out cost of materials
  - Finalize Report
- D Term
  - Prepare for presentation and finalizing report as required

6. References

Taylor, Herbert Foster. *Seventy Years of the Worcester Polytechnic Institute*. Worcester, Mass: WPI, 1937.

WPI Tech Bible. Feb 7, 2006. Worcester Polytechnic Institute. Sep 24, 2006 <http://www.wpi.edu/Academics/Library/Archives/TechBible/>

11.2 Interviews

11.2.1 Academic Programs: Charles J. Kornik

Interview with Academic Programs:

Charles J. Kornik

Administrator

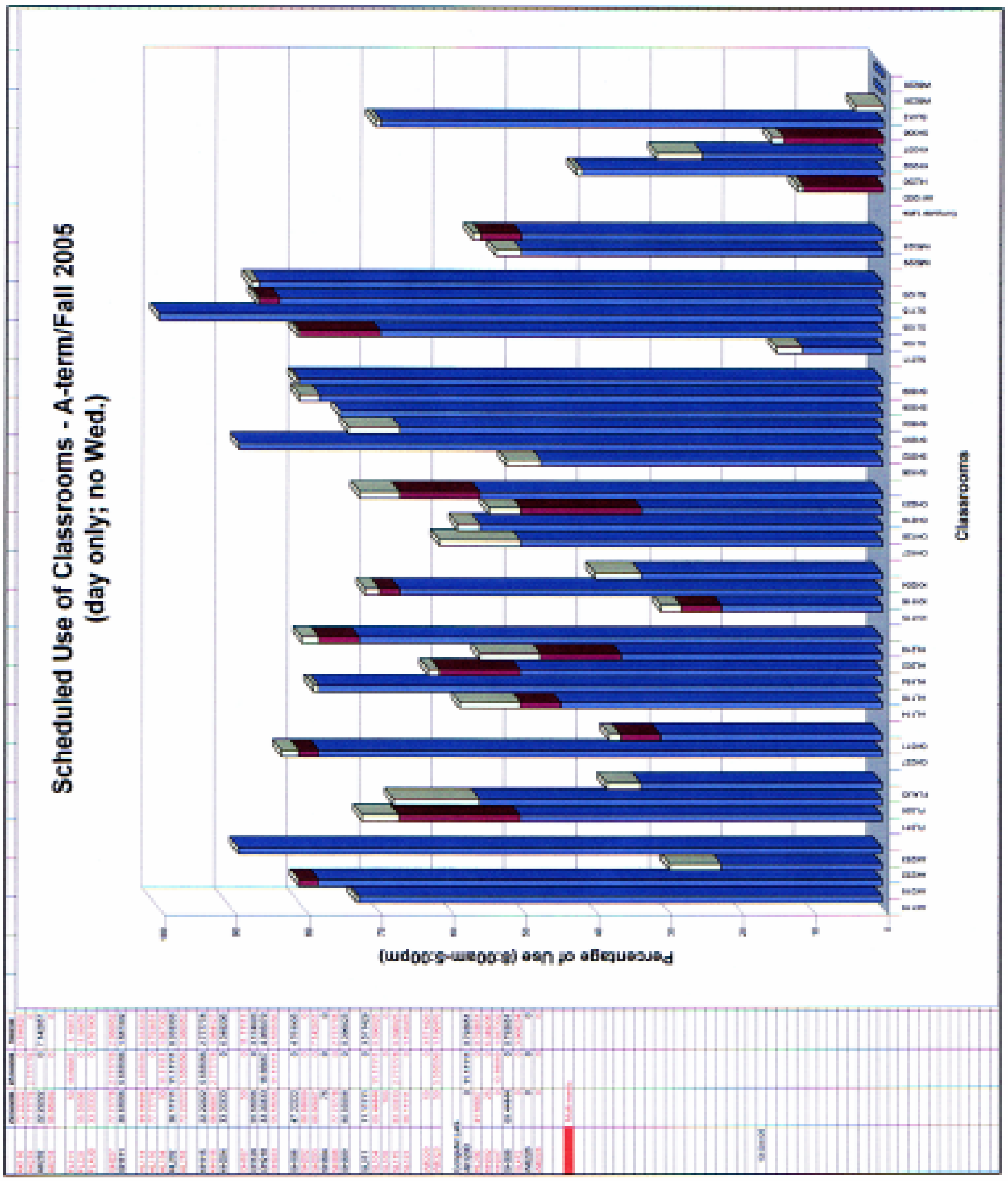
Interview conducted on Wednesday, 10-04-2006

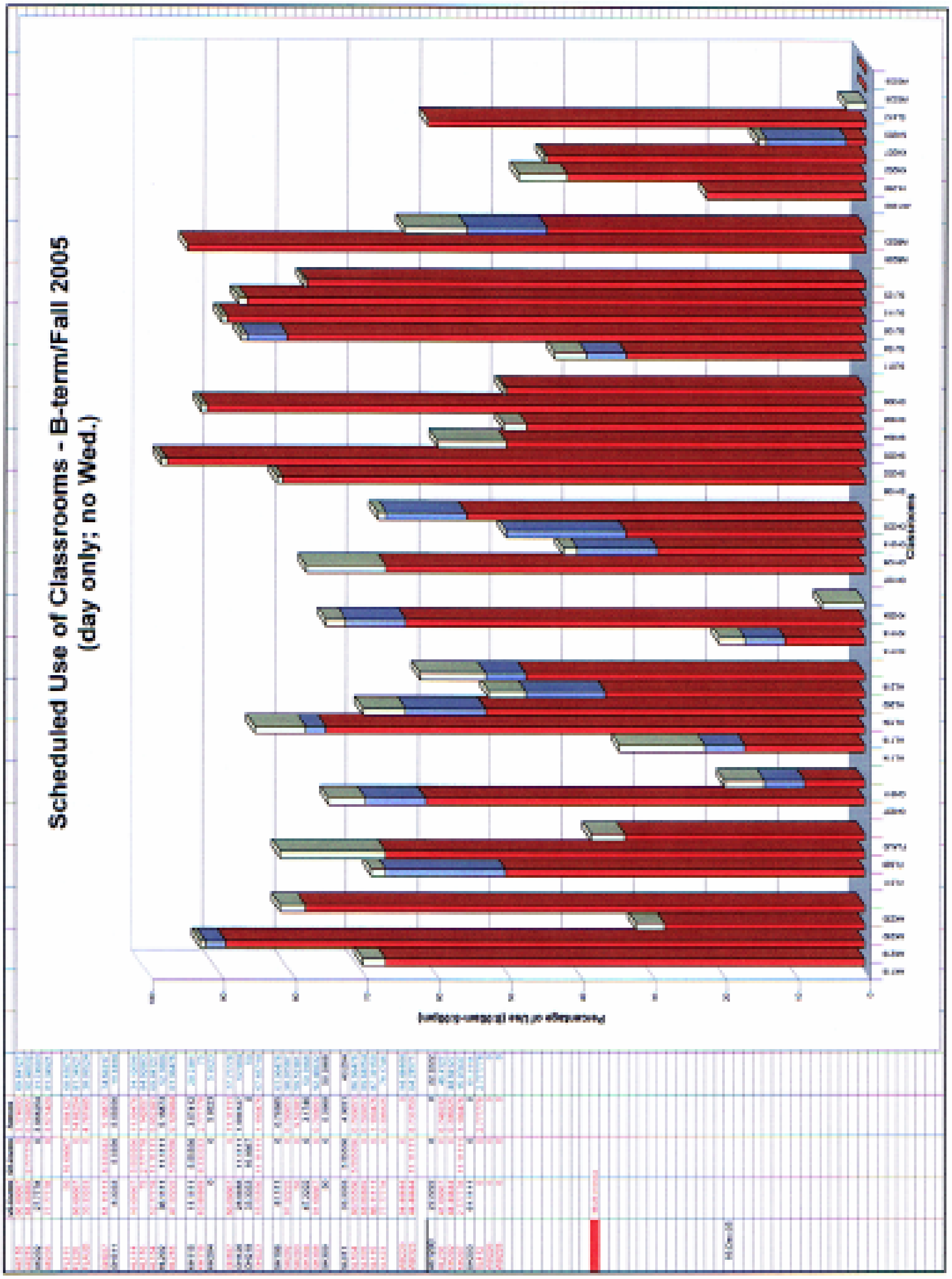
David Laramee

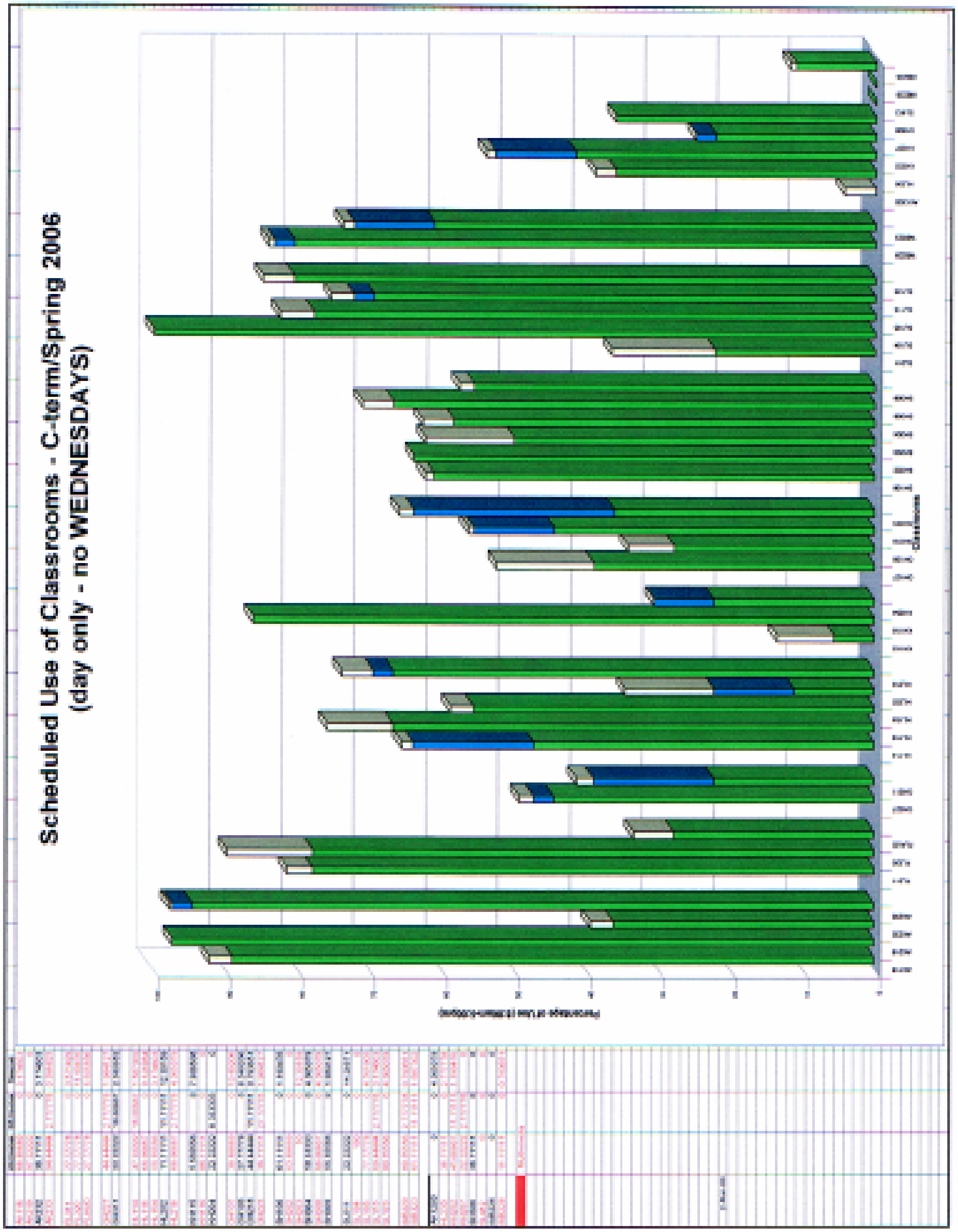
Ben Mies

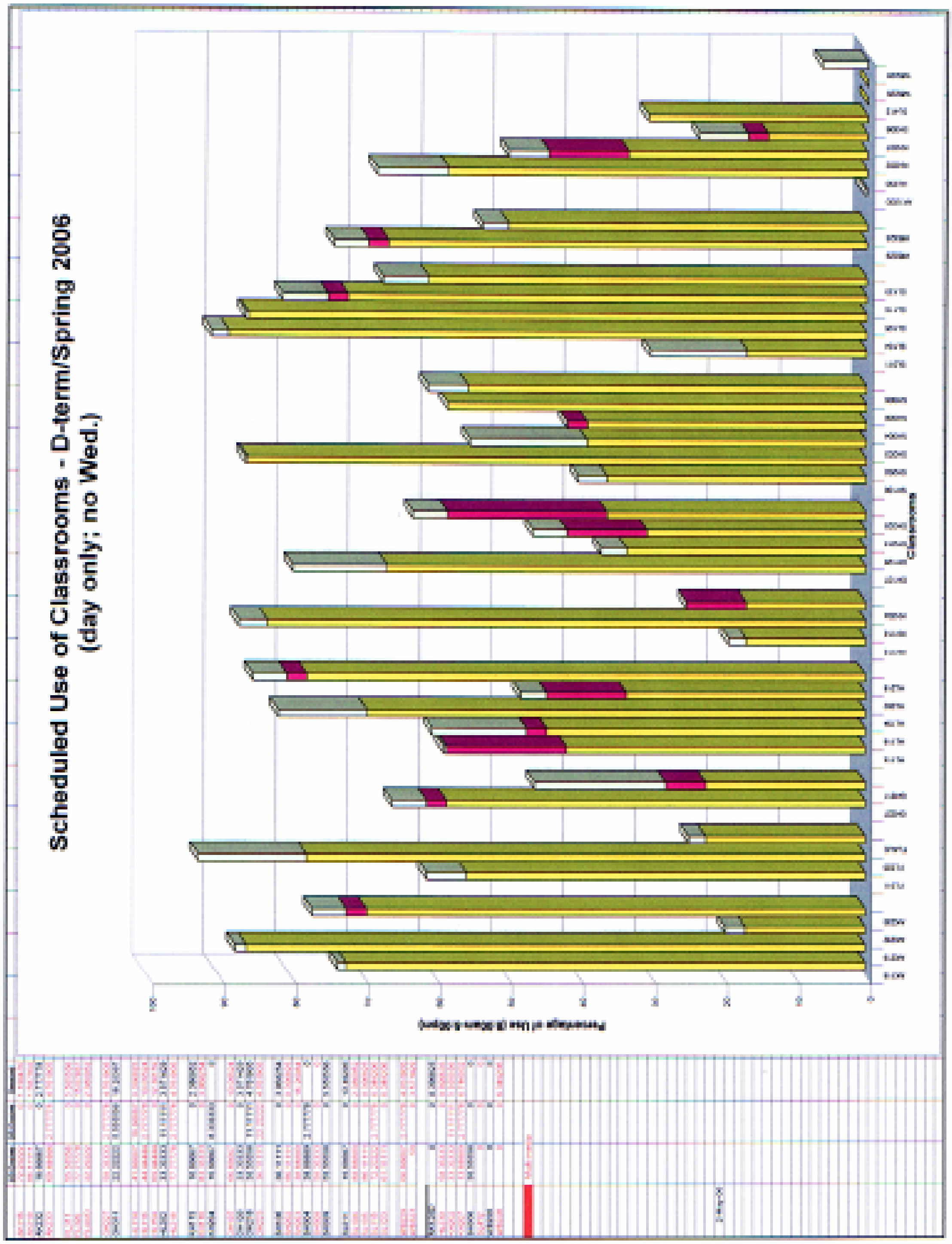
- WPI only has 34 classrooms
- WPI does need more classrooms, would like to see Alumni Gym become classrooms.
- He would like to see…as many as possible
  - 50 to 60 seats like it is SL105
  - maybe 60 to 80 as it is in KH 116
  - or Higgins 222 which holds less than 40 seats
- suggested us to talk with the Academic Technology Center at WPI
  - Mary Beth Harrity to know about the technology that goes into each type of academic room on campus
- sent us some good data on the operation of classrooms, has charts on what classrooms are used and how often they are used, as seen in 11.2.1.1 Classroom Charts

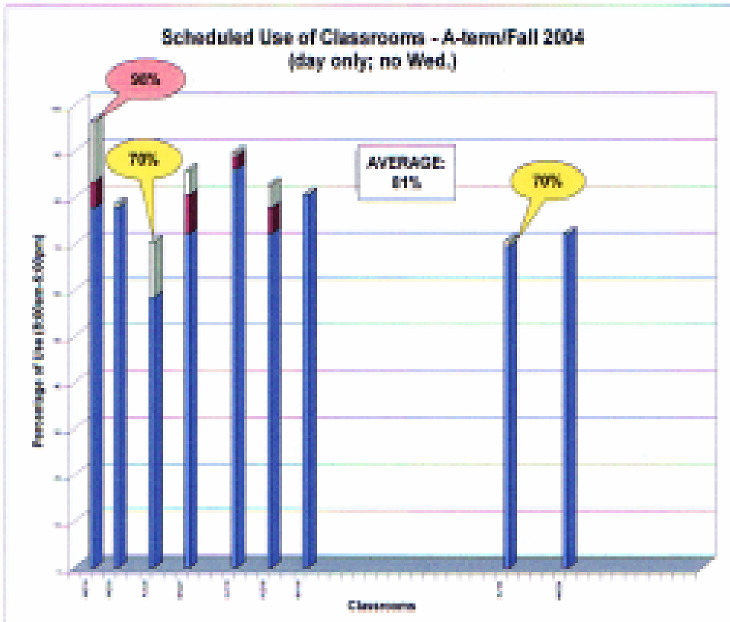
11.2.1.1 Classroom Charts



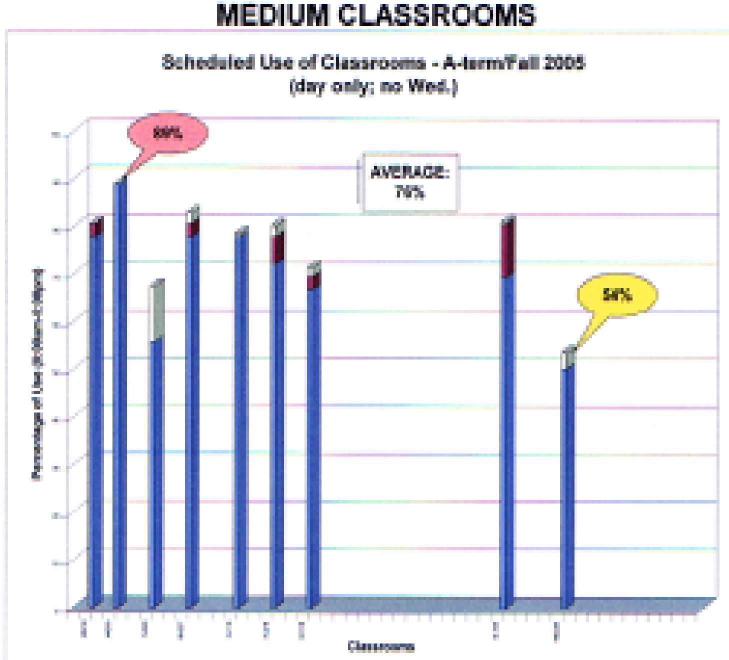

Scheduled Use of Classrooms - B-term/Fall 2005
(day only; no Wed.)

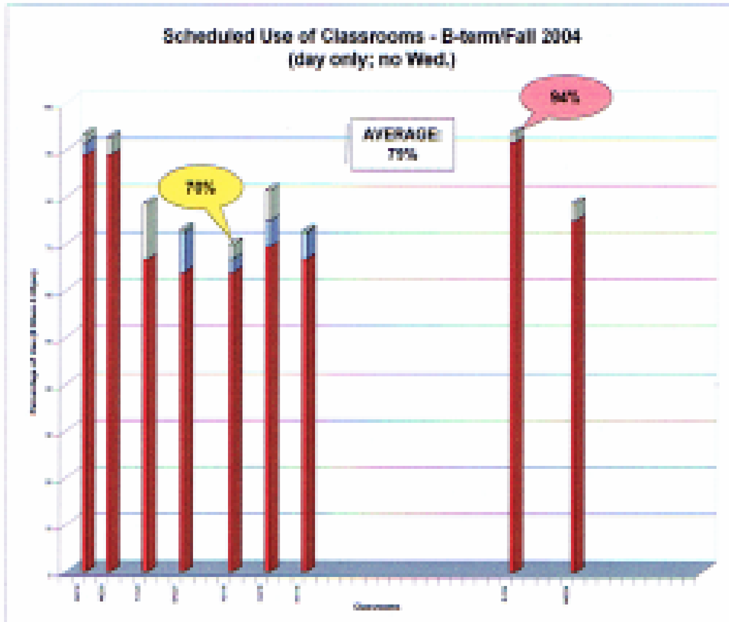

Scheduled Use of Classrooms - C-term/Spring 2006
(day only - no WEDNESDAYS)


Scheduled Use of Classrooms - D-term/Spring 2006
(day only; no Wed.)



MEDIUM CLASSROOMS





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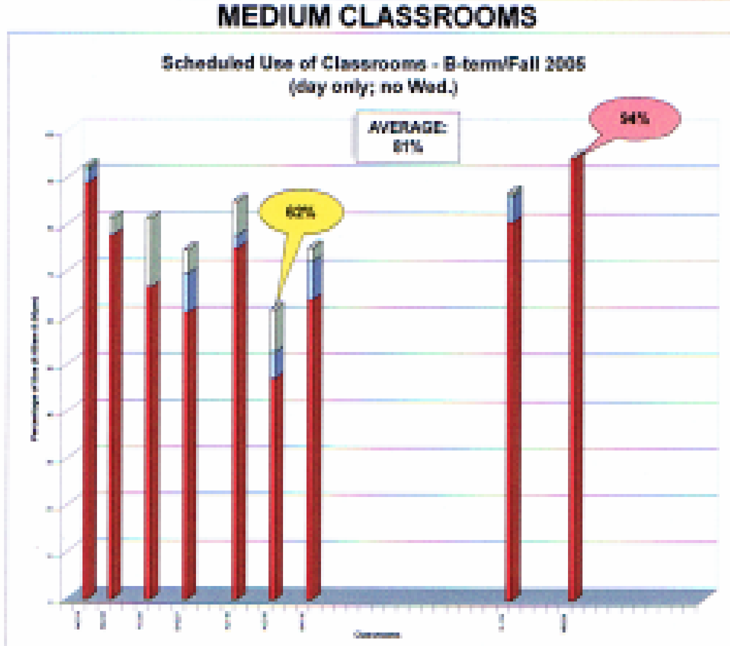

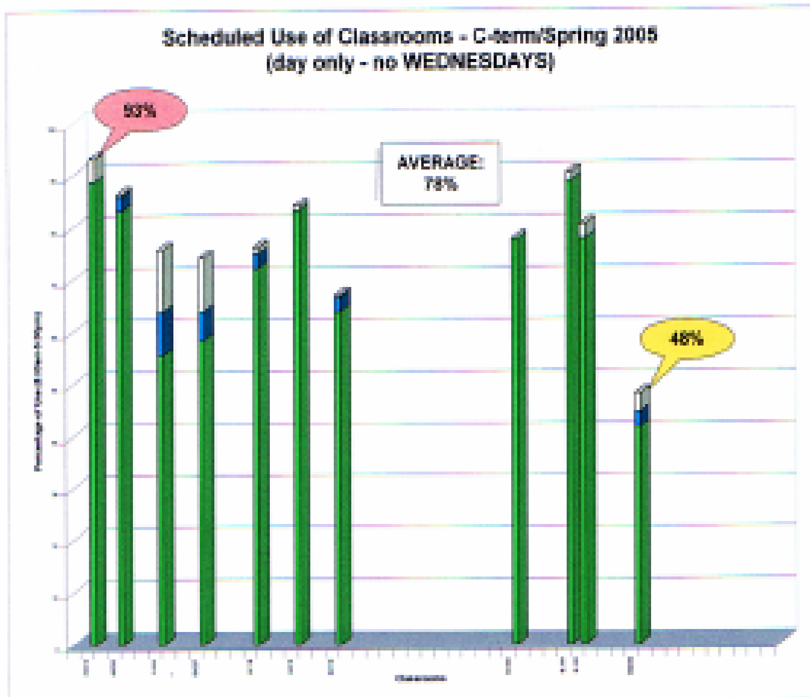

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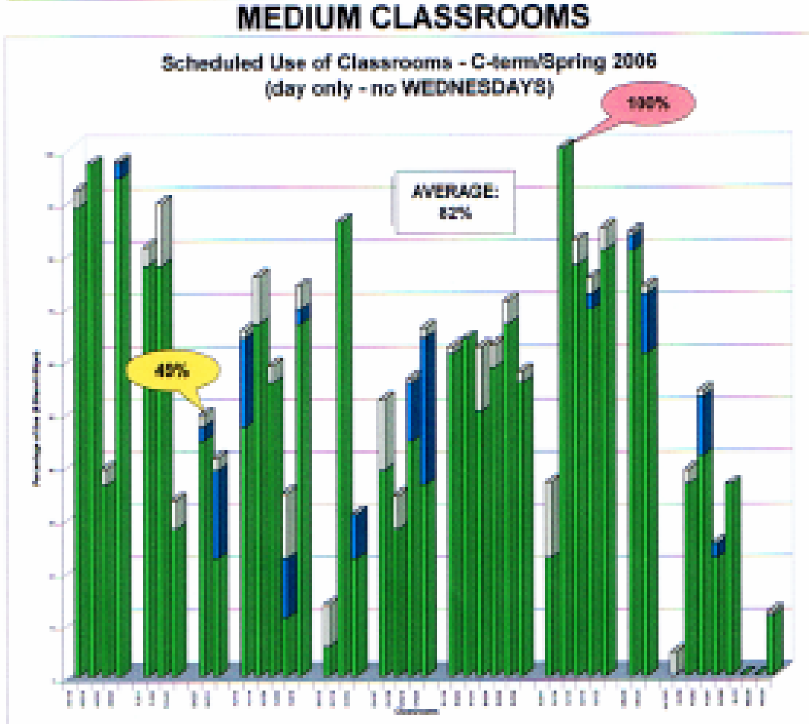

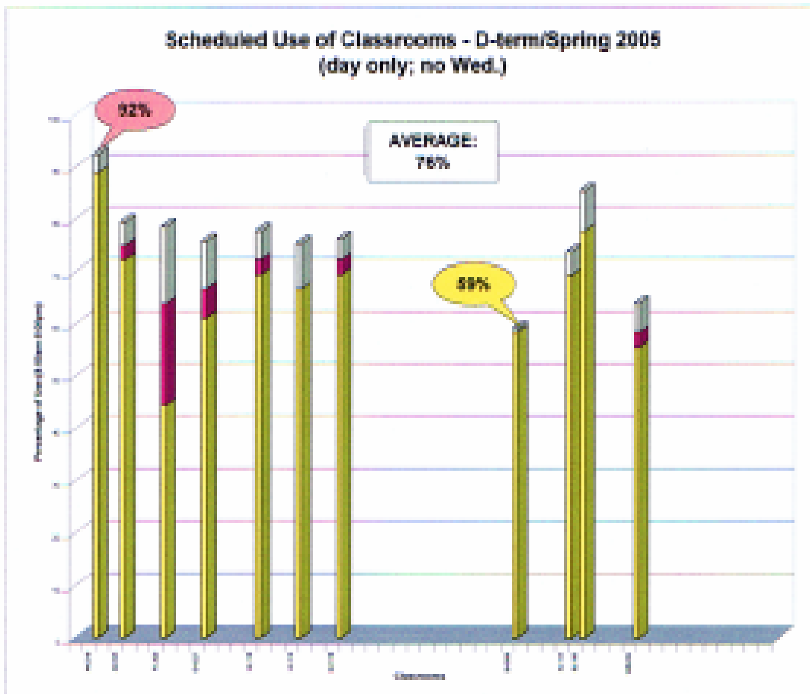

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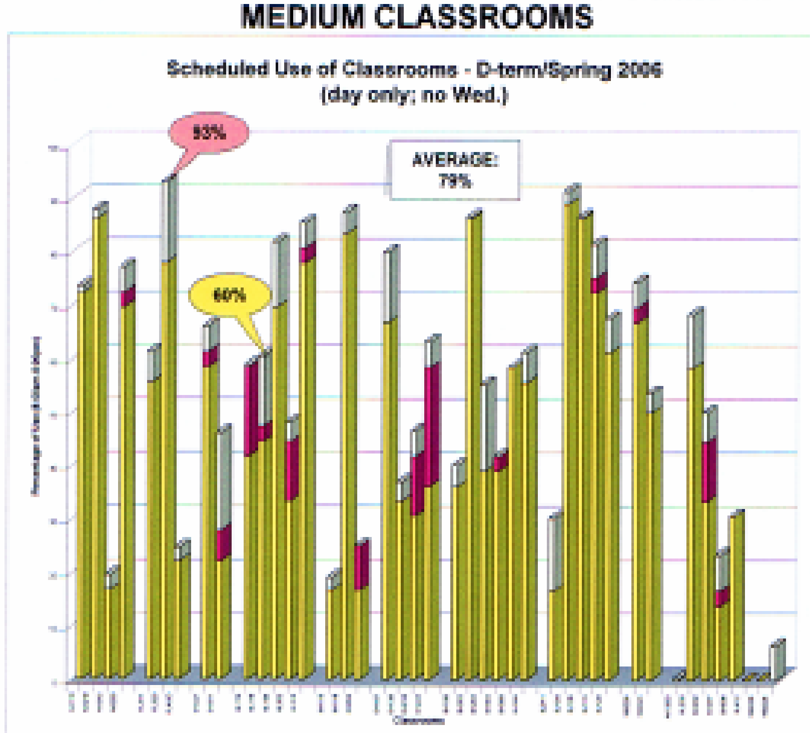


WPI CLASSROOMS

Building	Room #	Seats	Style	AKA	Dept.	MULTI-MEDIA	WHITEBOARDS	AIR-CONDITIONED
Atwater Kent					ECE; SSPS			
	AK116	206	T	Newell Hall		w/ DVD		
	AK120D(Lab)	23	FT - MC	"Garden Lab"		w/ DVD		
	AK219	86	FT - MC - TL			w/ DVD		
	AK232	30	TA					
	AK233	70	FT - MC - TL			w/ DVD		
Fuller Labs					CS			
	FL311	38	FT - MC					
	FL320	65	TA					
	FLAUD	386	T	Perreault Hall		w/DVD		
Goddard Hall					CHE; CH			
	GH227	80	FT - MC - TL			w/ DVD		
	GH011	31	TA					
Higgins labs					ME; FPE			
	HL114	35	TA					
	HL116	90	FT - MC - TL			w/ DVD		
	HL154	35	TA			w/DVD		
	HL202	35	TA			w/DVD		
	HL218	90	FT - MC - TL	Discovery Classroom		w/ DVD		
	HL230(Lab)	40	FT - MC	Geometric Modeling Lab		w/DVD		
Kaven Hall					CEE			
	KH115	26	FT - MC					
	KH116	70	FT - MC - TL			Key-card		
	KH202(Lab)	25	FT - MC	"CAR Lab"		Key-card		
	KH204	26	MT - MC					
	KH207(Lab)	30	FT - MC	"STAT Lab"		Key-card		
Olin Hall					PH			
	OH107	202	T			w/DVD		
	OH126	35	TA					
	OH218	35	TA					
	OH223	42	TA			w/DVD		
Stratton Hall					MA			
	SH106	40	TA					
	SH202	45	TA					
	SH203	30	FT - MC			Key-card		
	SH304	38	TA					
	SH306(Lab)	40	FT - MC	MA-only Computer Lab				
	SH308	54	TA					
	SH309	48	TA					
Salisbury Labs					BB; BME; HUA			
	SL011	25	MT - MC					
	SL104	78	FT - MC - TL			w/DVD		
	SL105	54	FT - MC - TL			w/DVD		
	SL115	220	T	Kinnicutt Hall		w/DVD		
	SL123	40	TA			w/DVD		
	SL328	30	TA	(BB or BME use only)				
	SL412 (Lab)	12	FT - MC	BME Computer lab				
Washburn Shops					MFE; MTE; MG			
	WB226 (Lab)	14	FT - MC	"Flower Lab"				
	WB228 (Lab)	24	FT - MC	MG-only Computer Lab		need laptop		
	WB229	85	FT - MC - TL			Key-card		
	WB323	36	TA					

Seating Style code = TA : Tablet Armchairs; MC : Movable Chairs; FT : Fixed Tables; MT : Movable Tables; TL : Tiered Levels; T : Theater

34 Classrooms; 8 computer labs (Lab)

11.2.2 Plant Services: John E. Miller

Interview with Plant Services:

John E. Miller

Director of Physical Plant

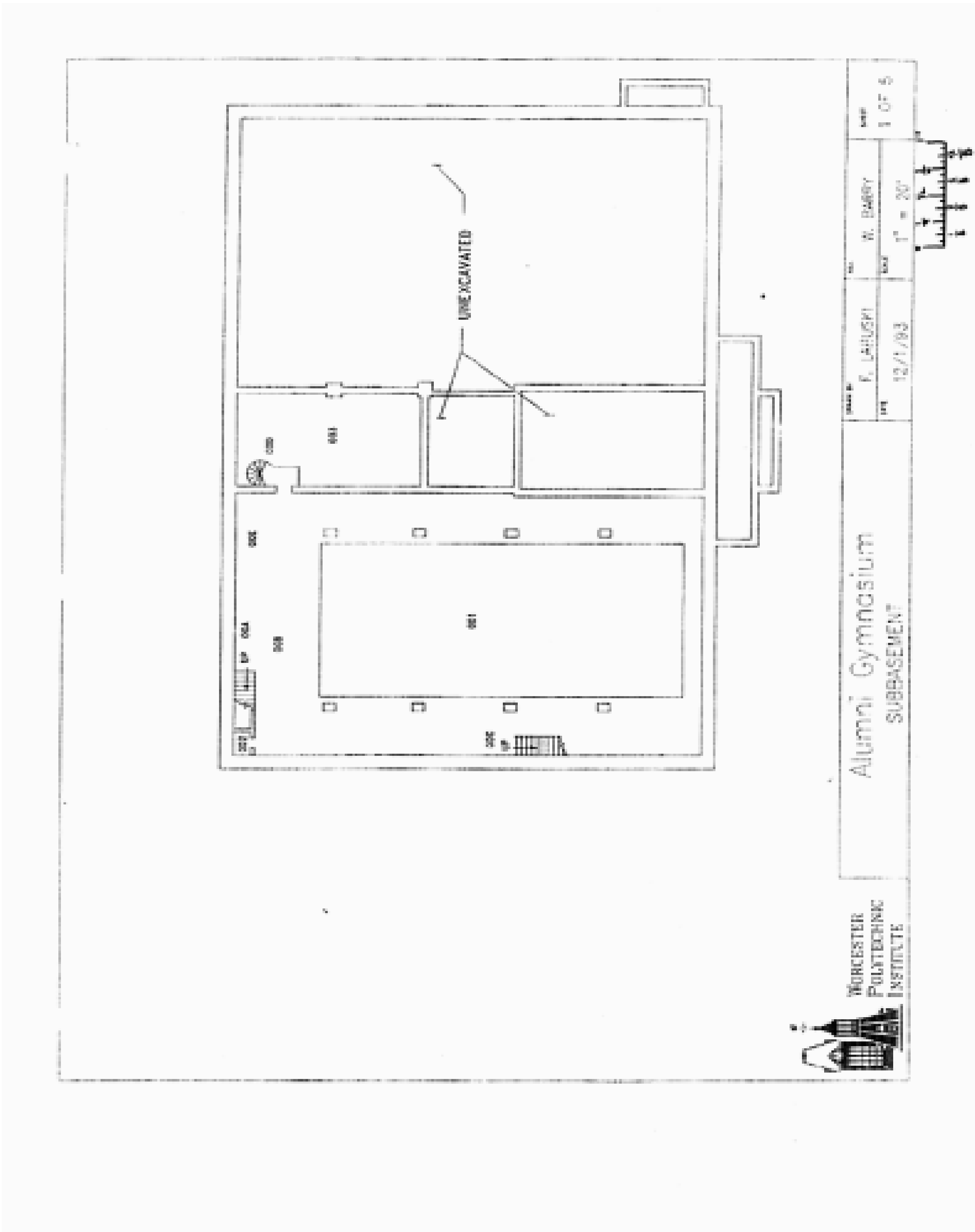
Interview conducted on Friday, 09-29-2006

David Laramee

Ben Mies

- Told us there is no set plans for the gym or design for Alumni Gymnasium
- Most likely that the gym will be renovated into class rooms
- just that Alumni Gymnasium will be given back to the school for academic proposes; once the completion of the new Recreational Center is constructed
    - Expected data for the Recreational Center to be built by 2015 for the 150 anniversary of WPI
- Also told us that there are CAD drawings of the existing floor plan of Alumni Gym and he will find them for us, as seen in 11.2.2.1 Existing Floor Plans.
- Renovations have been made on Alumni Gymnasium, this was when Harrington Auditorium was connected to the Existing Gym
- Suggested to talk to Charles Kornik

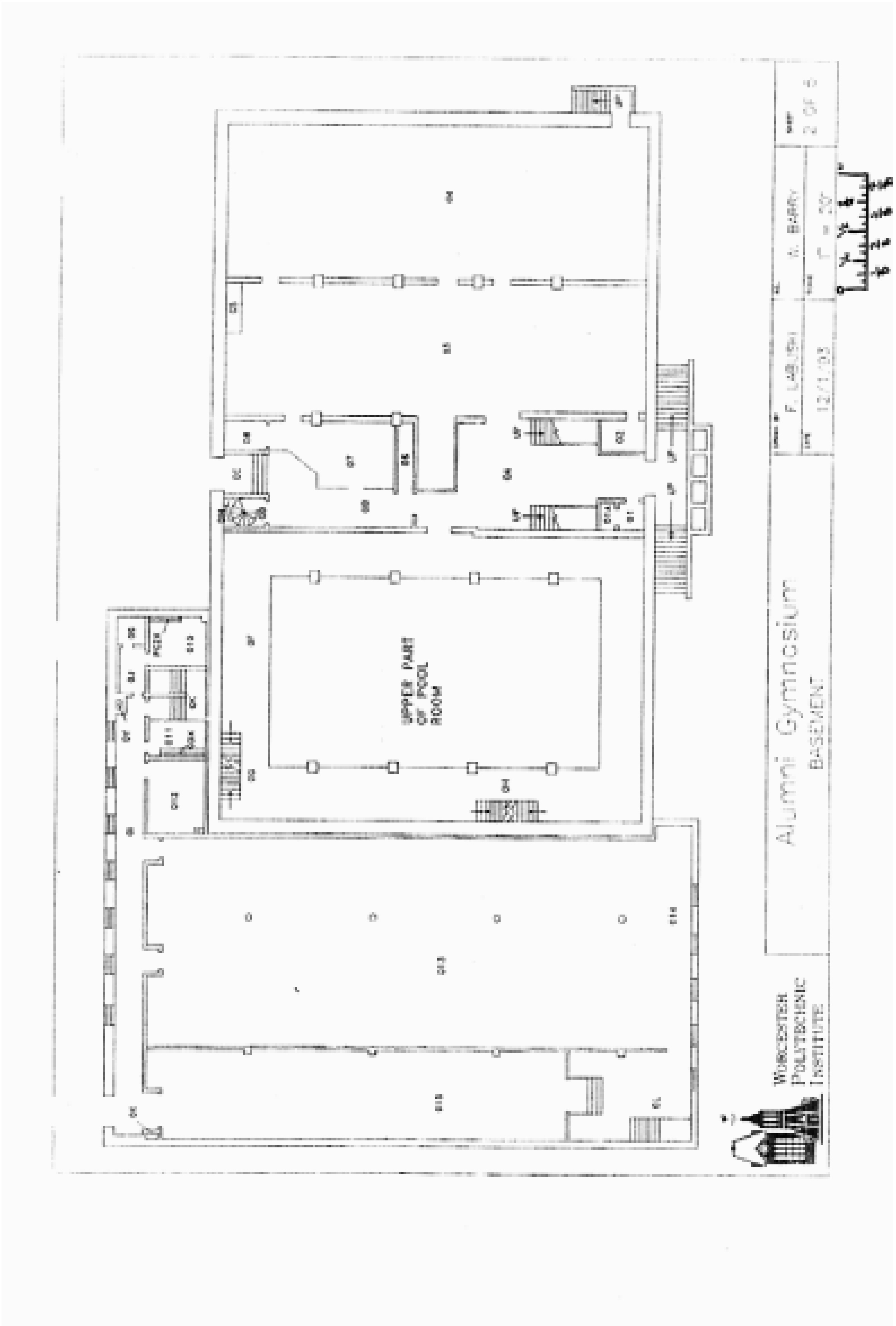
11.2.2.1 Existing Floor Plan



18 94 06:07:39

W.P.I. Student . .rmation [WPIROOM]
Prepared by : PTARNAWSKICZ

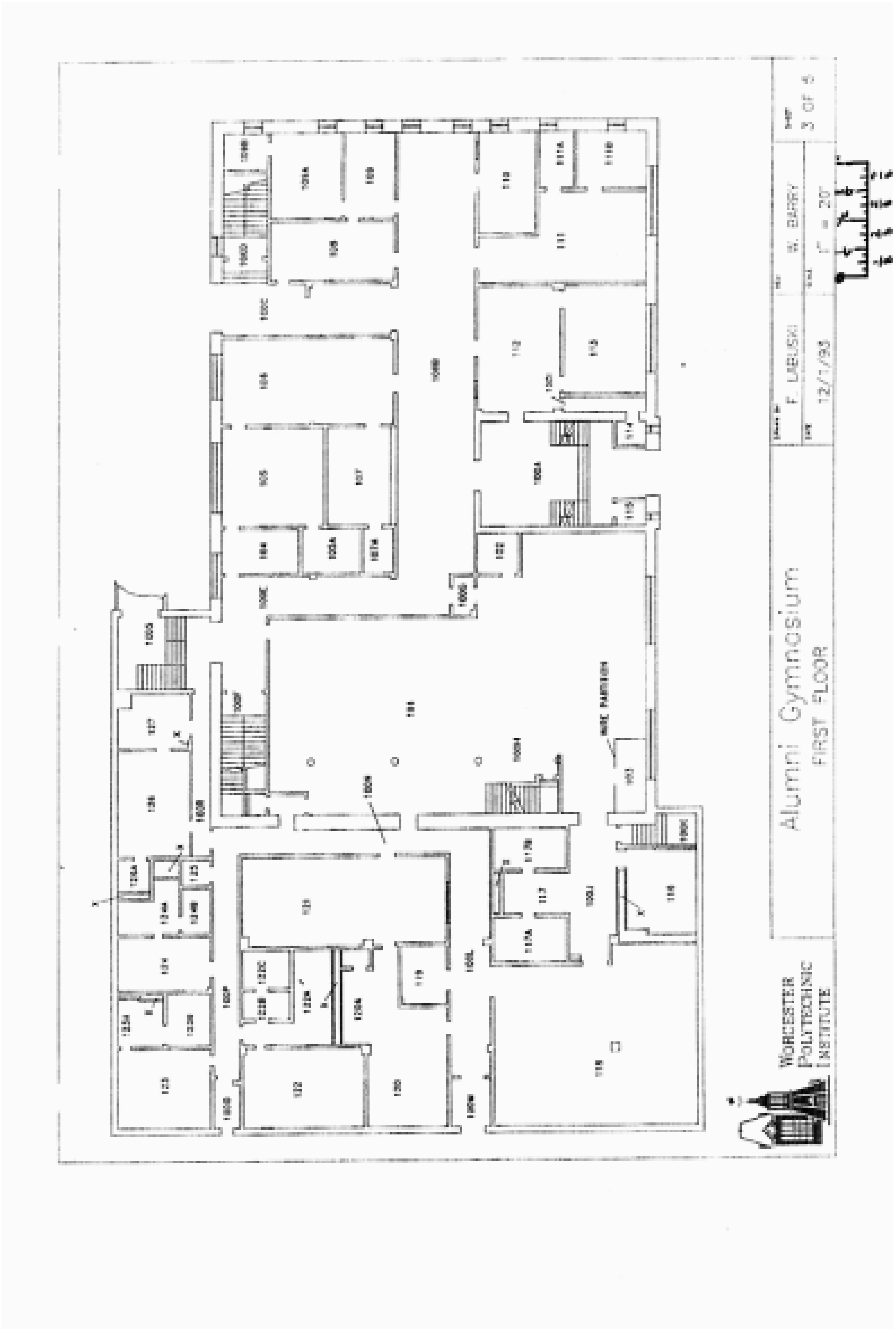
Building	Description	Number	Room description	Occupant	Hcd	Sq. Feet
Alumni Gym	PE/Athletics	001	Swimming Pool		520	1920.00
	PE/Athletics	002	Storage		525	17.00
	Building Service	00A	Stairs		WWW	38.00
	Building Service	00B	Walkway		WWW	221.00
	Building Service	00C	Stairs		WWW	37.00
	Building Service	00D	Stairs		WWW	34.00
	PE/Athletics	00E	Support		525	160.00
sum						2427.00


Alumni Gymnasium
BASEMENT
UPPER PART OF POOL ROOM
WORCESTER POLYTECHNIC INSTITUTE

[illegible] 2

W.P.I. [illegible]
Prepared by : [illegible]

Building	Description	Number	Room description	Occupant	[illegible]	Sq. Feet
Alumni Gym	Building Service	[illegible]	Stairs		[illegible]	[illegible]
	Building Service	[illegible]	Stairs		[illegible]	[illegible]
	Building Service	[illegible]	Stairs		[illegible]	[illegible]
	PE/Athletics	[illegible]	Walkway/Gallery		[illegible]	[illegible]
	Building Service	[illegible]	Stairs		[illegible]	[illegible]
	Building Service	[illegible]	Stairs		[illegible]	[illegible]
	Building Service	[illegible]	Corridor		[illegible]	[illegible]
	Building Service	[illegible]	Passage		[illegible]	[illegible]
	Building Service	[illegible]	Stairs		[illegible]	[illegible]
	Building Service	[illegible]	Stairs		[illegible]	[illegible]
	Building Service	[illegible]	Custodian	[illegible]	[illegible]	[illegible]
	Building Service	[illegible]	Bathroom		[illegible]	[illegible]
	Building Service	[illegible]	Bathroom		[illegible]	[illegible]
	PE/Athletics	[illegible]	Storage		[illegible]	[illegible]
	PE/Athletics	[illegible]	Bowling Alley		[illegible]	[illegible]
	PE/Athletics	[illegible]	Bowling Alley Service		[illegible]	[illegible]
	PE/Athletics	[illegible]	Batting Cage		[illegible]	[illegible]
	Building Service	[illegible]	Custodian		[illegible]	[illegible]
	PE/Athletics	[illegible]	Storage		[illegible]	[illegible]
	PE/Athletics	[illegible]	Fitness Center	[illegible]	[illegible]	[illegible]
	PE/Athletics	[illegible]	Fitness Center	[illegible]	[illegible]	[illegible]
	Building Service	[illegible]	Mechanical		[illegible]	[illegible]
	PE/Athletics	[illegible]	Storage		[illegible]	[illegible]
	PE/Athletics	[illegible]	Laundry Room		[illegible]	[illegible]
	PE/Athletics	[illegible]	Storage		[illegible]	[illegible]
	Building Service	[illegible]	Custodian		[illegible]	[illegible]
[illegible]						[illegible]


Alumni Gymnasium
FIRST FLOOR
WORCESTER
POLYTECHNIC
INSTITUTE
F. LABUSKI
12/1/93
W. BARRY
3 OF 5

18- 94 06:07:58

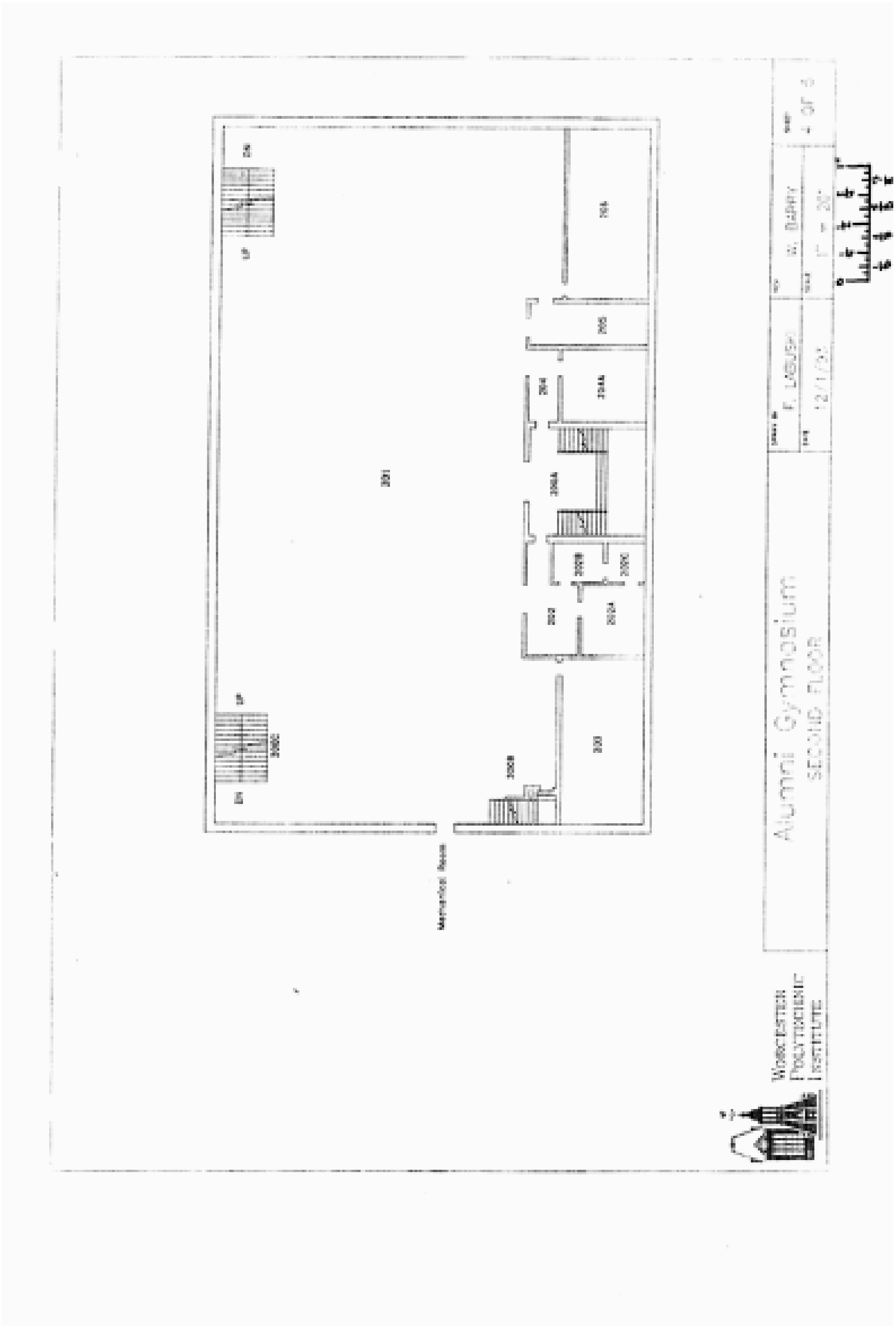
W.P.I. Student I .mation [WPIROOM]
Prepared by : PTARNASEWICZ

Building	Description	Number	Room description	Occupant	Rod	Sq. Feet
Alumni Gym	Building Service	100A	Stairs & Hall		WWW	559.00
	Building Service	100B	Corridor		WWW	1382.00
	Building Service	100C	Corridor		WWW	174.00
	Building Service	100D	Stairs		WWW	135.00
	Building Service	100E	Corridor		WWW	365.00
	Building Service	100F	Stairs		WWW	223.00
	Building Service	100G	Vestibule		WWW	37.00
	Building Service	100H	Stairs		WWW	65.00
	Building Service	100I	Corridor		WWW	51.00
	Building Service	100J	Corridor		WWW	214.00
	Building Service	100K	Stairs		WWW	75.00
	Building Service	100L	Corridor		WWW	376.00
	Building Service	100M	Vestibule		WWW	73.00
	Building Service	100N	Corridor		WWW	205.00
	Building Service	100O	Vestibule		WWW	40.00
	Building Service	100P	Corridor		WWW	326.00
	Building Service	100R	Corridor		WWW	146.00
	Building Service	100S	Stairs		WWW	253.00
	PE/Athletics	101	Locker Room	–	525	2833.00
	Building Service	102	Custodian		XXX	53.00
	PE/Athletics	102B	Showers	–	525	116.00
	PE/Athletics	103	Storage	–	525	87.00
	Building Service	104	Bathroom		XXX	133.00
	PE/Athletics	105	Locker Room	–	525	314.00
	PE/Athletics	105A	Showers	–	525	87.00
	PE/Athletics	106	Offices		311	529.00
	PE/Athletics	107	Storage	–	525	224.00
	PE/Athletics	107A	Storage	–	525	48.00
	PE/Athletics	108	Classroom		110	255.00
	PE/Athletics	109	Office		310	147.00
	PE/Athletics	109A	Office		311	216.00
	Building Service	109B	Bathroom		XXX	63.00
	PE/Athletics	110	Office		311	197.00
	PE/Athletics	111	Lounge	–	650	456.00
	PE/Athletics	111A	Office		311	138.00
	PE/Athletics	111B	Office		311	79.00
	PE/Athletics	112	Office		311	393.00
	PE/Athletics	113	Office		311	320.00
	Building Service	114	Bathroom		XXX	27.00
	Building Service	115	Custodian		XXX	27.00
	Building Service	116	Bathroom		XXX	219.00
	PE/Athletics	117	Drying Area		XXX	98.00
	PE/Athletics	117A	Shower		525	116.00
	PE/Athletics	117B	Shower		525	116.00
	PE/Athletics	118	Locker Room		525	1200.00
	PE/Athletics	119	Drying Room		525	95.00
	PE/Athletics	120	Office		311	476.00
	PE/Athletics	120A	Storage		525	17.00
	PE/Athletics	121	Equipment Room		525	627.00
	PE/Athletics	122	Locker Room		525	359.00
	Building Service	122A	Bathroom		XXX	175.00

18- 94 06:07:58 2

W.P.I. Student [illegible] (WPIROOM)
Prepared by : PTARNASEWICZ

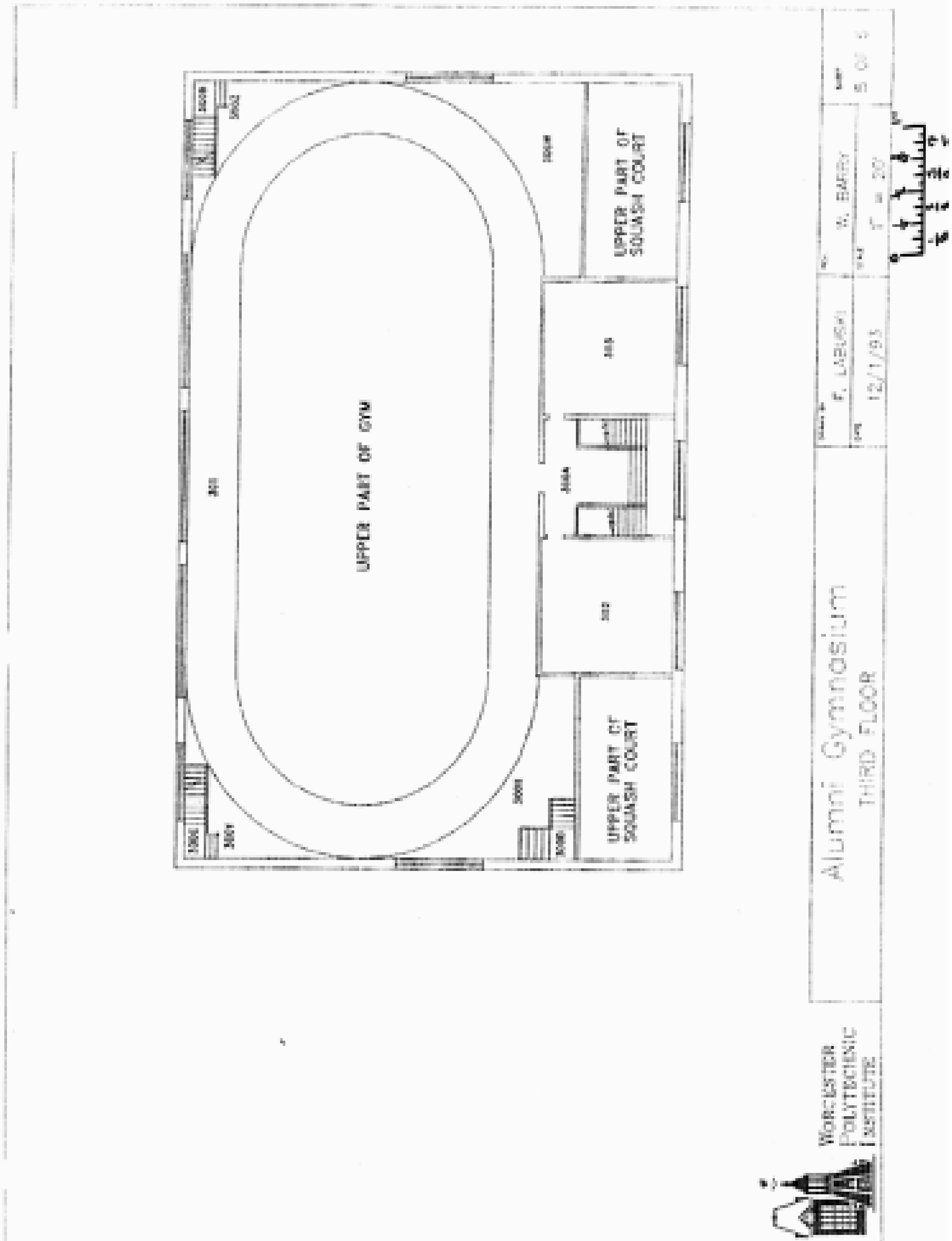
Building	Description	Number	Room description	Occupant	Mod	Sq. Feet
Alumni Gym	PE/Athletics	122B	Drying Area		525	48.00
	PE/Athletics	122C	Shower		525	69.00
	PE/Athletics	123	Locker Room		525	275.00
	Building Service	123A	Bathroom		XXX	83.00
	PE/Athletics	123B	Shower		525	73.00
	PE/Athletics	124	Locker Room		525	195.00
	Building Service	124A	Bathroom		XXX	89.00
	PE/Athletics	124B	Shower		525	48.00
	Building Service	125	Custodian		XXX	26.00
	PE/Athletics	126	Office		311	256.00
	Building Service	126A	Bathroom		XXX	34.00
	PE/Athletics	127	Office		311	118.00
******************						
sum						16129.00


Alumni Gymnasium
SECOND FLOOR
Mechanical Room
WORCESTER
POLYTECHNIC
INSTITUTE

10- -94 15:07:28

W.P.I. Student I rmation (WPIROOM)
Prepared by : PTANNASEWICZ

Building	Description	Number	Room description	Occupant	Mcc	Sq. Feet
Alumni Gym	Building Service	200A	Stairs/Corridor		WWW	424.00
	Building Service	200B	Stairs		WWW	80.00
	Building Service	200C	Stairs		WWW	184.00
	Building Service	200D	Stairs		WWW	184.00
	PE/Athletics	201	Gym	–	520	7325.00
	PE/Athletics	202	Storage	–	525	364.00
	PE/Athletics	202A	Office	–	311	350.00
	PE/Athletics	202B	Locker & Shower	–	525	73.00
	Building Service	202C	Bathroom		XXX	48.00
	PE/Athletics	203	Storage	–	525	480.00
	PE/Athletics	204	Lounge	–	650	78.00
	Building Service	204A	Bathroom		XXX	215.00
	Building Service	205	Custodian		XXX	170.00
	PE/Athletics	206	Squash Court	–	520	480.00
	Building Service	207	Mechanical		YYY	750.00
sum						10085.00


UPPER PART OF GYM
UPPER PART OF SQUASH COURT
UPPER PART OF SQUASH COURT
Alumni Gymnasium
THIRD FLOOR
WORCESTER POLYTECHNIC INSTITUTE
F. LABUSKI
W. BARRY

18- 96 06:27:28

W.P.I. Student 1 ...ation (WPIROOM)
Prepared by : PTARNASEWICZ

1

Building	Description	Number	Room description	Occupant	Mod	Sq. Feet
Alumni Gym	Building Service	302W	Corner Floor Space		WWW	389.00
	Building Service	302X	Corner Floor Space		WWW	318.00
	Building Service	302Y	Corner Floor Space		WWW	123.00
	Building Service	302Z	Corner Floor Space		WWW	123.00
	PE/Athletics	301	Track	—	520	3410.00
	PE/Athletics	302	Crew Storage	—	525	476.00
	PE/Athletics	303	Exercise Room	—	525	476.00
******************						
[illegible]						4315.00

18-   94 06:07:55

W.P.I. Student : .rmation   (WPIROOM)

Prepared by : PTARNASEWICZ

4

Building	Description	Number	Room description	Occupant	Mod	Sq. Feet
mm						57128.84

18- 94 06:07:29

W.P.I. Student [illegible] rmation (WPIROOM)
Prepared by : PTARNAWSKICZ

Building	Description	Number	Room description	Occupant	Hod	Sq. Feet
Alumni Gym	PE/Athletics	R04	Storage	-	525	158.00
	PE/Athletics	R05	Bowling Alley	-	520	4126.00
	PE/Athletics	R06	Storage	-	525	1255.00
	PE/Athletics	R101	Men's Toilet	-	525	219.00
	PE/Athletics	R102	Drying Area	-	525	98.00
	PE/Athletics	R102A	Showers	-	525	116.00
	PE/Athletics	R103	Lockers	-	525	1201.00
	PE/Athletics	R104	Drying Area	-	525	95.00
	PE/Athletics	R105	Training Room	-	525	493.00
	PE/Athletics	R107	Lockers	-	525	360.00
	PE/Athletics	R107A	Women's Toilet	-	525	175.00
	PE/Athletics	R107B	Drying Area	-	525	48.00
	PE/Athletics	R107C	Showers	-	525	69.00
	PE/Athletics	R108	Lockers	-	525	275.00
	PE/Athletics	R108A	Toilet	-	525	72.00
	PE/Athletics	R108B	Shower	-	525	82.00
	PE/Athletics	R109	Lockers	-	525	195.00
	PE/Athletics	R109A	Toilet	-	525	89.00
	PE/Athletics	R109B	Shower	-	525	48.00
	PE/Athletics	R111	Office	Staf	310	256.00
	PE/Athletics	R112	Trainers Room	-	525	118.00
******************						
sum						9548.00

11.2.3 Plant Services: Chris Salter

Interview with Plant Services:

Chris Salter

Associate Director

Manager of Technical Trades

Interview conducted on Thursday, 02-22-2007

David Laramee

Ben Mies

- Told how there once was a plan to turn the Alumni Gymnasium into the Campus Center back when they were building the new campus center. This idea did not happen and another site was chosen.
    - Gym was not chosen due to cost of Renovation, money at the time was not there for it
    - HVAC is what ran the cost up.
- Gave the cost of rooms on campus in dollars per square foot:
    - state-of-the-art lecture hall - $200
        - like SL 104
    - smaller classrooms - $100
        - like Higgins 222
    - Offices - $75
    - Restrooms - $150
    - Research Labs - $150
    - All these numbers include the equipment and the walls and finishing of that type of room
    - Suggested to talk with Mary Beth Harrity

11.2.4 Academic Technology Center: Mary Beth Harrity

Interview with Academic Technology Center:

Mary Beth Harrity

Director

Interview conducted on Thursday, 02-22-2007

David Laramee

Ben Mies

- Talked about the cost of the technology that goes into two types of rooms not included by Chris Salter calculations
    - I.T Labs or Tech Suites – about $15,000 per room
    - Computer labs cost about:
        - $1,500 per computer
        - Plus 20,000 for all of the technology that makes the room an interactive room, where the instructor can show what they are doing on the computer with the help of a digital projector and screen.

11.3 1911 Building Codes

CHARTER

LAWS AND ORDINANCES

OF THE

CITY OF WORCESTER

1911

WORCESTER, MASSACHUSETTS

PRINTED BY

THE BLANCHARD PRESS

CHAPTER III

BUILDINGS DEPARTMENT

Definitions

SECTION 1. In this chapter the following terms shall have the meanings respectively assigned them:

"Alteration" means any change or addition.

"Basement" shall be taken to mean that portion of a building the floor of which is below the curb level at the centre of the front of the building not more than three-fourths of the height of said portion, measuring from the floor to the ceiling.

"Block granite" means that all stones are laid with aid of derrick and each stone full thickness of wall.

"Building of the first class" means a building of fire-proof construction throughout.

"Building of the second class" means any building not of the first class, the walls of which are of brick, stone, iron, or other equally substantial and non-combustible material.

"Building of the third class" means any building not of the first or second class.

"Cellar" shall be taken to mean the lowest portion of a building the floor of which is below the curb level at the centre of the front of the building more than three-quarters of the height of said portion, measuring from the floor to the ceiling.

"External wall" means every outer wall or vertical enclosure of a building other than a party wall.

"First class rubble" means rubble laid with aid of derrick.

"First story" is the next story above the basement.

"Foundation" means that portion of a wall below the level of the street or curb, and when the wall is not on a street, that portion of the wall below the level of the highest ground next to the wall; but if under party or partition walls, may be construed by the inspector to mean that portion below the cellar floor.

"Hand rubble" means rubble laid by hand without the use of derrick.

"Height of a building" means the perpendicular distance of the highest point of the roof above the average grade of the principal front.

"Height of a wall" means the height from the mean grade of the sidewalk or adjoining ground to the highest point of the wall.

"Inspector" means the inspector of buildings of the City of Worcester.

"Lodging house" means a building in which persons are accommodated with sleeping apartments, and includes hotels and apartment houses where cooking is not done in the several apartments.

"Partition wall" means any interior wall of masonry in a building.

"Party wall" means every wall used or built in order to be used as a separation of two or more buildings.

"Repairs" means the reconstruction or removal of any existing part of a building or of its fixtures or appurtenances, by which the fire risk is not affected or modified, and not made in the opinion of the inspector, for the purpose of converting the building in whole or in part to a new one.

"Rubble" means stones of irregular size and shape.

"Tenement house" means a building which, or any portion of which, is occupied, or intended to be occupied, as a dwelling by three or more families living independently of one another, or by more than two families above the second floor so living.

"Thickness of a wall" means the minimum thickness of such wall.

Superintendent of Public Buildings

SECTION 2. The superintendent of public buildings shall have charge of the construction and inspection of buildings. He shall be an experienced architect, builder or civil engineer, and shall not be engaged in any other business, or be interested in any contract for building or for furnishing materials.

SECTION 3. The superintendent of public buildings shall superintend the construction of all buildings erected by the City, and all repairs upon all the City buildings, except those of the City Hospital, Free Public Library, the Worcester Home Farm, Hope Cemetery and the Independent Industrial Schools, and see that the conditions of contracts and plans and specifications, if any, are faithfully carried out. He shall have the care and custody of all the buildings belonging to the City, except as otherwise provided; shall keep himself acquainted with the condition of such buildings; shall employ suitable mechanics to make alterations and repairs, and shall render such service in relation to such buildings as properly belongs to the office. He shall have the power and responsibility of initiating all ordinary repairs upon school buildings, and shall be the sole judge of the necessity and expediency of making such repairs, and shall have the entire charge and control thereof, and shall alone be responsible therefor, and shall purchase all fuel and janitors' supplies for such buildings. He shall keep an accurate record of all buildings belonging to the City which are in his department, and lands appurtenant to such buildings, and he shall submit a report to the City Council annually showing their condition and the nature and amount of expenditures that have been made upon them by him during the year next preceding. He shall prepare for meetings the rooms designated for ward rooms, and shall have them cleaned and in good order after any meeting therein.

General Provisions

Building, repairing, etc.

SECTION 4. No person shall construct, alter, restore or repair, raise or move any building or structure of any kind, except in conformity with the provisions of this chapter, except buildings built or altered by the United States of America or the Commonwealth of Massachusetts.

Material

SECTION 5. All buildings or parts of buildings hereafter erected and not hereinafter specifically described, shall be of sound material, abundantly strong for the purpose intended, and the sizes of material used therein shall be such as have been determined by the best authorities and demonstrated to be proper for structural purposes, and if subjected to transverse strains shall be loaded to not more than one-fourth their ultimate strength; if subjected to shearing or tensile strains to not more than one-fifth their ultimate strength; and the piers and columns of less than five diameters in height, to not more than one-sixth their crushing strength. Columns or piers of more than five diameters are to be increased according to the formula of the best authority.

Alterations and additions

SECTION 6. Any alterations in or additions to any building already erected or hereafter to be erected except necessary repairs not affecting the construction of the external walls, roof, chimneys, or stairways, shall to the extent of such work be subject to the regulations of this chapter. No

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forth in such plans, specifications and statement, and all such matters and things connected with such work shall be done in strict compliance with this chapter. If it appears from said statement, plans and specifications that the building to be erected, altered or repaired will conform to the provisions of this chapter, so far as applicable thereto, then the inspector shall issue a permit. No person shall repair, construct, or materially alter any building without such permit. No person shall lath, plaster or otherwise cover or conceal the spaces between studs, joists or frame-work of any building or part thereof without first notifying the superintendent of public buildings that such part or parts are ready to cover or conceal, and the superintendent when so notified shall inspect, or cause to be inspected, such building or part thereof, and if upon inspection it is found that suitable fire-stops are in place and the building properly framed and braced, then, and not till then, shall he issue a supplementary permit allowing the work to proceed, and no person shall lath, plaster or otherwise cover or conceal the spaces above enumerated until such supplementary permit has been duly granted.

SECTION 12. All excavations shall be properly guarded and protected in such manner as may be approved by the superintendent of public buildings, by the person causing the excavations to be made, so as to prevent the same from becoming dangerous to life or limb, and shall be sheet piled whenever the superintendent of public buildings shall so direct, to prevent the adjoining earth from caving in.

Piling

SECTION 13. Where the nature of the ground requires it, all buildings shall be supported on foundation piles not more than three feet apart, on centres in the direction of the wall, and the number, diameter, and bearings of such piles shall be sufficient to support the superstructure. Proposed buildings over seventy feet high shall rest, where the nature of the ground requires, upon at least three rows of piles or an equivalent number of piles arranged in less than three rows, and cut below the lowest water level. All piles shall be capped with block granite levelers, each leveler having a firm bearing on the pile or piles it covers. The inspector may require any applicant for a permit to ascertain, by boring or otherwise, the nature of the ground upon which he proposes to build.

Foundations

Materials

SECTION 14. Every building, except buildings erected upon solid rock, shall have foundations of brick, stone, iron, steel or concrete, laid not less than four feet below the surrounding surface of the earth exposed to frost on the solid ground or level surface of the rock, or upon piles or ranging timbers when solid earth or rock is not found. Foundation walls of hand rubble shall not be used in buildings over forty feet in height, except third-class buildings outside the fire limits. Where rubble is used, two-thirds of the bulk of the wall shall be built of through stone thoroughly bonded. No round or boulder stones shall be used. If the foundation is on piles the lower course shall be of block stone not under sixteen inches high. Foundations of hand rubble shall be twenty-five per cent. thicker than is required for first-class rubble granite foundations. Foundations of first-class rubble shall be eight inches thicker than brick walls next above. Foundations of block granite shall be at least four inches thicker than the walls next above them, to a depth of twelve feet below the street grade, and for every additional ten feet or part thereof deeper, they shall be increased four inches in thickness. Foundations of brick shall be at least twelve inches thick and at least four inches thicker than the walls next above them to a depth of twelve feet below the street grade, and for every additional ten feet or part thereof deeper, they shall be increased in thickness, to resist any lateral pressure, and the inspector may order an increase for that purpose. The footing shall be of stone or concrete, or both, or of concrete and stepped-up brick-work of sufficient thickness to safely bear the weight to be imposed thereon, and to properly distribute such weight upon the surface on which it rests. If of stone they shall be not less than twelve inches thick, and at least twelve inches wider than the bottom width of the foundation walls, and at the least twelve inches wider on all sides than the bottom width of any pier, column or post resting upon them. All footing stone shall be well bedded and laid cross-wise, edge to edge. If stepped-up brick are used in place of stone above the concrete, the steps of offsets, if laid in single courses, shall not exceed one and one-half inches, or if laid in double courses, then each shall not exceed three inches.

...ork

SECTION 15. All brick-work shall be of marketable, well-shaped brick, well laid and bedded with joints well filled with mortar, as required hereinafter, and well flushed up at every course with mortar. In the months of April to September inclusive, bricks, when laid, shall be wet, and in the remaining months of the year they shall, when laid, be dry, unless otherwise directed by the inspector. All walls of brick or stone, or other similar material, shall be well built, properly bonded and tied, and laid with mortar, as hereinafter described.

The inside four inches of any wall may, upon a special permit issued by the inspector, be built of hard-burned hollow clay bricks of quality and dimensions satisfactory to the inspector and thoroughly tied and bonded into the wall. Every seventh course, at least, of a brick wall shall be a header course, except where walls are faced with face brick, in which case every eighth course shall be bonded with Flemish headers, or by cutting the corners of the face brick and putting in diagonal headers behind the same, or an approved wall tie.

Thickness of brick walls

SECTION 16. The thickness of all brick walls of all business, manufacturing and public buildings shall not be less than the number of inches shown in the following tables:

Outside, Party and Division Walls

Stories	B.	1	2	3	4	5	6	7	8	9	10	11	12
1	12	8											
2	16	12	12										
3	16	12	12	12									
4	20	16	16	12	12								
5	24	20	16	16	12	12							
6	24	20	20	16	16	16	12						
7	24	20	20	20	16	16	16	12					
8	28	24	20	20	20	16	16	16	12				
9	28	24	24	20	20	20	16	16	16	12			
10	28	24	24	24	20	20	20	16	16	16	12		
11	32	28	24	24	24	20	20	20	16	16	16	12	
12	32	28	28	24	24	24	20	20	20	16	16	16	12

Buildings having the first story or basement designed for business purposes, and the upper stories for dwellings, shall have the walls of brick-work of the thickness as follows, to wit:

Outside, Party, and Division Walls

Stories	B.	1	2	3	4	5	6	7	8	9	10	11	12
2	16	12	8										
3	16	12	12	8									
4	20	16	12	12	12								
5	20	16	16	12	12	12							
6	20	20	16	16	12	12	12						
7	24	20	20	16	16	12	12	12					
8	24	24	20	20	16	16	12	12	12				
9	24	24	20	20	20	16	16	12	12	12			
10	28	24	24	20	20	20	16	16	12	12	12		
11	28	24	24	24	20	20	16	16	16	12	12	12	
12	32	28	24	24	24	20	20	16	16	16	12	12	12

The above shall apply to all walls sixty feet and under in length; walls exceeding sixty feet in length shall not be allowed to have more than two upper stories twelve inches thick.

The figures in the following table shall be the thickness of brick walls for all walls of dwelling houses;

Brick Walls for Dwellings

Stories	B.	1	2	3	4	5	6	7	8	9	10	11	12
1	12	8											
2	16	12	8										
3	16	12	12	8									
4	16	16	12	12	12								
5	20	16	16	12	12	12							
6	20	16	16	16	12	12	12						
7	24	20	16	16	16	12	12	12					
8	24	20	20	16	16	16	12	12	12				
9	24	20	20	20	16	16	16	12	12	12			
10	28	24	20	20	20	16	16	16	12	12	12		
11	28	24	24	20	20	20	16	16	16	12	12	12	
12	32	28	24	24	20	20	20	20	16	16	12	12	12

The above shall apply to all walls sixty feet and under in length; when over sixty feet in length such wall shall not be allowed to have more than two upper stories twelve inches thick.

The height of stories for all given thicknesses of walls shall not exceed

1st story ....seventeen feet,
2d story ....fifteen feet,
3d and upper stories..............thirteen feet,

and for any story exceeding the foregoing heights, the walls of any such story and all walls below that story shall be increased four inches in thickness.

The height of a story shall be the perpendicular distance from the top of the finished floor in one story to the top of the finished floor in the next story.

All party or divison walls of a less thickness than twelve inches shall be corbelled, not less than three inches on sides, to receive the floor joists.

Said corbelling shall not be done in a less height than six courses of brick, which shall be well bonded into the wall.

Concrete Block Buildings

Requirements for hollow blocks

SECTION 17. A. Hollow concrete building blocks may be used for buildings four stories or less in height where said use is approved by the superintendent of public buildings, provided, however, that such blocks shall be composed of at least one part standard Portland cement, and not to exceed five parts of clean, coarse, sharp sand or gravel, or a mixture of at least one part of Portland cement to five parts of crushed rock or other suitable aggregate.

Provided, further, that this section shall not permit the use of hollow blocks in party walls; said party walls must be built solid.

B. All material shall be of such fineness as to pass a one-inch ring and shall be properly mixed and manipulated, and the hollow space in said blocks shall not exceed the percentage given in the following table for different height walls:

Stories,	1st	2d	3d	4th
1 and 2	33	33		
3 and 4	25	33	33	33

In no case shall the walls or webs of each block be less in thickness than one-fourth of the height of said block.

Thickness of walls

C. The thickness of walls for any buildings where hollow concrete blocks are used shall not be less than is required by this chapter for brick walls.

Age

All hollow concrete building blocks, before being used in the construction of any building, or part of a building, shall have attained the age of at least three weeks, and shall be properly cured by being kept moist and shaded from the sun's rays during that time.

Supporting blocks to be made solid

D. Wherever girders or joists rest upon walls so that there is a concentrated load on the block of over two tons, the block supporting the girder or joist shall be made solid; where such concentrated load exceeds five tons, the blocks for at least two courses below and for a distance extending at least eighteen inches each side of said girder shall be made solid.

Wherever walls are decreased in thickness, the top course of the thicker wall shall be made solid.

Concrete lintels and sills shall be re-enforced by iron or steel rods in a manner satisfactory to the superintendent of public buildings, and any lintels spanning over four feet six inches in the clear shall rest on solid concrete blocks.

E. A brand or mark of identification must be impressed in, or otherwise permanently attached to each block for the purpose of identification.

The manufacturer and user (either or both) of any such hollow concrete blocks as are mentioned in this regulation shall, at any and all times, have made such tests of the cement used in making such blocks, or such further tests of the completed block or of each of these, at their own expense, under the supervision of the Buildings Department, as the superintendent of public buildings may require.

No concrete blocks shall be used in the construction of any building, or part thereof, within the City of Worcester, until they have been inspected, and average samples of the lot tested, approved and accepted by the superintendent of public buildings.

Ashler

Required backing and thickness

SECTION 18. In reckoning the thickness of walls no allowance shall be made for ashler, unless it is eight inches or more thick, in which case the excess over four inches shall be reckoned part of the thickness of the wall. Ashler shall be at least four inches thick and properly held by metal clamps to the backing, or properly bonded to the same.

Iron or Steel External Walls

Iron and steel

SECTION 19. External walls may be built of iron or steel, and when so built may be of less thickness than is above required for external walls, provided such walls meet the requirements as to strength, and provided that all constructional parts are wholly protected from heat by brick or terra-cotta, or by plastering three quarters of an inch thick, with iron furring and wiring.

Party and Bearing Walls of Brick Buildings

In first and second-class buildings

SECTION 20. In first and second-class buildings all party and bearing partition walls above the foundation shall be of brick, and no such party or partition walls shall be furred with wood without plastering flush between furrings, but all such walls shall be plastered on masonry or metal lathing. No wall of any second-class building shall be increased in height unless the entire building is to be altered so as to conform to the requirements of this chapter.

Shall be built above roof coverings

SECTION 21. In buildings hereafter built, all party walls and the partition walls required by this chapter shall be built through and at least two feet above or distant from the roof boarding at the nearest point; shall be entirely covered with stone or metal securely fastened and corbelled to the outer edge of all projections, provided that a gutter stone of suitable dimensions and properly balanced may be inserted in place of the corbelling, and provided further that in buildings not over forty-five feet in height the distance that any wall is carried above the roof need not exceed twelve inches.

Recesses in Walls

SECTION 22. Recesses and openings may be made in external walls, provided the thickness of the backs of such recesses be not less than eight inches. No recesses shall be nearer to each other than eight feet, and no continuous vertical recess for more than four inches in depth shall be made in any twelve-inch wall, and no recess of any kind shall be made in any eight-inch wall.

Partition Walls in Second-class Buildings

In second-class buildings

SECTION 23. Second-class buildings hereafter built shall be divided by brick or terra-cotta partition walls. Walls, if of brick, shall be of the thickness prescribed for bearing partition walls and two feet above the roof.

Except as hereinafter provided no space inside such buildings shall exceed in area eight thousand square feet, unless such space is equipped to the satisfaction of the superintendent of public buildings with automatic sprinkler heads to the number of not less than one for every hundred square feet of floor area; and if so equipped no such space shall exceed twelve thousand square feet in area. In factory buildings of mill construction, no space shall exceed twelve thousand square feet in area unless equipped with automatic sprinkler heads as above provided.

No existing wall in any second-class building shall be removed so as to leave an area greater than is above provided.

Hollow Walls

SECTION 24. Hollow walls for dwellings may be built with the approval of the inspector, and shall have a base of not less than sixteen inches, and brick withes of eight inches in thickness against all door and window frames and for the support of all floor beams or trusses, and be properly tied to outside courses in the most approved manner. The remainder of the walls shall be tied to outer walls as often as once in every thirty-two inches with brick thoroughly bonded to outer and inner walls, or approved tie irons thoroughly coated with coal tar or other approved coating. Hollow walls for other buildings may be built, provided the same amount of brick is used as if the walls were solid, and are properly tied and bonded to outer and inner walls.

Trusses, Columns and Girders

SECTION 25. First and second-class buildings hereafter built shall have floor bearing supports not over thirty feet apart. These supports may be brick walls, trusses or columns and girders. Such brick walls may be four inches less in thickness than is required by this chapter for external and party walls of the same height, provided they comply with the provisions of this chapter as to strength of materials, but in no case less than twelve inches thick. Where trusses are used, the walls upon which they rest shall be at least four inches thicker than is otherwise required for every addition of twenty-five feet or part thereof to the length of the truss over thirty feet.

Walls, How Anchored

SECTION 26. All walls of first or second-class buildings meeting at an angle and built at separate times shall be united every ten feet of their length by anchor irons, made at least two inches by half an inch of wrought iron, securely built into the side of partition walls not less than three feet, and into the front and rear walls at least one half the thickness of such wall.

Openings in party or partition walls

SECTION 27. Openings or doorways in party walls or in partition walls shall not exceed two in number for each floor, and the combined area of such openings on each floor shall not exceed one hundred square feet. Area of openings may be increased fifty per centum in case automatic sprinklers are provided. Each opening must be provided with two sets of metal-covered doors, separated by the thickness of the wall, and hung to rabbeted iron frames or to iron hinges in brick-work or iron rabbets.

Cornices

SECTION 28. When a wall is finished with a stone cornice, the greatest weight of material of such cornice shall be on the inside of the face of the wall. All cornices hereafter built or replaced on first or second-class buildings shall be of brick or other incombustible material, and the walls shall be carried up to the boarding of the roof, and where the cornice projects above the roof, masonry shall be carried up to the top of the cornice and covered with metal as required for parapet walls. All metal cornices shall be supported on metal lookouts.

Columns

SECTION 29. Every column shall rest upon a cap or plate sufficient to properly distribute the load. Columns set one above another shall have proper connections. All bearing parts of columns or plates shall be true surfaces. The inspector may require columns to be drilled for inspection.

Piers

SECTION 30. Piers and walls shall have caps or plates, where needed, sufficient to properly distribute the load, and shall be built of good hard-burned brick of uniform size, laid in cement and sand mortar, and of sufficient size to carry safely the load for which they are intended; joints not to exceed three-eighths of an inch. One whole course over the surface of the pier shall be laid and joints slushed full of mortar before the next course shall be laid. The top of the pier when finished shall be level for the capstone, plate or other covering.

Binders

Every interior brick pier sixteen by twenty inches, or more than three hundred and twenty square inches in area, shall have one or more binders built therein of stone not less than six inches thick, and such binders shall be the full size of the pier. The distance between any two binders, or between either of them and the capstone or base of the pier, shall be not more than four feet. Brick piers shall not be more than eight times higher than the width of the base.

Floors

SECTION 31. Dead loads in all buildings shall consist of the actual weight of walls, floors, roofs, partitions, and all permanent construction.

Live or variable loads shall consist of all loads other than dead loads.

Every floor shall be of sufficient strength to bear safely the weight to be imposed thereon in addition to the weight of the materials of which the floor is composed.

If to be used in a dwelling house, apartment house, apartment hotel, tenement house, hotel or lodging house, each floor shall be of sufficient strength in all its parts to bear safely upon every square foot of its surface not less than sixty pounds.

If to be used for office purposes, not less than seventy-five pounds upon every square foot of its surface above the first floor, and for the latter floor one hundred and twenty-five pounds.

If to be used in a school or place of instruction, not less than one hundred pounds upon every square foot.

If to be used for stable and carriage house purposes, not less than seventy-five pounds upon every square foot.

If to be used for stores, light manufacturing and light storage, not less than one hundred and twenty-five pounds upon every square foot.

If to be used in a place of public assembly, not less than one hundred pounds upon every square foot.

If to be used in a store where heavy materials are kept or stored, warehouse, factory, or for other manufacturing or commercial purposes, not

less than two hundred pounds upon every square foot.

The strength of factory floors intended to carry running machinery shall be increased above the minimum given in this section in proportion to the degree of vibratory impulse liable to be transmitted to the floor, as may be required by the superintendent of public buildings.

For sidewalks between the curb and building lines, the live load shall be taken at not less than three hundred pounds upon every square foot.

Every column, post or other vertical support shall be of sufficient strength to bear safely the weight of the portion of each and every floor depending upon it for support, in addition to the weight required, as before stated, to be supported safely upon said portions of said floors. For the purpose of determining the carrying capacity of columns in dwellings, office buildings, stores, stables and public buildings, when over five stories in height, a reduction of live loads shall be permissible as follows:

For the roof and top floor, the full live loads shall be used. For each succeeding lower floor, it shall be permissible to reduce the live load by five per cent., until fifty per cent. of the live loads fixed by this section is reached, when such reduced loads shall be used for all remaining floors.

Roof and Floor Timbers

SECTION 32. The ends of all wooden floor or roof beams in second-class buildings shall enter the wall to a depth of at least four inches, unless the wall is properly corbelled, so as to give a bearing of at least four inches, and the end of all such beams shall be so arranged that in case of fire they may fall without injury to the wall. Each floor shall have its beams so tied to the walls with an-

5

chors placed on under side of joists or girders turned down in the wall, and to each other with wrought iron straps or anchors, at least three-eighths of an inch thick by one and one-half inches wide, so as to form a continuous tie across the building, not more than ten feet apart. Walls running parallel, or nearly parallel, with floor beams shall be properly tied once in ten feet to the floor beams by iron straps or anchors of the size above specified. Every wooden header or trimmer more than four feet long, carrying a floor load of more than seventy pounds per square foot, shall at all connections with other beams be hung in stirrup irons and joints bolted. All tail beams and similar beams of wood shall be framed or hung in stirrup irons. All iron beams shall have standard connections.

Cutting beams for piping

SECTION 33. Cutting for piping or other purposes shall not be done so as to reduce the strength of the supporting parts below that required by the provisions of this chapter. No part of any floor timber shall be within one and one-half inches of any chimney. No studding or furring shall be within one inch of any chimney. Metal strips shall be laid in the joints of all chimneys hereafter built, or secured to the joists surrounding such chimneys so as to form an effectual fire-stop at each floor.

Fire-stops

SECTION 34. Every second-class building, except as hereinafter provided, shall have a sufficient fire-stop at each floor, covering the whole floor of each story. Every air duct, except those expressly sanctioned, shall be effectually stopped at each story. Such fire-stop shall consist of magnesocalcite, or its equivalent, or a solid air-tight cohesive layer, at least one inch thick, of tile, brick, terra-cotta, or like fire-proof material, plaster, cement, cinders or ashes, or a combination of the same or of equally non-inflammable, non-heat-con-

ducting material, laid between the under and upper floors, or between the space between the timbers level with top of floor timbers; provided, that all second-class buildings hereafter erected of forty-five feet or more in height, which are used above the first floor for stores, storage, warehouses, or manufacturing, shall have a tight spliced or tongued and grooved under floor of plank at least two inches thick, with upper floor one inch thick, matched and breaking joints, and in such buildings fire-stops need not be used. In all second-class buildings of the character last described, all stairways and elevator shafts forty-five feet or more in height shall be enclosed in walls of non-inflammable material, and all openings in said walls shall be provided with metal-covered doors hung to rabbeted iron frames with iron thresholds. The foot of each partition and of each tier of studding or furring shall be filled solid between the uprights to the full width thereof, and to the height of six inches above the floor with the same non-combustible material as above described for fire-stops, or some combination thereof. The spaces between parts of floor joists which rest upon partition heads shall be filled with material above required. The space between stringers of staircases and joists at landing, unless unceiled, shall be so stopped with some of the non-combustibles above mentioned at three places at least in every flight of stairs so as to prevent the passage of air. All buildings shall have suitable fire-stops at the outside and partition wall, at each floor, as may be approved by the superintendent.

Stairways

Partitions

Spaces between joists

Chimneys

SECTION 35. All chimneys shall be built of brick or other non-combustible material. Brick chimneys may have terra-cotta flue linings, plastered upon the outside below the roof, but if built of brick, without terra-cotta lining, shall be not less than eight inches thick, plastered upon the outside, with struck joints on the inside. All boiler chimneys shall be at least eight inches thick, and shall have in addition a terra-cotta flue lining or an additional four inches of brick. In no case shall any metal be driven into the masonry of any flue. No smoke flue shall be built of a less area than eight inches by eight inches, and no chimney shall have a less area than the combined areas of the thimbles entering it.

Thimbles

SECTION 36. All chimney thimbles shall be of fire-clay, artificial stone, or soapstone, not less than two inches thick around the pipe hole, or of cast or wrought iron not less than one-fourth of an inch thick, with an inch air space around the outside, and so constructed that no woodwork shall be allowed within four inches of the pipe hole. All shall be thoroughly built into the chimney and shall be of such length as to finish flush with the plastering or sheathing.

Hearths and Arches

How built and guarded

SECTION 37. All hearths shall be supported by trimmer arches of brick or other fire-proof material, or of single stones built at least six inches into the chimney and supported by masonry or otherwise rest upon non-combustible support. The brick jambs of every fireplace, range or grate opening shall be at least eight inches wide each, and the backs of such openings shall be at least eight inches thick. All hearth and trimmer arches shall be at least twelve inches longer on either side than the width of such openings, and at least eighteen inches wide in front of the chimney breast. Brick-work over fireplaces and grate openings

shall be supported by proper iron bars or brick or stone arches.

Hot Air and Smoke Pipes

How built and guarded

SECTION 38. No smoke pipe shall project through any external wall or window. No smoke pipe shall pass through any wooden partition without a ring of some hard non-combustible material of the thickness of the partition and extending four inches from the pipe, or a double metal collar of the thickness of the partition, with a ventilated air space of not less than four inches around the pipe, and shall not be placed within eight inches of any wood unless the same is protected with a metal shield two inches distant from the wood, in which case the smoke pipe shall not be less than six inches from the wood. The tops of all heating furnaces set in brick shall be covered with brick supported by iron bars and so constructed as to be perfectly tight; said covering to be in addition to and not less than six inches from the ordinary covering of the hot-air chamber.

Heating furnaces set in brick

Heating furnaces not set in brick

SECTION 39. The tops of all heating furnaces not set in brick shall be at least eight inches below the nearest wooden beams or ceiling, with a shield of tin plate made tight, suspended not less than two inches below such beams or ceiling, and extending one foot beyond the top of the furnace on all sides. All hot-air register boxes hereafter placed in floors or partitions of buildings shall be set in soapstone or equally non-combustible borders, not less than two inches in width, and shall be made of tin plate and have double pipes and boxes properly fitted to soapstone. Hot-air pipes and register boxes shall be at least one inch from any woodwork, and register boxes fifteen inches by twenty-five inches, or larger, and their connecting pipes shall be two inches from any woodwork. The requirements of this section may be modified or dispensed with by the inspector in first-class buildings. No woodwork shall be placed within one inch of any metal pipe to be used to convey heated air or steam unless such pipe is protected by a soapstone or earthen ring, metal tube or metal casing. In all first or second-class mercantile or manufacturing buildings hereafter built over thirty feet in height, or increased above that height, outside openings in party walls or in any rear or side wall within twenty feet of an opposite wall or building, shall have metal frames and sashes and shall be glazed with wire glass or shall be protected by shutters. Such shutters shall be covered both sides with tin or shall be made of other substantial, fire-proof material, and hung on the outside, either upon independent metal frames or upon metal hinges attached to the masonry, and shall be made to be handled from both inside and outside.

Setting Boilers, Furnaces, Etc.

Permit

SECTION 40. No boiler to be used for steam heat or motive power, and no furnace or hot-water heater, shall be placed on any floor above the cellar floor, unless the same is set on non-combustible beams and arches, and in no case without a permit from the inspector.

How enclosed

SECTION 41. Every steam boiler in a building to be used for office, mercantile or manufacturing purposes, or in a building used or intended to be used as a lodging house or hotel with ten or more rooms above the second story, shall be enclosed in a fire-proof room in brick, iron, or other non-combustible material, with openings closed with metal-covered doors hung to iron frames or to hinges in brick. This shall not apply to fire-proof buildings.

Roofs

SECTION 42. All new or renewed roofs having a pitch of less than twenty degrees shall be proportioned to bear safely fifty pounds upon every square foot of their surface, in addition to the weight of the materials composing the same. If the pitch be more than twenty degrees, the live load shall be assumed at thirty pounds upon every square foot measured on a horizontal plane with additional allowance for a horizontal wind pressure of thirty pounds per superficial square foot. All thin glass skylights upon roofs shall be covered with wire netting. The roof of every second-class building hereafter built shall be covered with tin, iron, slate, gravel, composition or like substantial roof material not readily inflammable. All buildings over forty-five feet high shall have suitable water-tight, metallic leaders, and all buildings shall have leaders sufficient to carry all water to the street, gutter or sewer in such manner as not to flow upon the sidewalk or to cause dampness in any wall. All buildings over twenty feet high, except dwelling houses, shall have permanent means of access to the roof from the inside; the opening shall not be less than eighteen by thirty inches.

Frame Buildings

As amended by ordinance approved July 28, 1911

SECTION 43. Outside the fire limits buildings of frames of wood may be erected, but no frame building to be occupied or used as a workshop or manufactory shall be built more than two stories or twenty-five feet in height. No wooden tower or spire shall be built or rebuilt to a greater height than sixty feet without a license first obtained from the license board; nor without a license from said board shall any building to be used as a barn or

SECTION 44. Balloon frame buildings may be built outside the fire limits, provided they are thoroughly built, framed into suitable sized sills, with corner posts of not less thickness than width of studding, and six inches wide, with corners thoroughly braced, and braced in the middle partition as near as possible, with suitable sized floor joists notched into ledger board and thoroughly spiked to studs. All stud partitions shall have caps and soles with the partition studs set perpendicularly over each other as far as practicable. Main bearing stud partitions shall be of not less than four-inch studding; the cap shall be used as sole for studding above. All wooden buildings shall have suitable fire-stops.

First-Class Buildings

Construction and material

SECTION 45. A first-class building shall consist of non-inflammable material throughout, with floors constructed of iron or steel beams, filled in between with terra-cotta or other arches, except that wood may be used for under and upper floors, windows, door-frames, sashes, doors, standing finish, handrails for stairs, necessary sleepers bedded in concrete, and for isolated furring blocks bedded in the plaster. There shall be no air-space between the top of any floor arches and the floor boarding and no air-space behind any wood-work. Every building hereafter erected over seventy feet high shall be a first-class building, and this provision shall apply to all buildings hereafter increased in height to over seventy feet. Every building hereafter erected or enlarged, as a hotel containing more than fifty sleeping-rooms, shall be a first-class building.

Limitation on buildings in fire district

SECTION 46. No building, except of the first or second class, shall hereafter be erected within the fire district established by ordinance.

SECTION 47. No wooden addition to any building now existing within such fire district shall be made, except upon license therefor first obtained from the license board, who may prescribe such terms, conditions, limitations and restrictions as it deems wise. Before any such license is granted a notice of the application therefor shall be published three days successively in some one daily newspaper printed in the City of Worcester. Such wooden addition shall be made in accordance with the requirements of this chapter.

SECTION 48. No wooden building shall be moved from one lot to another in the fire district, nor from without said district into the same.

SECTION 49. No wooden building shall be moved from place to place on the same lot within the fire district without a special license being first obtained therefor from the license board.

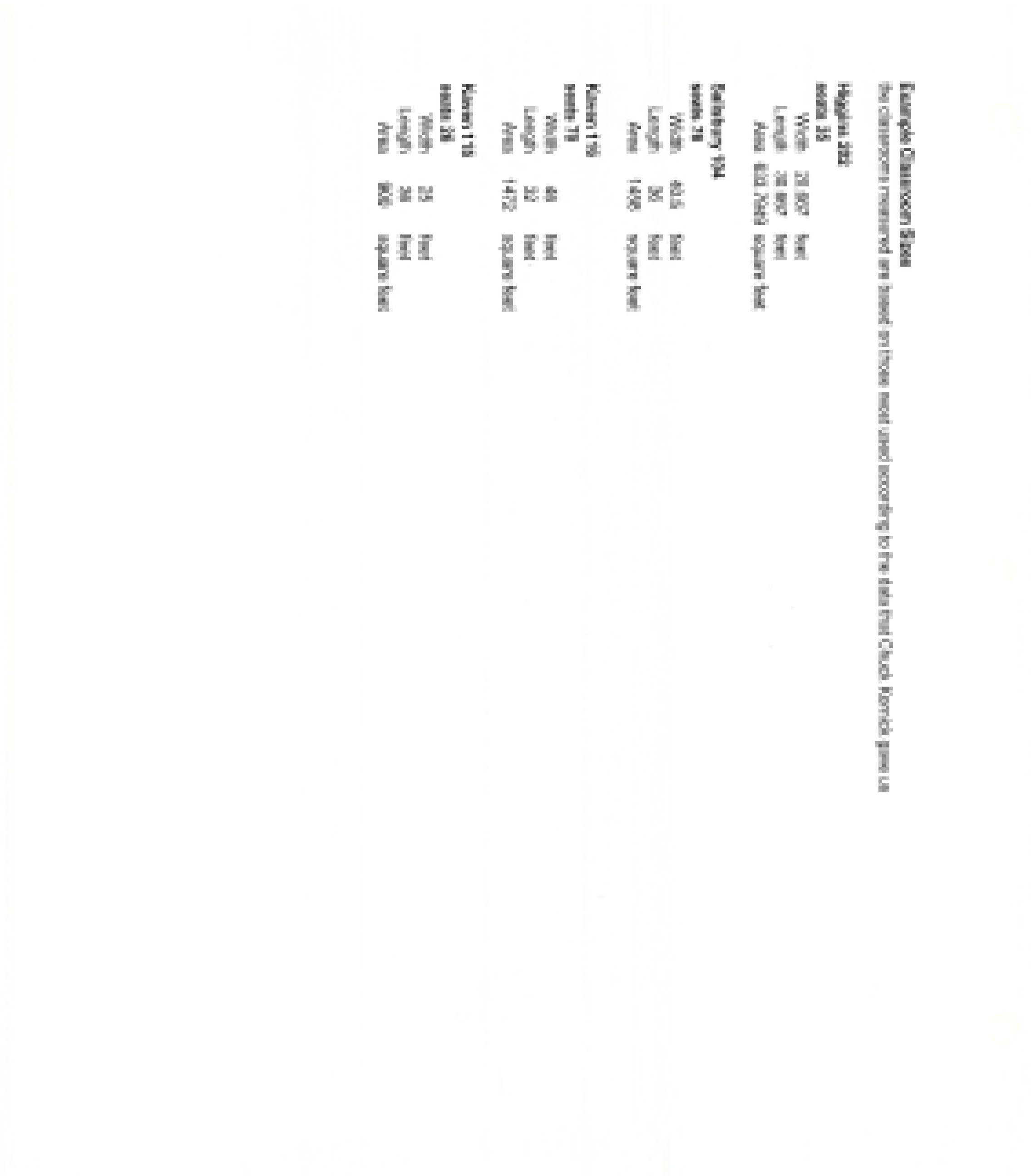
SECTION 50. No bay window or other structure shall be placed upon any building so as to project over any public way or square.

Fire District As amended by ordinance approved April 28, 1911

SECTION 51. For the purpose of securing the prevention of fire in the City of Worcester a fire district is hereby establish therein, the boundaries of which shall be as follows, to wit: Beginning at a point on the northeasterly side of Main street, one hundred fifty feet southwesterly of Gardner street; thence running southeasterly parallel to and one hundred fifty feet southwesterly of Gardner street to a point one hundred fifty feet southeasterly of the southeast side of Main street; thence running northeasterly parallel to and one hundred fifty feet southeasterly of Main street to a point one hundred fifty feet southwesterly of Lagrange street; thence running

11.4 Walk-through

11.4.1 Classroom Measurements


Example Classroom Sizes
the classrooms measured are based on those most used according to the data that Chuck Ravnik gives us

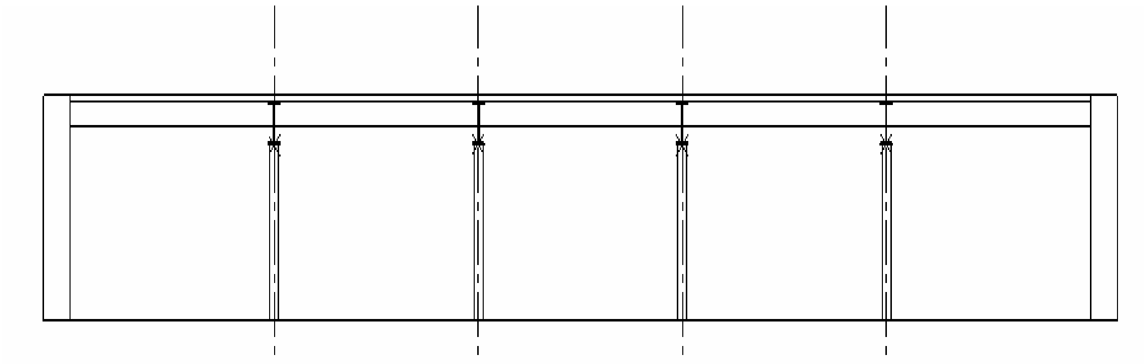
Higgins 202
seats 35
Width 23.667 feet
Length 26.667 feet
Area 631.1049 square feet

Salisbury 104
seats 78
Width 40.5 feet
Length 36 feet
Area 1458 square feet

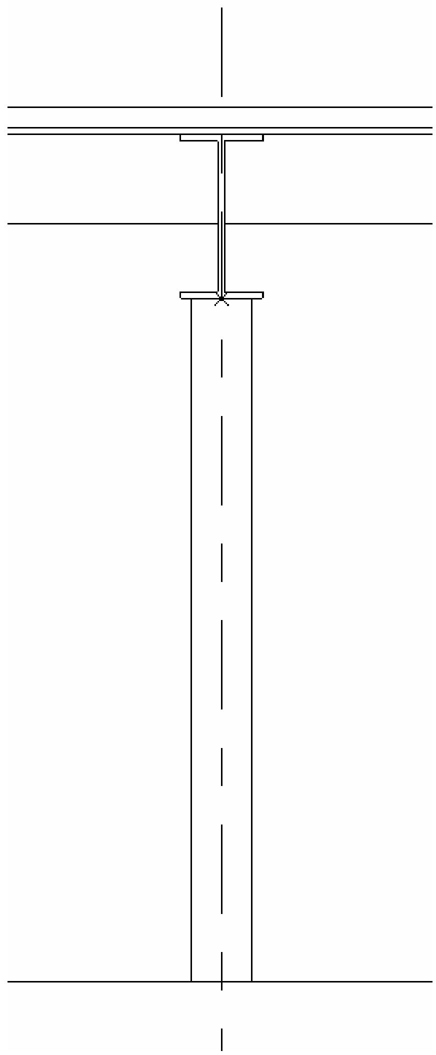
Kaven 116
seats 78
Width 46 feet
Length 32 feet
Area 1472 square feet

Kaven 115
seats 38
Width 25 feet
Length 36 feet
Area 900 square feet

11.4.2 Alumni Gymnasium Elevation of Existing Framework



Elevation of First Floor supporting Gym



Elevation Showing Column, Beam, Wood Beam, Floor Boards, and Gym Flooring

11.4.3 Floor Data

Sub-basement

Basic Dimensions

Length	130	feet
Width	90	feet
Total Area	11700	square feet
Existing Floor Space	5004	square feet
Stairwell Area	168	square feet

Our Requirements of the Space Available

Bathrooms	
Elevator	
Open Computer Lab	in existing pool space
Computer Classroom	in existing pool space
Retain Both Stairwells	

Basic Dimensions

Length	130	feet
Width	90	feet
Total Area	11700	square feet
Existing Floor Space	9801.275	square feet
Stairwell Area	778.975	square feet

Our Requirements of the Space Available

Bathrooms	
Elevator	
Lab Area	over existing pool
2 Conference rooms	in existing fitness center space
5 Offices	in existing fitness center space
3 TI Labs	in existing fitness center space
Retain Existing Stairwells	
Retain Higgins Side Exit	

First Floor

Basic Dimensions

Length	130	feet
Width	90	feet
Total Area	11700	square feet
Existing Floor Space	8342.75	square feet
Stairwell Area	1357.5	square feet

Our Requirements of the Space Available

Bathrooms	
Elevator	
2 Smaller Classrooms	each will require removal of a column
Offices	
Lounge Space	
Retain All Stairwells	
Remain All 3 Exits	

2nd Floor

Basic Dimensions

Length	130	feet
Width	90	feet
Total Area	11700	square feet
Existing Floor Space	10035.75	square feet
Stairwell Area	856.875	square feet

Our Requirements of the Space Available

- Bathrooms
- Elevator
- 2 Large Classrooms
- Lounge Areas
- Retain All Stairwells
- Tall Partitioning Wall

3rd Floor

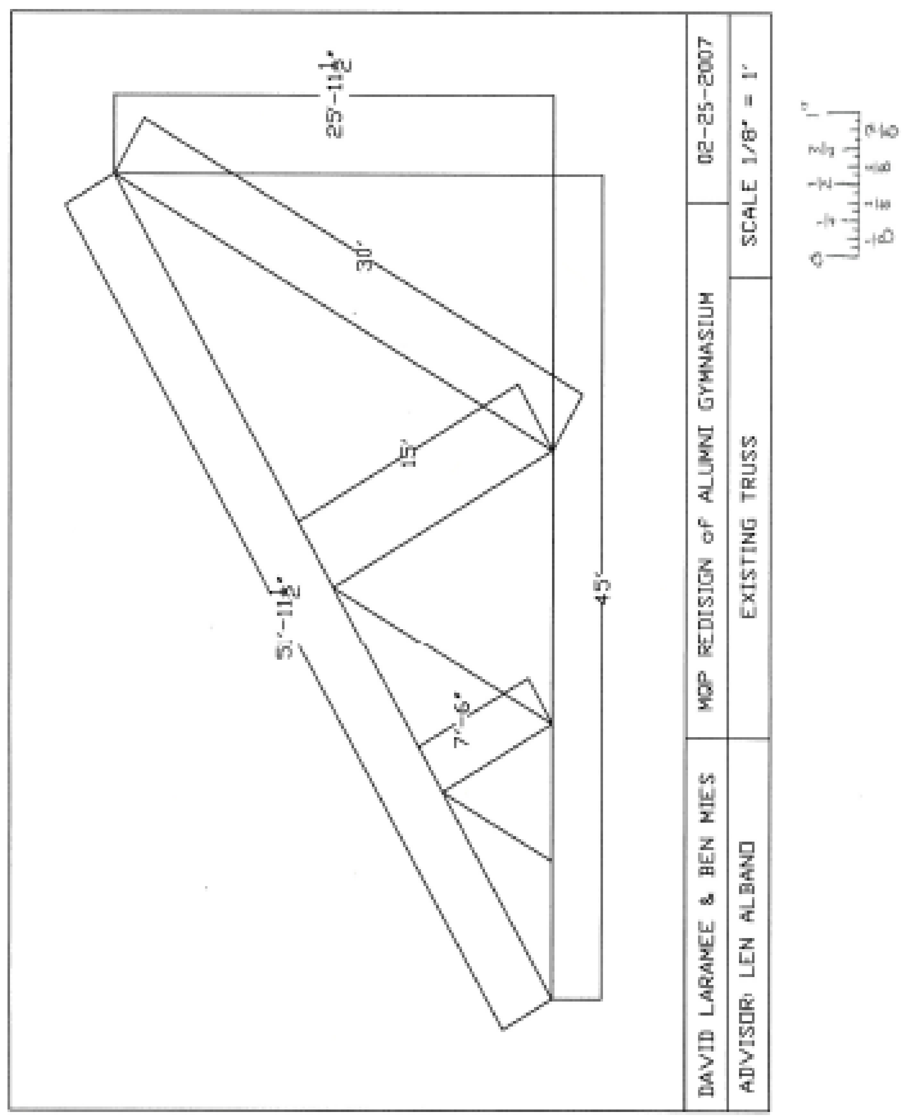
Basic Dimensions

Length	130	feet
Width	90	feet
Total Area	11700	square feet
Existing Floor Space	3547.625	square feet
Stairwell Area	562.5	square feet

Our Requirements of the Space Available

Removal of Track
18 Offices
2 TA Offices
Retain Stairwell

11.4.4 Truss System



Truss System of Alumni Gymnasium Roof

11.5 Floor and Fire Summary Charts

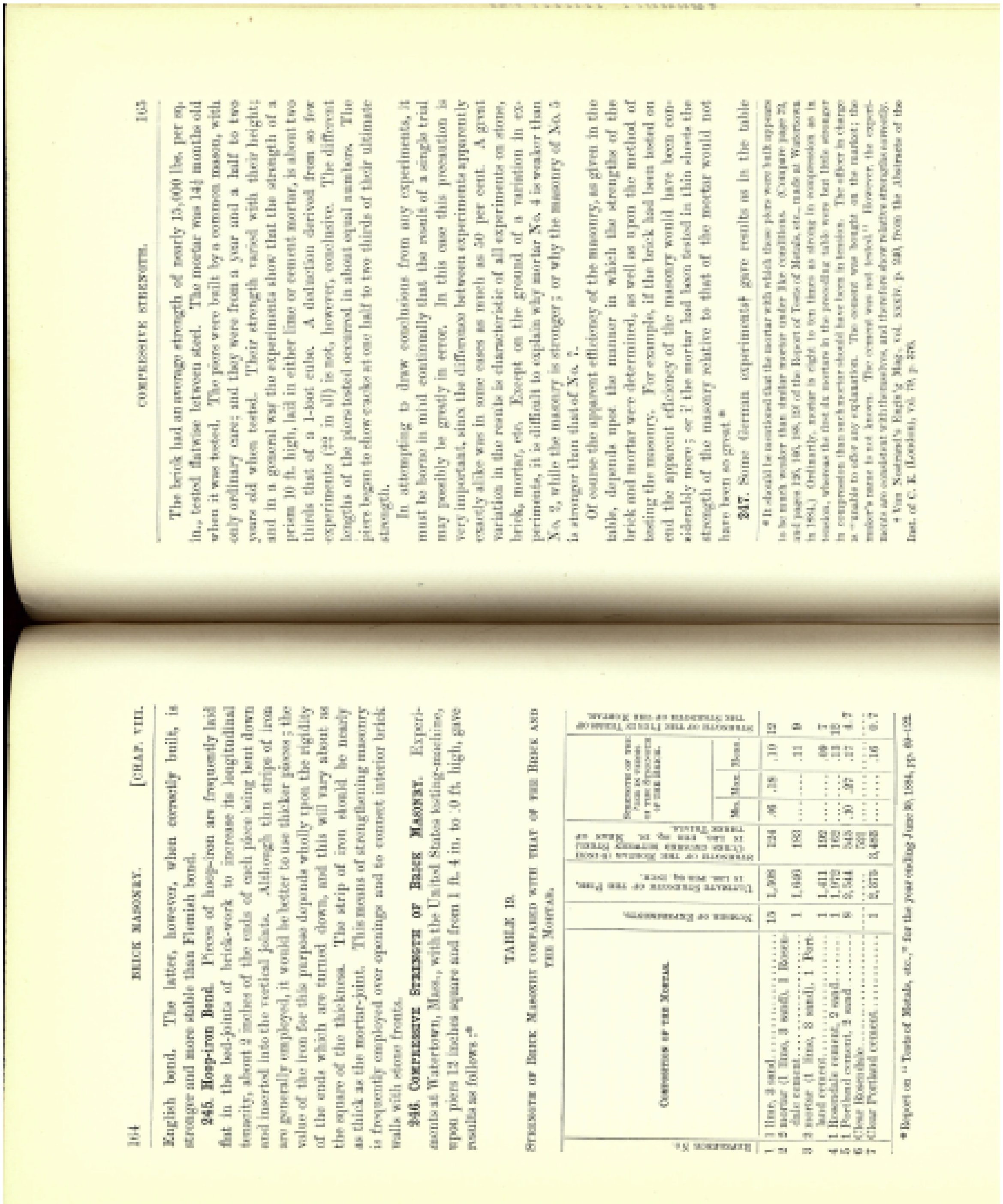
				NUMBER OF PEOPLE			
CODE	**TYPE**	**SQUARE FOOTAGE**		**OCCUPANCY FACTOR**	**ALLOWED BY CODE**	**WORST CASE BY CODE**	**INTENED**
SB 01	LAB	1,145.25	ft^2	50.00	22.905	23	2[illegible]
SB 02	LAB	1,145.25	ft^2	50.00	22.905	23	2[illegible]
SB 03	MEN'S BATHROOM	170.10	ft^2	50.00	3.402	4	[illegible]
SB 04	WOMEN'S BATHROOM	260.40	ft^2	50.00	5.208	6	[illegible]
SB 05	CLOSET	18.00	ft^2	300.00	0.06	1	[illegible]
SB STAIRS 01		90.00	ft^2	100.00	0.9	1	[illegible]
SB STAIRS 02		92.00	ft^2	100.00	0.92	1	[illegible]
SB HALLS		1,827.86	ft^2	100.00	18.2786	19	1[illegible]
				78			
B 01	COMPUTER LAB	2,039.00	ft^2	15.00	135.9333333	136	4[illegible]
B 02	CONFERENCE	667.00	ft^2	15.00	44.46666667	45	3[illegible]
B 03	MEN'S BATHROOM	366.00	ft^2	50.00	7.32	8	[illegible]
B 04	WOMEN'S BATHROOM	352.30	ft^2	50.00	7.046	8	[illegible]
B 05	CLOSET	56.70	ft^2	300.00	0.189	1	[illegible]
B 06	I.T LAB	269.00	ft^2	50.00	5.38	6	[illegible]
B 07	I.T LAB	269.00	ft^2	50.00	5.38	6	[illegible]
B 08	I.T LAB	269.00	ft^2	50.00	5.38	6	[illegible]
B 09	I.T LAB	269.00	ft^2	50.00	5.38	6	[illegible]
B 10	I.T LAB	269.00	ft^2	50.00	5.38	6	[illegible]
B 11	I.T LAB	269.00	ft^2	50.00	5.38	6	[illegible]
B STAIRS 01		192.00	ft^2	100.00	1.92	2	[illegible]
B STAIRS 02		276.50	ft^2	100.00	2.765	3	[illegible]
B STAIRS 04		622.25	ft^2	100.00	6.2225	7	[illegible]
B HALLS		3,617.85	ft^2	100.00	36.1785	37	3[illegible]
				283			
101	CLASS ROOM	1,300.00	ft^2	15.00	86.66666667	87	8[illegible]
102	CLASSROOM	1,916.25	ft^2	15.00	127.75	128	8[illegible]

103	OFFICE	806.50	ft^2	100.00	8.065	9	9
104	CONFERENCE	206.50	ft^2	15.00	13.76666667	14	14
105	STUDENT LOUNGE	301.30	ft^2	100.00	3.013	4	4
106	WOMEN'S BATHROOM	268.41	ft^2	50.00	5.3682	6	6
107	MEN'S BATHROOM	187.50	ft^2	50.00	3.75	4	4
108	OFFICE	109.60	ft^2	100.00	1.096	2	[illegible]
109	OFFICE	109.60	ft^2	100.00	1.096	2	[illegible]
110	OFFICE	109.60	ft^2	100.00	1.096	2	[illegible]
111	OFFICE	109.60	ft^2	100.00	1.096	2	[illegible]
112	FACILITY LOUNGE	274.50	ft^2	100.00	2.745	3	3
113	CLOSET	122.75	ft^2	300.00	0.409166667	1	[illegible]
114	CLOSET	114.00	ft^2	300.00	0.38	1	[illegible]
1 STAIRS 01		367.50	ft^2	100.00	3.675	4	4
1 STAIRS 02		328.34	ft^2	100.00	3.2834	4	4
1 STAIRS 03		253.00	ft^2	100.00	2.53	3	3
1 STAIRS 04		672.50	ft^2	100.00	6.725	7	7
1 HALLS		4,403.91	ft^2	100.00	44.0391	45	4[illegible]
				328			
201	CLASS ROOM	2,124.90	ft^2	15.00	141.66	142	8[illegible]
202	CLASSROOM	2,124.90	ft^2	15.00	141.66	142	8[illegible]
203	CLOSET	247.50	ft^2	300.00	0.825	1	[illegible]
204	CLOSET	243.80	ft^2	300.00	0.812666667	1	[illegible]
205	WOMEN'S BATHROOM	254.25	ft^2	50.00	5.085	6	6
206	MEN'S BATHROOM	165.00	ft^2	50.00	3.3	4	4
207	OFFICE	126.00	ft^2	100.00	1.26	2	[illegible]
208	OFFICE	126.00	ft^2	100.00	1.26	2	[illegible]
209	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
210	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
211	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
212	CLOSET	78.00	ft^2	300.00	0.26	1	[illegible]
213	CLOSET	78.00	ft^2	300.00	0.26	1	[illegible]
214	OFFICE	153.00	ft^2	100.00	1.53	2	[illegible]
215	OFFICE	153.00	ft^2	100.00	1.53	2	[illegible]
216	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
217	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]

218	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
2 STAIRS 01		262.50	ft^2	100.00	2.625	3	[illegible]
2 STAIRS 03		266.25	ft^2	100.00	2.6625	3	[illegible]
2 STAIRS 04		446.00	ft^2	100.00	4.46	5	[illegible]
2 STAIRS 05		200.00	ft^2	100.00	2	2	[illegible]
2 HALLS		2,155.00	ft^2	110.00	19.59090909	20	[illegible]
				351			
301	OFFICE	207.40	ft^2	100.00	2.074	3	[illegible]
302	OFFICE	126.00	ft^2	100.00	1.26	2	[illegible]
303	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
304	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
305	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
306	CLOSET	78.00	ft^2	300.00	0.26	1	[illegible]
307	OFFICE	153.00	ft^2	100.00	1.53	2	[illegible]
308	OFFICE	186.50	ft^2	100.00	1.865	2	[illegible]
309	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
310	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
311	OFFICE	144.00	ft^2	100.00	1.44	2	[illegible]
3 STAIRS 04		446.00	ft^2	100.00	4.46	5	[illegible]
S STAIRS 05		215.10	ft^2	100.00	2.151	3	[illegible]
3 HALLS		890.80	ft^2	100.00	8.908	9	[illegible]
				39			

11.6 Masonry

11.6.1 Baker



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English bond. The latter, however, when correctly built, is stronger and more stable than Flemish bond.

245. Hoop-iron Bond. Pieces of hoop-iron are frequently laid flat in the bed-joints of brick-work to increase its longitudinal tenacity, about 2 inches of the ends of each piece being bent down and inserted into the vertical joints. Although thin strips of iron are generally employed, it would be better to use thicker pieces; the value of the iron for this purpose depends wholly upon the rigidity of the ends which are turned down, and this will vary about as the square of the thickness. The strip of iron should be nearly as thick as the mortar-joint. This means of strengthening masonry is frequently employed over openings and to connect interior brick walls with stone fronts.

246. Compressive Strength of Brick Masonry. Experiments at Watertown, Mass., with the United States testing-machine, upon piers 12 inches square and from 1 ft. 4 in. to 10 ft. high, gave results as follows:*

TABLE 19.

Strength of Brick Masonry compared with that of the Brick and the Mortar.

Reference No.	Composition of the Mortar.	Number of Experiments.	Ultimate Strength of the Piers, in lbs. per sq. inch.	Strength of the Mortar (1-inch cubes), in lbs. per sq. in. Mean of three trials.	Strength of the Piers in terms of the Strength of the Brick. Min.	Max.	Mean.	Strength of the Piers in terms of the Strength of the Mortar.
1	1 lime, 3 sand	13	1,308	124	.06	.18	.10	12
2	2 mortar (1 lime, 3 sand), 1 Rosendale cement	1	1,640	183	.....	.....	.11	9
3	2 mortar (1 lime, 3 sand), 1 Portland cement	1	1,411	192	.....	.....	.09	7
4	1 Rosendale cement, 2 sand	1	1,072	162	.....	.....	.11	12
5	1 Portland cement, 2 sand	8	2,544	545	.10	.27	.17	4.7
6	Clear Rosendale	.....	.....	521	.....	.....	.....	.....
7	Clear Portland cement	1	2,375	3,488	.....	.....	.16	0.7

* Report on "Tests of Metals, etc.," for the year ending June 30, 1884, pp. 69–122.

COMPRESSIVE STRENGTH. 165

The brick had an average strength of nearly 15,000 lbs. per sq. in., tested flatwise between steel. The mortar was 14½ months old when it was tested. The piers were built by a common mason, with only ordinary care; and they were from a year and a half to two years old when tested. Their strength varied with their height; and in a general way the experiments show that the strength of a prism 10 ft. high, laid in either lime or cement mortar, is about two thirds that of a 1-foot cube. A deduction derived from so few experiments (22 in all) is not, however, conclusive. The different lengths of the piers tested occurred in about equal numbers. The piers began to show cracks at one half to two thirds of their ultimate strength.

In attempting to draw conclusions from any experiments, it must be borne in mind continually that the result of a single trial may possibly be greatly in error. In this case this precaution is very important, since the difference between experiments apparently exactly alike was in some cases as much as 50 per cent. A great variation in the results is characteristic of all experiments on stone, brick, mortar, etc. Except on the ground of a variation in experiments, it is difficult to explain why mortar No. 4 is weaker than No. 2, while the masonry is stronger; or why the masonry of No. 5 is stronger than that of No. 7.

Of course the apparent efficiency of the masonry, as given in the table, depends upon the manner in which the strengths of the brick and mortar were determined, as well as upon the method of testing the masonry. For example, if the brick had been tested on end the apparent efficiency of the masonry would have been considerably more; or if the mortar had been tested in thin sheets the strength of the masonry relative to that of the mortar would not have been so great.*

247. Some German experiments† gave results as in the table

* It should be mentioned that the mortar with which these piers were built appears to be much weaker than similar mortar under like conditions. (Compare page 73, and pages 126, 160, 188, 191 of the Report of Tests of Metals, etc., made at Watertown in 1884.) Ordinarily, mortar is eight to ten times as strong in compression as in tension, whereas the first six mortars in the preceding table were but little stronger in compression than such mortar should have been in tension. The officer in charge is "unable to offer any explanation. The cement was bought on the market; the maker's name is not known. The cement was not tested." However, the experiments are consistent with themselves, and therefore show relative strengths correctly.

† Van Nostrand's Engin'g Mag., vol. xxxiv. p. 240, from the Abstracts of the Inst. of C. E. (London), vol. 79, p. 376.

below. It is not stated how the strength of the brick or of the masonry was determined.* The term cement refers to Portland cement. According to the building regulations of Berlin, the safe load for brick masonry is one tenth of the results in the table.

TABLE 30.

RELATIVE STRENGTH OF BRICK AND BRICK MASONRY.

Kind of Brick.	Average Crushing Strength of Brick, in lbs. per sq. in.	Ultimate Strength, in lbs. per sq. in., of Brick-work with Mortar composed of—			
		1 Lime, 2 Sand.	1 Lime, 1 Cement, 10 Sand.	1 Cement, 6 Sand.	1 Cement, 3 Sand.
Clinker stock..........	5,290	2,370	2,590	2,940	3,410
Selected "	3,669	1,620	1,760	2,030	2,220
Ordinary "	2,980	1,290	1,380	1,610	1,890
Perforated..............	2,759	1,210	1,320	1,530	1,720
Porous	2,617	1,150	1,250	1,440	1,650
Porous perforated......	1,195	530	570	650	780

Both of the preceding series of experiments show conclusively that the strength of brick masonry is mainly dependent upon the strength of the mortar. An increase of 50 per cent. in the strength of the brick shows no appreciable effect on the strength of the masonry. Notice, however, that the masonry in the fifth line of Table 19 is 70 per cent. stronger than that in the first, due to the difference between a good Portland cement mortar and the ordinary lime mortar. In the second table notice that brick laid in a 1 to 3 Portland cement mortar is nearly 50 per cent. stronger than in a 1 to 2 lime mortar. Similar experiments† show that masonry laid in mortar composed of 1 part Rosendale cement and 2 parts sand is 56 per cent. stronger than when laid in mortar composed of 1 part lime and 4 parts sand. A member of the Institute of Civil Engineers (London) says‡ that brick-work laid in lime is only one fourth as strong as when laid in clear Portland cement. Probably the difference in durability between cement mortar and lime mortar is considerably greater than their difference in strength.

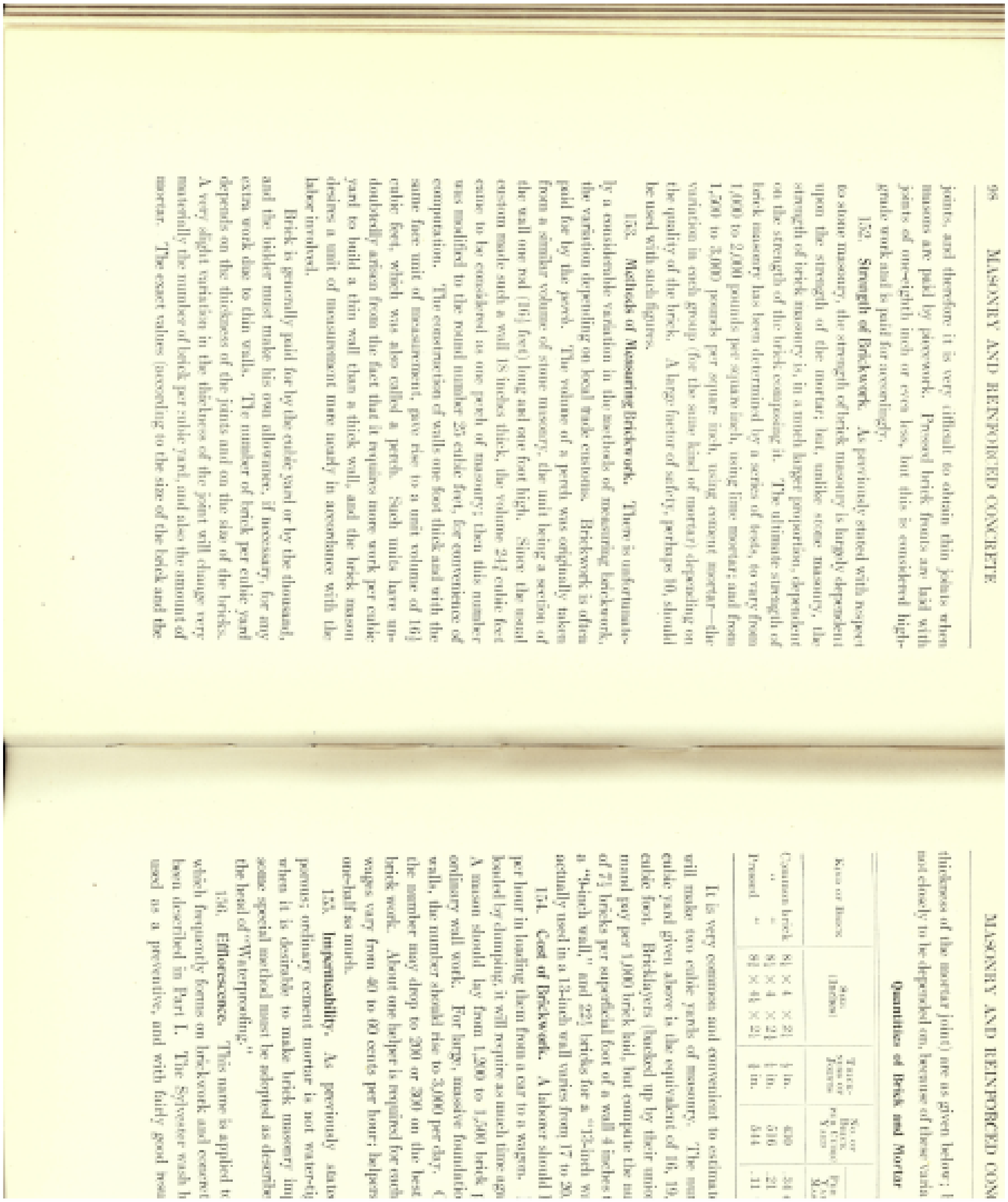
* If the strength of the brick (in any line of the table) be represented by 100, that of the masonry is 44, 48, 55, and 63, respectively, which shows that the values in the table were not derived directly from experiments.

† Report of Experiments on Building Materials for the City of Philadelphia with the U. S. testing-machine at Watertown, Mass., pp. 33, 38.

‡ Proc. Inst. of C. E., vol. xvii. p. 441.

248. Pressure allowed in B
a brick shot-tower in Baltimo
tons per sq. ft. (about 90 lbs. p
of a brick chimney at Glasgow
at 9 tons per sq. ft. (about 12
this is increased to 15 tons p
leeward side. The leading Ch
ft. (140 lbs. per sq. in.) on the
land cement mortar; 8 tons fo
cement mortar; and 5 tons fo
Ordinary brick piers have bee
(560 lbs. per sq. in.) for severa
Tables 19 and 20 appear to
conservative with regard to th
According to Table 19 (page 1
brick laid in ordinary lime mo
in 1 to 2 Portland cement mo
166) the strength of ordinary b
per sq. ft., and in 1 to 3 Portl
the above, it would seem tha
lime mortar should be safe un
and that the best brick in good
under 30 tons per sq. ft. The
masonry depends upon the kin
care with which it is executed
manent, an important or un
added, the care with which the
249. TRANSVERSE STRENG
seldom employed where any
come upon it, but sometimes
transverse strength of brick-
tensile strength of the brick
of the mortar, but practicall
mines the strength of the m
a high wall whose upper porti
pressure of any kind, the fail
the adhesion in the bed-joints
or (2) to the rupture of the
latter method of failure, howe

11.6.2 Webb



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joints, and therefore it is very difficult to obtain thin joints when masons are paid by piecework. Pressed brick fronts are laid with joints of one-eighth inch or even less, but this is considered high-grade work and is paid for accordingly.

152. **Strength of Brickwork.** As previously stated with respect to stone masonry, the strength of brick masonry is largely dependent upon the strength of the mortar; but, unlike stone masonry, the strength of brick masonry is, in a much larger proportion, dependent on the strength of the brick composing it. The ultimate strength of brick masonry has been determined by a series of tests, to vary from 1,000 to 2,000 pounds per square inch, using lime mortar; and from 1,500 to 3,000 pounds per square inch, using cement mortar—the variation in each group (for the same kind of mortar) depending on the quality of the brick. A large factor of safety, perhaps 10, should be used with such figures.

153. **Methods of Measuring Brickwork.** There is unfortunately a considerable variation in the methods of measuring brickwork, the variation depending on local trade customs. Brickwork is often paid for by the perch. The volume of a perch was originally taken from a similar volume of stone masonry, the unit being a section of the wall one rod (16½ feet) long and one foot high. Since the usual custom made such a wall 18 inches thick, the volume 24¾ cubic feet came to be considered as one perch of masonry; then this number was modified to the round number 25 cubic feet, for convenience of computation. The construction of walls one foot thick and with the same face unit of measurement, gave rise to a unit volume of 16½ cubic feet, which was also called a perch. Such units have undoubtedly arisen from the fact that it requires more work per cubic yard to build a thin wall than a thick wall, and the brick mason desires a unit of measurement more nearly in accordance with the labor involved.

Brick is generally paid for by the cubic yard or by the thousand, and the bidder must make his own allowance, if necessary, for any extra work due to thin walls. The number of brick per cubic yard depends on the thickness of the joints and on the size of the bricks. A very slight variation in the thickness of the joint will change very materially the number of brick per cubic yard, and also the amount of mortar. The exact values (according to the size of the brick and the

MASONRY AND REINFORCED CON

thickness of the mortar joint) are as given below; b
not closely to be depended on, because of these varia

Quantities of Brick and Mortar

Kind of Brick	Size (Inches)	Thickness of Joints	No. of Brick per Cubic Yard	Per Ya Ma
Common brick	8¼ × 4 × 2¼	½ in.	430	.34
" "	8¼ × 4 × 2¼	¼ in.	516	.21
Pressed "	8⅜ × 4⅛ × 2⅜	⅛ in.	544	.11

It is very common and convenient to estimat
will make two cubic yards of masonry. The nu
cubic yard given above is the equivalent of 16, 19,
cubic feet. Bricklayers (backed up by their unio
mand pay per 1,000 brick laid, but compute the nu
of 7½ bricks per superficial foot of a wall 4 inches t
a "9-inch wall," and 22½ bricks for a "13-inch wa
actually used in a 13-inch wall varies from 17 to 20.

154. **Cost of Brickwork.** A laborer should l
per hour in loading them from a car to a wagon.
loaded by dumping, it will require as much time aga
A mason should lay from 1,200 to 1,500 brick p
ordinary wall work. For large, massive foundatio
walls, the number should rise to 3,000 per day. C
the number may drop to 200 or 300 on the best
brick work. About one helper is required for each
wages vary from 40 to 60 cents per hour; helpers
one-half as much.

155. **Impermeability.** As previously state
porous; ordinary cement mortar is not water-tig
when it is desirable to make brick masonry imp
some special method must be adopted as describe
the head of "Waterproofing."

156. **Efflorescence.** This name is applied to
which frequently forms on brickwork and concret
been described in Part I. The Sylvester wash h
used as a preventive, and with fairly good resu

11.7 Sample Calculation

Sample Calcs For Existing Members -1

Live Load Reduction Factor

$L_0 = 100$ psf
$D_0 = 20$ psf
$A_t = 600$ ft²
$A_0 = 250$ ft²

$N_1 = 1 - .0008(600\ ft^2 - 250\ ft^2) = .72$ ← highest

$N_2 = .75 - .26(20\ psf/100\ psf) = .71$

$N_3 = .6$

Z_x of Steel Girders

$Z_x = A_f(d - t_f) + A_w(T/2)$
$= 12(24 - 1) + 11(22/2) = 397\ in^3$

Required Z_x

Live Load
Partition · Trib width + Assembly · Trib width
20 psf · 17.3 ft + 60 psf · 17.3 psf = 1381.3 plf

Reduction

LL · factor = 1381.3 · .74 = 1013.6 plf

Load Cases

1.4 · DL = 1.4 · 3239.1 plf = 4534.7 plf
1.2 · DL + 1.6 · LL = 1.2 · 3239.1 plf + 1.6 · 1013.6 = 5508.7 plf

$M_u = (5508.7\ plf \cdot span^2)/8/1000 = 784.3$ ft-k
(span² = 33.8²)

Z_x for 36 ksi

$(M_u \cdot 12)/36 = 261.4\ in^3 < 397\ in^3$

Timber Beam — Sample calcs for existing members - 2

Example Birch - Transverse Direction

Density (lb/in³)	.02746	Material Prop
Comp. Strength (KSI)	1.723	
Elongation (%)	2.59	
MOR (KSI)	1.102	
Poissons Ratio	.04	
Shape factor	5.1	
Shear Modulus (10^6 psi)	.01784	
Tensile Strength (KSI)	1.102	
Yield Strength (KSI)	.6614	
Youngs Modulus (10^6 psi)	.1407	

length (in)	214	Geometry
Side (in)	12	
Cross Section (in²)	144	
Volume of Girder (in³)	30816	length · cross section area
Trib. width (in)	72	
Trib. Area (in²)	15408	
Moment I (in⁴)	1728	(side^2)^3/12
Moment K (in⁴)	2903	side · side²/6
Moment Z (in⁴)	288	

Load - Dead

weight of girder (lb/ft)	47.5	volume · density / (length/12)
materials weight (psf)	10	

Load - Live

partition (psf)	20
Assembly (psf)	60

load cases, moment, and required Z calculated the same way as steel girder

Column

sample calcs for existing members - 3

	loads	floors	
A_T	571.2	2	
Steel beam	4821.47	2	30.71 × 157
wood beam	3137.47	2	5 × 18.62 × 33.7
live load	45696.0	2	80 · 571.2
dead load	5712	2	10 · 571.2
Total	107309.88		4821.47 + 3137.47 + 45696
t	.25		
L	102		
f_y	36,000		
E	29000000		
I	71.53		3.14 × 4.5^3 · .25
P	1965912.34		

New Structural Members

calculations were done in the same manner as the existing members