

# THESIS PROPOSAL

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Proposed Redesign

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UNIVERSITY SCIENCES BUILDING

Northeast USA

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## Executive Summary

The main purpose of this proposal is to identify a problem, propose a solution to the problem, and outline the methods, tasks, tools, and schedule which will be used to solve the problem for the University Sciences Building (USB). This is a new, 138,000 square foot laboratory and classroom building located on an urban university campus in the Northeast USA. It has a construction cost of approximately \$50 million, and has several unique architectural features, such as a biowall and a 5-story atrium through the core of the building. The main gravity system consists of voided filigree slabs and beams resting on cast-in-place columns, but the mechanical penthouse is constructed of steel. The lateral system consists of 15 shear walls scattered throughout the building, augmented above the concrete-steel transition by five braced frames.

As it is originally designed, the USB has very few structural problems. Therefore, a scenario has been created where the California State University, Northridge (CSUN) has requested the design of an identical building. It is of interest to the designer to incorporate performance-based design, and therefore the proposed solution will meet the FEMA 356 "S-1-B Immediate Occupancy" seismic drift and damage criteria. The proposed solution offers two comparable structural steel moment frames: one which is designed as a traditional steel moment frame, and a second which is designed as a traditional steel moment frame meeting the code-minimum "S-3 Life Safety" seismic drift and damage criteria augmented with viscous fluid dampers to meet S-1-B criteria. A geotechnical report has been obtained for a site on the CSUN campus which is similar to the site in the Northeast USA. This geotechnical report will be used for all design at the Northridge, CA site.

The design will follow a logical progression. First, a steel moment frame for the S-3 criteria will be developed for the current location (Northeast USA) for comparison purposes between the required lateral system for a seismic and non-seismic region. Then, a steel moment frame for the S-3 criteria will be designed in the Northridge, CA location to serve as the basis for the two proposed solutions. Members in this S-3 frame will be increased in size to create the traditional steel moment frame meeting S-1-B criteria. Finally, the S-3 moment frame at the Northridge, CA site will be augmented with horizontal viscous fluid dampers on concentric steel braces to reduce seismic drift and damage below the acceptable limits for S-1-B design.

In addition to this structural depth, two breadth studies will also be conducted. The first will be a construction management breadth which will consist of a schedule and a detailed cost analysis for the steel structural systems which will be designed. This will assist in the comparison of the steel systems. A sustainability breadth will also be undertaken which will assess the viability of adding solar photovoltaic panels or a green roof to the AHU Mechanical Room Roof at the Northridge, CA location. Practicality of both systems will be determined based on cost of the system, savings as a result of using the system, additional LEED points, a life cycle assessment, a carbon footprint, and a payback period.

The MAE coursework incorporated into the proposed designs, the methods through which these designs will be achieved, the tasks required to complete them, and the tools which will be used are also discussed in this proposal. Finally, a schedule is enclosed to ensure work will be completed by the deadline.

## Building Introduction

The University Sciences Building (USB) is a new building located on an urban university campus in the Northeast USA. The site chosen was previously a parking lot serving adjacent campus buildings (See Figure 1). However, the USB provides a much more appealing image on this busy street corner. It is a departure from typical campus architecture in both material usage and architectural style. However, these differences serve as a visible indication of the university's new commitment to building sustainable, functional buildings.

While most other campus buildings have brick facades with narrow, strip-like windows, the USB is clad largely in a prefabricated natural stone panel with aluminum-honeycomb back-up, which enables the façade to be very light. Seemingly in homage to the surrounding buildings, the USB also utilizes tall, narrow windows. However, they are of varying widths and placement on the building, which adds interest to the façade (See Figure 2). An additional feature is the 5 story atrium that forms the core of the building. It provides significant focal points such as a sweeping spiral staircase and a four-story "biowall," the first of its kind on a US university campus (See Figure 3). The biowall is used to help mitigate air quality within the building, and it is just one of many features that will help to earn the building a LEED Silver rating upon completion.

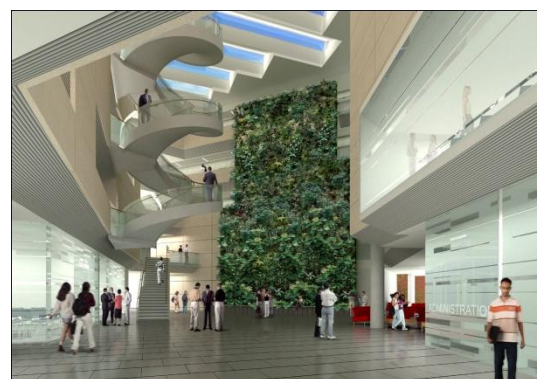
The USB is a multi-use building, incorporating four large lecture-hall style classrooms, an auditorium, several teaching and research laboratories, and faculty offices. It locates the large classrooms and administrative functions on the ground floor of the building for easy public access, but removes the laboratories and offices to the upper four stories for additional privacy. Including the mechanical penthouse, the building stands 94'-3" above grade with a partial basement. It provides the university with 138,000 square feet of new space, and has a construction cost of approximately \$50 million. Construction began in August of 2009, and has an expected completion date of September 2011.



**Figure 1** Aerial map from Google.com showing the location of the building site.



**Figure 2** Exterior rendering showing the stone façade and variation of windows on the USB.



**Figure 3** Interior rendering of the atrium.

## Structural Overview

The University Sciences Building rests on drilled concrete caissons ranging in diameter from 36" to 58" capped by caisson caps and then grade beams. The lower five floors utilize a voided filigree slab and beam system with cast-in place concrete columns. The mechanical penthouse, however, uses steel columns and floor framing. The lateral system consists of several shear walls spanning from ground to various heights. Masonry infill walls are used between columns on the lower floors to help dampen sound from the surrounding urban environment. These non-structural walls are used solely as back-up walls to support the cladding, and were not a part of this technical report, but their design is an important consideration.

The importance factors for all calculations were based on Occupancy Category III. This was chosen because the USB fits the description of a "college facility with more than 500 person capacity," which requires Occupancy Category III.

### Foundations

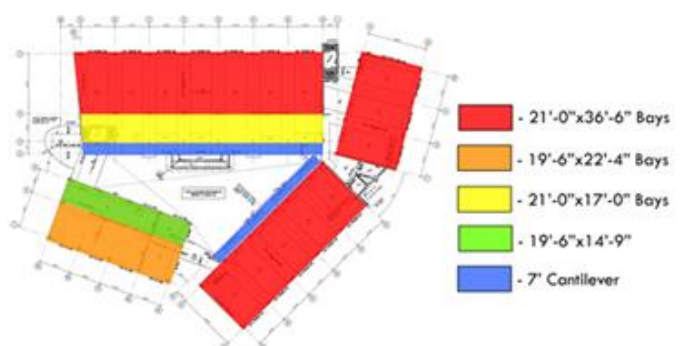
Geosystems Consultants, Inc. performed several test borings on the proposed site of the USB in October 2007. They found that the subsurface conditions consisted largely of extremely loose brick and rubble fill, followed by alluvium and finally residual soils with relatively low load-bearing capabilities. However, comparatively intact bedrock was encountered approximately 25 feet to 34 feet below the surface of the site.

In light of these conditions, traditional shallow spread footings would not be acceptable. Both driven steel H-piles and drilled caissons were considered as options for deep foundations, but H-piles were rejected due to vibration concerns within the subway station adjacent to the site, as well as noise concerns for the surrounding academic buildings. Instead, drilled caissons ranging in diameter from 36" to 58" were chosen to carry the loads from grade beams to the bedrock below. It was also recommended that the fill under the slab on grade (SOG) comprising the majority of the first floor be removed to a level of approximately 4 feet below the surface, followed by heavy compaction of subsurface materials, and then backfilled with structural fill to minimize settlement of the SOG due to the extremely poor load-bearing capacity of the brick/rubble fill.

Lastly, groundwater observation wells were installed, and groundwater was found to be present approximately 13 feet to 18 feet below the surface of the site. This is a potential concern, because some of the basement walls are 14 feet underground, and could encounter some loading due to hydrostatic pressure, particularly in seasons where the groundwater table rises due to rain. This was not evaluated in this technical report, but is a consideration for future design.

### Floor Systems

Although it may not appear so upon first glance at the very irregular shape of the building, the bay sizes are relatively consistent throughout the USB. It simply rotates the bays as necessary to accommodate the different rotations of the wings of the building. Figure 4 shows a typical floor plan with the different bay sizes highlighted with different colors. The legend lists the bay sizes with the span required for the slab first, and then the span required for the girder (if one is present).

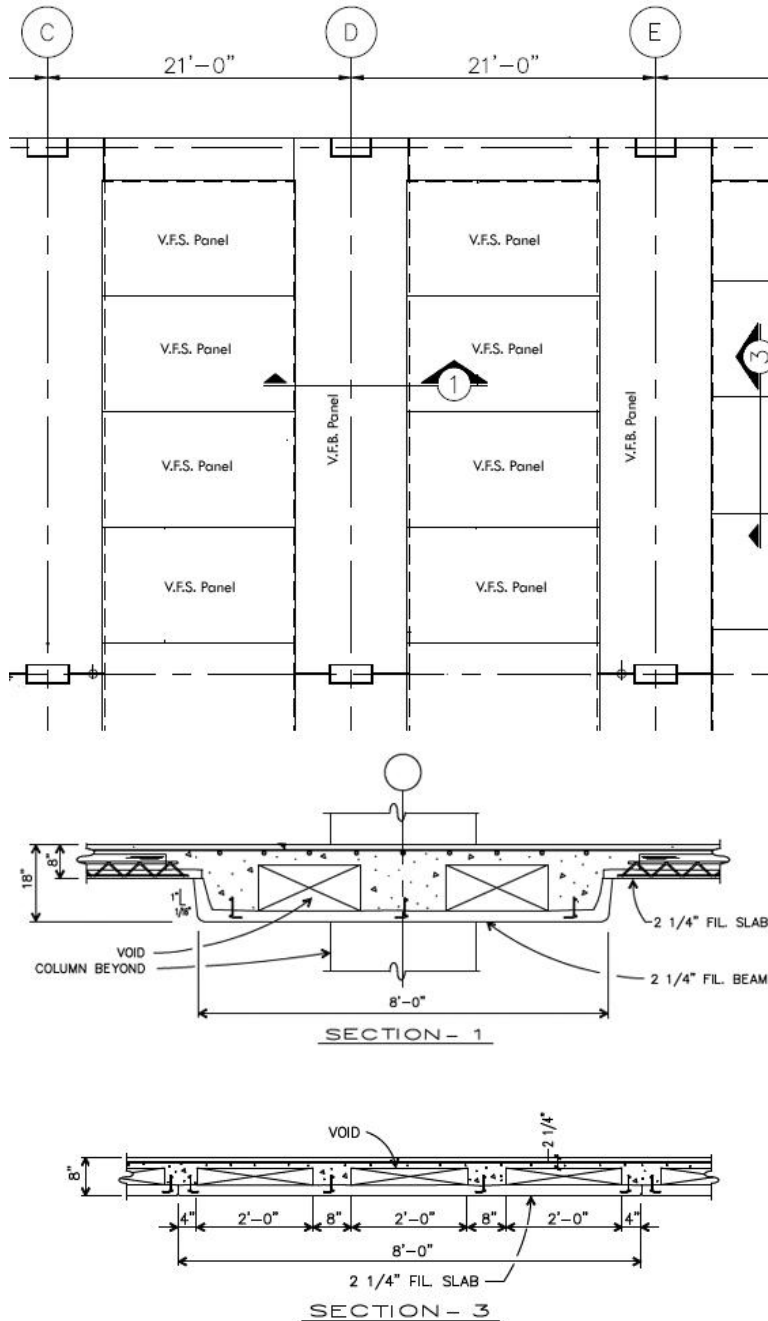


**Figure 4** Floor plan from Sheet S203 showing typical bay sizes.

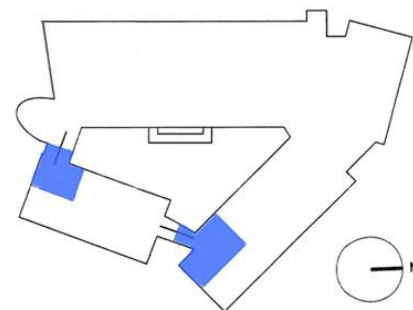
All of the elevated floors of the USB are a voided filigree system. This is a hybrid of precast, prestressed concrete and cast-in-place concrete. In essence, it consists of 2 1/4" of precast, prestressed concrete that functions as leave-in formwork. This is assembled and shored on site, followed by the placement of top and additional bottom reinforcing (if required, placed on rebar chairs on the bottom of the precast), and then further concrete is cast in place to unite the system. To help reduce the weight of the structure,

polystyrene voids are incorporated where the concrete is not required for structural strength. Wire joists referred to as "filigree trusses" are used to transfer horizontal shear over the cold joint between precast and cast-in-place concrete.

Three separate systems were used, depending on the required spans and uses. For areas that include a span above 36 feet (typically laboratories), an 8" voided filigree slab (V.F.S.) was used to span between 18" deep voided filigree beams (V.F.B.). A schematic layout of this type of system, used in the majority of the building, is shown in Figure 5. In the Office Wing (shown in Figure 4 in green and orange), where shorter spans were allowed, the beams were removed from the system and the slab was thickened to 10 inches total depth. However, the cross section of this slab remains similar to the condition shown in the "Section 3" within Figure 5. Lastly, in the two "links" (shown in Figure 6), this flat plate is thickened to 12 inches total depth, again with a similar condition to "Section 3" in Figure 5. These links are the uniting elements in the building, and had to be cast last on every floor. These are united to the building with rebar across the cold joint rather than an official expansion joint.



**Figure 5** Typical bay with section cuts showing the condition within the beam and the slab. Modified from the filigree slab shop drawings and not to scale (NTS).



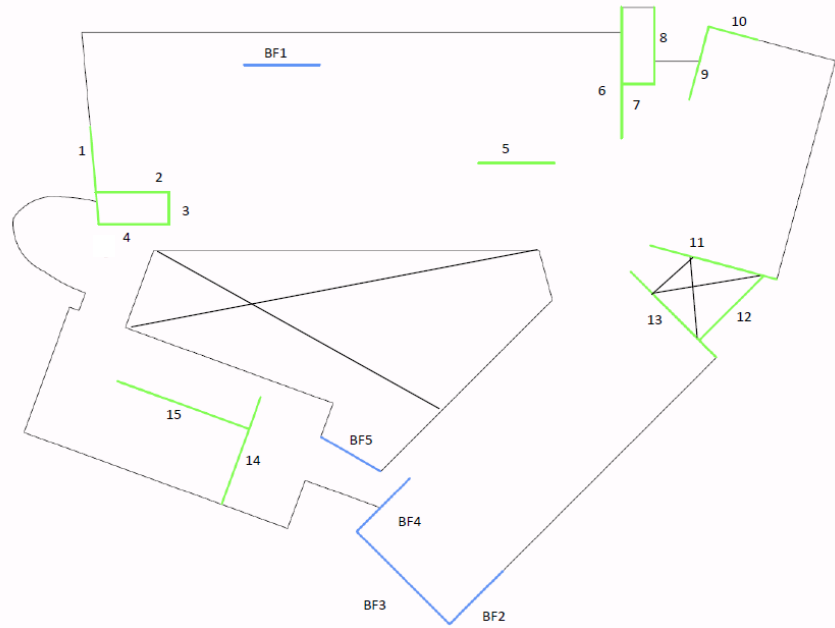
**Figure 6** Modified keyplan from Sheet S202 showing the "link" areas in blue.

## Framing System

The columns in the lower five stories of the USB are all cast-in-place concrete. The columns closest to the atrium on the ground floor are round columns 2 feet in diameter. Most are changed at the second level to 36"x16" rectangular columns. All other columns are 36"x16" columns, rotated as required to fit into walls. At the penthouse level, the columns change to A572 steel W-shapes. These columns range in size from W8x40 to W8x67.

## Lateral System

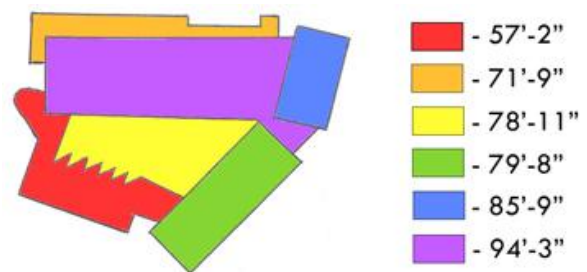
Shear walls are the main lateral force resisting system in the USB. They are scattered throughout the building to best resist the lateral forces in the building (See Figure 7). All of these walls are 12" thick cast-in-place concrete. Most span from ground level to the roof, but since roof heights vary, they are not necessarily the same height. They are anchored at the base by grade beams that run the full length of the walls. Above the concrete-to-steel transition are also five braced frames (see Figure 7). These are extremely important in resisting the lateral forces on some of the roof levels.



**Figure 7** Typical floor plan simplified from Sheet S203. Shear walls indicated in green, braced frames indicated in blue. All elements have been labeled for ease of reference.

## Roof Systems

There are six different roofs on the USB, due mostly to architectural reasons. Figure 8 shows these roofs and their heights above the ground reference elevation of 0'-0". The Office roof (shown in red) is at the same elevation as the fifth floor. Its structure is a 10" flat plate filigree slab system, similar to the office floors below it. The "Ledge" roof (shown in orange) is at the same level as the Penthouse floor, and is a continuation of the 10" V.F.S./24" V.F.B. system used in the adjacent AHU Mechanical Room. The atrium roof, 5<sup>th</sup> Level Mechanical



**Figure 8** Modified keyplan image from Sheets S205, & S206 showing different roof heights in relation to 0'-0"

Room roof, and AHU Mechanical Room roof (shown in yellow, green, and purple, respectively) are all 3" P2404 Canam roof deck on steel W-shape framing. The Chiller Mechanical Room roof (shown in blue) is 3" of cast-in-place concrete topping on 3" P2432 Canam composite deck (6" total depth) supported by W-shape framing. This heavier structure is necessary because this roof supports two large cooling towers and a diesel generator. This roof is also the only one with a parapet, which serves as a screen to hide the mechanical equipment and stretches from this roof level to 94'-3".

Regardless of the underlying structure, all roofs receive the same finish. This consists of sloped rigid insulation under Thermoplastic-Polyolefin (TPO) single-ply membrane.

## Problem Statement

As it is designed, there is very little that could be done to the USB to improve it. All structural systems are adequate in strength and reasonable in comparison to typical alternatives. Redesigning the building as a different concrete system (such as the post-tensioned concrete slab with wide-shallow beams considered in Technical Report 2) would produce minimal differences. In its current location, significant reduction of building weight (such as redesigning the building in steel) would also cause wind forces to control the lateral design instead of seismic forces. The author of this proposal is extremely interested in seismic design because it is one of her career goals to work on the west coast. Therefore, having wind forces control the lateral design was an undesirable condition.

Therefore, a scenario has been created in which the California State University, Northridge (CSUN) is requesting the design and construction of a building identical to the University Sciences Building. The CSUN campus is essentially located on top of the Northridge fault, a fault line which produced the disastrous Northridge Earthquake in 1994. It will have significant seismic demands which will far exceed the wind force requirements. The geotechnical report for a site on the CSUN campus has been secured, and will be used for all design. The site is located on the corner of two major streets, and is similar in dimensions and proximity to existing buildings to the original site of the USB.

Also, in the last decade, a major movement in building design has been to improve the performance of buildings above the minimum design requirements without significant cost impacts. Therefore, the owner in the proposed scenario has requested the building be designed for a FEMA Structural Performance Level of "S-1-B Immediate Occupancy" to ensure the university will be able to have immediate access to their facilities following an earthquake with only potential minor damage to non-structural components. A comparison of the requirements for S-1-B requirements and the more traditional "S-3 Life Safety" requirements can be found in Figure 9, taken from FEMA 356.

Therefore, a viable structural system must be designed to provide sufficient strength and serviceability resistance to achieve an S-1-B structural performance level (as defined in FEMA 356) when resisting all dead loads, live loads, and seismic loads with as little negative impact as possible to the architecture, cost, and schedule of the building as it is currently designed.



**Table C1-3 Structural Performance Levels and Damage<sup>1, 2, 3</sup>—Vertical Elements (continued)**

Elements	Type	Structural Performance Levels		
		Collapse Prevention S-5	Life Safety S-3	Immediate Occupancy S-1
Concrete Walls	Primary	Major flexural and shear cracks and voids. Sliding at joints. Extensive crushing and buckling of reinforcement. Failure around openings. Severe boundary element damage. Coupling beams shattered and virtually disintegrated.	Some boundary element stress, including limited buckling of reinforcement. Some sliding at joints. Damage around openings. Some crushing and flexural cracking. Coupling beams: extensive shear and flexural cracks; some crushing, but concrete generally remains in place.	Minor hairline cracking of walls, <1/16" wide. Coupling beams experience cracking <1/8" width.
	Secondary	Panels shattered and virtually disintegrated.	Major flexural and shear cracks. Sliding at joints. Extensive crushing. Failure around openings. Severe boundary element damage. Coupling beams shattered and virtually disintegrated.	Minor hairline cracking of walls. Some evidence of sliding at construction joints. Coupling beams experience cracks <1/8" width. Minor spalling.
	Drift	2% transient or permanent	1% transient; 0.5% permanent	0.5% transient; negligible permanent
Steel Moment Frames	Primary	Extensive distortion of beams and column panels. Many fractures at moment connections, but shear connections remain intact.	Hinges form. Local buckling of some beam elements. Severe joint distortion; isolated moment connection fractures, but shear connections remain intact. A few elements may experience partial fracture.	Minor local yielding at a few places. No fractures. Minor buckling or observable permanent distortion of members.
	Secondary	Same as primary.	Extensive distortion of beams and column panels. Many fractures at moment connections, but shear connections remain intact.	Same as primary.
	Drift	5% transient or permanent	2.5% transient; 1% permanent	0.7% transient; negligible permanent

**Figure 9** Comparison of performance requirements for different Structural Performance Levels for Concrete Walls and Steel Moment Frames, taken from FEMA 356.

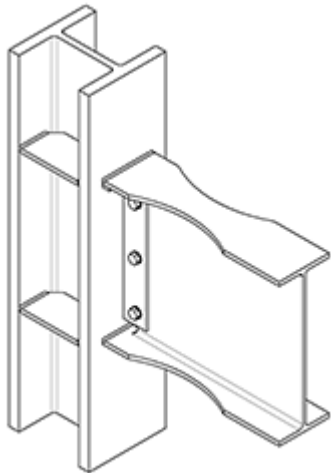
## Proposed Solution

Two solutions have been proposed for comparison, both in steel. As this is a different construction type than the original design, the gravity system shall be redesigned first. Upon completion of a suitable gravity system, the building will be designed for two lateral systems complying with the S-1-B requirements:

- Traditional steel moment frame
- Traditional moment frame designed for S-3 requirements augmented with viscous fluid dampers (VFD's)

For comparison purposes, a traditional steel moment frame for the loads in the present location (Northeast USA) and S-3 requirements will also be designed.

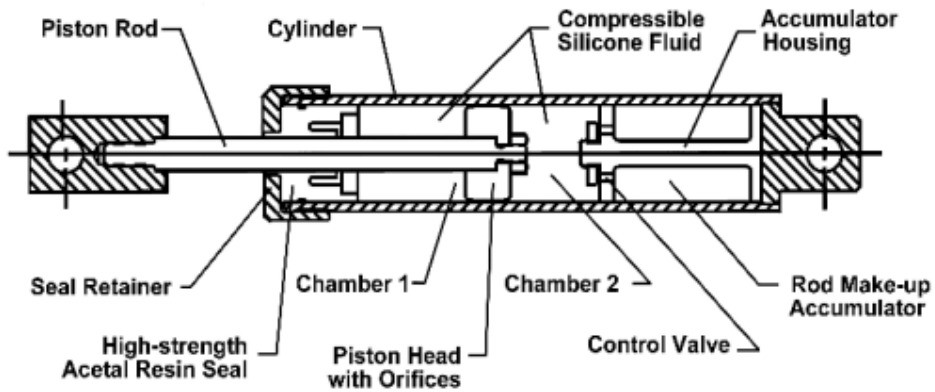
In earthquakes, buildings are typically designed to fail at predicted locations in an expected manner, also known as “plastic design”. In traditional steel moment frame design, this is most commonly accomplished by reducing the cross-section of the beam near the moment connection as shown in Figure 10, also known as “dog bones.” These dog bones provide a weak location for plastic hinges to form, causing the structure to yield slightly and increase its ductility. Although effective, plastic design can lead to permanent deformations of a building in a strong earthquake, which means a building may have to undergo expensive repairs. In keeping with the performance-based design trend in the industry, many designers are now seeking a solution which will reduce or eliminate this concern.



**Figure 10** Image of a reduced beam section used in seismic design, from an article in *Modern Steel Construction*.

One such solution is the use of hysteretic dampers. These are a range of different devices which deform in response to an applied load or acceleration, thereby creating a weak point in the structure. However, as these dampers provide some resistance to deformation, they also help to damp (or reduce) deflections caused by sudden motion, thereby decreasing both structural and non-structural component damage. Some of these dampers must be replaced following an earthquake as they will undergo permanent deformation, whereas others are able to deform without permanent damage to the damper. The most practical of these is the viscous fluid damper, or VFD, which will not undergo permanent deformation due to an earthquake provided they are designed adequately.

VFD's, an example of which can be seen in Figure 11, are similar to the closures on fire doors. The fluid inside the damper provides resistance whenever the building experiences sudden accelerations, such as those induced in an earthquake. As the piston is depressed or retracted, fluid flows through the orifices in the piston head. The viscosity of the fluid provides resistance to this motion, thereby reducing the distance which the piston moves. Subsequently, the displacement of any object attached to the piston is also reduced.



**Figure 11** Image of the interior of a viscous fluid damper (VFD), taken from Taylor Device's website.

The chosen configuration for the VFD's can be seen in Figure 12. This was selected because simple static equilibrium dictates that the dampers are most effective at resisting horizontal displacements when they are placed horizontally. The top connection of concentric steel brace is designed as a sliding connection, which enables the dampers to engage when the frame deflects. The braces add negligible stiffness to the structure, instead acting purely as a connecting element to integrate the dampers into the system.



**Figure 12** Image of chosen VFD configuration, taken from Taylor Device's website.

## Breadth Topics

### **Construction Management – Cost and Schedule**

The main purpose of the construction management breadth is to develop a cost and schedule for the original structure as well as both of the proposed steel structures for comparison purposes. Key comparisons will be: which system (concrete or S-3 steel moment frame) is more efficient for the Northeast USA site, how much additional cost is accrued in moving the S-3 frame from a non-seismic region to a high seismic region, how much cost results from designing for a higher performance rating, and which S-1-B system is more efficient.

Of particular interest is the comparison between the traditional moment frame and a moment frame incorporating VFD's. A common perception in the industry is that more technology increases efficiency. A direct cost and schedule comparison between the traditional and high-tech systems of equal performance will either support or disprove this belief. Because the structures will be designed to equal performance levels, the structure which is able to be constructed more quickly and at the least cost will be deemed the most efficient.

The schedule analysis must be performed first, as some items in the cost are dependent on construction duration. Schedules will be developed using faculty advice and the author's personal knowledge. Costs will include structural components, general conditions items, and any upcharges additional architectural features (such as drop ceilings or additional façade) which will be required as a result of the redesign. These will be determined using a detailed take-off of materials in typical bays and cost data from RS Means.

### **Sustainability – Viability Study**

Most industry professionals are now at least familiar with the sustainability ranking system produced by the United States Green Building Council (USGBC) known as LEED (which stands for Leadership in Energy and Environmental Design). This system allocates a certain number of points to various technologies or design practices which are deemed to be sustainable. At certain point totals, the building can earn LEED ratings to indicate how sustainable it is. However, there are some industry professionals that feel that LEED is not a fair evaluation of a building's sustainability because it encourages spending on so-called "green" technology without considering the full picture of the product's costs. These professionals advocate the use of other sustainability measurement methods, such as life cycle assessments, carbon footprints, and payback periods.

The life cycle assessment (LCA) takes into account the cost of the product under consideration over the life of the product. It is important to carefully define the "life" of the product to ensure fair comparisons are being made by designers. A carbon footprint (CF) of a product accounts for the carbon produced in the production, transportation, installation, and maintenance, and demolition/recycling of the product under consideration. A standard exists for how a life cycle assessment and a carbon footprint analysis should be conducted. This document, the Ecological Footprint Standard 2009, is published by the Global Footprint Network.

Payback periods (PP's) are simply a number which relates how much a premium product costs to how much it saves in comparison to a standard product. This is achieved by expressing how long it will take for the savings due to the premium product to equal the additional cost of the product. There is no standard governing the calculation of a payback period because there is only one way to calculate it.

As it is presently designed, the USB aims to achieve a LEED Silver rating. In the Northeast USA, which is characterized by fewer days of sun per year and long, cold winters, technologies such as green roofs and solar photovoltaic panels may have been deemed impractical and therefore not included in the building design. However, upon relocating the building to California, both of these systems may become viable. The proposed breadth study is to evaluate the viability of including solar photovoltaic panels (PV's) or a green roof on the AHU Mechanical Room Roof on the redesigned steel structure in Northridge, CA. The criteria on which the viability of these systems will be evaluated includes system cost (both for the system itself and additional costs accrued for structural/MEP/schedule changes associated with incorporating the system), the monetary savings per year, the number of additional LEED points the system will earn, a life cycle assessment, a carbon footprint, and a payback period.

### **MAE Material Incorporation**

Much of the calculation of the proposed redesign will draw upon material learned in MAE courses. Computer modeling techniques as taught in AE 597A – Computer Modeling will be an integral tool in the completion of this redesign. Concepts such as insertion points, rigid diaphragm constraints, panel zone modeling, property modifiers, and modal analysis results determination were taught for ETABS and SAP 2000. These skills will be applied to ETABS and potentially SAP as well as extrapolated to assist with modeling in RAM Structural System, which was not taught in depth AE 597A.

The design of the steel moment frames and VFD's will rely heavily on material presented in AE 538 – Earthquake Design. The limitations and requirements for a steel special moment frame and the procedures used to implement performance-based design will be of particular use.

Finally, coursework from AE 534 – Steel Connections will be integrated into the design of representative beam-to-column moment connections, damper-to-column connections, and concentric steel brace sliding connections. Although the beam-to-column moment connection is the only one of the three mentioned which was specifically taught in the class, the information presented regarding typical limit states will be extrapolated to design reasonable connections for the other two conditions.

## Methods

The study will begin with a gravity system redesign in steel in compliance with the AISC steel manual. This will incorporate the original superimposed dead load and live loads of the building. Typical bays in each wing at the 2<sup>nd</sup>, 5<sup>th</sup>, and Penthouse Levels will be designed by hand to minimize the increase in structural depth in comparison to the existing structure. These preliminary sizes will be input into RAM Structural System, and a verification of gravity strength will be performed on all members. RAM will be used to optimize the structure where possible. Finally, gravity footings will be designed for the new loads using the allowable bearing capacities given in the geotechnical report.

Upon completion of the gravity system, the lateral system will be considered. For comparison purposes, a steel moment frame meeting the S-3 criteria will be designed to resist the controlling lateral loads at the existing location. This will require the calculation of seismic forces for the steel gravity system in the existing location using ASCE 7-05. These seismic loads will then be compared to the wind loads calculated for the existing location in Technical Report 3. Once the controlling load case is established, moment frames will be designed using the AISC steel manual if wind loading controls (most likely scenario) or the AISC 341-05 (Seismic Provisions for Structural Steel Buildings) if seismic loading controls. Moment frame layout will be established such that the moment frames are continuous throughout the height of the wing in which the frame is located and there is sufficient length of frames in each wing to resist the applicable lateral forces. Gravity foundations will be resized as required under moment frames to resist any additional forces induced by lateral loading, including uplift.

The building will then be relocated to Northridge, CA. New seismic and wind loads will be calculated according to ASCE 7-05 to verify seismic loads are the controlling lateral case. The moment frame will then be designed to resist these seismic loads according to the code minimum S-3 criteria. Plastic design will be the basis for this design, and is governed by AISC 341-05. However, for a site in California, the requirements of Title 24 (the California Code of Regulations) will also have to be considered.

Once the layout of the S-3 moment frames has been optimized, members will be increased in size as required to achieve a design which complies with S-1-B requirements. Finally, the moment frame design meeting S-3 criteria will also be fit with a VFD system to reduce drift below S-1-B design requirements, thereby alleviating some of the strain on the structural system and reducing structural damage below the S-1-B design limits. All design calculations will be performed for a representative frame by hand. AISC 341-05 will dictate the requirements for the traditional moment frame, whereas the design of the VFD's will be controlled by Chapter 18 in ASCE 7-05. The remaining frames will be designed in a finite element modeling program, such as RAM or ETABS. It is likely that RAM will be used for the traditional frame modeling, whereas ETABS will be used for the frame including VFD's. This choice was made because ETABS has predetermined elements which model the behavior of VFD's, which will significantly reduce any error in attempting to model these elements.

Upon completion of the linear analysis, a single non-linear analysis will be performed on both the S-1-B moment frame and the S-1-B moment frame with VFD's using a finite element software program, such as ETABS. This will include a time history load mimicking the accelerations induced in an actual earthquake typical for the region around Northridge, CA. This will serve as verification of the linear analysis which composes the bulk of the design.

## Tasks and Tools

### **Depth – Traditional Steel Moment Frame vs. Steel Moment Frame Incorporating VFD's**

#### *Task 1: Design steel gravity system*

- Determine slab/deck size based on loading established in the original structural drawings
- Size beams/girders/columns in typical bays by hand for required loading, serviceability concerns, and structural depth limitations using AISC steel manual
- Use finite element software (likely RAM) to model gravity system and optimize as required
- Design gravity footings using bearing capacity given in geotechnical report and applicable provisions from ACI 318-08

#### *Task 2: Design S-3 Moment Frame (Northeast USA)*

- Recalculate Equivalent Lateral Force seismic loads according to ASCE 7-05, compare to Main Wind Force Resisting System wind loads
- Create moment frame layout to minimize torsion, irregularities, and architectural impacts
- Size beam/column in a representative frame by hand for controlling lateral loads
- Use finite element software (likely RAM) to model/design remaining frames

#### *Task 3: Design S-3 Moment Frame (Northridge, CA)*

- Recalculate Equivalent Lateral Force seismic loads and Main Wind Force Resisting System wind loads according to ASCE 7-05, verify seismic loading controls
- Size beam/column in a representative frame by hand according to AISC 341-05
- Use finite element software (likely RAM) to model/design remaining frames

#### *Task 4: Design S-1-B Moment Frame (Northridge, CA)*

- Size beam/column/connection in a representative frame by hand according to AISC 341-05 for reduced allowable drift
- Use finite element software (likely RAM) to model/design remaining frames
- Verify damage and deflection criteria are met for S-1-B rating as given in FEMA 356.
- Resize foundations for additional forces, including uplift, as required using bearing capacity given in geotechnical report and applicable provisions from ACI 318-08

#### *Task 5: Design S-1-B Moment Frame with VFD's (Northridge, CA)*

- Become familiar with provisions for the design of structures incorporating dampers, as given in ASCE 7-05 Chapter 18, select design method
- Calculate seismic loads as required for selected design method using Ch. 18 of ASCE 7-05
- Size damper/brace as required for AISC 341-05
- Model system in a finite element program (likely ETABS) to verify adequacy of system
- Verify damage and deflection criteria are met for S-1-B rating as given in FEMA 356.
- Design a representative sliding connection at top of concentric steel brace and damper-to-column connection for required forces according to the AISC steel manual
- Resize foundations for additional forces, including uplift, as required using bearing capacity given in geotechnical report and applicable provisions from ACI 318-08

#### *Task 6: Non-Linear Analysis*

- Locate a time history record for an appropriate earthquake
- Apply time history loading to models of both S-1-B systems as created in a finite element program (likely ETABS) and perform non-linear analysis
- Compare results to linear results

**Breadth 1 – Construction Management: Cost and Schedule Analysis***Task 1: Material Take-off*

- Use typical bays to determine material quantities required

*Task 2: Schedule Analysis*

- Research typical productivity rates, likely via RS Means
- Produce schedule for structural activities for each structural system using a scheduling program such as Microsoft Project

*Task 3: Cost Analysis*

- Research typical unit costs (RS Means or vendor)
- Produce cost estimate for each structural system and any additional architectural components required, likely using Microsoft Excel

**Breadth 2 – Sustainability: Viability Study***Task 1: Obtain/Determine Original LEED Point Breakdown*

- Contact project team for original point breakdown
- If not obtained by 1 week prior to the beginning of Task 2 of Breadth 2, attempt to determine using LEED Rating System Documentation

*Task 2: Solar Photovoltaic Panels Design and Assessment*

- Research typical PV system types using faculty advice and reputable websites
- Choose a system type
- Contact vendor to determine cost/energy savings of a typical system
- Identify standards governing system design using faculty advice, previous research, or professional discussion board
- Design the system using any applicable standards
- Determine additional costs associated with increased structure/MEP/schedule requirements
- Perform life cycle assessment meeting the requirements outlined in the Ecological Footprint Standards 2009 (published by Global Footprint Network)
- Perform carbon footprint analysis meeting the requirements outlined in the Ecological Footprint Standards 2009 (published by Global Footprint Network)
- Determine payback period

*Task 3: Green Roof Design and Assessment*

- Research typical green roof types using faculty advice and reputable websites
- Choose a system type
- Contact vendor to determine cost/energy savings of a typical system
- Identify standards governing system design using faculty advice, previous research, or professional discussion board
- Design the system using any applicable standards
- Determine additional costs associated with increased structure/MEP/schedule requirements
- Perform life cycle assessment meeting the requirements outlined in the Ecological Footprint Standards 2009 (published by Global Footprint Network)
- Perform carbon footprint analysis meeting the requirements outlined in the Ecological Footprint Standards 2009 (published by Global Footprint Network)
- Determine payback period



# Schedule

The University Sciences Building - Northeast USA		Proposed Spring Semester Thesis Schedule																																			
Kathryn Gromowski   Structural Option		Faculty Advisor: Dr. Andrés Lepage Submitted: 12/10/10																																			
Milestone 1:	Milestone 2:	Milestone 3:	Milestone 4:																																		
1/28/11	2/14/11	2/28/11	3/25/11																																		
1/10/2011	1/17/2011	1/24/2011	1/31/2011	2/7/2011	2/14/2011	2/21/2011	2/28/2011	3/7/2011	3/14/2011	3/21/2011	3/28/2011	4/4/2011	4/11/2011	4/18/2011	4/25/2011																						
Design Steel Gravity System		Design SMF, S-3 Criteria (NE USA)		Design SMF, S-3 Criteria (Northridge, CA)		Design SMF, S-1-B Criteria (Northridge, CA)		Design SMF with VFD's, S-1-B Criteria (Northridge, CA)		Perform Non-Linear Analyses		Depth Write-Up		Obtain Existing Cost/Schedule Information		Quantity Take-Off for Steel Designs		Create Schedules for Steel Designs		Determine Costs for Steel Designs		Breadth 1 Write-Up		Breadth 1 Write-Up		Solar PV Design and Assessment		Green Roof Design and Assessment		Breadth 2 Write-Up		Final Report Organization/Editing		Final Presentation Creation and Preparation		ABET Evaluation and CPEP Finalization	
Senior Banquet on April 29th, 2011		Faculty Jury Presentations		Final Reports Due April 7th, 2011																																	

Milestones
1- Gravity frame and code minimum (S-3) moment frame design (both locations)
2- All linear/by-hand structural calculations
3- Cost and schedule of all systems considered
4- Sustainability System Design

Depth Study - Traditional SMF vs. SMF w/ VFD's
Breadth 1 - CM: Cost & Schedule Analysis
Breadth 2 - Sustainability; Viability Study

## Conclusion

The proposed redesign of the USB focuses on building performance and efficiency while creating a viable solution for the building's structure in steel. It is expected that changing construction material from primarily concrete to all steel will cause seismic forces to no longer control the building design. Therefore, it is proposed that the building be moved to a site on California State University, Northridge's (CSUN's) campus. Following the design of a steel gravity system, four steel lateral systems will be considered: a code-minimum Life Safety (S-3) criteria steel moment frame at the Northeast USA site, an S-3 criteria steel moment frame at the Northridge, CA site, a steel moment frame using performance-based design for Immediate Occupancy (S-1-B) criteria at the Northridge, CA site, and a steel moment frame designed for S-3 criteria augmented with viscous fluid dampers to achieve S-1-B criteria at the Northridge, CA site.

A construction management breadth focusing on creating a schedule and detailed estimate for the structural systems will facilitate comparison of the structural systems. Of particular interest are: which system (concrete or S-3 steel moment frame) is more efficient for the Northeast USA site, how much additional cost is accrued in moving the S-3 frame from a non-seismic region to a high seismic region, how much cost results from designing for a higher performance rating, and which S-1-B system is more efficient.

Lastly, a sustainability viability study will be conducted for the addition of solar photovoltaic panels or a green roof to the AHU Mechanical Room Roof upon moving the building to California. While both technologies may not be feasible in the Northeast USA, it is possible that the additional sun and the lack of a winter season in southern California will result in either or both system being deemed practical. To achieve a complete picture of sustainability, both systems will be assessed based on cost of the system, savings as a result of using the system, additional LEED points gained, a life cycle assessment, a carbon footprint, and the payback period of each system.