

Ryan L. Solnosky's Research, Teaching, and Creative Portfolio

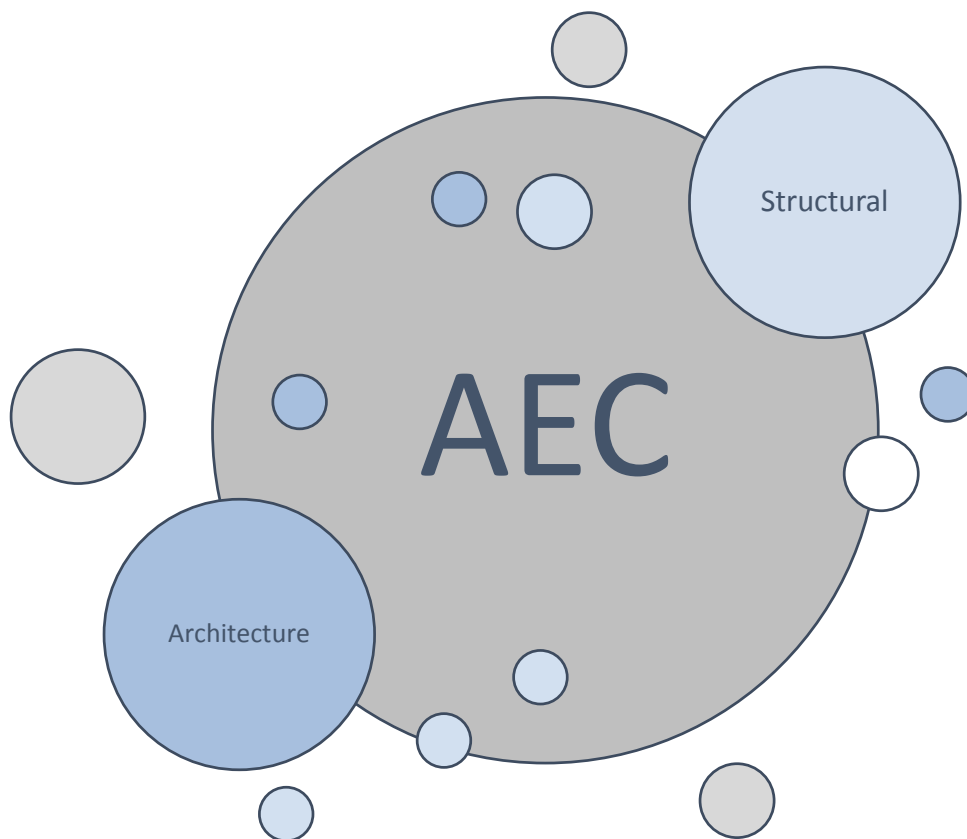


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Research Focus

This section provides a sampling of research work I had the opportunity to partake in.

Teaching Focus

This section provides a sampling teaching work I had the opportunity to partake in with architectural students.



Research Material



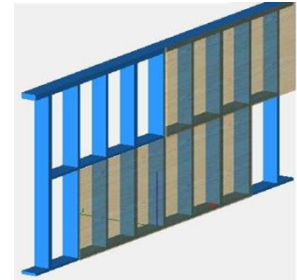
Shear wall Opportunities in Residential Construction

Duration: 7/1/2014-6/31/2015

Funder: [Pennsylvania Housing Research Center \(PHRC\) \(Seed Fund\)](#)

Investigators: [Ryan Solnosky](#)

Outcomes: [TBD](#)



Background

Current building codes and standards for residential construction are complex and easily misunderstood when it comes to the requirements pertaining to wood shear walls. Whether they are engineered or prescriptive the design intent has the potential to be lost resulting in improper construction of walls that can lead to poor performance and failure (both aesthetically and structurally). This pilot study will cumulate the vast knowledge residential shear walls options, provide comparisons between behavior and design steps, and finally recommend best practices for constructing. The results will give designers and builders a better understanding of the complexity shear wall code provisions and how to go about designing and constructing shear walls through clarifying code intent.

Project Goals

This study's main research goal is to conduct a comprehensive and detailed literature review on the current available opportunities implementing as shear walls in residential homes.



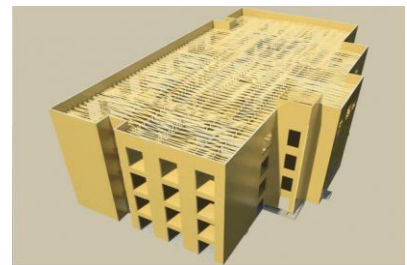
- 1) The possibilities for wind and seismic applications relevant to Pennsylvania will be listed and summarized in a recommendation format.
- 2) The relevant subsections within shear walls for a variety of materials and configurations (panels, backup studs, and nail spacing) will be provided in a manner that builders can easily understand relative to available options.
- 3) Differences between engineered and non-engineered designs will be documented to allow builders to know how designs could differ but also select the method they would prefer.

Essentially, conducted research will provide, step the reader through a process for how to determine design and construction options, relevant code provisions, recommendations for design, and checklists for verifying constructed walls are compliant. Within this, tables, figures, and lists will be leverage to provide comparisons between the options and the procedures that must be followed. The applicability of this research will focus on Pennsylvania loading and construction techniques however, the study will be applicable to other zones with similar lateral loading demands.

Research Plan

To conduct this research, a detailed literature review will be undertaken to look at new trends and existing methods in the design of shear walls and map them to the identified code provisions. The following steps will be performed:

- 1) Conduct a thorough code and standard review of all relevant shear wall provisions for residential construction related to engineered and non-engineered designs.
- 2) Perform a literature review on state-of-the-art techniques not covered by the codes there are beneficial to residential construction.
- 3) Provide a comparison between literature and codes and show what has been done what has not been studied that could be viable.



Wall Systems Collaboration with PHRC in Sustainability and Hazard Performance

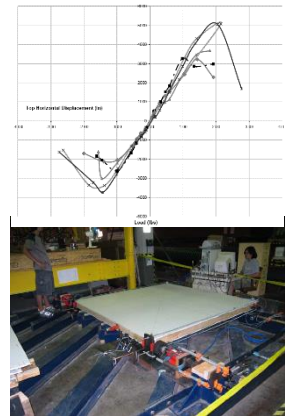
Duration: 7/1/2013- Present

Investigators: Ryan Solnosky as a collaborator with Ali Memari and PHRC

Outcomes: 4 Journals, 1 Conference, 1 Technical Report, and 2 Journals in development

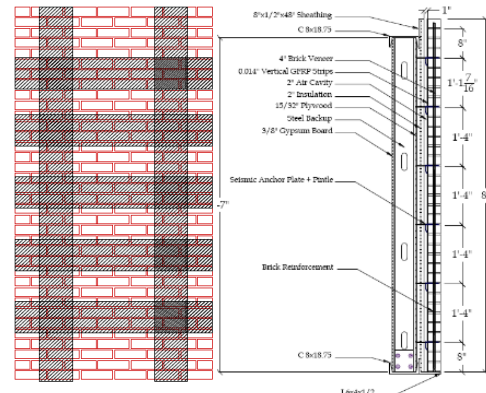
Project I: Wood-Framed Drywall Sheathing Wall Systems

A pilot study was conducted to determine whether the type of drywall joint compound would influence the shear strength of wood-frame stud walls sheathed with Gypsum Wall Board (GWB or drywall). Based on the experimental testing of the specimens, the results show that the use of cement based joint compound on drywall joints produces higher shear capacity for the wall system as compared to similar specimens finished with conventional non-cement based joint compound. The result of the study is particularly important for high seismic regions where interior stud walls in residential construction effectively take part in seismic resistance even though wood shear walls are normally used on exterior walls. This study showed that the type of joint compound finish material can make a difference in the level of over-strength and reserve capacity that interior drywalls could provide to the overall lateral force resistance



Project II: Multi-hazard resistant panelized brick veneer steel stud backup (PBVSS) system

This study investigated a multi-hazard resistant panelized brick veneer with steel stud backup (PBVSS) system capable of being developed off-site with specialized veneer enhancements. The specimens consist composite (GFRP) and spray polyurea. A comparison of specimen test results against a baseline shows that it is possible to successfully reinforce the interior side of brick veneer and they each configuration does provide enhancements into veneer capacity. Beyond the performance of the veneer, the study shows that it is indeed possible to reinforce the interior side of a brick veneer surface if it is constructed in panelized segments in a factory setting.



Project III: Comparative Study of Various Wall Systems' Performance Attributes

This study investigates residential wall systems performance and metrics utilized in design and construction. Although there have been many metrics studied under isolated criteria, there have been limited studies documented in multi-disciplinary metric comparisons of wall systems. The following metric categories have been considered:

- 1) Multi-hazard resistance
- 2) Design and serviceability
- 3) Sustainability

Wall systems examined were: insulated concrete forms, wood-frame, steel stud, structural insulated panels, concrete masonry unit, autoclaved aerated concrete, straw bales, and precast concrete panels.

Table 4: Design and Serviceability Performance Attribute Rating Matrix

Wall Type	Design and Serviceability Attributes				
	Moisture Control	Thermal Resistance	Constructability	Design Flexibility	Skilled Labor
WF	1	1	2	2	1
SS	1-2	1	1-2	2	1-2
SIP	1	2-3	1-2	2	2
PCP	3	2-3	2	3	3
CMU	2-3	2	2	2	2
AAC	2-3	2	2-3	2	2
ICF	3	3	1	2	1
SB	1	3	3	1	2

3-level Moisture, thermal, and flexibility rating are: 1=poor, 2=average, and 3=good

3-level Constructability rating where: 1=Difficult, 2=average, and 3=easy

3-level Skilled labor rating where: 1=minimal, 2=average, and 3=specialty training.

Early Parametric and Generative Design

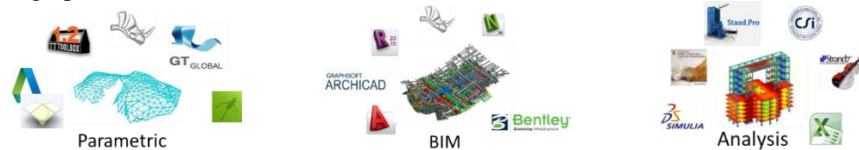
Duration: 7/2013-Present

Investigators: Ryan Solnosky and Thornton Tomasetti

Outcomes: 1 Journal Paper (under review)

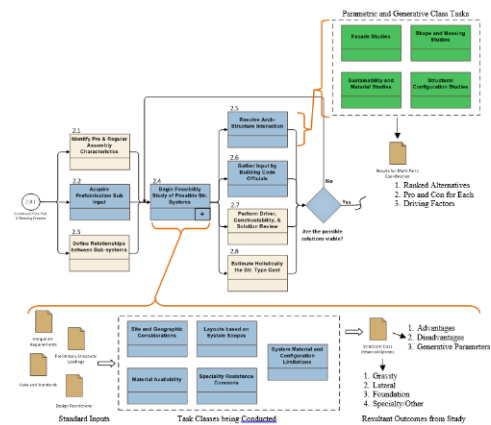
Background

Unusually shaped and sometimes very complex buildings are being sought after by owners around the world. Building now are often are being designed by firms and often must reevaluate and adapt their traditional means and methods in order to determine the fundamental concepts for the building systems. Publicized research to date and many practicing firms have offered little detail on how the process of parametric design in the early phases should be conducted. Furthermore, focus on the modeling details has centered on the algorithms and equations used to solve and generate the alternatives. In close collaboration with Thornton Tomasetti's Advanced Computational Modeling Group has been looking into how parametric and generative modeling technologies and techniques are altering the design process.



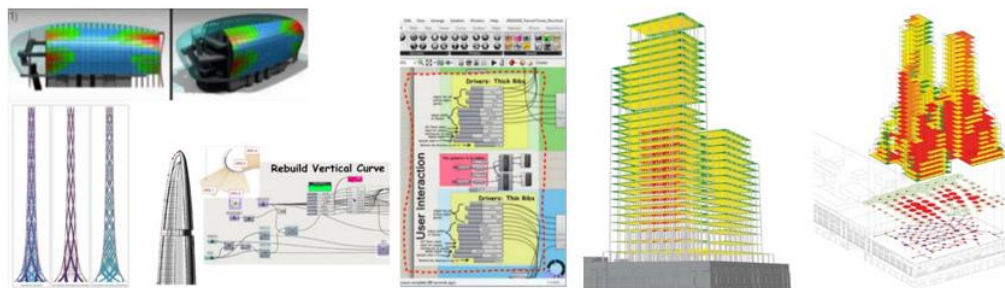
Scope

Publicized research to date has offered little detail on how the process of parametric design in the early phases should be conducted. Furthermore, focus on the modeling details has centered on the algorithms and equations used to solve and generate the alternatives. Little has been published identifying the different building sectors that can use these methods and what variables control. This study looked at how the design process should be conducted and what studies should be done. The research was an accumulation of industry interviews, case study validation, and the researchers' expertise in the subject matter. The resulting focus of this study is on parametric structural studies or studies that have the potential for a structural impact.



Two areas are the focus:

- 1) how these new technologies and techniques are altering the design process and making the workflows more collaborative
- 2) the primary sectors that parametric and generative designs are being used and the parameters



(Courtesy of Thornton Tomasetti)

Integrated Structural Process Model

Duration: 1/1/2011-5/10/2013 (Completed)

Investigators: Ryan Solnosky

Outcomes: 3 Journal Papers, 2 Conference Papers, a dissertation, 3 Presentations

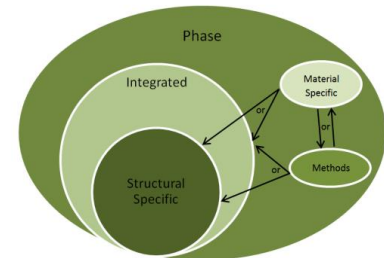
Background

Within the modern era, building industry has been known to be highly fragmented amongst the different disciplines. In recent years, the industry has seen vast technological developments and is moving towards a digital environment where computer modeling is becoming the industry standard. Furthermore, the builds are becoming more and more complex and require cutting edge practices, technologies and delivery methods to successfully execute these projects. Less integration can lead to more time invested in less efficient designs.



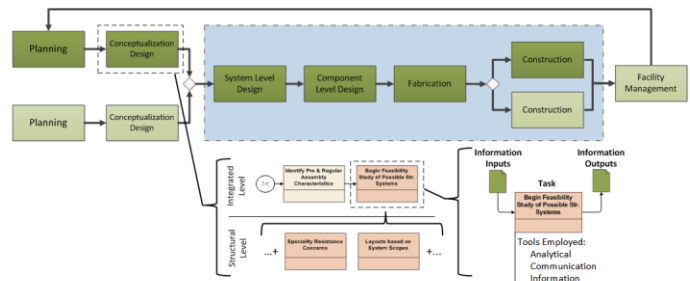
Solution Approach

The Integrated Structural Process Model (ISPM) consists of process maps that show necessary information exchanges for structural systems when utilizing BIM and integrated practices throughout a project. The ISPM looks at the structure system in a project from the planning stage through design and into construction. It is meant to help researchers/developers/designers define what needs to be considered in software so that no variables are left out while also guiding firms on how to utilize these new methodologies into a new planning, design, and construction process.



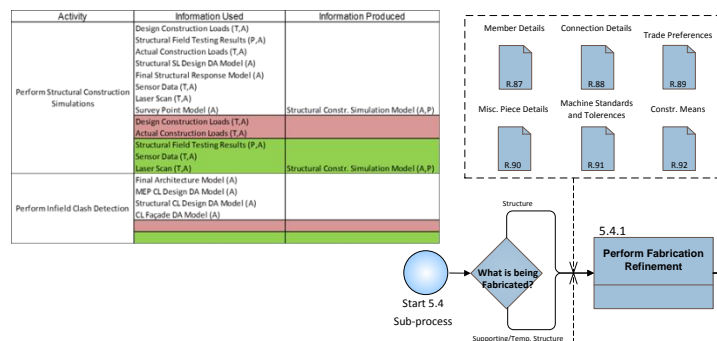
Integrated Practice for Professionals Approach

From practitioner standpoint, the ISPM is intended to help any player, team, or discipline better comprehend the interactions between the systems. Companies not familiar with integrated means can use this document as a guide to help them work through projects that they are required to participate using this process. To understand its intent and show correlation, a detailed hierarchy of processes and exchanges were developed.



BIM Interoperability Approach

The purpose behind developing the ISPM is that current models and manuals created to address structural software interoperability limitations and a narrow scope presently. Having determined extra information by highlighting new exchanges between players will show software programmers areas where they may not have considered software compatible exchanges before.



A Building Information Modeling Platform for Modular Construction

Duration: Projected (8/1/2015-7/31/2018)

Funder: Memari is current funding student through PHRC. Additional fund are under review with NSF CMMI Sector

Investigators: Ali Memari (PI) and Ryan Solnosky (Co-PI)

Outcomes: 2 conference papers

Background

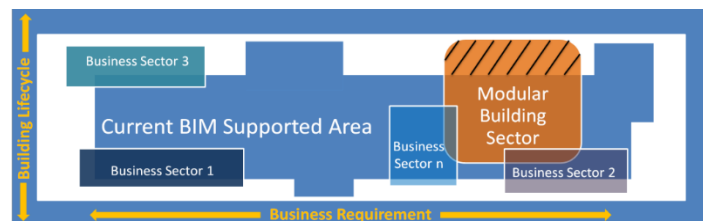
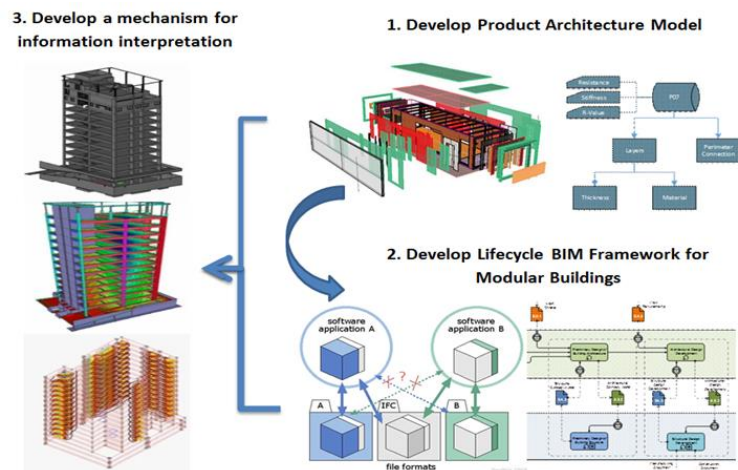
Modular construction and prefabrication in the Architecture, Engineering, and Construction (AEC) industry is a growing trend. Based on the McGraw Hill Smart Market Report, the size of this industry expanded by more than 50 percent in five years from 2006 to 2011. Many components of buildings can be prefabricated, whether or not the project is truly modular in nature. Modular buildings (made up of volumetric modules) share about 42% of the prefabricated building industry in North America, which has about 2.1 billion dollar annual revenue. With increase in the number of stories, the construction method and engineering issues become more complicated. Although interest exists in multi-story low-rise, mid-rise and high-rise modular construction, in particular in urban and metropolitan areas, there is a serious lack of well-developed methods for design, manufacturing, and construction of such multi-story constructions.

Research Vision and Goals

The primary goal of the proposed research is to develop a BIM platform framework to encourage and improve design and construction of mid- and high-rise buildings using factory-built modular units. Doing so would provide the industry with more options for economical, energy efficient, sustainable, and more affordable construction. The goal will be achieved through accomplishing several objectives that are also bound by a global holistic multidisciplinary approach considering information technology, design frameworks, and principles of different engineering disciplines. To have cohesiveness in the modular BIM platform, the research must take into consideration the relationships of these principles. Figure 2 depicts the main three objectives of this proposed research, which address the product architecture, lifecycle BIM framework, and engineering analysis of the modular buildings.

To meet the goal of this proposed study, the research team as developed three main objectives that must be studied and completed successfully for this study to be an advancement in the modular sector. They are:

- Objective 1: Develop a Product Architecture Model based on conventional modular systems.
- Objective 2: Develop a modular buildings lifecycle BIM framework.
- Objective 3: Develop a mechanism for information interpretation using open standard data schema.



A Scalable Virtual Prototyping Framework for Multi-Hazard Design Decisions and Assessment

Duration: Projected (8/1/2015-7/31/2018)

Funder: Currently under review with NSF Hazard Mitigation and Structural Engineering Sector.

Investigators: Ryan Solnosky

Outcomes: TBD

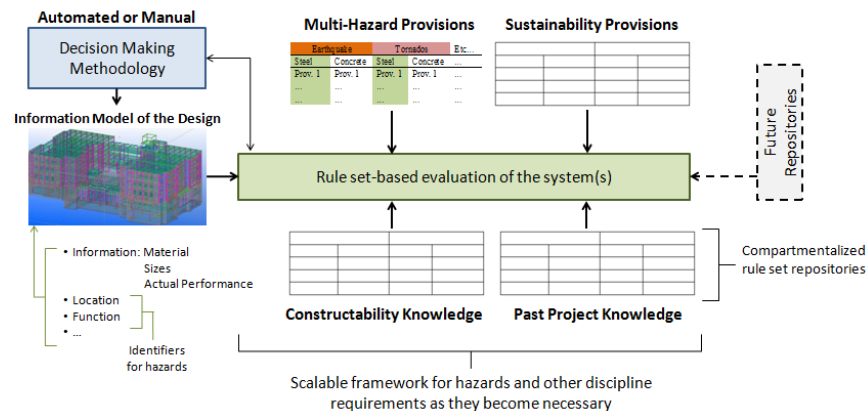
Background

Multi-hazard resistance is becoming more pronounced in terms of necessity and incorporation in how we approach building design. Multi-hazard resistance is not just a structural engineering concern although it is perhaps the most documented. Challenges in the building and infrastructure industry that impede the design generation and execution include: fragmented design and construction environments; more detailed, stricter, and obscure building code provisions; condensed timeframes with greater design complexity; new design provisions for various situations for various conditions; and a lack of rigorous multi-disciplinary methodologies to select alternative conceptual solutions.

Research Vision and Goals

Structural engineering has many detailed methodologies to technically design building foundation-structural-envelope (FSE) systems. However, holistic frameworks for alternative selection in early conceptual design that can consider multiple disciplines are very limited particularly for multiple hazards. The overarching research question this study seeks to answer is: *“Can a virtual prototyping framework (VPF) be developed to aid in and improve current design decision-making practices for multi-hazard resistance situations with other external input?”* To achieve this goal, the PI has constructed concise research objectives as follows:

1. To formulate and develop the VPF that deploys rule-based design verification and compliance checking through coupling: Building Information Modeling (BIM); programmable rule-sets; and knowledge databases on performance code provisions, industry practices, sustainability, and constructability.
2. Develop a decision-making framework to select alternative designs based upon heuristic knowledge populated from the rule-sets that capture multi-hazard and other discipline parameters. This framework will be founded in modern engineering design methodologies.
3. Investigate the necessity and detail of modeling content for decision making as part of the framework.



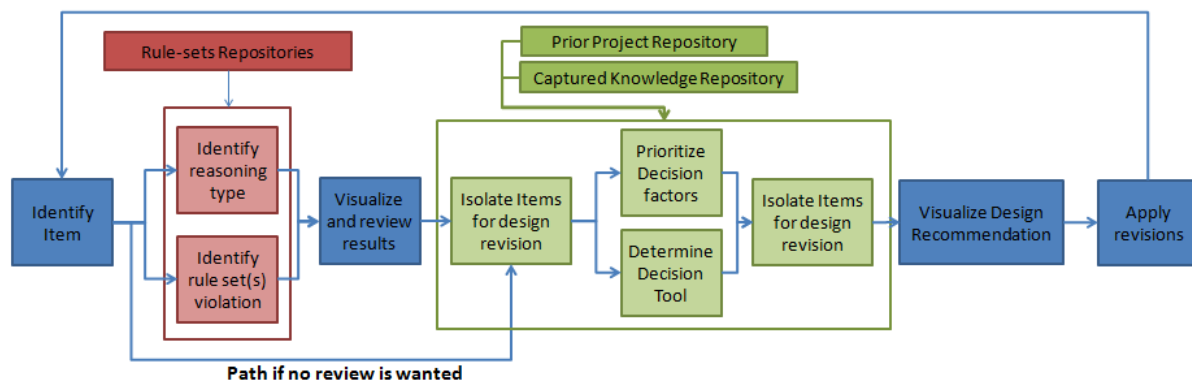
The core contribution of this research lies in the development of a scalable framework to support a new decision-making methodology for generating then selecting FSE system designs that fulfill multi-hazard resistance and multi-discipline requirements. The scalability of the VPF is both unique as well as enticing in that as new hazards emerge or as there becomes a deeper understanding of current hazards so too can the VPF, all while being

able to integrate across disciplines. The novel merit originates from the investigation of the development and testing of the original methodology within the VPF that provides comprehensive opportunities to transform how engineers select and develop alternative structural systems for a variety of trades. The VPF is rooted in the fundamentals of: resiliency, decision support systems, and multi-disciplinary design, none of which they has yet been explored through interconnections in such multi-hazard frameworks.

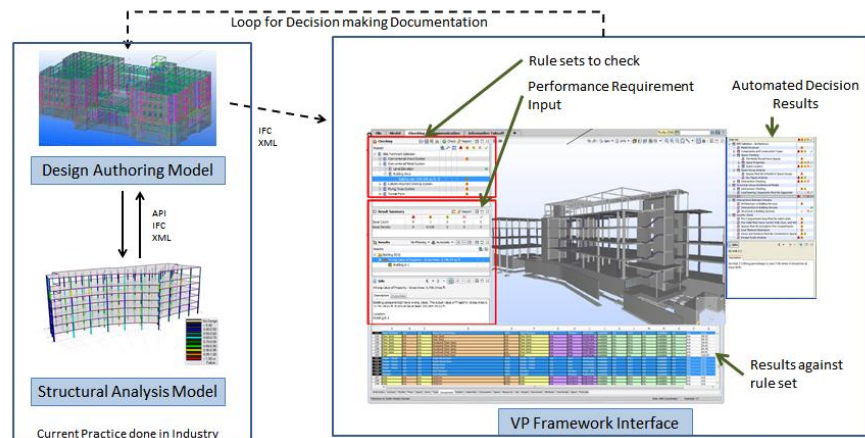
Expected Outcomes

To date, frameworks that aid in the decision making process which incorporate multiple disciplines for a Multi-hazard FSE systems design, as well as provide proactive feedback on code performance and compliance are limitedly available. This study develops a new state-of-the-art into the field of multi-hazard design in four ways.

1. Provisions in how to adopt the virtual prototyping framework (VPF) as a decision-making methodology in design to develop a FSE design that has enhanced performance attributes.
2. A VPF that is scalable across multiple hazards and disciplines to proactively check for code compliance, constructability and system performance (as a starting point).
3. A framework that inherently supports the ability to provide meaningful quality assurance through first and third party peer reviews in an active and dynamic real-time manner that ensures safety and resiliency.
4. The ability to capture knowledge during use and placing it into a framework that can be recalled later in the lifecycle or on future projects to aid in other Multi-hazard FSE decision making situations.



It is important to take away that this proposed framework, and how it is utilized as a methodology for improving design through leveraging technology, is not solely software development but rather a collaborative effort to incorporate subject matter experts and code provisions into a common language and environment that can utilize human-in-the-loop techniques to enhance design decision making.



BIM Implementation Guide for Academic Institutions

Duration: 7/1/2014-5/31/2015 (Ongoing)

Funder: Raymond A. Bowers Program (Seed Fund)

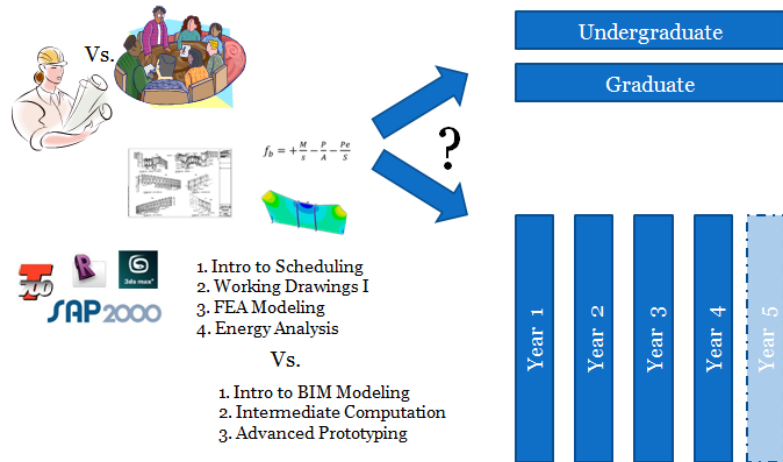
Investigators: Ryan Solnosky

Outcomes: 1 Conference Paper

This study aims to develop a state-of-the-art BIM Academic Implementation Guide that will be a recommendation for academic institutions who teach mechanical, structural, lighting, electrical and structural engineering, and also construction and architecture. This guideline will provide a variety of options to adopt different technologies and methodologies present in industry depending on the department's infrastructure.

Background

Emerging technologies and methodologies are entering the mainstream built environment industry. This has resulted in a call from practitioners to ensure students are educated upon entering the workforce on these topics. Consequently, countless efforts have been placed on studying the efforts to employ Building Information Modeling (BIM) and integrated methodologies into various programs and courses within different academic departments on a multitude of topics. Topics range from: clash detection, generative modeling, scheduling, and system design to even site layout. Furthermore, some work has looked at the means of educating through projects, assignments, and various course structures like single course or a multi course sequence. Course types are also being studied such as studios, entry and advanced level courses, and undergraduate vs. graduate education. Based on this brief summary, the number and types of methods for teaching and integrating BIM into building related architecture and engineering related curriculums is as varied as the Architecture, Engineering, and Construction (AEC) industry itself according to the literature.



Overall Aim & Research Objectives

With the massive variability of research on teaching BIM and integrated methodologies in the various fields, there is a limited cohesiveness amongst the previous work. This factor provides a strong motivation to strengthen and provide uniformity to AEC based departments. This study envisions the development of a BIM Academic Implementation Guide that conveys the best practices in a variety of sub classes within BIM and engineering education. A single document will promote adoption through recommends with examples of what to do and why based on proven research success. To meet the research goal of developing a state-of-the-art BIM Academic Implementation Guide, concise research objectives were formulated. The core components to the guide relating to education topics, learning styles, and assessment techniques will be shaped by the objectives. In addition, these objectives define the current status and need more research.

1. Determine status quo of BIM education research
2. Identification of topics and courses viable for BIM implementation
3. Develop best practice methods for:
4. Identify areas for future BIM education research

Upon successful completion of this research study, the results conveyed in the BIM Academic Implementation Guide will be a vessel for transforming curricula to where the industry wants it to be in educating the next generation engineer.

Multidisciplinary Industrial Heritage Learning

Duration: 7/1/2013-5/31/2014 (Completed)

Funder: Raymond A Bower Program (Seed Funding)

Investigators: Ryan Solnosky, Thomas Boothby,

Outcomes: 1 Technical Report, 1 Journal Paper (in progress)

Background to Intent

In the northeastern and central US, industry has left a landscape rich with historic buildings and other structures. As our students become professionals, they will at some point encounter traces of this industrial heritage, and will be faced with the social, environmental, and technical challenges of adaptation, reuse, or reclamation. At the very least, education about our industrial heritage will allow our students to enter the debate about how such structures should be adapted. The courses proposed for this interdisciplinary project, based on the unifying theme of Industrial Heritage and sharing similar site-specific problems in Pittsburgh, will challenge students from Architectural Engineering, Landscape Architecture and Architecture to apply sustainable principles that ground the theory.



Multidisciplinary Learning Structure

The proposed project is a two semester long set of coordinated activities between two Architecture studios, a Landscape Architecture studio, and two Architectural Engineering courses, in which students will spend parts of the semester studying in common and working collaboratively on the theme of industrial heritage.

Fall Semester 2013:

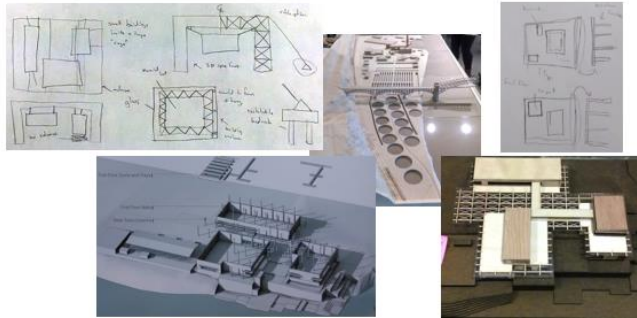
- **Architecture students** (third-year) in their studio will focus their semester design on an industrial heritage based project.
- **Architecture students** (third-year) in their architectural theory will focus will engage in focused historic preservation and cultural heritage topics.
- **AE structural students** will have a weekly to bi-weekly collaboration with the architecture students with advising on appropriate structural design strategies.

Spring Semester 2014:

- **Landscape architecture students** (third-year) in their studio will undertake a large scale site design project in an industrial heritage setting
- **Architecture students** (third-year) in their studio will focus on a project in the same site area to aid in collaborations.
- **AE structural students:** will have a three week collaboration process with Arch. and Larch focusing on industrial heritage issues from the point of view of resource management, use of existing building stock, and infill construction.

Fall Semester

The project is sited in Pittsburgh with its rich industrial heritage, which includes the development of Pittsburgh's municipal water system in the first decade of the 1800s. The goal of the studio design will be to design a public program and research laboratory for a new water treatment facility. The structure includes items such items as a research laboratory, visitors' center, and a host other spaces. In rethinking the water treatment facility's public interface and production exploration in the following will be including landscape, infrastructure, environmental design, ecology, sustainability, earthworks, interdisciplinary approaches, and accessibility.



IPD/BIM Multidisciplinary AE Capstone Course Development

Duration: 8/1/2009-5/15/2013 (Completed)

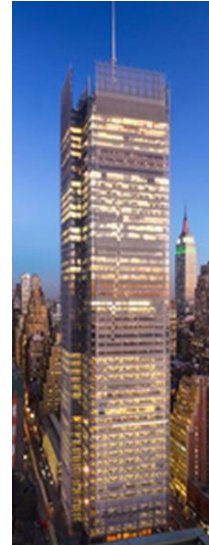
Funder: The Leonhard Center (Penn State) and Thornton Tomasetti Foundation

Investigators: Kevin Parfitt (PI), Robert Holland (Collaborator), and Ryan Solnosky (Grad. Research Assistant)

Outcomes: 3 journal papers, 5 conference papers

Background

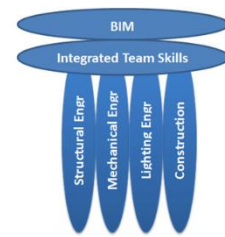
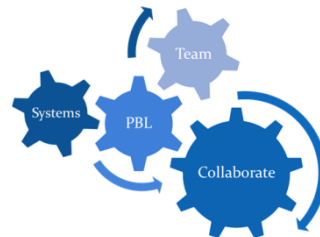
Department of Architectural Engineering (AE) at Penn State University launched a three-year IPD / BIM Capstone Project Program under industry and institutional sponsorship. The project was co-funded by the Thornton Tomasetti Foundation and The Leonhard Center for Advancement of Engineering Education of Penn State. Consisting of a year-long two course sequence pilot program, this capstone initiative is organized and managed around IPD/BIM concepts involving multidisciplinary teams of architectural engineering students. Three teams were formed consisting of one student from each of the four Penn State AE engineering disciplines: Construction, Lighting/Electrical, Mechanical, and Structural. The basis of the entire 5th year of the program functions around the capstone course and how it represents the professional application of engineering knowledge.



Pilot Formulation

In order to understand how to develop such a course with forward things mentalities on relatively new topics, a comprehensive literature review was conducted. This work provided guidance into setting the foundation of the pilot. Areas of literature considered included but not limited to:

- BIM and IPD topics to incorporate
- Practice/problem based learning
- Learning objective via ABET
- Implementation strategies
- Evaluation methods



The focus of this project is extensive in the results determined through the three year offering. The outcomes from the pilot included:

- The formulation a curriculum outline and required deliverables
- Developing best practices for implementing IPD philosophy and BIM technology
- Determining the effectiveness of:
 - The course objectives
 - Student interaction
 - Industry integration
 - Teaching methods

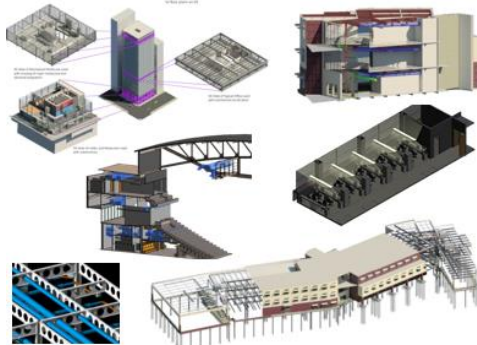


Student Trends from Developed Objectives and Guidance

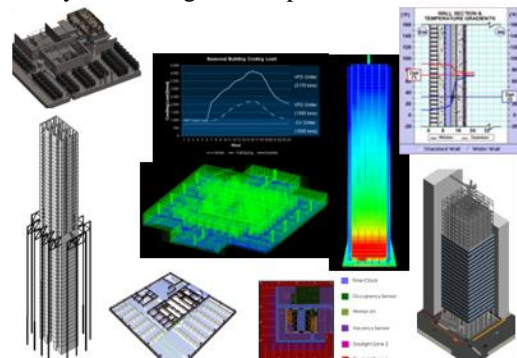
Within the student results collected over 4 years, there were several noticeable trends. Systems integration across disciplines is the most collaborative among the trends. Student generated designs require the input of at least two team members but can have as many as four providing input and suggesting design considerations. Topical studies included:

- Architectural concept and enclosure
- Day lighting and electrical system control
- Mechanical system integration
- Constructability of building systems
- Sustainability studies
- High performance structures

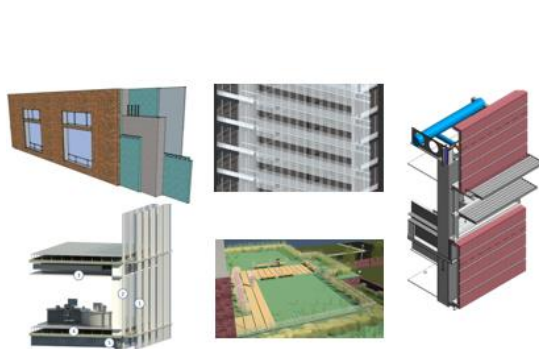
Advanced computer modeling technology was another prevalent trend. The generated outputs organized into this area rely on computer modeling through analysis, design, and simulations of the project for different purposes. The models can be used collectively for the group decision making or customized for more discipline specific studies. Model uses have been common to date in this trend match the systems integration topics.



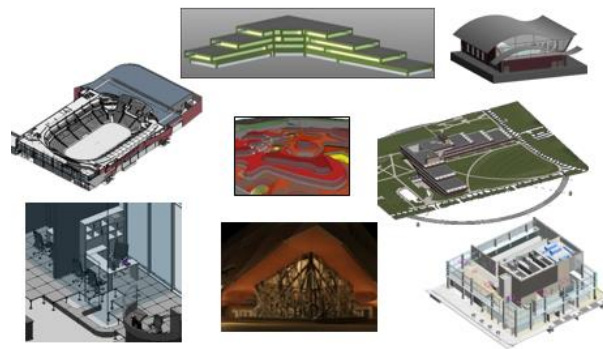
a) Systems Integration Examples



b) System Optimization Studies Examples



c) Building Enclosure Examples



d) Architectural and Site Context Examples

Structural Expertise in Education through Parametric Modeling & Multi-disciplinary System Integration

Duration: 1/1/2014-Ongoing (Pilot Testing)

Funder: Seeking NSF through: IUOE Solicitation

Investigators: Ryan Solnosky (PI), Charles Cox, Kevin Parfitt

Outcomes: TBD

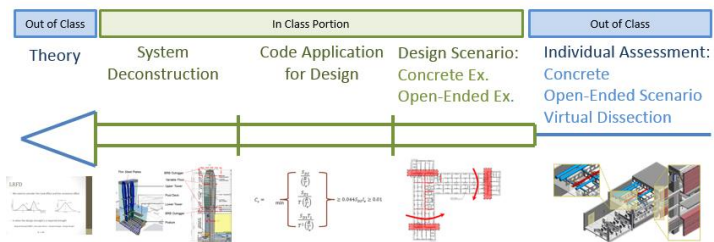
Background

Traditional instruction of structural engineering often takes the hands-off approach that results in the minimal effects on a student's cognition that are associated with mere surface learning. The product of this is student fixation on number crunching instead of more critical ideas related to creative and integrative applications. Industry has identified these issues and are advocating for reformulation. This is particularly true in that the building industry is becoming ever more complex due to an evolving cultural and architectural expressiveness, and globalization.

Project I: Multi-Disciplinary Systems Interactions

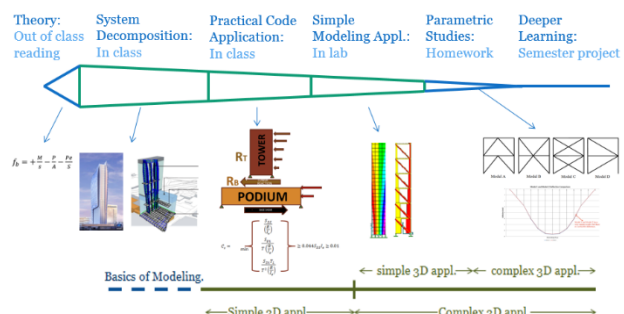
Most structural courses only consider idealistic examples and isolated material. As a result, students do not know how to approach large complex systems and cannot provide address multi-disciplinary integration with their designs. These areas formulate the main research question: "How can we improve undergraduates' conceptual knowledge of complex structural systems behaviors, considered both exclusively and in relationship to other systems? To create a solution, this study will apply the following learning theories (based on Kolb's model) and content delivery methods: active learning using by scenario-based assignments, building system deconstruction through visual dissection aids, and classroom inversion to allow for application of theory to integrated structural designs. Three concise research objectives were constructed:

- 1) Develop the course approach exploiting classroom inversion's reallocation of contact time, allowing for guided exploration into complexity and integration;
- 2) Provide course media that connect theory and code, establishing and supporting in-the-moment engagement and long term retention; and
- 3) Assess the impact course and material structure s on student retention and transfer mechanisms, with regard to system level designs that encompass complexity and integration.



Project II: Developing Expertise through Parametric Modeling

This research study is to improve conceptual knowledge of how complex structural systems behave to heighten their engineering intuition skills. This intuitive thought process will allow students to conceptually visualize how future project solutions can be formulated in their specific context. The proposed lecture and exercise format are intended to educate students by having them relate modeling techniques and to structural engineering theory. The connections between the two are supported with discussions around building codes and standards to better understand how various practical constraints affecting design decisions.



Immersing Students through Virtual Dissection

Duration: 9/1/2013-5/31/2014 (Pilot Testing)

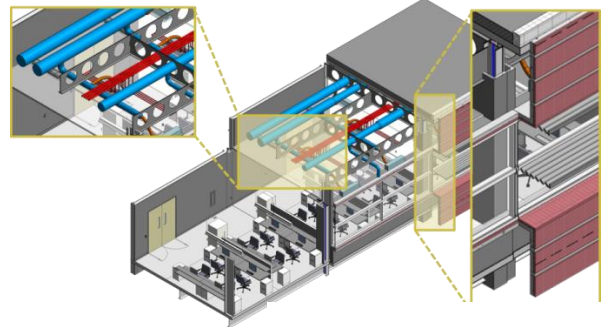
Funder: Not funded (Tried NSF but was rejected, currently revising and doing further pilot testing)

Investigators: Robert Leicht, Ryan Solnosky

Outcomes: 1 Conference Paper

Background

Critical to the education of engineers is the conceptual understanding of how discipline specific requirements integrate into the design. This conceptualization of systems and interdisciplinary interactions can be particularly challenging with buildings and infrastructure environments. Current techniques to bridge theory and real world applications are varied but a prominent educational technique is product dissection and more recently virtual dissection. Virtual building dissection has been limitedly studied and the environment that it is delivered through. First, the environment's effects on student engagement and its ability to translate knowledge at the conceptual level needs to be assessed.



Project Goals

The primary research goal of the proposed study is to advance our understanding of immersive virtual environments in education settings. Specifically we will look to develop a framework of virtual reality display attributes and test the impacts on spatial visual learning for system conceptual relationship retention. The scenario modules used in this study will leverage virtual prototyping interactivity, virtual dissection relationships and different display attributes of immersive virtual environments.

Virtual Dissection Benefits

- Navigate more complex systems
- Access to more complex products
- Couple engineering principles
- Increase awareness of the design process

Research Objectives

- Conceptual learning of system level designs
- Student engagement into different engineering topics
- Reducing cognitive load to increase analytical skills

- Increase attention due to the peripheral vision
- Develop more accurate cognitive maps of the space
- Variability for increased realism

Virtual Manipulative Benefits

- Amplification or reduction of temporal and spatial dimensions
- Manipulation of reified objects
- Alter the values of parameters
- Probe conditions and to observe the results

This study rests in developing a scalable framework for the ability to support novel approaches in engaging students on virtual project dissection exercises. The significant contributions to engineering education theory include:

- 1) Generalizable knowledge on how different scales of immersive display implementing large scale projects decrease cognitive demand to allow for greater conceptual learning,
- 2) Educational assessment procedures for evaluating student engagement
- 3) Recommendations on the value that different immersive virtual displays can with support when extrapolated to virtual product dissection.



Teaching Material



Bringing Industry into the Classroom

By bringing in industry into the classroom, stronger ties can be developed to connect theory to practice. Additionally, these opportunities allow for students to hear how engineering is conducted and what makes architectural engineering and structural engineering unique.

Practitioners often focus their lectures on practical applications of material to give students guidelines for selecting systems for different types of buildings. Lecture material can vary depending on the course but has included in my courses to date as follows:

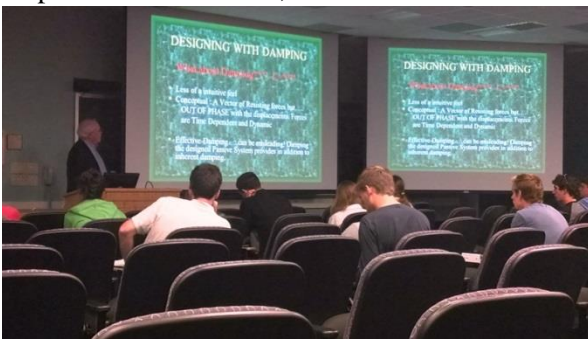
Senior Capstone	Structural Courses	
HoK for Façade Design Consulting	Structural Modeling	Concrete Design
Thornton Tomasetti for long span structures and labs	Scia Software Training	Holbert Apple
McNamara/Salvia for high-rise design	Thornton Tomasetti ACM	Nitterhouse Concrete
Hope Furrer Associates for architectural integration	Hinman Consulting	
	LERA	



Hope Furrer Associates, Inc.



Thornton Tomasetti



McNamara/Salvia



Holbert Apple Associates

Graduate Course

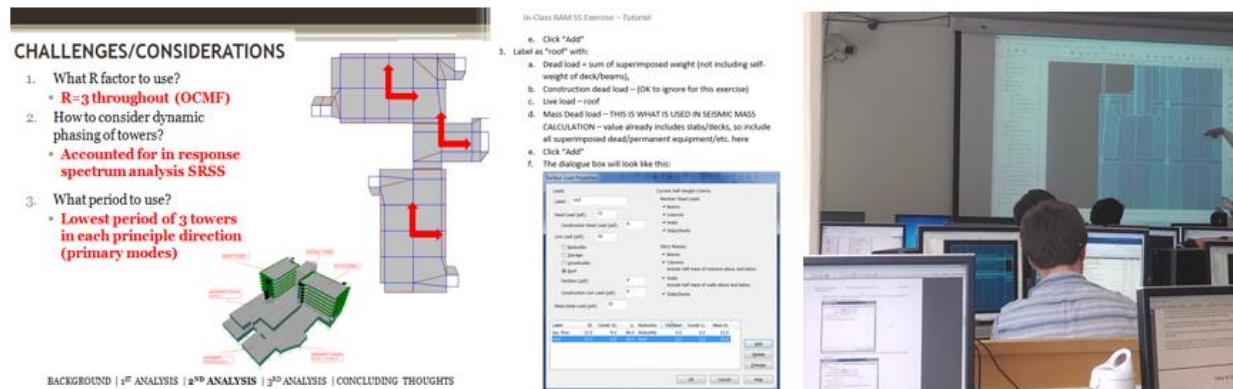
Course Description:

AE 530: Computer Modeling of Building Structures. Theory and application of structural analytical methods with commercial computer programs for two- and three-dimensional structures. Validation and interpretation of results from computer analysis. Practical analysis and design of building structures to satisfy building code requirements.

This course is designed to provide students, upon completion, with an ability to:

- Perform and comprehend various structural modeling techniques using commercial software.
- Be able to identify and organize required information for describing a structural model.
- Be able to validate and interpret results from computer analysis.
- Interpret building codes and standards to understand modeling and behavior provisions.

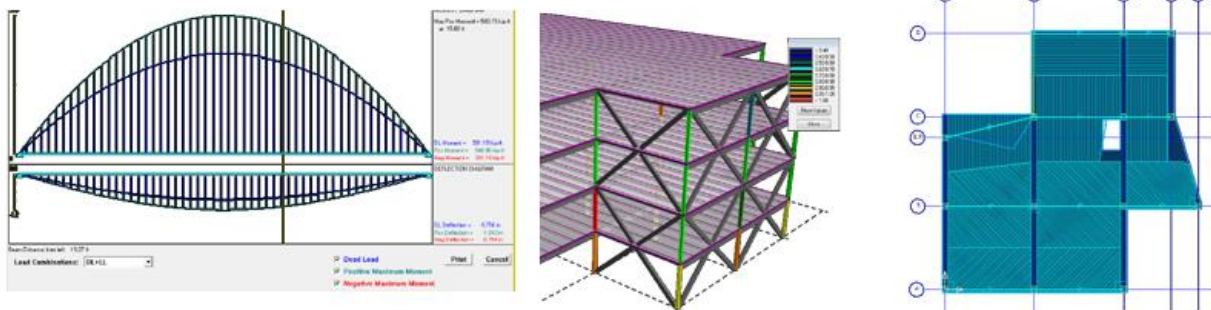
Sample Material and Classroom Interaction:



Project:

The project is intended to advance self-comprehension through self-exploration of a topic of personal interest or one touched on in class but in greater detail by researching and implementing the concept for a building. The intent of the project is to develop one of two things. 1). Detailed comprehension about a topic at a level lighter than what was covered in the lectures or 2) Learn new material that was not covered in the course that is of interest to you.

- Paper containing the theory, conclusions, background and results
- Input sequence and screenshots of the models to replicate the results
- A copy of the model in the drop box



Undergraduate Service Course

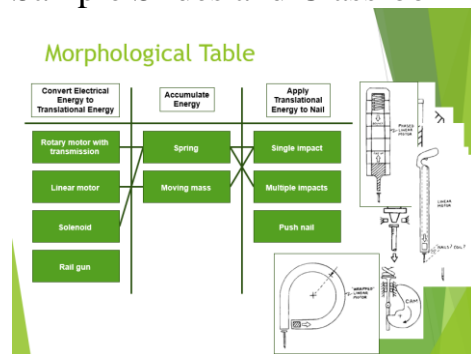
Course Description:

EDSGN 100 is a first year engineering course that is required in most engr. majors. The course has received numerous awards and is the model for similar courses at other universities. This is a design driven curriculum where you will learn the tools of the design process. Other skills such as teamwork, communication, and computer modeling will be learned throughout the design process. Two major design projects will be assigned during the semester.

This course is designed to provide students, upon completion, with an ability to:

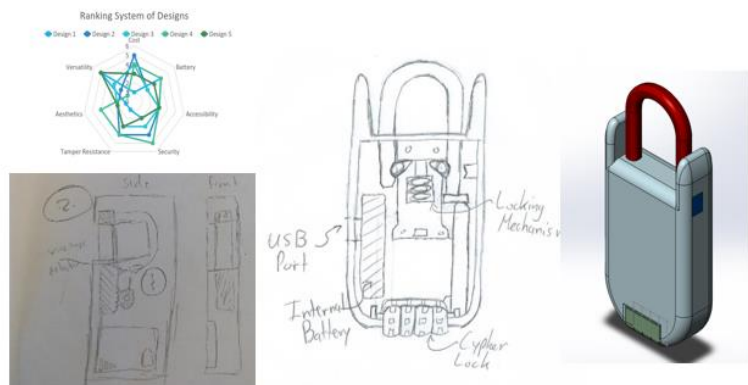
- Design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- Identify, formulate, and solve engineering programs
- Identify client needs from a situation with which you are presented
- Propose solutions in response to the needs
- Determine how to assess solutions in order to evaluate them
- Collect data to inform comparisons among solutions
- Apply graphic and modeling conventions in order to explain the solutions to others

Sample Slides and Classroom Interaction:



Project 1:

Upper management at Company Lock has put your team in charge of developing a concept for a new padlock in their long standing history of successful similar products. Recently, competitors have made advancements in remote controlled locking mechanisms for homes controlled by cell phones. Company Lock is envisioning a new line of padlocks that are able to control by a cellular app in the event you share secured items and you need to allow another access. Your task is to analyze the current offerings in the market and design this novel product that meets the Company Lock's requirements.



Information Science and Technology: Systems Integration

AEC Industry

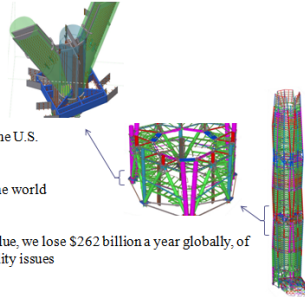
Design and Construction industry is a:

\$826 billion dollar per year industry in the U.S.

\$4.8 trillion dollar per year industry in the world

Assuming we waste 30% of potential value, we lose \$262 billion a year globally, of which \$15.8 billion is from interoperability issues

The industry is moving away from 2-D drawings and moving towards digital computer models.



Data Structures

Here are a sampling of the many formats used when generating data structures.

Table 3-1 Common exchange formats in AEC applications

<p>Image (vector) formats</p> <p>JPG, GIF, BMP, PNG, PNM, TGA, RLE</p> <p>3D Vector formats</p> <p>DXF, DWG, AL, CGM, ENIG, IGS, WMF, DGN</p> <p>3D Surface and Shape formats</p> <p>IGS, VRML, STL, IGS, SAT, DXF, OBJ, DGN, PRT, STEP, DXF, DWG, IFC, PRTS</p> <p>3D Object Exchange formats</p> <p>STEP, EXR, OSQ2</p>	<p>Raster formats vary by terms of compressibility, number of possible colors per pixel, some compress with some data loss.</p> <p>Vector formats vary regarding compression, line weights and pattern control, colors, layering and types of curves supported.</p> <p>3D surface and shape formats vary according to the types of surfaces and edges represented, whether they represent surfaces and/or solids, any material properties or shape (color, image, texture, feature) map or viewpoint information.</p> <p>Product data model formats represent geometry according to the 2D or 3D types represented. They also carry object properties and relations between objects.</p>	<p>Game formats</p> <p>RINQ, X, GOG, FACT</p> <p>Game file formats vary according to the types of software, whether they carry hierarchical structure, types of material properties, texture and lighting map parameters, animation and shading.</p> <p>GIS formats</p> <p>SHP, SHX, DEB, DEB, NED</p> <p>Geographical information system formats</p> <p>XML formats</p> <p>XML, XSL, OAS, ADO, XSL, AG-XML</p> <p>XML schemes developed for the exchange of building data. They vary according to the information exchanged and the workflows supported.</p>
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The industry as a whole is just starting to move away from many types and move to a single format.

The new format will be Industry Foundation Classes.

Architecture: Design Studio V

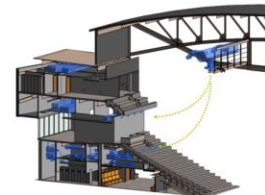
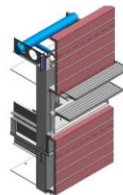
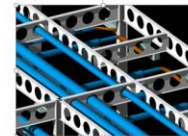
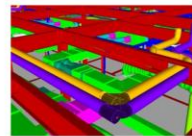
Needed by the Parties

Requested by Structural

- Building shape
- Building size
- Floor to floor dimensions
- Ceiling plenum thickness
- Finishes
- Wall locations and thickness
- Desired materials
- Locations of major areas

Requested by Architects

- Structural objectives
- Spatial impacts
- Performance
- Where and how many



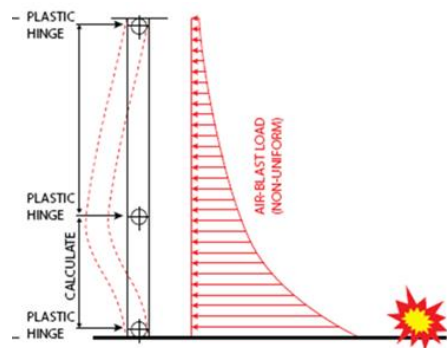
Mentoring Project Sample: Capstone Blast Redesign

Described here is the work the student produced. I assisted in answering technical questions, offered solutions, and helped with modeling issues. The work discussed was generated by Rebecca Dick in spring of 2012. She won second place in structural depth within the class for her work.

National Business Park- Building 300 is a seven story office building located in Annapolis Junction, Maryland. It was designed in 2007 and construction was completed in 2009. The structure of NBP-300 is composed of a composite steel system and utilizes four eccentrically braced frames for the lateral system located at the core of the building. National Business Park-Building 300 was not designed to resist blast, and therefore, were an attack made on the building, heavy structural damage would likely result. For this reason, NBP-300 was redesigned as a high risk building for terroristic threats, and as such would be required to meet certain criteria.

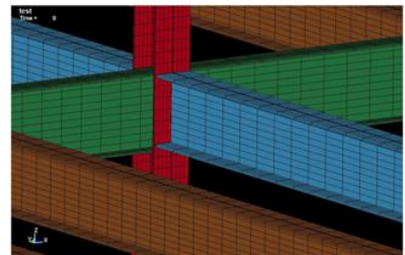


(Courtesy of Baker and Associates)



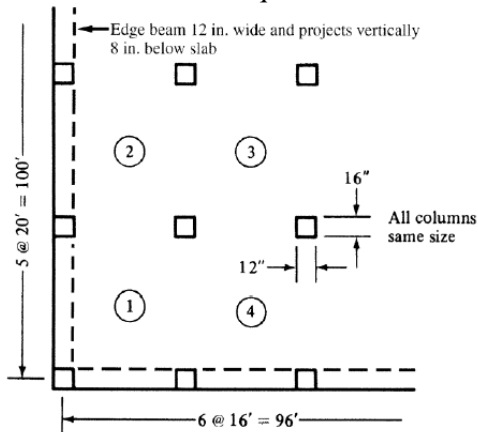
A specific situation has been created for the design. The UFC -340-02 in conjunction with FEMA guidelines were used to identify threat levels, design site security, and find blast loads. LS-DYNA Blast Modeling software was used to analyze a critical portion of the original and redesigned structure. Additionally, the façade of NBP-300 was redesigned to allow venting of the interior during the blast. The large percentage of glass currently on the façade could potentially be harmful to occupants when the façade fails.

Two breadth studies were also performed, including a site redesign and a facade redesign. The site redesign included site security designs and landscaping. The facade redesign included a glazing system design using a top anchored film system to allow ventilation of the interior space during a blast. Additionally, heat transfer calculations were performed on the new facade to determine the practicality of the new design.

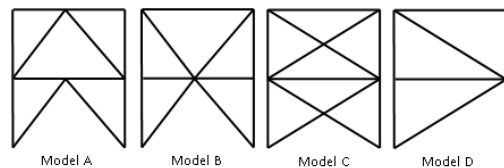


Sample Homework Questions

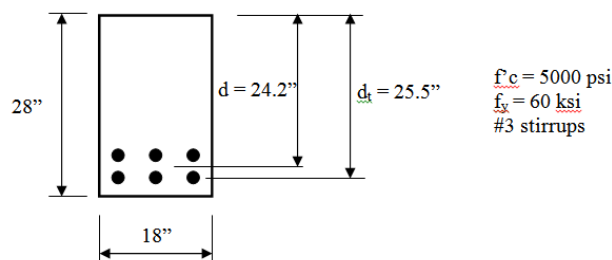
- Go to the hub parking deck on campus. Look at the back/end of one of the stems of one of the double tees and count the number of $\frac{1}{2}$ " diameter pre-stressed strands. Estimate the eccentricity of the strand group. Using an effective pre-stress of 60% of the strand strength, estimate the total effective pre-stress. Using the self-weight and a superimposed dead load (DL) of 20 lb/ft² and 40 lb/ft² parking garage live load (LL), estimate the top and bottom stresses at mid-span.
- Using the floor system shown, determine the min slab depth (rounded to the nearest $\frac{1}{2}$ in) to avoid the need for deflection calculations. The edge beams are projecting vertically 4in below the slab. Include solutions for the required minimum slab depths based on the interior panel and the corner panel.



- For each frame drawn below you are to generate 2 models: one with a fixed based and the other with a pinned base. The load should be applied from the left and be pushing to the right. Compare the drifts between the concentric frames for a pinned based and draw conclusions about the effect of the configuration in regards to stiffness. Then draw conclusions about the effect of the configuration in regards to displacement as each level (which is best and worst). Then compare each model drift against pinned and fixed base and draw conclusions about the effect of the configuration and base fixity in regards to displacement as each level



- Assuming that there is no compression reinforcing; determine the maximum ultimate moment capacity, ϕM_n , of the beam shown while still maintaining a tension-controlled section. In your answer next to the value of ϕM_n clearly show the value of ρ used. (Hint: Calculate A_s for a neutral axis depth c meeting $\epsilon_t = 0.005$. Consider the steel lumped at d but when checking ϵ_t use d_t).



Sample Assignment for AE Structural Consulting to Arch.

The goal of this assignment is for you to become familiar with two things, 1) industrial heritage and 2) multi-disciplinary teams through engineering consulting. In essence, you are tasked to provide input and support for structural system selection on architecture student projects in their design studio.

What is required of you:

- Attend the mandatory lectures designated (note these reviews last from 1pm-:
 - Sept 20th (this is their Concept Review)
 - Sept 27th
 - Oct 9th (SD Reviews)
 - Oct 18th
 - Nov 8th (DD Reviews)
- Schedule weekly or biweekly meetings with your assigned student(s) outside the designated classes during the following weeks or as the architecture students request (meetings should be ~ 1hr long):
 - Week of Sept 30th
 - Week of Nov 11th or 18th
 - Week of Dec 2nd or 9th
- Provide critical review of architectural ideas, and promote collaboration and what is best for all systems.
- Support and help the architecture student select framing plans and approximate member sizes (rules of thumb are permitted at the earlier phases).

What is due:

- For the reviews:
 - Comments, opinions and suggests on their ideas focusing on:
 - Structural feasibility, constructability, issues in the design, arch aesthetics, material choices, suggestions on improvements, the relationship between their idea and their design, etc.
- Sample calculations of designs and analysis that you performed
 - Min 1 beam and 1 column design (Steel or Concrete is acceptable)
 - Load take down for a single column (roof to foundation)
 - LL reduction included
 - A full bay load summary and resulting moments and shears for members
 - Determine appropriate loading with justifications
- Meeting minutes of what happened during each consultation
- Sketches and images of the project that show where the structural feedback was implemented and why.
- Report on summarizing the events that took place over the entire semester
 - Between 2-4 pages single spaces about: what you learned and took away from the project, the driving forces in engineering consulting, how the notion of industrial heritage drove the AE designs and what are the important aspects to consider, and the relationship between how Arch and AE works (this does not include meeting minutes, review comments, or calculations).