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Schüco is an ideal partner for Northwestern University in providing innovative, top quality solutions for application on this medical center building project. Let us tell you why. To start with, we have a history of excellence in building facade technology dating back to the mid-twentieth century, and a long history of successfully completed facade programs on the most challenging of buildings. If you are unfamiliar with the storied history of Schüco, we invite you to peruse the Organizational History section starting on page 8.

More significantly, the documentation contained in the Organizational History section evidences Schüco’s ability to harness the power of design. Schüco facade systems are built on a bedrock of German engineering. The design quality of our systems catalog is well known, widely acknowledged, and easily recognized in our product detailing. This results from decades of highly technical facade systems development, resulting in a unique capability for system design – one of Schüco’s core strengths. We deliver this capability to key clients in a novel process that marries emergent design-assist facade delivery strategies with our classic system development practices, a process we call Accelerated Design-Assist Product Development (ADAPD). This service is delivered through the Virtual Construction Lab of Schüco (VCL). The VCL and ADAPD are discussed in detail in the Virtual Construction Lab section starting on page 20.

In order to successfully deliver the facade systems for the Northwestern University Feinberg School of Medicine, we propose using the ADAPD process. The process puts the VCL team side-by-side with the Northwestern University design team, developing the design while providing real-time feedback on such considerations as cost, schedule, constructability, and maintenance, while also creating an optimal decision-making environment; every decision made with the full understanding of relevant impacts. The result will be a customized modification of a Schüco standard system, thereby combining the benefits of established performance with a novel appearance. We have gathered the information provided to us by the Northwestern University team, and proceeded with preliminary conceptual design to demonstrate capability and a possible approach. This work is captured in this proposal, and includes design, engineering, installation methodology, and air and water infiltration performance.

In addition to our leading-edge systems and product development capabilities, Schüco also boasts a unique product delivery strategy that has evolved over decades of endless refinements. Schüco delivers more than mere facade systems to your building project requirements – we deliver a comprehensive supply chain that spans the building process from concept design through fabrication and installation, to lifecycle maintenance and, ultimately, renovation. The supply chain bears the Schüco USA stamp of approval in the form of a vendor/supplier certification program that qualifies the material supplier, fabricator, and/or installer as a Schüco supply chain partner. The supply chain services are discussed in detail in the Schüco Business Model section on page 12 of this volume.
The development process at Schüco does not end with the product design. Any customized modifications to a Schüco standard system as proposed herein are evaluated in the context of the existing supply chain to assure that the customization will be seamlessly handled throughout the entire delivery process. This evaluation includes existing component supply lines, fabrication processes, machinery and equipment, material workflows, installation procedures, QA assurance protocols, software tools, operation manuals, and training programs required to fully support the system from design application through final installation, lifecycle maintenance, and renovation.

The facade system for the Feinberg School of Medicine will be no exception. We will work at the direction of the Northwestern University team in developing the system and then fine tune the supply chain to assure delivery through our network of suppliers, fabricators, and installers, enterprises that have been certified by Schüco in their role with respect to this specific project, in providing the following:

- System design including structural calculations
- Inventory, material storage, quality management and material handling practices
- Fabrication and assembly procedures
- Fabrication QA systems, procedures, and reporting requirements
- Installation and maintenance procedures

If this proposal is viewed favorable by Northwestern University, the proposed next step is to enter a contractual design development phase using a mutually acceptable derivation of the ADAPD process. Schüco proposes to contribute the following resources to the Northwestern University/Schüco development team:

**Schüco USA**
- Executive Direction: Attila Arian
- Project Manager: Brad Groenenboom

**Virtual Construction Lab of Schüco**
- Strategic Oversight: Mic Patterson, LEED AP BD+C
- Principal Designer & Executive Manager: TJ DeGanyar Ph.D., PE
- Design Manager: Katie Gould
- Visualization Manager: Chris Chin

Few, if any, firms are so uniquely positioned to provide such a comprehensive and robust service offering, and we extend it only to a select few. It would be our great pleasure to build the facade systems for the Feinberg School of Medicine with Northwestern University, and to build a productive and mutually rewarding ongoing client relationship in the process.
1951 The birth of Schüco

Heinz Schürmann, a pioneer in the young Federal Republic of Germany, founds the company Heinz Schürmann & Co. in Porta Westfalica. In a small backyard with six employees, he produces shop windows, awnings and rolling grilles.

1954 A new home During the West German economic miracle, innovative windows and facades become more and more important. Schüco supplies them. The company is at the forefront of progress using light and modern aluminum. By moving to Bielefeld, Schüco finds a new home.

1955-1963 Crossing borders The rapid growth of Schüco requires new distribution channels. Commercial branches are established in Düsseldorf, Frankfurt, Stuttgart and Hamburg. License agreements and agency contracts enable new cooperation across Europe. In 1958, Schüco enters into a partnership with Alu König Stahl that still endures today.

1964 A strong connection that lasts to the present day The sale of Schüco to technology company Otto Fuchs KG opens up new business and technological horizons. Schüco founder Heinz Schürmann hands over management of the company to Dr.-Ing. Ernst von Wedel.

1964-1969 Ascending together Schüco presses ahead with expansion internationally. In 1964, subsidiaries are set up in France, the Netherlands and Denmark. Schüco Design is established in Borgholzhausen in the same year.

1970s A system-based approach

Schüco develops into a system supplier for aluminum windows and doors. The company establishes new sites across Germany, continually expanding its sales network.

1970-1971 Ahead of the times Aluminum windows, doors and facades, as well as large sliding systems with outstanding thermal insulation: Two years before the oil crisis, Schüco is already focusing on climate protection and conserving resources with innovative products.

1972 The customer is king The topic of service becomes ever more important. Here too, Schüco is a pioneer. Schüco Service GmbH is founded as a fully owned subsidiary with three employees. The company provides software to help its metal fabrication customers with calculations and construction.
1980s A global player with new material

Schüco is also becoming increasingly international with licenses in Europe.

1980 Right on track Since the mid-1970s, the Schüco Express has been rolling through West Germany. Inside the carriages, customers can marvel at the latest window and facade technology – a unique form of product presentation.

1982 One step ahead Schüco has been meeting noise protection and environmental protection requirements successfully for years. Now the company also sets standards for fire security with the first approved fire protection system.

Market launch Schüco presents the new ISKOTHERM aluminum window system. The thermally insulated profiles are used for residential buildings and renovation projects in particular.

1990s A turning point

After the fall of the Berlin wall, building renovation with ecofriendly building materials in East Germany and Eastern Europe presents a major challenge. Schüco seizes this opportunity and expands its international business further. At the same time, the company enters the solar market and targets large commercial projects.

1990 An historic result Thanks to the construction boom in the east, Schüco turnover crosses the magical one billion D-mark threshold for the first time.

1992 Aiming high A new high-rise cassette warehouse in Bielefeld provides 22,000 storage areas across 81,000 m².

Inexhaustible source of energy Schüco adds a third business division with solarthermal and photovoltaic products, taking responsibility for sustainable development.

Strong cooperation A combined steel company for Germany and Switzerland forms under the name Schüco Jansen Steel Systems.
2000s Growing together and conserving resources

Schüco identifies opportunities for globalization and extends its business into the USA, South America and China. With its divisions – Metal and Solar – the company is a specialist for the entire building envelope.

2005 Ultra-high performance The Schüco Technology Center is accredited as an independent and certified test institute for the building envelope.

Aluminum innovation The Schüco AWS / ADS window and door system sets new standards and replaces the renowned Royal S system.

2009 Temperature control Schüco presents the 2° Concept for the building envelope at BAU 2009. With pioneering, energy-efficient technology, the company makes an important contribution to restricting global warming to 2 degrees Celsius.

2011 Intelligent networking At BAU 2011, Schüco thrills visitors with the energy self-sufficient Schüco Energy3 Building. By networking windows, doors and facades, it produces more energy than it consumes.

2013 People. Nature. Technology. This is the Schüco slogan at BAU 2013. Four topic studios make the Schüco content interactive and an emotional experience. At the world’s leading exhibition for architecture, materials and systems in Munich, the company records 11,000 contacts – a record number of visitors.

A good investment A new production hall measuring 6,300 m² is built in Weißenfels with 11 highly automated laminating lines for foiling and foil lamination of colored PVC-U profiles.

2014 Strong together The successful union between Otto Fuchs KG and Schüco International KG has now been in place for 50 years.

Technology you can touch The Schüco Showroom opens in Bielefeld, an interactive exhibition of metal construction products. Spread across 800 m², Schüco presents fascinating technologies and impressive systems using aluminum.

2015 Under the motto “Home. Work. Life” Schüco exhibited many innovative and stylish system solutions in Munich featuring ideal home, living and working environments. With approximately 13,000 registered guests Schüco set a new visitor record.
Historical Timeline

1951

**Founded, Germany**
Heinz Schürmann founds Schüco and Company in Porta Westfalica, specialising in aluminium shop windows.

1960

**Window System Launched**

1970

**National Expansion, Germany**
Founding of sites across Germany and development of the sales network. Schüco becomes a systems provider.

1980

**European Expansion**
Internationalization within Europe and entry into the PVC-U business.

1990

**Global Distribution**
Worldwide expansion and entry into the solar business.

2003

**United States Market**
Schüco is the specialist for sustainable solutions for the entire building envelope.
The Schüco Business Model

Market-Leading Building Facade Technology with a Focus on Supply Chain Management

Schüco combines best-in-market high-performance facade system products with a powerful design-to-site delivery strategy powered by a deep supply chain of multiple Schüco certified fabricators and installers.

Discerning Design Teams Choose Schüco

Schüco facade products are built on a bedrock of German engineering.

The standard-setting quality of Schüco systems is widely recognized, with design quality you can see. You don’t need a specification sheet, test report, or even a gage or measuring device; you can see it, easily, with your own eyes. Just look at the mitred-corner framing detail of a Schüco unitized window or curtainwall system, and try to find its equal in the marketplace.

We also make our unique facade product development capabilities available to clients and our supply chain partners. This includes a form of design-assist product development for both one-off project applications, or for the development of new systems exclusive to our client. These latter would include retail chains, for example, desirous of novel entry or lobby systems available as part of an exclusive brand. These services are discussed in detail in the following section on the Schüco Virtual Construction Lab (VCL).

Discerning Building Teams Choose Schüco

Many in the building industry are familiar with Schüco’s innovative high-performance facade systems. Most are less familiar with our equally innovative facade program delivery strategy, the process by which the requirements of the most demanding building facade programs are realized, with comprehensive services ranging from design through fabrication, assembly, installation, and even ongoing system maintenance if required. This strategy involves a sophisticated international supply chain of fabrication/installation partners capable of providing you with virtually unlimited capacity, consistent quality, competitive pricing, and timely delivery, most often from local or regional providers.

As a global facade system supplier, Schüco has over 12,000 trained and prequalified fabrication/installation partners in 78 countries. Each supply chain partner is supported by a regional Schüco organization, all of which have full access to central services provided by the headquarters in Bielefeld, Germany. These services include:

- Pre-construction services; preliminary estimating, product consult
- Design-assist services; real time estimating, scheduling, constructability review (through the Virtual Construction Lab of Schüco, see following section)
- Product development
- Design-assist product development; development of exclusive systems for key clients through Virtual Construction Lab of Schüco (ADAPD process), see following section
- Material supply
- Warehousing
- Machinery design and supply
- Software development and support
- Testing and certification
- Fabrication training
- Installation training
Schüco leaves the fabrication and installation responsibilities to this highly trained network of service providers, which allows us to focus on further enabling this network with:

- Next-generation systems development and management practices
- Advanced digital fabrication processes, machinery, and know-how
- Intensive training programs
- A range of novel software tools to expedite fabrication, installation and management processes

We provide the fuel to our supply chain in the form of optimal product designs, digital fabrication processes, machinery to optimize workflows, and training programs that deliver know-how necessary to implement this advanced technology. A variety of special tools, punches, jigs and presses are made available to ensure optimal quality while reducing fabrication time. The proprietary software package SchüCal creates a digital platform that facilitates an efficient flow of data from design through fabrication. The machinery developed and provided to fabricators by Schüco can read and process the SchüCal data and drive fabrication processes, enabling file-to-fabrication workflows at speed.

The attributes of our strategic supply chain are many, and are reviewed following.

Why Schüco: Standard or Customized Systems, Your Choice

As a system supplier with an unparalleled line of existing products, coupled with deep product development capabilities, Schüco can deliver a standard or customized facade program that can be supplied, fabricated, installed and serviced in 78 countries by prequalified and trained local and regional fabrication/installation partners. This strategy enables our clients to control the supply chain on their projects, optimizing cost, quality, lead time, and system solution.

Managing an Adaptive Delivery Process, Your Options

Upon development of a system design, we provide clients with two pathways to procurement:

- Contract directly with local Schüco partners for complete supply, fabrication, and installation services, or
- Contract directly with local Schüco partners for fabrication and installation services only. Procure product material kits directly from Schüco for delivery to the select Schüco partner.

For mission-critical facilities, or as desired to support delivery and emergency response times, a predetermined quantity of materials can be inventoried at strategically located Schüco or Schüco partner facilities internationally to expedite installation, repair, or replacement.
Consistent Quality, Optimal Economy

Schüco has a long history of facade product development yielding a catalog of standardized systems unequaled in quality and performance. Moreover, we’ve developed a product delivery supply chain of extensively vetted and highly qualified fabrication and erection service providers. This international supply chain has successfully delivered thousands of challenging facade programs with consistent and predictable results as measured by schedule, quality, and economy. For its part, Schüco manages a stock of 44,000 pre-engineered components for delivery to its supply chain partners. These partners also benefit from the tools we provide them to seamlessly manage their processes from estimating through project close out, tools including our proprietary estimating and fabrication software, SchüCal.

This extensive, internationally distributed network of fabrication/installation partners provides significant advantages.

- Advantageous market labor rates can be leveraged.
- Multiple fabrication and installation service providers assure competitive pricing and delivery scheduling.
- Even the highest capacity product requirements can be met through the employment of multiple service providers.
- Travel and shipping costs can be minimized.
- Consistent top quality resulting from the intimate familiarity with system requirements by Schüco licensed fabrication/installation partners.
- Top level technical support provided to all licensed fabrication/installation partners by Schüco.
Design & Delivery Services

Schüco employs 2,500 engineers worldwide:

• developing and applying standard systems,

• providing customized solutions for bespoke building projects,

• and performing client-driven product development for key clients employing our novel ADAPD (Accelerated Design-Assist Product Development) process. (See the following Virtual Construction Lab section for more detail.)

In addition to the usual spectrum of design and engineering services, Schüco staff provide the drawings, technical support to fabrication/installation partners, develop tools, training programs, and assembly, fabrication, and installation manuals for the application of all Schüco products.

An application design team is assigned to project applications, and typically includes the technical department of a Schüco facility of local country organization (e.g., Schüco USA), the central design department at Schüco headquarters in Bielefeld, Germany, and the technical personnel of the select fabrication/installation partner(s).

The fabrication/installation partners typically carry the construction contract, servicing the Owner or General Contractor as required, while the local or regional Schüco office provides technical support. The technical groups at the Schüco regional facilities have deep familiarity with all of Schüco’s product catalog, and are also familiar with local codes and regulations pertaining to the building facade. The central technical department at headquarters in Germany reviews the work of the regional teams and interfaces with Schüco’s supply chain partners as required to ensure optimal design, constructability, scheduling, and economy.
Strategic Partners: Supply Chain Fabrication and Installation Service Providers and Certification

As a central element of the Schüco USA delivery strategy, we undertake the training and certification of qualified fabricators/installers to contract the supply, fabrication, installation and maintenance services required for the delivery of our products within the US. The training includes:

- Designing with the systems, including structural calculations, code considerations, etc.
- Material storage, quality management, and material handling, plant organization and workflow
- Intensive hands-on fabrication, assembly, and installation workshops

The qualification process also involves the review and approval of key vendor metrics including financial reports, QA/QC systems, facilities organization, machinery, reference projects, workforce skill and training, and health and safety planning.

Managing the Process

A delivery team is assigned for each Schüco project. The team makeup will vary as a function of project size, location, and the systems involved, but the core team is generally comprised of:

- Schüco project manager (from local/regional office)
- VCL team manager (if the Virtual Construction Lab is involved)
- Schüco HQ design manager
- Installation/fabrication manager(s) (certified Schüco service providers)

The fabrication/installation service providers carry full contractual responsibility for the provision of their services, and are solely responsible for the management and execution of their work. Schüco local/regional organizations in conjunction with Schüco headquarters support the fabrication and installation processes through the provision of materials and technical support.
Supply Chain Coordination

Schüco is flexible in working with clients and our supply chain partners. We will work with certified Schüco fabricators/installers to prepare a proposal in response to specific project requirements, either in a lead or supporting role. Or we will nominate to the building team the certified service providers we think are most appropriate for the project, leaving the vendor qualification, design and procurement entirely to the building team and service providers. We can also provide coordination services from early on in the design process through the entire facade delivery process to final installation.

Procurement Planning

Each project provides a unique context. Schüco can manage the procurement of all materials and components required for a facade program, coordinating just-in-time delivery directly to select certified fabricators or to certified installers at the building site. Schüco manages the global inventory and warehousing of some 44,000 components in support of its products, minimizing lead time and greatly expediting the order-delivery process. Our deep supply chain comprised of multiple partners for all key components assures the fastest possible delivery regardless of project size.

Prefabricated Systems

All Schüco facade systems are based on prefabricated design strategies. Components come together at a certified Schüco fabricator on a just-in-time basis for assembly under qualified factory controlled conditions and under approved QA/QC procedures, with integrated reporting transparency. Prefabricated units are carefully packed and shipped to the building site ready for installation with minimal site work required.

Unit Assembly

As part of its facade product development practices, Schüco designs the machines and processes for product fabrication. The machines and know-how are then made available to our supply-chain partners. It is this digital fabrication technology that enables the quality product detailing, like mitered corner connections, at competitive pricing.
Quality Assurance

The QA and QC systems and practices of all certified fabricators/installers are subject to review as part of the certification process, with the prerequisite to certification that they meet demanding Schüco standards. These practices are well established with the catalog of Schüco products. New product development at Schüco includes the development of the systems and practices required to assure the determined standard of quality for that product. These systems and practices are then systematically transferred to the fabricators and installers as part of the product technology transfer.

Just-in-time Delivery and Site Logistics

Schüco certified fabricators and installers are trained to coordinate just-in-time site deliveries as required to support site logistics and planning. Storage and staging areas are often limited, especially on dense urban building sites, and organization and coordination of deliveries can be vital in maintaining installation progress and minimizing impact to adjacent trades. In particularly demanding situations, offsite storage can be arranged to optimize material deliveries to site.

Visual and Performance Mockups

Schüco standard products have all been subject to some level of performance testing, but local requirements may vary. Schüco will coordinate with the select fabricator and installer service providers to accommodate both visual and performance mockup and testing programs.

Closeout Documents and Final Site Inspection

Schüco is available to review closeout documents and provide a final site inspection of installed products.

Ongoing Maintenance Services

In addition to fabrication and installation services, Schüco supply chain partners are also available to provide ongoing maintenance services as required for a given installation.

The following section explores the capabilities and services of the Virtual Construction Lab of Schüco (VCL).
The Virtual Construction Lab (VCL) is a powerful resource to Schüco clients. The Lab is based on a conceptual model that was initially developed to facilitate project delivery strategies structured to meet the challenges of novel and highly complex building facade projects. These strategies—often referenced under the umbrella term of design-assist—were highly collaborative, characteristically involving key design and delivery providers very early in the design process. Design-assist project delivery strategies quickly proved to be effective in delivering innovative solutions to complex building problems, while mitigating the risk that accompanies innovation in the building construction market. VCL is an adaptation of this model to the nuanced requirements of product development as opposed to the one-off nature of building design.
**Product versus project**

The Lab has developed a work process called Accelerated Design-Assist Product Delivery or ADAPD. There are substantive differences between products and projects, and successful development processes are shaped by these differences; ADAPD is a process carefully attuned to the particular challenges of product development in the AEC (Architecture, Engineering, and Construction) industry. ADAPD is a strategic product development framework that transcends the limited boundary of product design to consider the full context of the product lifecycle from initial market research and concept development through post launch performance monitoring and evaluation. With a prospective client’s involvement, the ADAPD framework is customized to the specific requirements of each individual product development project.

VCL amplifies innovation in product development through the application of strategic design principles. While there are goals common to both product and project development, such as general considerations of economy, optimal product development demands special consideration of the following:

- Strategic product development that considers the full contextual environment of the product development life cycle.
- Product and production design to provide efficient fabrication and assembly at the projected scale of unit production.
- Product design for ease of installation across the range of applications.
- Robust supply chain development, matching projected program requirements with supply chain capacity, quality, inventory and delivery scheduling, geographic distribution, and installation, across the spectrum of site conditions.
Organization and Service Offerings

VCL is comprised of a small multi-disciplinary team of designers from disciplines ranging from architecture to product design, from building physics to parametric modeling. The concept embodied in VCL is unique in focusing on new product and technology development in the AEC market and has proven a powerful asset in developing niche product solutions as well as highly adaptive product technologies capable of wide variations in application. The ADAPD work process employed by the VCL includes a variety of strategies and techniques including sophisticated rapid visualization processes that speed conceptual design development, combined with progressive budgeting, scheduling, and constructability services that provide an optimized environment for early decision-making by a collaborative design team comprised of representative stakeholders.

The Lab is structured as an independent business unit of Schüco acting as a specialty consultant to multiple clients, but is also capable of adopting a specialty team role while embedded within a partner organization. The Lab model, combined with the unique technical depth of the VCL team, is easily tuned to the specific requirements of a wide variety of research and product development initiatives. The following are among the services offered by the VCL as part of a collaborative product development program.
Services

1. Product design
2. Value-engineering of new and value-analysis of existing products and systems
3. Parametric design
4. Complex geometry and geometric optimization
5. Rapid visualization: 3D modeling, rendering, animation, digital printing
6. Performance analysis: thermal, acoustical, structural, durability, environmental life cycle assessment and analysis, supported by various simulation and analytical techniques
7. Finite element and CFD modeling
8. Facade physics optimization: thermal, acoustical, moisture
9. Code checking
10. LEED, Energy Star, Green Globes, and other rating system facilitation
11. Rapid prototyping and visual mockup services
12. Digital fabrication and automation assistance
13. Manufacturing capacity analysis, production planning and monitoring
14. Constructability analysis, site operations planning and logistics
15. Maintenance programs, planning and training
16. Product commissioning through post-occupancy
17. Personnel training programs
18. Visual mockup construction and management
19. Performance mockup
20. Quality control program development and monitoring
21. Sales and presentation tools: proposal development, graphics, slideshows, animations, mockups
22. Product packaging design
23. Print and web promotional services
24. Event planning and production (conferences, workshops, etc.)
25. Branding, strategic planning, communication, infographics

Your project may require few or many of these capabilities. VCL will provide a proposal custom tailored to your project’s needs, drawn from the ADAPD framework.
Preplanning and the Basis of Design

VCL commences a product development project by working with the client to establish a clear set of goals and objectives for the product, which are documented in the Basis of Design (BOD). The BOD then becomes the reference for decision-making as the project moves forward, and its contents become the predominant criteria for evaluating progress. Ultimately, the success of the product will be determined by the extent to which the goals embedded in the BOD are met or exceeded. The BOD is a living document hosted by VCL but shared between VCL and the client, and subject to ongoing revision as the development process unfolds.

The BOD is finely tuned to the product development program, but generally includes definitions regarding the following:

- Market research and analysis requirements
- The standard of quality
- Scheduling milestones
- Market program: Budgets, price points, financial models, branding and identity, test marketing, promotion, sales
- Technical program: Performance requirements, engineering, analysis, production and facilities design, installation, service life, maintenance, supply chain development
- The user experience
- Program specific goals
- Testing and prototyping requirements
- Implementation: Plant and production, product management
- Environmental considerations: Green product certification, embodied energy profile, operational energy consumption, materials red list, recycling or reuse requirements
- Post-launch monitoring and evaluation
Designing the User Experience

The VCL team understands the importance of end-user considerations to guide the product development process. VCL works with the client and representative user groups as required to assure understanding of the user experience and the client’s goals for the user experience. This information can either be provided as an input to the VCL development process, or VCL can manage the acquisition and evaluation of this information. The user experience can be considered from pre-purchase market exposure through the use cycle and end-of-life disposal.

Design, Engineering, and Analysis: Implementing Innovative Building Technology

The core strength of VCL is a deep technical capability supporting creative problem-solving processes that consistently yield innovative solutions that are both practical and economical. Moreover, our work processes are purposefully designed to mitigate the risk associated with product innovations, yielding novel product solutions stripped of the risk and uncertainty that may accompany innovation in the challenging context of the built environment. Using a wide assortment of powerful tools, VCL in-house analytical capabilities include:

- Design development in various scales and materials
- Structural engineering
- Mechanical engineering
- Thermal and condensation analysis
- Acoustical analysis
- Kinetics and control systems
- Durability analysis
- Security assessment and analysis

The VCL works with a spectrum of design and analysis tools, including some self-developed software tools proprietary to Schüco that can be shared with clients as appropriate. Modeling tools such as Revit can be used by VCL to develop custom tailored BIM systems in support of new product developments. These models can be handed off to the client as part of the VCL service offering.
Rapid Multimedia Visualization

VCL’s design and technical capability is amplified by 3D visualization techniques embedded throughout the Lab’s digital workflows. These include 3D renderings in 2D media, including video animations, but quickly progresses to full scale mockups and prototypes with the goal of getting into physical 3D as quickly as possible. Digital printing and other model-making techniques are a key output of the product development process. Video animations are often used to demonstrate function, supply chain design, and means-and-methods of assembly and installation.

Collaborative Digital Workflows

VCL work processes are steeped in collaboration. We stand shoulder-to-shoulder with our clients through the product development process, enabling decision-making by informing them in real time of the impacts of design decisions as they are made. Consequently, design progresses in the context of known impacts to the BOD, including such critical factors as cost, deployment, and maintenance.
Cost Management (CM), Value Engineering (VE), and Continuous Cost Modeling (CCM)

Cost is invariably a key metric in a product development program, and CM is the process by which that metric is controlled. A cost model is typically built for a VCL product development program and used as the basis for continuous budgeting throughout the design development process, thereby integrating cost management with ADAPD workflows. VE is also integrated into ADAPD as a means to optimize value outcomes as the design progresses. The process brings supply chain development forward and into design development by formally engaging key materials suppliers, vendors, fabricators, and specialty contractors to participate in the development of innovative and economical solutions that satisfy the product design intent.

Continuous cost modeling is a VCL management practice involving the definition of the basic elements and cost structure of the development program in detail. Budget targets along with VE opportunities are identified, prioritized, scheduled and incorporated into the model. The cost model provides a real-time picture of the program budget as it evolves through design development and VE, thus facilitating accurate budget review throughout ADAPD process. The model helps to define areas where VE exercises may be most productive, and the results of the various VE exercises can easily be dropped into the cost model to evaluate impact.

Supply Chain Development

The engine of the ADAPD process is supply chain development. This begins with the involvement of key material and process providers early in design development, and continues right through to product launch, at which time the task of supply chain management can be handed off either to the client, or to Schüco as a value-added service. Supply chain development will drive the product delivery strategy, and must consider the entire product lifecycle from concept development through the operation and maintenance phase, and finally to end-of-life strategies of reuse, recycling, or disposal. The supply chain is critical to the development process, as it will ultimately play the dominant role in determining product quality, service life, lifecycle cost, the user experience, and environmental impacts.
Mockups and Prototypes

Mockups and prototypes play an integral role in the ADAPD process, varying in scale, material, and quality based on their role in the design development process. Sketch mockups may be relatively crude of cardboard; visual mockups are likely to be full scale and built from production materials. Digital printing is often used in the assembly of full-scale facade product mockups.

Testing

Facade systems and products typically require testing, and performance mockups are often constructed for this purpose. Whether actual production products or mockups are tested, VCL can develop and execute the testing program in conformance with specification and/or relevant code requirements. Durability testing is another common testing protocol. Tests can be scheduled at a client’s facility, at the facility of an independent third-party certified testing laboratory, or at Schüco’s Technology Center in Bielefeld, Germany.
Durability Analysis, Maintenance Requirements and Lifecycle Planning

Lifecycle considerations of new product development begin early in the ADAPD process, starting with the definition of the design service life for the product in the BOD document. The new product or system is subject to durability analysis, and maintenance strategies are explored as a strategy to extend service life. This often involves testing in various forms as discussed above. Operable elements, for example, will be subject to repetitive cycling testing of a defined magnitude. Maintenance requirements can then be defined and published as part of the product offering. VCL can even develop personnel training programs to support operations and maintenance procedures, including print and digital manuals, videos, webinars, and workshops. A program of value assessments of defined frequency during the operational phase of a product can monitor the effectiveness of maintenance practices and evaluate the approach of obsolescence.

Environmental Impacts and Sustainability Considerations

Sustainability considerations are gradually shifting from voluntary standards to codified requirements, while concerned enterprises are increasingly layering on their own program goals for environmental performance. Materials red lists are becoming more common. Resilience has become a predominant buzzword in the discussion of urban habitat. New product rating systems such as Green Globes and C2C have emerged with certification protocols. Environmental Product Declarations (EPDs) and their variant cousins are becoming a common requirement on building projects. VCL can evaluate a product and determine the most appropriate scheme and perform the required analysis or otherwise facilitate a program to achieve certification, or simply to assure a targeted level of environmental performance.

VCL as a Flexible and Adaptive Product Development Partner

Perhaps the most valuable components of the VCL–ADAPD equation is the flexibility of VCL team and the broad range of adaptability of the ADAPD process to the myriad nuances that comprise a product development program. It’s the technical depth and range of experience of the VCL team that makes this possible. As a Schüco client, you may be able to bring the VCL onboard as part of your product development team. A specific proposal to accomplish just this — tuned to your program requirements — is either included in or accompanies this document, or is otherwise available on request.
Strategic Fabrication Partners

Strategic fabrication partners for the Landmark Pinnacle project will meet the following requirements:

- Demonstrable experience fabricating Schüco systems.
- Possession of the machinery, equipment, and training to fabricate the system according to K drawings.
- Completion of a certification program specifically tailored to the Landmark Pinnacle project.
Certification Program

Fabrication partners will be required to attend and satisfactorily complete a training program in at the Schüco headquarters in Germany. Only select companies will be invited to participate. The program is intended to ensure that these fabrication partners can consistently meet the required standard of quality.

The fabrication partners will be trained in:

- Understanding shop drawings and the specifics of the system.
- Cutting and assembly of the profiles and fittings.
- QA/QC procedures for all fabrication processes.
- Packaging and crating for shipment.

Global partner network

Schüco’s global fabrication/installation partners number in the thousands, easily accommodating the global chain required for the project program. Our regional managers on every continent will be involved in the selection of qualified fabrication/installation partners in their local or regional territory.
This section covers the proposal drawings and concepts for the Northwestern University fin wall. The building incorporates a series of complex facade types; however, this section demonstrates the features of the segmented-curved unitized system with integrated vertical glass blades.

The following pages depict the componentry and their assembly of a modified Schüco UCC 65 SG system. The units are 4572mm tall and 1219mm wide on average. The glazing is comprised of two vision areas and one spandrel.

The serpentine nature of the wall’s geometry required the use of special coupling gaskets as well as an adaptive anchoring system, which together allow for moderate rotation of the units as they install along the curved slab’s edge. The vertical gaskets are modified to accommodate higher slab deflections required by the project.

The glass fins are attached to the vertical mullions using stainless steel plates with adjustable positioning screws for lineup after the final placement of the units. There is a set of aluminum extrusions that covers the attachment hardware.
Top Anchor
Legend

1. Aluminium Horizontal
2. Aluminium Vertical
3. Insulated Glass
4. Coupling Gasket
5. Saddle Gasket
6. Glass Fin
7. Aluminium Bracket
8. Steel Bracket
9. Tolerance Pads
10. Set Screws
11. Aluminium Fin Cover
12. Insulation
13. Aluminium Insulation Holder
14. Anchor
15. T-Bolt
16. Structural Bracing
17. Foam Insert
18. Glazing Support
19. Aluminium Gasket Backing
Spandrel
Legend

1. Aluminium Horizontal
2. Aluminium Vertical
3. Insulated Glass
4. Coupling Gasket
5. Saddle Gasket
6. Glass Fin
7. Aluminium Bracket
8. Steel Bracket
9. Tolerance Pads
10. Set Screws
11. Aluminium Fin Cover
12. Insulation
13. Aluminium Insulation Holder
14. Anchor
15. T-Bolt
16. Structural Bracing
17. Foam Insert
18. Glazing Support
19. Aluminium Gasket Backing
Intermediate Transom
Legend

1. Aluminium Horizontal
2. Aluminium Vertical
3. Insulated Glass
4. Coupling Gasket
5. Saddle Gasket
6. Glass Fin
7. Aluminium Bracket
8. Steel Bracket
9. Tolerance Pads
10. Set Screws
11. Aluminum Fin Cover
12. Insulation
13. Aluminum Insulation Holder
14. Anchor
15. T-Bolt
16. Structural Bracing
17. Foam Insert
18. Glazing Support
19. Aluminium Gasket Backing
Base
Legend

1. Aluminium Horizontal
2. Aluminium Vertical
3. Insulated Glass
4. Coupling Gasket
5. Saddle Gasket
6. Glass Fin
7. Aluminium Bracket
8. Steel Bracket
9. Tolerance Pads
10. Set Screws
11. Aluminium Fin Cover
12. Insulation
13. Aluminium Insulation Holder
14. Anchor
15. T-Bolt
16. Structural Bracing
17. Foam Insert
18. Glazing Support
19. Aluminium Gasket Backing
Overall Plan and Section

D = Detail
V = View
S = Spandrel

Scale: 1:64
Anchor

Fin Wall – Detail 11
Alternate Anchor

Fin Wall – Detail 11

Scale: 3:8
Intermediate Transom

Fin Wall – Detail 11

Scale: 3:8
Spandrel

Fin Wall – Detail 12

Scale: 3:8
Anchor at Spandrel

Fin Wall – Detail 1
Intermediate Transom

Fin Wall – Detail 2
The system employed in this project is a customization of the standard Schüco UCC 65 SG unitized system, to accommodate higher stack movements. Schüco UCC 65 SG (Unitized Customized Construction) combines the high-quality look of a structural glazing facade with the standardized project processing of a high-performance and flexible modular system, while providing individual design options.

The units are 4572mm high and typical width of approximately 1219mm. The units are planar but follow a serpentine curve in plan. The unit is subdivided into three sections, two vision and one spandrel. The mullions are miter cut at the corners and are joined via corner cleats. The intermediate transoms are attached via screw raceways.

A vertical glass fin with a width of 457mm is attached to one side of each unit. The attachment is through intermittent bolted aluminum connections, with a continuous top cover.

The units are hung from the upper floor and engage interlock to the unit below via a set of two logs protruding from the unit below. The self-weight is assumed to be carried by top two anchors, and the lateral loads are resisted by all four anchors. The anchors are shared by two adjacent units, and each anchor carries the total weight of two units. The anchors have ±38mm of tolerance in each direction.

Wind loads are dictated by wind tunnel tests and load cases and combinations comply with ASCE 7-10 standards. Dead loads are computed based on individual compost weights. The lateral load transfer both through vertical spanning members to the attachment at anchors and connection logs.

The following sections present typical unit calculations for various components of the system, including framing, glass, hardware, and anchorage system. These calculations are for typical unit dimensions and configurations. More detailed analysis and calculations will be required for the final design.
**S1 Design Criteria**

Sizes:
- **Maximum Door Width:** \( D_w = 4 \text{ ft} + 1.625 \text{ in} = 1.26 \text{ m} \)
- **Maximum Door Height:** \( D_h = 15 \text{ ft} + 6 \text{ in} = 4.72 \text{ m} \)
- **Maximum Glass Thickness:** \( G_t = 0.625 \text{ in} = 15.88 \text{ mm} \)

Safety Factors:
- **Tensile Rupture:** \( \Omega_{\text{rupture}} = 1.95 \)
- **Tensile Yielding:** \( \Omega_{\text{yield}} = 1.65 \)
- **Compression:** \( \Omega_c = 1.65 \)
- **Flexure Rupture:** \( \Omega_{\text{frupture}} = 1.95 \)
- **Flexural Other:** \( \Omega_{\text{fother}} = 1.65 \)
- **Shear Rupture:** \( \Omega_{\text{srupture}} = 1.95 \)
- **Shear Other:** \( \Omega_{\text{sother}} = 1.65 \)
- **Tortion Rupture:** \( \Omega_{\text{torrupture}} = 1.95 \)
- **Tortion Other:** \( \Omega_{\text{torother}} = 1.65 \)

Material Property \( I = 101 \)

- **Alloy:** \( F(I, 1) = 6005 \)
- **Temper:** \( F(I, 2) = \text{“T5”} \)
- **E:** \( 10100 \text{ ksi} \)
- **\( F_{tu} \):** \( F(I, 6) \cdot 1 \text{ ksi} = 38 \text{ ksi} \)
- **\( F_{ty} \):** \( F(I, 7) \cdot 1 \text{ ksi} = 35 \text{ ksi} \)
- **\( F_{cy} \):** \( F(I, 7) \cdot 1 \text{ ksi} = 35 \text{ ksi} \)
- **\( F_{uw} \):** \( F(I, 8) \cdot 1 \text{ ksi} = 24 \text{ ksi} \)
- **\( F_{yw} \):** \( F(I, 9) \cdot 1 \text{ ksi} = 13 \text{ ksi} \)
- **\( k_t \):** \( F(I, 10) = 1.25 \)
- **\( F_{su} \):** \( 0.6 \cdot F_{tu} = 22.8 \text{ ksi} \)
- **\( F_{sy} \):** \( 0.6 \cdot F_{ty} = 21 \text{ ksi} \)
- \( G = 3800 \text{ ksi} \)
S2 Computer Model

A computerized analytical model created in the software program SpaceGASS represents the structural elements arranged according to the configuration in the following sketch. The section and material properties, deformation characteristics, and connectivity of the members are considered.

The panel is pinned near the top and bottom corner of the pivot bar with the vertical translation released to allow up and down movement. Only lateral movements are restrained at the two bottom lock locations.

The unitized frame is modeled as aluminum beams, with the cross section described in section S2.3. The outside frame is made of the cross section 1 while the interior stiffner shares the cross section 2. The section properties are extracted from the software program IES ShapeBuilder and assigned to the Finite Element Model in the SpaceGASS.
S2 Computer Model

A computerized analytical model created in the software program SpaceGASS represents the structural elements arranged according to the configuration in the following sketch. The section and material properties, deformation characteristics, and connectivity of the members are considered.

The panel is pinned near the top and bottom corner of the pivot bar with the vertical translation released to allow up and down movement. Only lateral movements are restrained at the two bottom lock locations. The unitized frame is modeled as aluminum beams, with the cross section described in section S2.3. The outside frame is made of the cross section 1 while the interior stiffner shares the cross section 2. The section properties are extracted from the software program IES ShapeBuilder and assigned to the Finite Element Model in the SpaceGASS.

---

S3 Section Properties

Section 1. The cross section of the outer frame.

Section 2. The cross section of the interior Transom.
The dead load of the glass panel is added to the frame as point load at stiffner and the bottom of the frame, as well as the moment induced by the eccentricity of the glass panel. The wind load is extracted from the wind tunnel test conducted by Rowan Williams Davies & Irwin Inc. The 30 psf wind pressure is considered for the main structure while 50 psf for the vertical glass fin.
The dead load of the glass panel is added to the frame as point load at stiffner and the bottom of the frame, as well as the moment induced by the eccentricity of the glass panel. The wind load is extracted from the wind tunnel test conducted by Rowan Williams Davies & Irwin Inc. The 30 psf wind pressure is considered for the main structure while 50 psf for the vertical glass fin.

### S5 Reactions

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<tr>
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<td></td>
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<tr>
<td></td>
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<td>562.50</td>
<td>0.00</td>
<td>967.71</td>
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### Load Cases

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<th>Unit</th>
<th>Value</th>
<th>Unit</th>
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<td>Self-weight</td>
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<td>kip</td>
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<td>kip</td>
<td>0.20</td>
<td>kN</td>
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<td>Dead load of cladding</td>
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<td>0.177</td>
<td>kip</td>
<td>0.20</td>
<td>kN</td>
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<td>4</td>
<td>Moment induced by cladding</td>
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<td>kft</td>
<td>0.00</td>
<td>kNm</td>
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<td>5</td>
<td>Wind load on glass fin</td>
<td>-x</td>
<td>50</td>
<td>psf</td>
<td>2.29</td>
<td>kPa</td>
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<tr>
<td>6</td>
<td>Wind load on cladding</td>
<td>2</td>
<td>50</td>
<td>psf</td>
<td>1.44</td>
<td>kPa</td>
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### Load Combinations

<table>
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<th>Load Combination</th>
<th>LC 1</th>
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<th>LC 3</th>
<th>LC 4</th>
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<td>103</td>
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<td>1.0</td>
<td>0.7</td>
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</table>
**S6 Displacements**

**Load Case 101: 1.0 Dead Load + 1.0 Wind Load on Glass Fin**

Vertical Mullion
\[ \delta_z = 0.27 \text{ in} = 6.858 \text{ mm} \]
\[ \frac{D_h}{\delta_z} = 689 \]

Horizontal Mullion
\[ \delta_x = 0.01 \text{ in} = 0.254 \text{ mm} \]
\[ \frac{D_w}{\delta_x} = 4963 \]

**Load Case 102: 1.0 Dead Load + 1.0 Wind Load on Cladding**

Vertical Mullion
\[ \delta_z = 0.62 \text{ in} = 15.748 \text{ mm} \]
\[ \frac{D_h}{\delta_z} = 300 \]
Load Case 103: 1.0 Dead Load + 0.7 Wind Load on Glass Fin + 0.7 Wind Load on Cladding

Vertical Mullion
\[ \delta_z = 0.47 \text{ in} = 11.938 \text{ mm} \]
\[ \frac{D_h}{\delta_z} = 396 \]

Horizontal Mullion
\[ \delta_y = 0.04 \text{ in} = 1.016 \text{ mm} \]
\[ \frac{D_w}{\delta_y} = 1241 \]
S7 The Head Mullions Check --- Member Number 2

Section Properties

\[ A_s := S(5,1) \text{ in}^2 = 0.969 \text{ in}^2 \]
\[ d := S(1,1) \text{ in} = 8.071 \text{ in} \]
\[ I_{xx} := S(6,1) \text{ in}^3 = 6.494 \text{ in}^3 \]
\[ r_{xx} := \frac{I_{xx}}{A_s} = 2.589 \text{ in} \]
\[ I_{yy} := S(7,1) \text{ in}^3 = 0.191 \text{ in}^3 \]
\[ r_{yy} := \frac{I_{yy}}{A_s} = 0.444 \text{ in} \]
\[ S_{xv} := S(11,1) \text{ in}^3 = 1.55 \text{ in}^3 \]
\[ S_{yv} := S(13,1) \text{ in}^3 = 0.192 \text{ in}^3 \]
\[ J := S(48,1) \text{ in}^4 = 0.722 \text{ in}^4 \]
\[ x_s := S(45,1) \text{ in} = -0.517 \text{ in} \]
\[ y_s := S(46,1) \text{ in} = -0.344 \text{ in} \]
\[ Z_x := S(31,1) \text{ in}^3 = 1.406 \text{ in}^3 \]
\[ Z_y := S(32,1) \text{ in}^3 = 0.239 \text{ in}^3 \]
\[ \beta_s := S(49,1) \cdot \text{ in} = 1.031 \text{ in} \]

Member Forces

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tr>
<td>101</td>
<td>Max Sh.</td>
<td>0.000</td>
<td>-0.070</td>
<td>0.000</td>
<td>0.070</td>
<td>-0.020</td>
<td>-0.270</td>
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<tr>
<td>102</td>
<td>Max. mom.</td>
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<td>0.180</td>
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<td>0.180</td>
<td>0.000</td>
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</tbody>
</table>

---

Virtual Construction Lab of Schüco
Northwestern University Feinberg School of Medicine – Engineering Considerations
Check Compression

There is no axial force. The check for compression is satisfied.

Check Flexure

There is no moment in Y-Axis, so one only need to check the flexure in X-Axis

\[
M_{nx} := \min \left( \frac{M_{nY_{YieldX}}}{\Omega_{other}}, \frac{M_{nY_{ruptureX}}}{\Omega_{rupture}} \right) = 1.827 \text{kip} \cdot \text{ft}
\]

\[
\begin{align*}
M_1 &= \frac{M_{nx}}{M_{nx}} = 0.148 \\
M_2 &= \frac{M_{nx}}{M_{nx}} = 0.104
\end{align*}
\]

Check Shear

There is no shear in X-Axis, so one only need to check the flexure in Y-Axis

\[
Type := 0 \quad 1 \text{ stands for the support on both edges, while } 0 \text{ stands for the support on one edge.}
\]

\[
b_s := 1.5 \text{ in} \quad t_s := 0.17 \text{ in} \quad d_s := 8.0625 \text{ in}
\]

The available shear strength is

\[
V_r := \min \left( \frac{V_{rup}}{\Omega_{rupture}}, \frac{V_{yield}}{\Omega_{other}} \right) = 3.245 \text{ kip}
\]

\[
\begin{align*}
\frac{V_1}{V_r} &= 0.022 \\
\frac{V_2}{V_r} &= 0.028
\end{align*}
\]

\[
\left( \frac{M_1}{M_{nx}} \right)^2 + \left( \frac{V_1}{V_r} \right)^2 = 0.022
\]

\[
\left( \frac{M_2}{M_{nx}} \right)^2 + \left( \frac{V_2}{V_r} \right)^2 = 0.012 \quad \text{OK}
\]
The Bottom Mullions Check - Member Number 15

Section Properties

\[ A_i = S(5, 1) \text{ in}^2 = 0.969 \text{ in}^2 \]
\[ d = S(1, 1) \text{ in} = 8.071 \text{ in} \]
\[ l_{xx} = S(6, 1) \text{ in}^4 = 6.494 \text{ in}^4 \]
\[ l_{yy} = S(7, 1) \text{ in}^4 = 0.191 \text{ in}^4 \]
\[ S_{xx} = S(11, 1) \text{ in}^3 = 1.55 \text{ in}^3 \]
\[ S_{yy} = S(13, 1) \text{ in}^3 = 0.192 \text{ in}^3 \]
\[ J = S(48, 1) \text{ in}^4 = 0.722 \text{ in}^4 \]
\[ x_i = S(45, 1) \text{ in} = -0.517 \text{ in} \]
\[ Z_x = S(31, 1) \text{ in}^3 = 1.406 \text{ in}^3 \]
\[ \beta_i = S(49, 1) \cdot \text{ in} = 1.031 \text{ in} \]

\[ w_g = A_i \cdot 170 \text{ pcf} = 1.144 \text{ lb/ft} \]

Member Forces

<table>
<thead>
<tr>
<th>Member One</th>
<th>Name</th>
<th>Axial Force (kN)</th>
<th>X-Axis Shear (kN)</th>
<th>X-Axis Moment (kN-m)</th>
<th>Y-Axis Moment (kN-m)</th>
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<tr>
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<td>0.181</td>
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</table>

Project  Northwestern University  Date  09.06.2016
Subject  Structural Calculations
The member buckling strength \( P_{ncl} = 1.205 \text{ kip} \)

Local Buckling

\[
P_{ncl} = \frac{0.85 \cdot r^2 \cdot E}{(P_{ncl})^2} \cdot F_{r\text{inter}} \cdot A_y = 20.932 \text{ kip}
\]

The governing load is:

\[
P_{ncl\text{govern}} = \min(P_{ncl}, P_{ncl}, P_{ncl}) = 1.205 \text{ kip}
\]

The available compression strength is

\[
P_{nc} = \frac{P_{ncl\text{govern}}}{\Omega_c} = 0.73 \text{ kip} \quad \frac{P_f}{P_{nc}} = -0.139 \quad \text{OK}
\]

Check Flexure

Check Yielding

\[
M_{npyield\text{X}} = \min (Z_x \cdot F_{cy}, 1.5 \cdot S_x \cdot F_{cy}, 1.5 \cdot S_x \cdot F_{cy}) = 4.101 \text{ kip} \cdot \text{ft}
\]

\[
M_{npyield\text{Y}} = \min (Z_y \cdot F_{cy}, 1.5 \cdot S_y \cdot F_{cy}, 1.5 \cdot S_y \cdot F_{cy}) = 0.698 \text{ kip} \cdot \text{ft}
\]

Check Rupture

\[
M_{nprup\text{X}} = Z_x \cdot \frac{F_{tu}}{K_t} = 3.562 \text{ kip} \cdot \text{ft} \quad M_{nprup\text{Y}} = Z_y \cdot \frac{F_{tu}}{K_t} = 0.606 \text{ kip} \cdot \text{ft}
\]
Check Local Buckling - Flexure

\[ F_b = 45.91 \text{ ksi} \quad F_c = F_{ncl} = 19.789 \text{ ksi} \]

\[ M_{nclb} = F_c \frac{I_r}{c_{ef}} + F_b \frac{I_w}{c_{cw}} = 60.523 \text{ kip \cdot ft} \]

\[ M_{nclby} = F_c \frac{I_r}{c_{ef}} + F_b \frac{I_w}{c_{cw}} = 5.767 \text{ kip \cdot ft} \]

Check Lateral Torsional Buckling

X Axis (Strong Axis)

\[ M_{nmbx} = 3.027 \text{ kip \cdot ft} \quad k_2 = 2.27 \]

Y Axis (Weak Axis)

\[ M_{nmby} = 0.661 \text{ kip \cdot ft} \]

\[ M_{ux} = \min \left( \frac{M_{nclb}}{\Omega_{other}}, \frac{M_{nclby}}{\Omega_{nclb}}, \frac{M_{nmbx}}{\Omega_{nmbx}}, \frac{M_{nmby}}{\Omega_{nmby}} \right) = 1.827 \text{ kip \cdot ft} \]

\[ M_{uy} = \min \left( \frac{M_{nclb}}{\Omega_{other}}, \frac{M_{nclby}}{\Omega_{nclb}}, \frac{M_{nmbx}}{\Omega_{nmbx}}, \frac{M_{nmby}}{\Omega_{nmby}} \right) = 0.311 \text{ kip \cdot ft} \]

\[ \frac{M_{ux}}{M_{ux}} = 0.301 \quad \frac{M_{uy}}{M_{uy}} = -0.257 \]

OK
Check Local Buckling - Flexure

\[ F_{b} = 45.91 \text{ ksi} \]

\[ F_{c} = 19.789 \text{ ksi} \]

\[ M_{nL} = + \cdot F_{c} \cdot I_{c} \cdot c_{f} \cdot F_{b} \cdot I_{w} \cdot c_{f} \cdot 60.523 \text{ kip ft} \]

\[ M_{nL} = + \cdot F_{c} \cdot I_{c} \cdot c_{f} \cdot F_{b} \cdot I_{w} \cdot c_{f} \cdot 5.767 \text{ kip ft} \]

Check Lateral Torsional Buckling

\[ M_{nmbX} = 3.027 \text{ kip ft} \]

\[ k_{2} = 2.27 \]

\[ M_{nmbY} = 0.661 \text{ kip ft} \]

\[ k_{1} = 0.301 \]

\[ M_{nmbX} = \min \left( \frac{M_{y}}{M_{nbX}}, \frac{M_{y}}{M_{nmbY}} \right) = 1.827 \text{ kip ft} \]

\[ M_{1x} = 0.301 \]

\[ M_{nmbY} = \min \left( \frac{M_{y}}{M_{nbY}}, \frac{M_{y}}{M_{nmbY}} \right) = 0.311 \text{ kip ft} \]

\[ M_{1y} = 0.257 \]

Check Shear

Check the Y direction Shear

\[ \text{Type} = 0 \]

1 stands for the support on both edges, while 0 stands for the support on one edge.

\[ b_{y} = 1.5 \text{ in} \]

\[ t_{y} = 0.17 \text{ in} \]

\[ d_{y} = 8.0625 \text{ in} \]

The available shear strength is

\[ V_{y} = \min \left( \frac{V_{rup}}{\Omega_{rupture}}, \frac{V_{yield}}{\Omega_{other}} \right) = 3.245 \text{ kip} \]

\[ V_{frupture} \]

\[ V_{yield} \]

\[ V_{y} = 0.042 \text{ kip} \text{ OK} \]

Check the X direction Shear

\[ \text{Type} = 0 \]

1 stands for the support on both edges, while 0 stands for the support on one edge.

\[ b_{x} = 1 \text{ in} \]

\[ t_{x} = 0.125 \text{ in} \]

\[ d_{x} = 1.75 \text{ in} \]

The available shear strength is

\[ V_{x} = \min \left( \frac{V_{rup}}{\Omega_{rupture}}, \frac{V_{yield}}{\Omega_{other}} \right) = 1.591 \text{ kip} \]

\[ V_{frupture} \]

\[ V_{yield} \]

\[ V_{x} = 0.114 \text{ kip} \text{ OK} \]

Check Torque

\[ t = 0.125 \text{ in} \]

\[ C = \frac{5.773}{t} \text{ in}^3 \]

\[ T_{rupture} = \frac{F_{n}}{k_{t}} \cdot C = 8.775 \text{ kip} \cdot \text{ ft} \]

\[ T_{yield} = F_{yield} \cdot C = 10.102 \text{ kip} \cdot \text{ ft} \]

\[ T_{n} = \min \left( \frac{T_{rupture}}{\Omega_{rupture}}, \frac{T_{yield}}{\Omega_{other}} \right) = 4.5 \text{ kip} \cdot \text{ ft} \]

\[ Safety = \frac{T_{1}}{T_{n}} = 0.193 \]

Check the Combination of Loads

\[ \frac{P_{t}}{P_{nc}} + \left( \frac{M_{tx}}{M_{nx}} \right)^2 + \left( \frac{M_{ty}}{M_{ny}} \right)^2 + \left( \frac{V_{tx}}{V_{nx}} \right)^2 + \left( \frac{V_{ty}}{V_{ny}} \right)^2 + \left( \frac{T_{tx}}{T_{nx}} \right)^2 = 0.07 \text{ OK} \]
S9 The Vertical Mullions Check

Section Properties

\[ A_j := S(5, 1) \text{ in}^2 = 0.969 \text{ in}^2 \]
\[ w_d := A_j \cdot 170 \text{ pcf} = 1.144 \text{ lbf \/ ft} \]
\[ d := S(1, 1) \text{ in} = 8.071 \text{ in} \]
\[ I_{xx} := S(6, 1) \text{ in}^4 = 6.494 \text{ in}^4 \]
\[ r_{xx} := \sqrt{\frac{I_{xx}}{A_d}} = 2.589 \text{ in} \]
\[ I_{yy} := S(7, 1) \text{ in}^4 = 0.191 \text{ in}^4 \]
\[ r_{yy} := \sqrt{\frac{I_{yy}}{A_d}} = 0.444 \text{ in} \]
\[ S_{xj} := S(11, 1) \text{ in}^3 = 1.55 \text{ in}^3 \]
\[ S_{ym} := S(12, 1) \text{ in}^3 = 1.673 \text{ in}^3 \]
\[ S_{yj} := S(13, 1) \text{ in}^3 = 0.192 \text{ in}^3 \]
\[ S_{yn} := S(14, 1) \text{ in}^3 = 0.381 \text{ in}^3 \]
\[ J := S(48, 1) \text{ in}^4 = 0.722 \text{ in}^4 \]
\[ C_w := S(47, 1) \text{ in}^3 = 4.004 \text{ in}^3 \]
\[ x_j := S(45, 1) \text{ in} = -0.517 \text{ in} \]
\[ y_j := S(46, 1) \text{ in} = -0.344 \text{ in} \]
\[ Z_{xj} := S(31, 1) \text{ in}^3 = 1.406 \text{ in}^3 \]
\[ Z_{yj} := S(32, 1) \text{ in}^3 = 0.239 \text{ in}^3 \]
\[ \beta_j := S(49, 1) \cdot \text{ in} = 1.031 \text{ in} \]

Member Forces

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<th>Y-Axis Shear (k)</th>
<th>X-Axis Shear (k)</th>
<th>Vx (k)</th>
<th>Torsion (dz)</th>
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<th>Y-Axis Moment (kft)</th>
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09.06.2016
Check Compression

Member Buckling

\[ L_x = 186 \text{ in} \quad L_y = 116 \text{ in} \quad L_z = 116 \text{ in} \]

The member buckling strength \( P_{ncM} = 1.205 \text{ kip} \)

Local Buckling

\[ F_{ncl} = 19.789 \text{ ksi} \quad P_{ncl} = 19.028 \text{ kip} \]

The member and local buckling interaction

\[
P_{ncl} = \left( 0.85 \cdot \frac{n^2 \cdot E}{b_{inter}^2 \cdot t_{inter}} \right)^{\frac{1}{3}} \cdot F_{ncl}^{\frac{2}{3}} \cdot A_y = 20.932 \text{ kip}
\]

The governing load is: \( P_{ngovern} = \min(P_{ncl}, P_{ncl}, P_{ncM}) = 1.205 \text{ kip} \)

The available compression strength is

\[ P_{nc} = \frac{P_{ngovern}}{\Omega_c} = 0.73 \text{ kip} \quad \frac{P_g}{P_{nc}} = 0.266 \quad \text{OK} \]

Check Flexure

Check Yielding

\[ M_{npYieldX} = \min(Z_x, F_{cy}, 1.5 \cdot S_y, F_{cy}, 1.5 \cdot S_e, F_{cy}) = 4.101 \text{ kip} \cdot \text{ft} \]

\[ M_{npYieldY} = \min(Z_y, F_{cy}, 1.5 \cdot S_y, F_{cy}, 1.5 \cdot S_e, F_{cy}) = 0.698 \text{ kip} \cdot \text{ft} \]
Check Rupture

\[ M_{\text{rupt,}X} = Z_x \cdot \frac{F_{tu}}{k_t} = 3.562 \text{ kip} \cdot \text{ft} \]
\[ M_{\text{rupt,}Y} = Z_y \cdot \frac{F_{tu}}{k_t} = 0.606 \text{ kip} \cdot \text{ft} \]

Check Local Buckling - Flexure

\[ F_b = 45.91 \text{ ksi} \]
\[ F_c = 19.789 \text{ ksi} \]

\[ M_{\text{flex,}x} = F_c \cdot \frac{I_f}{c_{ct}} + F_b \cdot \frac{I_w}{c_{cw}} = 60.523 \text{ kip} \cdot \text{ft} \]

\[ M_{\text{flex,}y} = F_c \cdot \frac{I_f}{c_{ct}} + F_b \cdot \frac{I_w}{c_{cw}} = 5.767 \text{ kip} \cdot \text{ft} \]

Check Lateral Torsional Buckling

X Axis (Strong Axis)

\[ M_{\text{mb,}x} = 3.027 \text{ kip} \cdot \text{ft} \]

Y Axis (Weak Axis)

\[ M_{\text{mb,}y} = 0.661 \text{ kip} \cdot \text{ft} \]

\[ M_\gamma = \min \left( \frac{M_{\text{rupt,}X}}{\Omega_{\text{rupt,}X}}, \frac{M_{\text{rupt,}Y}}{\Omega_{\text{rupt,}Y}}, \frac{M_{\text{mb,}X}}{\Omega_{\text{mb,}X}}, \frac{M_{\text{mb,}Y}}{\Omega_{\text{mb,}Y}} \right) = 1.827 \text{ kip} \cdot \text{ft} \]
\[ M_\gamma = 0.772 \text{ kip} \cdot \text{ft} \]

\[ M_\phi = \min \left( \frac{M_{\text{rupt,}X}}{\Omega_{\text{rupt,}X}}, \frac{M_{\text{rupt,}Y}}{\Omega_{\text{rupt,}Y}}, \frac{M_{\text{mb,}X}}{\Omega_{\text{mb,}X}}, \frac{M_{\text{mb,}Y}}{\Omega_{\text{mb,}Y}} \right) = 0.311 \text{ kip} \cdot \text{ft} \]

\[ M_\phi = 0.772 \text{ kip} \cdot \text{ft} \]
Check Shear

Check the shear in Y-axis

\[ \text{Type} := 0 \quad 1 \text{ stands for the support on both edges,} \]
\[ \text{while } 0 \text{ stands for the support on one edge.} \]

\[ b_y := 1.5 \text{ in} \quad t_y := 0.17 \text{ in} \quad d_y := 8.0625 \text{ in} \]

The available shear strength is

\[ V_Y := \min \left( \frac{V_{\text{rup}}}{D_{\text{rupture}}}, \frac{V_{\text{yield}}}{D_{\text{other}}} \right) = 3.245 \text{ kip} \quad \frac{V_{\text{rup}}}{V_Y} = 0.156 \]

Check the shear in X-axis

\[ \text{Type} := 0 \quad 1 \text{ stands for the support on both edges,} \]
\[ \text{while } 0 \text{ stands for the support on one edge.} \]

\[ b_x := 1 \text{ in} \quad t_x := 0.125 \text{ in} \quad d_x := 1.5 \text{ in} \]

The available shear strength is

\[ V_X := \min \left( \frac{V_{\text{rup}}}{D_{\text{rupture}}}, \frac{V_{\text{yield}}}{D_{\text{other}}} \right) = 1.591 \text{ kip} \quad \frac{V_{\text{rup}}}{V_X} = 0.064 \]

Check the Combination of Loads

\[ \frac{P_p}{P_{nc}} = \left( \frac{M_p}{M_{nc}} \right)^2 + \left( \frac{V_{gx}}{V_X} \right)^2 + \left( \frac{V_{gy}}{V_Y} \right)^2 = 0.89 \quad \text{OK} \]
S10 The Lower Transom Check

Section Properties

\[ A_s = S(5, 1) \text{ in}^2 = 2.585 \text{ in}^2 \]

\[ w_s = A_s \cdot 170 \text{ pcf} = 3.062 \text{ lbf/ft} \]

\[ d = S(1, 1) \text{ in} = 3.228 \text{ in} \]

\[ I_{sx} = S(6, 1) \text{ in}^4 = 5.184 \text{ in}^4 \]

\[ I_{sy} = S(7, 1) \text{ in}^4 = 20.16 \text{ in}^4 \]

\[ r_{sx} = \sqrt{\frac{I_{sx}}{A_s}} = 1.416 \text{ in} \]

\[ r_{sy} = \sqrt{\frac{I_{sy}}{A_s}} = 2.793 \text{ in} \]

\[ S_{v0} = S(11, 1) \text{ in}^3 = 3.211 \text{ in}^3 \]

\[ S_{vo} = S(12, 1) \text{ in}^3 = 3.211 \text{ in}^3 \]

\[ S_{v1} = S(13, 1) \text{ in}^3 = 5.32 \text{ in}^3 \]

\[ S_{vo} = S(14, 1) \text{ in}^3 = 4.752 \text{ in}^3 \]

\[ J = S(48, 1) \text{ in}^4 = 12.63 \text{ in}^4 \]

\[ C_v = S(47, 1) \text{ in}^6 = 3.99 \text{ in}^6 \]

\[ x_s = S(45, 1) \text{ in} = (2.51 \cdot 10^3) \text{ in} \]

\[ y_s = S(46, 1) \text{ in} = (1.378 \cdot 10^3) \text{ in} \]

\[ Z_{sx} = S(31, 1) \text{ in}^3 = 3.507 \text{ in}^3 \]

\[ Z_{sy} = S(32, 1) \text{ in}^3 = 6.381 \text{ in}^3 \]

\[ \beta_s = S(49, 1) \cdot \text{in} = -1.177 \text{ in} \]

Member Forces

Check Compression

Member Buckling

\[ L_x = 35 \text{ in} \]

\[ L_y = 35 \text{ in} \]

\[ L_z = 35 \text{ in} \]

The member buckling strength \( P_{nc,n} = 84.185 \text{ kip} \)
Local Buckling

\[ P_{\text{nc}} = \left( \frac{0.85 \cdot n^2 \cdot E}{b \cdot t} \right)^{\frac{1}{3}} \cdot \frac{F_{\text{ult}}^2}{t} \cdot A_y = 31.353 \ kip \]

The governing load is: \[ P_{\text{govern}} = \min(P_{\text{nc}}, P_{\text{L}}, P_{\text{M}}) = 31.353 \ kip \]

The available compression strength is \[ P_{\text{nc}} = \frac{P_{\text{govern}}}{\Omega_c} = 19.002 \ kip \]

Check Flexure

Check Yielding

\[ M_{\text{npYieldX}} = \min(Z_x \cdot F_{\text{cy}} \cdot 1.5 \cdot S_t \cdot F_{\text{ty}} \cdot 1.5 \cdot S_c \cdot F_{\text{cy}}) = 10.229 \ kip \cdot ft \]

\[ M_{\text{npYieldY}} = \min(Z_y \cdot F_{\text{cy}} \cdot 1.5 \cdot S_t \cdot F_{\text{ty}} \cdot 1.5 \cdot S_c \cdot F_{\text{cy}}) = 14.048 \ kip \cdot ft \]

Check Rupture

\[ M_{\text{npRupX}} = Z_x \cdot \frac{F_{\text{tu}}}{k_1} = 8.884 \ kip \cdot ft \]

\[ M_{\text{npRupY}} = Z_y \cdot \frac{F_{\text{tu}}}{k_1} = 16.165 \ kip \cdot ft \]
Check Local Buckling - Flexure

\[ F_b = 44.482 \text{ ksi} \quad F_c = F_{ncd} = 14.829 \text{ ksi} \]

\[ M_{lbx} := F_c \cdot \frac{l_f}{I_{cf}} + F_b \cdot \frac{l_w}{I_{cw}} = 11.054 \text{ kip} \cdot \text{ft} \]

\[ M_{lby} := F_c \cdot \frac{l_f}{I_{cf}} + F_b \cdot \frac{l_w}{I_{cw}} = 10.76 \text{ kip} \cdot \text{ft} \]

Check Lateral Torsional Buckling
X Axis (Strong Axis)

\[ M_{mbx} = 9.879 \text{ kip} \cdot \text{ft} \]

Y Axis (Weak Axis)

\[ M_{mbx} = 13.305 \text{ kip} \cdot \text{ft} \]

\[ M_{mx} := \min \left( \frac{M_{y yield} X}{\Omega_{fla}^{other}}, \frac{M_{y flup} X}{\Omega_{fla}^{rupture}}, \frac{M_{mbx} X}{\Omega_{fla}^{other}}, \frac{M_{mlbx}}{\Omega_{fla}^{other}} \right) = 4.556 \text{ kip} \cdot \text{ft} \]

\[ M_{ny} := \min \left( \frac{M_{y yield} Y}{\Omega_{fla}^{other}}, \frac{M_{y flup} Y}{\Omega_{fla}^{rupture}}, \frac{M_{mby} Y}{\Omega_{fla}^{other}}, \frac{M_{mlby}}{\Omega_{fla}^{other}} \right) = 6.521 \text{ kip} \cdot \text{ft} \]

\[ \frac{M_{101}}{M_{ny}} = 0.109 \quad \frac{M_{103}}{M_{ny}} = 0.077 \quad \text{OK} \]
Check Shear

Check Shear in X direction

\[ T_{type} = 0 \]
1 stands for the support on both edges, while 0 stands for the support on one edge.

\[ b_3 = 3 \text{ in} \quad t_s = 0.125 \text{ in} \quad d_j = 8.0625 \text{ in} \]

The available shear strength is

\[ V_X = 2 \cdot \min \left( \frac{V_{r_{\text{rupt}}}}{\Omega_{\text{rupture}}}, \frac{V_{\text{yield}}}{\Omega_{\text{other}}} \right) = 7.752 \text{ kip} \]

\[ \frac{V_{103X}}{V_X} = -0.022 \quad \frac{V_{103X}}{V_X} = -0.026 \]

Check Shear in Y direction

\[ b_3 = 8.0625 \text{ in} \quad t_s = 0.125 \text{ in} \quad d_j = 3 \text{ in} \]

The available shear strength is

\[ V_X = 2 \cdot \min \left( \frac{V_{r_{\text{rupt}}}}{\Omega_{\text{rupture}}}, \frac{V_{\text{yield}}}{\Omega_{\text{other}}} \right) = 3.252 \text{ kip} \]

\[ \frac{V_{103Y}}{V_X} = 0.019 \quad \frac{V_{103Y}}{V_X} = 0.019 \]

Check the Combination of Loads

\[ \left( \frac{M_{101}}{M_{ny}} \right)^2 + \left( \frac{V_{101X}}{V_X} \right)^2 + \left( \frac{V_{101Y}}{V_Y} \right)^2 = 0.015 \quad \text{OK} \]

\[ \left( \frac{M_{103}}{M_{ny}} \right)^2 + \left( \frac{V_{103X}}{V_X} \right)^2 + \left( \frac{V_{103Y}}{V_Y} \right)^2 = 0.01 \quad \text{OK} \]
S11 Anchor Design

Anchor Loads (From Reactions)

\[ P_x = 2 \cdot (678.84 \text{ lbf}) = 1.158 \text{ kip} \]
\[ P_y = 2 \cdot (319.27 \text{ lbf}) = 0.639 \text{ kip} \]
\[ P_{ymf} = 1500 \text{ lbf} = 1.5 \text{ kip} \]

Material

Aluminum Extrusions (6061-T5 or 6005A-T61)

\[ F_{br} = 31 \text{ ksi} = 214 \text{ MPa} \quad F_s = 12 \text{ ksi} = 82.737 \text{ MPa} \]
\[ F_b = 28 \text{ ksi} = 193.053 \text{ MPa} \quad F_t = 19 \text{ ksi} = 131 \text{ MPa} \]

Minimum Wall Thickness
\[ \tau_m = 0.125 \text{ in} = 3.175 \text{ mm} \]

Bolts (Steel A325 or M5)

Diameter
\[ d_b = 0.625 \text{ in} = 16 \text{ mm} \]

Shear Capacity
\[ V_{bs} = 3.58 \text{ kip} = 15.925 \text{ kN} \]

Bearing Capacity
\[ V_{bb} = F_{br} \cdot d_b \cdot \tau_m = 2.422 \text{ kip} \quad V_{bb} = 10.773 \text{ kN} \]

Generic Anchor-Bolt Pattern May Vary
Check the Anchor Bolt

Number of Bolts \( N := 4 \)

Number of Row \( \text{Row} := 2 \)

Eccentricities \( G_x := 2.825 \text{ in} \)
\( G_y := .625 \text{ in} \)

Tolerance \( T_x := 1.5 \text{ in} \)
\( T_y := 2.0 \text{ in} \)

Coordinates \( B_x := 2.0 \text{ in} \)
\( B_y := 2.0 \text{ in} \)

\[ x := \begin{bmatrix} 0 \\ 0 \\ -B_x \\ -B_y \end{bmatrix}, \quad y := \begin{bmatrix} 0 \\ B_y \end{bmatrix} \]

Group Centroid \( x_c := \frac{\sum x}{N} = -1 \text{ in} \)
\( y_c := \frac{\sum y}{N} = 1 \text{ in} \)

Applied Moment at Centroid of Bolts

\( M_{d,w} := P_y \cdot (G_x - x_c + T_x) + P_y \cdot (G_y + y_c + T_y) = 7.597 \text{ kip \cdot in} \)

\( M_{d,m} := (P_y + P_{vmd}) \cdot (G_y - x_c + T_y) = 11.388 \text{ kip \cdot in} \)
\( M_{d} := \max(M_{d,m}, M_{d,w}) = 11.388 \text{ kip \cdot in} \)

Torsion Constant:

\( J := \sum (y - y_c)^2 + \sum (x - x_c)^2 = 8 \text{ in}^2 \)

Resultant Shear Force at Each Fasterner:

\( V := \sqrt{\left( \frac{P_x}{N} + M_{d,x} \cdot \sqrt{\frac{(y - y_c)^2 + (x - x_c)^2}{J \cdot \sqrt{2}}} \right)^2 + \left( \frac{P_y}{N} + M_{d,y} \cdot \sqrt{\frac{(y - y_c)^2 + (x - x_c)^2}{J \cdot \sqrt{2}}} \right)^2} = \begin{bmatrix} 2.3 \\ 2.3 \\ 2.3 \\ 2.3 \end{bmatrix} \text{ kip} \)

\( V_{\text{max}} := \max(V) = 2.332 \text{ kip} \)

\( \frac{V_{\text{max}}}{\min(V_{bb}, V_{bb})} = 0.963 < 1.0 \text{ OK} \)
Check Anchor Hook

\[ d_a = \frac{3}{4} \text{ in} = 19 \text{ mm} \quad h = 1.5 \text{ in} = 38.1 \text{ mm} \]

\[ t_h = 0.625 \text{ in} = 15.875 \text{ mm}, t_{hh} = 0.675 \text{ in} = 17.145 \text{ mm} \]

**Location A**

**Shear**

\[ f_v = \frac{P_x}{t_h \cdot a_a} = 2.744 \text{ ksi} \quad F_v = 12 \text{ ksi} \quad \text{OK} \]

**Tension**

\[ f_t = \frac{P_y}{t_h \cdot a_a} = 1.514 \text{ ksi} \quad F_t = 19 \text{ ksi} \quad \text{OK} \]

**Bending**

\[ f_b = \frac{P_x \left( \frac{t_h - a_a}{2} \right)}{t_h^2} \cdot 6 = 9.147 \text{ ksi} \quad F_b = 19 \text{ ksi} \quad \text{OK} \]

**Combined**

\[ \left( \frac{f_b}{F_b} \right)^2 + \left( \frac{f_v}{F_v} \right)^2 = 0.159 \quad \text{OK} \]

**Point B**

**Shear**

\[ f_v = \frac{P_y}{t_h \cdot h} = 0.681 \text{ ksi} \quad F_v = 12 \text{ ksi} \quad \text{OK} \]

**Tension**

\[ f_t = \frac{P_y}{t_h \cdot h} = 1.235 \text{ ksi} \quad F_t = 19 \text{ ksi} \quad \text{OK} \]

**Bending**

\[ f_b = \frac{P_y \left( \frac{h - t_h - a_a}{2} \right)}{t_h^2} \cdot 6 = 5.6 \text{ ksi} \quad F_b = 19 \text{ ksi} \quad \text{OK} \]

**Combined**

\[ \left( \frac{f_b}{F_b} \right)^2 + \left( \frac{f_v}{F_v} \right)^2 = 0.043 \quad 1.0 \quad \text{OK} \]

\[ f_t + f_b = 0.263 \quad \text{OK} \]

**Maintenance Load**

**Shear**

\[ f_v = \frac{P_y + P_{ml}}{t_h \cdot h} = 2.281 \text{ ksi} \quad F_v = 12 \text{ ksi} \quad \text{OK} \]
Check Anchor

\[ w_s : = 10 \text{ in} = 254 \text{ mm} \quad t_s : = 0.5 \text{ in} = 12.7 \text{ mm} \]

\[ d_s : = 1.625 \text{ in} = 41.3 \text{ mm} \quad d_s : = 1.375 \text{ in} = 34.9 \text{ mm} \quad TOL_s : = 2 \text{ in} = 50.8 \text{ mm} \]

Shear

\[ f_v : = \frac{P_y}{t_s \cdot w_s} = 0.1 \text{ ksi} \]

\[ F_s : = 12 \text{ ksi} \quad \text{OK} \]

Bending

\[ f_b : = \frac{P_y \cdot d_y + P_y \cdot \left( d_s + TOL_y \right)}{\left( w_s - 2 \cdot \left( 1.0625 \text{ in} \right) \right) \cdot t_s^2} \cdot 6 = 11.9 \text{ ksi} \]

\[ F_b : = 28 \text{ ksi} \quad \text{OK} \]

Combined

\[ \left( \frac{f_v}{F_v} \right)^2 + \left( \frac{f_b}{F_b} \right)^2 = 0.2 \]

\[ \text{OK} \]

Maintenance Load

Shear

\[ f_v : = \frac{P_y + P_{ym}}{t_s \cdot w_s} = 0.4 \text{ ksi} \]

\[ F_s : = 12 \text{ ksi} \quad \text{OK} \]

Bending

\[ f_b : = \frac{\left( P_y + P_{ym} \right) \cdot \left( d_s + TOL_y \right)}{\left( w_s - 2 \cdot \left( 1.0625 \text{ in} \right) \right) \cdot t_s^2} \cdot 6 = 23.6 \text{ ksi} \]

\[ F_b : = 28 \text{ ksi} \quad \text{OK} \]

High-Tensile T-Bolts

\[ TOL_y : = 1 \text{ in} = 25.4 \text{ mm} \quad TOL_y : = 1 \text{ in} = 25.4 \text{ mm} \]

\[ d_{TB} : = 0.81 \text{ in} = 20.574 \text{ mm} \quad b_o : = 6.5 \text{ in} = 165.1 \text{ mm} \]

Allowable Loads

\[ V_{all} : = 3.45 \text{ kip} \quad T_{all} : = 5.2 \text{ kip} \]

\[ V_{TB} : = P_x \cdot 1.158 \text{ kip} \]

\[ t_{TB} : = \frac{P_y \cdot d_y + P_y \cdot \left( d_s + TOL_x + 0.1 \cdot b_o \right)}{b_o} = 0.567 \text{ kip} \]

\[ \left( \frac{V_{TB}}{V_{all}} \right)^2 + \left( \frac{t_{TB}}{T_{all}} \right)^2 = 0.124 \quad \text{OK} \]

Maintenance Load

\[ t_{TB} : = \frac{\left( P_y + P_{ym} \right) \cdot \left( d_s + TOL_y + 0.1 \cdot b_o \right)}{0.9 \cdot b_o} = 1.2 \text{ kip} \quad \text{OK} \]
Methodology

This section presents a thermal analysis by numerical simulation for the Northwestern University Feinberg School of Medicine. The models were created using THERM 7.4 and Window 7.4, specifically the latest version developed by Lawrence Berkley National Laboratory (LBNL). Finite Element Method (FEM) were implemented for simulation of combined steady state heat conduction and radiation. Where applicable and possible, the simulation procedures outlined in the National Fenestration Ratings Council (NFRC) Simulation Manual were followed. Temperature distribution and dew point isotherms, which corresponds to the interior room temperature and relative humidity, are simulated by the NFRC certificated programs mentioned above. Condensation is predicted to form on surfaces that exhibit lower than dew point temperature. All thermal transmittance calculations are based on the area weighted method as cited in Sec 4.1.3 of ISO 15099 for determining the thermal transmittance of fenestration products.

Observed Environmental Conditions

External Conditions:
1. Air and Effective Sky Temperature -0º F (Night)
2. Mean Wind Speed -12.3 MPH

Internal Conditions:
1. Room Temperature -70.0º F
2. Air Movement -Natural Convection
3. Relative Humidity -30%
4. Dew Point -37.14º F

Thermal Performance of Building Enclosure Systems

The building envelope system proposed for the Northwestern University Feinberg School of Medicine was developed to achieve a level of thermal performance that surpassed traditional curtainwall systems installed in Chicago.
## Material Properties

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<th>Material</th>
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<td>Polyurethane foam $\varepsilon = 0.9$</td>
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Virtual Construction Lab of Schüco

Northwestern University Feinberg School of Medicine – Engineering Considerations

Project
Northwestern University
Thermal Calculations

Date 09.06.2016
D2
Color Contour Diagram of Temperature

D2
Isothermal Line of Dew Point Temperature
D11
Color Contour Diagram of Temperature

D11
Isothermal Line of Dew Point Temperature
D12
Color Contour Diagram of Temperature

D12
Isothermal Line of Dew Point Temperature

Virtual Construction Lab of Schüco
Northwestern University Feinberg School of Medicine – Engineering Considerations
Color Contour Diagram of Temperature

Isothermal Line of Dew Point Temperature
Virtual Construction Lab of Schüco
Northwestern University Feinberg School of Medicine – Engineering Considerations

Project: Thermal Calculations
Date: 09.06.2016

D14
Color Contour Diagram of Temperature

D14
Isothermal Line of Dew Point Temperature
D15
Color Contour Diagram of Temperature

D15
Isothermal Line of Dew Point Temperature
D16
Color Contour Diagram of Temperature

D16
Isothermal Line of Dew Point Temperature
### Vision-A System Component Dimensions(IP)

<table>
<thead>
<tr>
<th>Perimeter Dimensions</th>
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<tr>
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<tr>
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## Vision-A System Component U-Values(IP)

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<th>Section V-2 [Btu/hr-sf-F]</th>
<th>Section V-3 [Btu/hr-sf-F]</th>
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## Vision-A System Results per Section(IP)

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## Overall Vision-A System Results(IP)

| Total Frame Area  | 12.52 sf                   |
| Total Edge of Glass Area | 7.55 sf                   |
| Total Center of Glass Area | 22.62 sf                 |
| Total Area       | 42.69 sf                   |

| Overall Frame U-Value | 0.70 [Btu/hr-sf-F] |
| Overall Edge of Glass U-Value | 0.234 [Btu/hr-sf-F] |
| Overall Center of Glass U-Value | 0.23 [Btu/hr-sf-F] |
### Vision-B System Component Dimensions (IP)

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<th>Perimeter Dimensions</th>
<th>Section V-1 [in]</th>
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<tr>
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### Vision-B System Component U-Values(IP)

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<th>[Btu/hr-sf-F]</th>
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<th>Section V-2 [Btu/hr-sf-F]</th>
<th>Section V-3 [Btu/hr-sf-F]</th>
</tr>
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<tbody>
<tr>
<td>Head</td>
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</tr>
<tr>
<td>Right Jamb</td>
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<tr>
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<tbody>
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### Vision-B System Results per Section(IP)

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### Overall Vision-B System Results(IP)

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## Spandrel System Component Dimensions (IP)

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<tr>
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## Spandrel System Component U-Values (IP)

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<th>Section V-2 [Btu/hr-sf-F]</th>
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</thead>
<tbody>
<tr>
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<td>Left Jamb</td>
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<table>
<thead>
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<th>[hr-sf-F/ Btu]</th>
<th>[hr-sf-F/ Btu]</th>
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<td>Infill U-Value</td>
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Spandrel System Results per Section(IP)

<table>
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<th>Section V-1 [Btu/hr-sf-F]</th>
<th>Section V-2 [Btu/hr-sf-F]</th>
<th>Section V-3 [Btu/hr-sf-F]</th>
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<tbody>
<tr>
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Overall Spandrel System Results(IP)

<p>| | |</p>
<table>
<thead>
<tr>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Total Frame Area</td>
<td>13.50 sf</td>
</tr>
<tr>
<td>Total Infill Area</td>
<td>29.72 sf</td>
</tr>
<tr>
<td>Total Area</td>
<td>43.23 sf</td>
</tr>
<tr>
<td>Overall Frame U-Value</td>
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</tr>
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<td>Overall Infill U-Value</td>
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Overall System Results(IP)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Frame Area</td>
<td>51.76 sf</td>
</tr>
<tr>
<td>Total Infill Area</td>
<td>167.19 sf</td>
</tr>
<tr>
<td>Total Area</td>
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<tr>
<td>Overall Frame U-Value</td>
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<td>Overall Infill U-Value</td>
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System U-Value (IP)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Vision Areas</td>
<td>0.35 [Btu/hr-sf-F]</td>
</tr>
<tr>
<td>Spandrel Areas</td>
<td>0.15 [Btu/hr-sf-F]</td>
</tr>
<tr>
<td>Overall U-Value</td>
<td>0.31 [Btu/hr-sf-F]</td>
</tr>
</tbody>
</table>
The system proposed here is designed to accommodate the glass fin unit installation methodology. All components will be manufactured to high tolerances to ensure a proper fit at the job site. The unit will come to site prefabricated in a protective bunk, with the fin attached separately from the tip table. This ensures no damage to the glass fin units during transportation. The following sequence of activity is recommended, starting with hoisting the units to floor and ending with the installation of the saddle gaskets on set floors.

1. **Hoist units.** Using either tower crane or material hoist, the units will be brought to the installation floor. From there, they will be unwrapped and put onto a tip table.

2. **Glass fin addition.** From the tip table, the glass fin will be installed into the support brackets.

3. **Installation at Floor Slab.** Units will be installed at the slab edge from the floor above. Using the Jekko 265 Spider Crane, we recommend 4 total workers, two above and two on the installation floor.

4. **Cover Caps.** Once the units are set, the final cover cap will be installed onto the glass fin.

5. **Saddle Gasket.** The last step is to install the saddle gasket for the installed floor, spanning multiple units. Gasket shears will be used to notch the bottom, as well as cut the top flap. Glue and aluminum plates will be used at the gasket connections to secure them. A gasket roller will be used to finalize the unit installation.
Cover cap installed after next unit is placed

Saddle gasket installed
Weathering performance of the curtainwall system is defined by an air and water primary line (plane) of demarcation between inside and out. Horizontally, this continuous barrier includes the exterior glass, its structural seal, the framing system, the framing internal seals, a horizontal primary gasket carried across unit joints and sealed at splices, and a silicone boot joining units and the primary gasket. Vertically, the barrier also includes glass, structural silicone, framing and seals, but the unit-to-unit seal is achieved through a vertical primary gasket sealed to the underside of the silicone boot and in contact with the primary horizontal seal gasket.

In the horizontal rainscreen, gaskets provide a first line of defense against water penetration by shielding the primary seal line and by creating a pressure equalized chamber in front of the primary seals.

This section diagrams the primary and secondary barrier lines of air and water infiltration for the key enclosure systems. Though only primary and secondary lines are shown, notice that a number of details have an additional third line of defense against the elements.

The concept of the split-mullion unitized curtainwall system is a standard in the construction of mid and high-rise buildings. The process involves the fabrication of aluminum extrusions that are then assembled into frames and glazed with glass or other material (typically aluminum) panels under factory-controlled conditions. The units are then shipped to the site, hoisted into position, and hung off the building structure, where the split-mullions interlock to form a weather seal. In this section, the following weathering characteristics of the unitized curtainwall are discussed:

1. **Water Penetration**

   Water penetration through a barrier is the result of the single or combined effect of three factors; an opening through the barrier; capillary action on the wall surface; a pressure difference across the barrier as the result of wind. Eliminating any one of these factors can prevent water penetration. Curtainwalls need to move, therefore it is not possible to close all openings. It is also very difficult to keep curtainwalls dry at all times. Controlling the third factor—pressure differential—has proven to be the most practical strategy. The concept of the rainscreen was introduced in the early 20th century and was adopted by the curtainwall industry in the 1960s as a primary means of preventing water penetration. The concept, generally referred to as pressure equalized rainscreen (PER) is illustrated in Figure 1 above.

   The PER concept is simple. If there is pressure equilibrium between the outside and the air chambers of the extrusions (Po=Ps), any water penetrating the rainscreen will be drained through the chambers to the outside.

2. **Vapor Barrier Control**

   The stack joint is the mating interface between upper and lower curtainwall units. It accommodates vertical movements imposed by structural live load deflections, temperature induced movements, and allowance for racking of the units during a seismic event. As a result the design of stack joint requires a high degree of articulation as well as the ability to maintain water and air seals. The concept of rainscreen is utilized in the design of the stack joint. A bulb gasket with positive continuous contact is placed in between the sill engagement groove and the head attachment gusset to insure a reliable air and water barrier. The outermost line of defense (in this case tertiary) is provided by creation of a pressure-equalized chamber in front of this air barrier using an exterior wiper gasket (see Figure 2). The pressure inside this chamber is equalized to the pressure outside through openings at quarter-points on the wiper flaps. This system will eliminate the migration of moisture due to pressure differential between the exterior wall and rainscreen cavity. In addition, the tertiary barrier is designed to prevent the movement of

3. **Condensation Control**

4. **Air Infiltration**
Figure 1 - Pressure Equalized Rainscreen (PER)

Figure 2 - Glazing Pocket
moisture due to capillary action, as well as providing protection against water penetration due to kinetic energy (driving rain) or other means of transport such as air stream or gravity.

**Vertical Mullions**

The diagram on page 110 represents the weathering system for the typical vertical split mullions. A two barrier system is also utilized here against water penetration. The primary water/air barrier is located at the back of the mullion, running along the outside face of glass and bridging the joint along the field-applied wet-seal. This is once again the result of the unique interior seal condition. For the secondary vertical, continuous contact is established at the gasket between aluminum components.

**Horizontal Mullions**

Horizontal mullions are factory sealed and designed with two lines of protection; the primary line of defense is the silicone caulk line factory applied at the glass joint. The secondary line of defense is the metal extrusion, which is mechanically fastened to the vertical mullions. All the joinery connections are sealed using silicone joinery pads or factory applied silicone.

**Glazing Pocket**

Glazing pockets are drained to the outside using drainage holes on quarter-points of the horizontal span, or the corner points (see Figure 2).

**Vapor Barrier Control**

Vapor diffusion through an exterior wall is sometimes the cause of cavity wall wetness or condensation in winter. However, because unitized curtainwalls have components that are resistant to vapor diffusion (aluminum extrusions, glass, sheet metal panels, and gaskets), cavity moisture due to diffusion is not a concern.

**Curtainwall Interface Details**

As a standard practice, all interface conditions provided by Schüco systems employ redundancy through a strategy of primary and secondary protection barriers.
Condensation Control

To be resistance to condensation the unitized aluminum curtainwall must incorporate various features, such as quality thermal breaks for the aluminum frames, double glazing for the vision area, and an insulated metal panel in spandrel areas. Connections and fasteners may also include thermal breaks or thermal separators. The condensation resistance of the curtainwall in winter is governed by the indoor conditions of temperature and relative humidity, and the outdoor temperature. In summer, the condensation resistance of the aluminum curtainwall is governed by the outdoor temperature, the outdoor relative humidity, and the indoor air-conditioned temperature. Condensation occurs on the glass or aluminum surfaces when the humidity of the surrounding air comes in contact with a cold surface and changes from a vapor to a liquid. Most of the unitized systems utilize thermal breaks to deal with the condensation issue. The Schüco system also provides a weep gutter at the stack joint. This feature offers an extra measure of protection against condensation. The weep-hole is only utilized in geographic regions of extreme climate or with facade specifications that require protection against humidity levels of 40% or more (see thermal performance report).

Air Infiltration

Air leakage at the glass/aluminum joint is minimized with either a wet silicone seal or a dry silicone gasket. In an unitized system, the mullions are split and therefore include an additional air barrier joint between the half mullions. Unitized systems perform well to common air infiltration standards (0.06 cfm psf at 6.24 psf pressure difference).