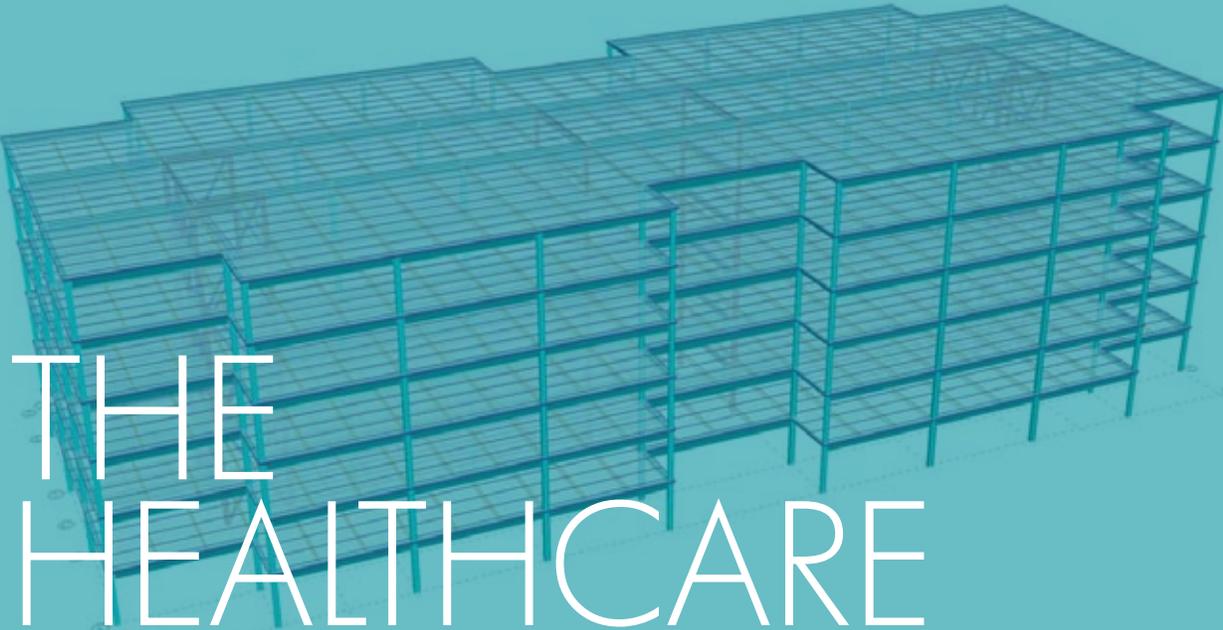


structural
STEEL

Steel
SolutionsCenter



THE
HEALTHCARE
STRUCTURE
PROTOTYPE II

Exploring Castellated Composite Framing

USING THE AISC STEEL SOLUTIONS CENTER

What's this?

This package illustrates a representative conceptual solution developed by the AISC Steel Solutions Center (SSC). The information typically received by the SSC and the conceptual solution provided in reply are both presented here. The conceptual solution also comes with continued support throughout the life of the project from the SSC and more directly, AISC's Regional Engineers.

Project Inquiries

Projects find their way to the SSC in a number of ways. Common scenarios include:

- An owner or architect is developing concepts for a new project. Interested in exploring the advantages of a structural steel framing system, they contact the SSC.
- Project bids are over-budget in another material such as concrete or wood, and a steel alternative is suggested. The architect, engineer, general contractor, or owner contacts a local steel fabricator for assistance who in turn contacts either the SSC or an AISC Regional Engineer for assistance.
- A fabricator learns about a new project in the early stages of development. They contact the owner or project architect to discuss similar steel projects and to highlight the advantages of various steel framed solutions for the project.

Developing a Solution

The AISC team and the client work together—often via conference call—to determine what can be done to move the project forward in steel. Depending on the time frame, the SSC can provide a wide range of solutions from a simple bay framing study to a full conceptual solution. All SSC services are FREE to our clients; however, a level of commitment from the project decision maker to seriously consider the steel alternative is expected.

What do I have here?

This prototype is one example of a conceptual solution that the SSC can provide. Because it is representative of many similar structures, SSC clients often use this prototype as the first step in moving the project forward in steel.

The SSC has been involved in a broad range of projects since its inception in 2001. SSC staff can help you find innovative economical steel solutions for parking garages, office buildings, multi-story residential buildings, healthcare facilities, educational facilities, industrial structures, bridges, and other projects where structural steel can compete.

Please let us know how we can assist you with your next project.



Skyhook Structural Engineering, P.C.

Frazier Rehab Institute Expansion
Louisville, KY
Constructed 2003

THE HEALTHCARE STRUCTURE PROTOTYPE II

This prototype illustrates a typical scenario of how the AISC Steel Solutions Center (SSC) can help a project decision maker evaluate a steel framed alternative. Below is an example of a healthcare structure challenge.

Healthcare Facility

The growing Medical Center in Austin, Texas needed to build a brand new state-of-the-art healthcare facility to take advantage of cutting-edge technology to treat its patients. The new hospital would include the latest in high-tech equipment throughout every part of the facility. After initial planning meetings, the owner realized that the initial scheme would require large floor-to-floor heights to accommodate the extensive MEP systems. In addition to the added height, the hospital needed an easy way to organize, modify, and potentially expand the various pipes and handling units for the systems. Meetings between the Center's owner and design team indicated that there were limitations in fulfilling all of these requirements when evaluating traditional building materials.

The project architect remembered a lunch presentation given by the AISC Great Plains Regional Engineer which focused on innovations in structural steel. The architect then contacted the Regional Engineer to see if steel had any innovative solutions that would satisfy the requirements of a high-tech hospital concept.

Engaging the Resources

The AISC Regional Engineer recognized that medical equipment changes often, and the framing system for the hospital needed to be adaptable in order to keep pace with these rapidly advancing technologies. The Regional Engineer noted that structural steel could easily provide the adaptability that the hospital required. Steel framing can be reinforced or altered easily for modifications in equipment and usages of areas. To address the need for the building framing to accommodate the changing MEP systems throughout the life of the facility, and to reduce the floor-to-floor heights, the Regional Engineer suggested using castellated steel beams instead of traditional wide-flange steel beams. The Regional Engineer noted the following advantages of using this system for the hospital:

- Castellated beams provide large openings that allow for access and organization of pipes for MEP systems
- By using an easily removable ceiling finish, the MEP systems could be easily accessed and modified
- By using the castellated beams on each floor, each floor of the hospital would be allowed to adapt and grow indefinitely with the needs of the patients and healthcare providers

The architect then met with the owner and design team and introduced the concept of using castellated beams for the project. The MEP team thought the idea was great; however, the owner had concerns about vibration and speed of construction for this system. The architect contacted the Regional Engineer again, and the Regional Engineer felt that having the Steel Solutions Center create a conceptual model of the facility would help to address these concerns as well as illustrate how castellated beams could provide the required adaptability.



Skyhook Structural Engineering, P.C.

Frazier Rehab Institute Expansion
Louisville, KY
Constructed 2003



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THE HEALTHCARE STRUCTURE PROTOTYPE II

Steel Conceptual Solution

The AISC Regional Engineer forwarded schematic drawings provided by the architect to the Steel Solutions Center advisor, and the SSC Advisor and design team discussed the design parameters for the building as well as serviceability requirements (vibration, deflection, etc.). A model of the structure was then created using general building design software, and a conceptual solution was provided to the architect. After the conceptual solution was delivered, the Regional Engineer contacted the architect to further discuss the conceptual solution. The Regional Engineer also informed the architect that a steel solution has many other advantages:

- The beam sizes selected for the project were able to accommodate MEP pipes up to 16 inches in diameter
- Castellated beam floor framing provided large bays and long column-free spans
- Castellated beams allowed the design team to consider numerous options for fire protection systems (sprinklers, SFRM, gypsum, intumescent paints, etc.)
- Compared to traditional wide flange beams, the castellated beams were lighter, which reduced the foundation loads for the superstructure

The structural steel framing system will meet the healthcare facility's changing needs and will provide cost savings up front and over the life of the project. A conceptual solution created by the SSC tailored to the project's requirements significantly helped to illustrate structural steel's advantages.



Skyhook Structural Engineering, P.C.



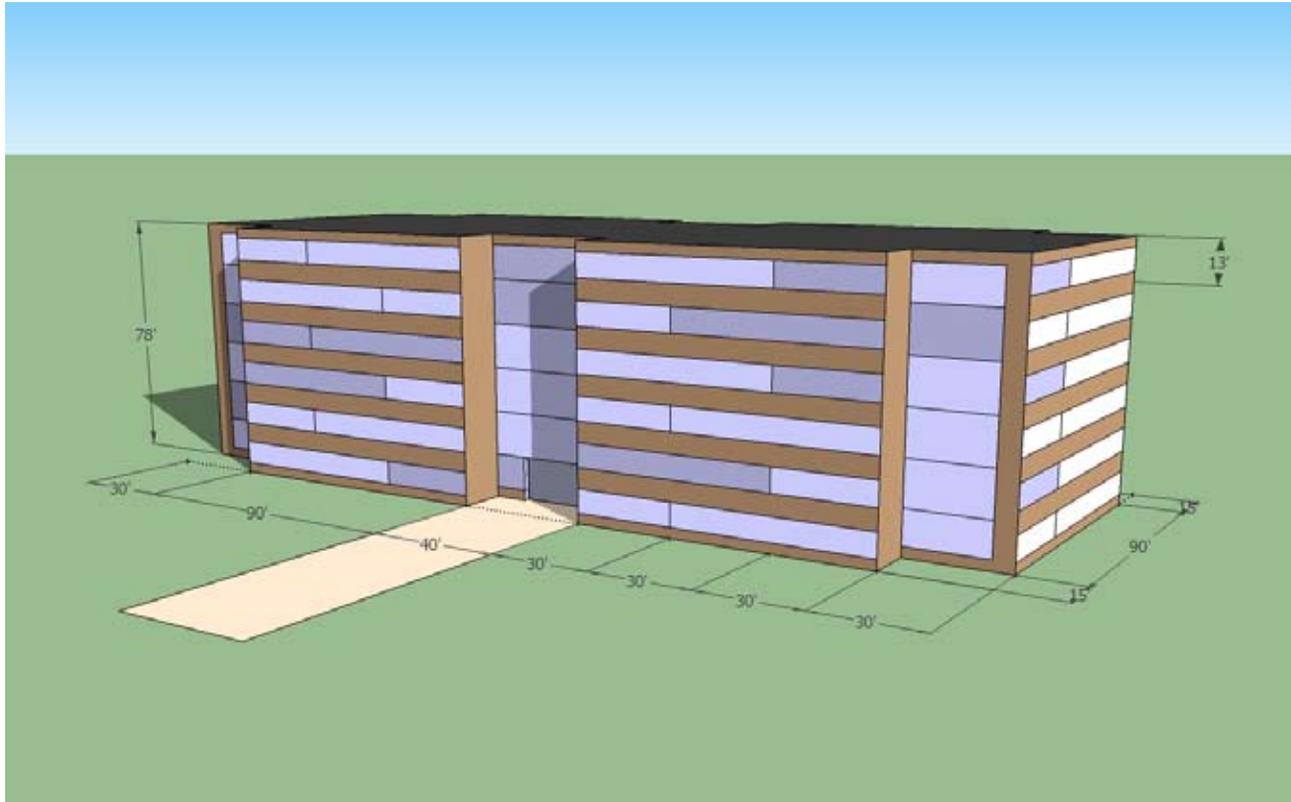
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CASTELLATED HEALTHCARE FACILITY



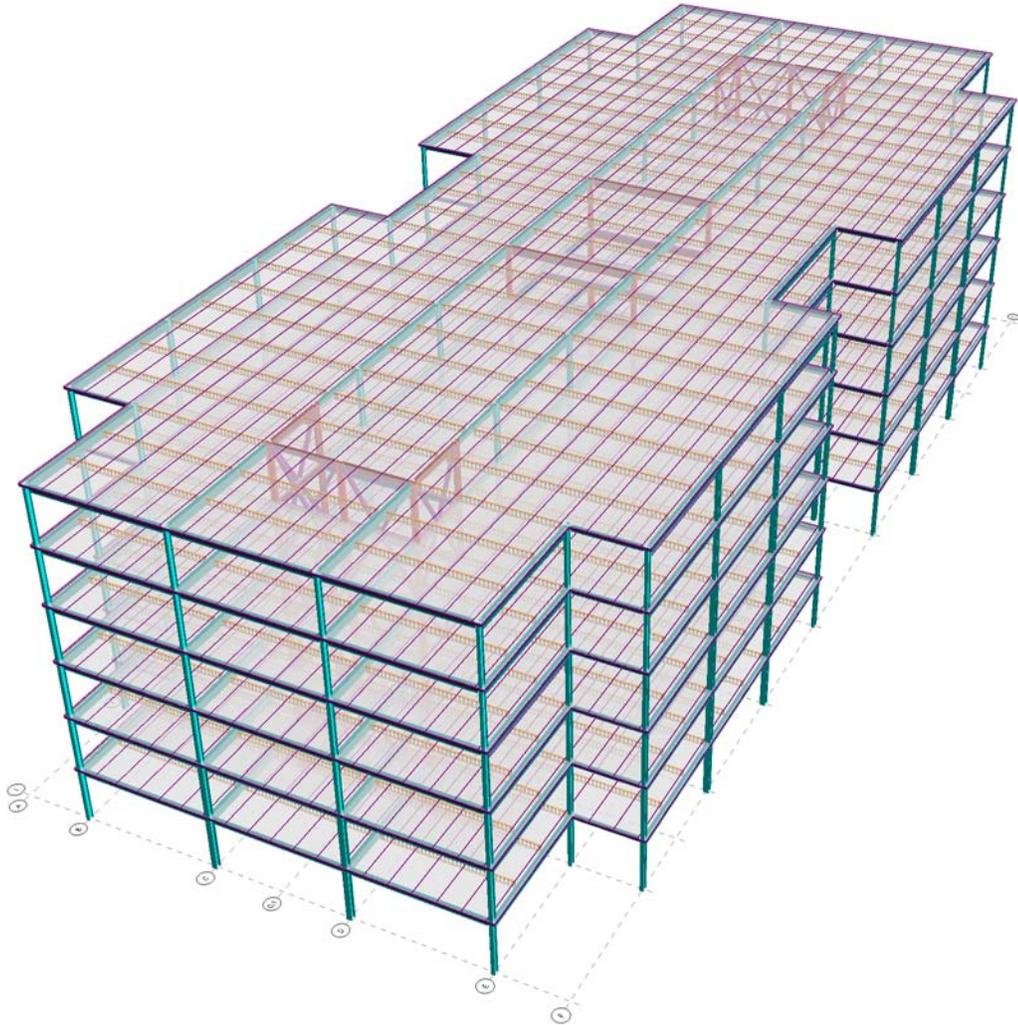
Information Provided to the SSC by the Architect



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CASTELLATED HEALTHCARE FACILITY

Basic SSC Conceptual Framing Model



This Package includes:

Comments on the Provided Solution
Steel Quantity Takeoff
Design Loads and Parameters
Typical Framing Plans
Gravity Column layout
Gravity Column Schedule
Special Concentrically Braced Frame Elevations
Comments on Sustainability in Structural Steel Construction
Standard Details for Castellated Beams
Comments on Building Information Modeling



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COMMENTS ON PROVIDED SOLUTION

Project Location: Austin, TX
Prepared for: Project Architect

Prepared by: SSC Advisor
Regional Engineer: Great Plains Regional Engineer

The information contained in this document is not intended as a basis for structural design for this or any project. Rather, it is a conceptual approach to the project that demonstrates the viability of the steel system for project requirements, budget, and schedule.

- 1) The design criteria per the *International Building Code 2006* (IBC 2006) is summarized and included in the Building Code Criteria page.
- 2) Based on the available options, the traditional composite floor framing system best satisfied the needs of the project. This system provides for long spans and column free spaces as well as the opportunity for future structural modifications. Castellated steel beams were selected for this project to accommodate the various mechanical, electrical, and plumbing systems through the openings in the web of the beam.
- 3) In a traditional floor framing system the fabricated steel framing supports a stay-in-place metal form deck with concrete slab or topping. A 2 in. metal deck with a 4½ in. normal weight concrete topping (total depth of 6½) was used for each floor of this project.
- 4) A mechanical load was placed upon the roof to estimate the effect of possible mechanical systems on the roof. The location of this mechanical area is illustrated on the roof framing plan.
- 5) The steel quantities and geometry of this investigation are provided on the Floor and Roof Framing Plans, the Column Layout Plan, the Column Schedule, and the Frame Elevations on the following pages.
- 6) Centrically braced frames and moment frames were used to estimate the lateral framing quantities of the building. AISC Seismic Provisions were not considered for this study. Lateral frame member sizes are shown in Frame Elevations page.
- 7) The floor framing system was optimized for general walking vibration criteria for computer systems/operating rooms (vibration criteria can be found in AISC Steel Design Guide Series, Design Guide Number 11, *Floor Vibrations Due to Human Activity*).
- 8) Sustainable design principles are being considered. Contributions for the structural steel systems for recycled content have been addressed in this packet. Further information on steel sustainability can be found at www.aisc.org/sustainability.



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QUANTITY TAKEOFF SHEET

Project Location: Austin, TX
Prepared for: Engineer-Of-Record

Prepared by: SSC Advisor
Regional Engineer: Great Plains Regional Engineer

Suspended Floor Areas:

187,917 ft² (~ 31,319 ft² Typical Floor)

Estimated Steel Quantities:

Gravity Columns			
W14's	124 tons	1.32 psf	120 pieces
Gravity Beams			
Wide Flange	239 tons	2.54 psf	320 pieces
Castellated	361 tons	3.84 psf	437 pieces
4,500 studs			
Lateral Frames			
Columns	62 tons	0.66 psf	42 pieces
Beams	26 tons	0.28 psf	60 pieces
Braces (HSS)	46 tons	0.49 psf	96 pieces
Miscellaneous 5%	43 tons	0.46 psf	
901 tons		9.6 psf	1,075 pieces

- The quantities are based on centerline dimensions.
- Steel not indicated in sketches accounts for framing not included in the estimate such as framing for openings or various members eliminated for simplification. It does not include connection material, slab edge material or façade attachments.

Material Specification

Wide flange shapes are A992, Gr. 50

Rectangular hollow structural sections are A500 Gr. B



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DESIGN PARAMETERS: INTERNATIONAL BUILDING CODE 2006

Project Location: Austin, TX
Prepared for: Engineer-Of-Record

Prepared by: SSC Advisor
Regional Engineer: Great Plains Regional Engineer

This investigation is based on the following criteria. The Steel Solutions Center does not assert that these are the criteria that apply to this project. The criteria are chosen based on the project location and the widely adopted model building code, IBC 2006. Requirements by local and state jurisdictions have not been considered. If actual project criteria differ significantly from those listed, the results presented may no longer be valid.

Gravity Loads

Dead Loads	Composite Deck=69 psf [2 in. metal deck with 4½ in. concrete slab]
Live Loads	Medical=100 psf [Typical Floors]
	Roof=20 psf [Portion Roof] Mechanical Roof=125 psf [Portion Roof]
Superimposed Dead Loads	Medical=15 psf [Partitions, CMEP, etc.]
	Roof=20 psf Mechanical Roof=20 psf
Cladding Loads	Façade=350 plf

Wind Load Parameters

Basic Wind Speed	90 mph
Wind Importance Factor, I_w	1.15
Exposure Category	B
Topographical Factor	1.00
Drift Limit	H/500

Basic Seismic-Force-Resisting System Concentrically Braced Frames & Moment Frames

Seismic Design Parameters

Site Class	D
Seismic Importance Factor, I_E	1.50
Seismic Design Category	A
Spectral Response Acceleration at Short Periods (0.2s), S_S	0.081 g
Spectral Response Acceleration at One Second Period (1.0), S_T	0.033 g

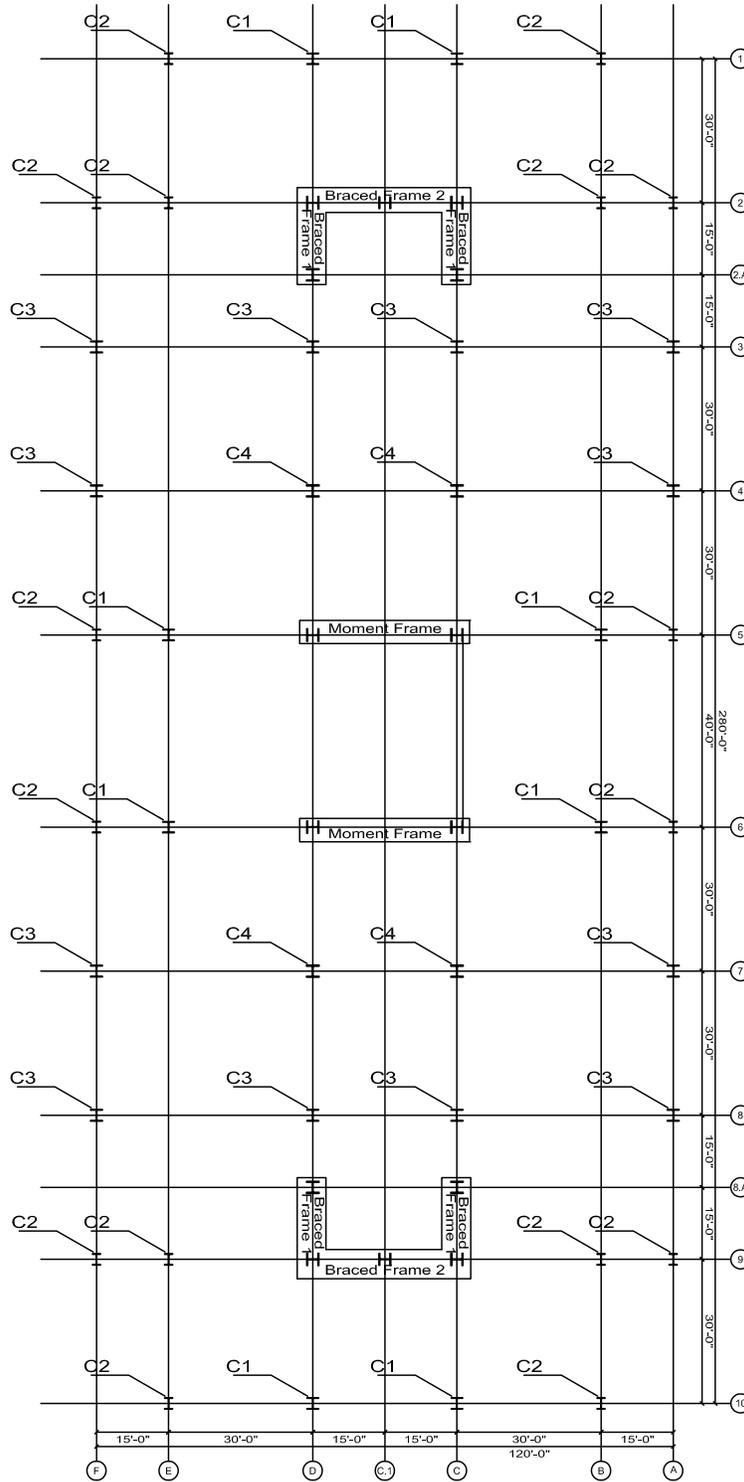
	X-axis	Y-axis
Building Period Coefficient, C_T	0.020	0.028
Response Modification Coefficient, R	3.0	3.0
System Overstrength Factor Ω_o	3.0	3.0
Deflection Amplification Factor, C_d	3.0	3.0

Note: The requirements of the AISC Seismic Provisions WERE NOT used in determining the quantity estimate for this project. Whether or not the special seismic requirements must be taken into account in the design is based on the applicable building code and local requirements.



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COLUMN LAYOUT



NOTES:

1) The columns located within the boxes are columns for the lateral system frames.

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COLUMN SCHEDULE

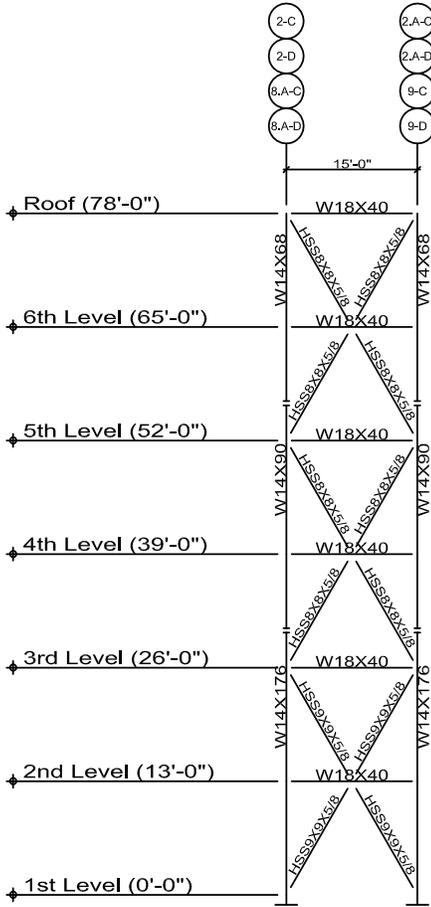
Roof (78'-0")	W14X43	W14X43	W14X68	W14X68
6th Level (65'-0")				
5th Level (52'-0")				
4th Level (39'-0")	W14X68	W14X68	W14X90	W14X120
3rd Level (26'-0")				
2nd Level (13'-0")	W14X90	W14X74	W14X132	W14X176
1st Level (0'-0")				
COLUMN MARK	C1	C2	C3	C4

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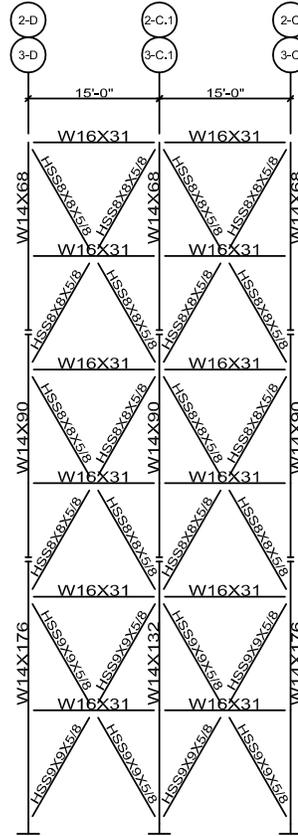


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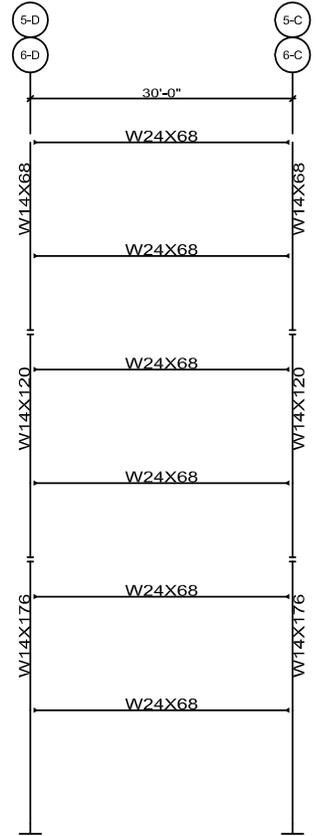
FRAME ELEVATIONS



Braced Frame 1



Braced Frame 2



Moment Frame

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The green buildings movement is increasing at a rapid pace. More and more owners, architects, engineers and contractors are realizing the benefits of sustainable design and construction practices. Selecting structural steel as the framing system is one step toward improving the green or sustainable performance of health-care facilities and other building types. There are multiple credit opportunities for structural steel under the U.S. Green Building Council's Leadership in Environmental and Energy Design (LEED®) for New Construction program. These include MR Credit 1.1: Building Reuse—Maintain Existing Walls, Floors and Roof, MR Credit 2: Construction Waste Management, MR Credit 3: Materials Reuse, MR Credit 4: Recycled Content, MR Credit 5: Regional Materials and ID Credit 1: Innovation in Design. (For more information on these credits, visit www.usgbc.org.) Structural steel also provides sustainability gains and opportunities beyond the LEED system.

Recycled Content

Steel made via the electric arc furnace process (all wide-flange members, channels and angles and some plate and hollow structural sections) has an industry-average recycled content of 93.3%.

Recycling Rate

There is an established market for steel scrap (structural and otherwise), and 98% of all structural steel is recycled at the end of a building's life.

Cradle-to-Cradle

Many materials can be recycled, but most are down-cycled to a different product. For example, concrete from a deconstructed building can be used again as road aggregate, but it can rarely be used again as aggregate for structural concrete. Steel, on the other hand, can be recycled over and over again, or "multi-cycled," without losing any of its strength or properties. This makes steel a true cradle-to-cradle product as opposed to a cradle-to-grave product. And it's not just structural steel. Steel products of all types can become steel products of all other types.

Offsite Fabrication, Onsite Erection

Steel is fabricated in highly automated facilities to strict tolerances, greatly minimizing additional work and the resulting additional labor hours and equipment required on a project site, thus lowering the steel-framed structure's environmental footprint.

Erection Schedule

The erection schedule for a steel-framed health-care structure is about one-third less than that of competing framing systems. This reduced construction schedule not only lowers the steel-framed structure's environmental footprint, it also allows the steel-framed health-care facility to open earlier.

Foundations

Lighter steel-framed health-care structures result in lighter foundation loads, thus decreasing the amount of material needed for the foundation.

Environmental Impact

A study conducted by independent consultants compared the environmental impact of two medical office buildings in Omaha—one framed with structural steel framed and one with concrete framed projects—and concluded that the steel building came out ahead in four of five categories: global warming potential, eutrophication potential, acidification potential and smog potential. The fact that the results in each category, including primary energy demand where steel lagged concrete by 1%, are within 10% of each other indicates that the choice of a structural framing system should not be made on the basis of the environmental impact of the materials alone. It is not just the selection of materials that is important from a sustainable perspective, but also the optimization of those materials in both the design and the actual construction process.

Early Involvement

Adopting a collaborative, integrated project delivery methodology on a steel-framed health-care project means getting the fabricator involved early. An experienced fabricator can help choose more efficient steel assemblies, saving time, materials, and money. Collaborative design combined with a steel framing system and building information modeling (BIM) can result in a project that uses less material, which results in less labor, less cost and less environmental impact.

Flexibility

Steel framing allows for easier reconfiguration or expansion of any type of structure. This is especially important with hospitals and other health-care-related structures where ever-evolving patient needs and equipment requirements mandate regular facility changes.

Deconstruction

Steel-framed health-care facilities can be easily deconstructed, and members can be remanufactured into new members or reused with minimal additional fabrication work. Only 2% of all structural steel from health-care projects ends up in a landfill, with 98% being recycled into new steel products.



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CASTELLATED BEAMS AND GIRDERS

Castellated Shape Usage

Castellated beams are structural steel beams with expanded web sections with repeated web openings. Castellated beams and girders have been used throughout the United States and Europe for many years for nearly every building usage and exhibit the inherent advantages of building with structural steel. Castellated beams can also provide additional advantages particularly allowing the MEP systems to move from being placed below the beams and girders to the openings of the castellated members. This can reduce the floor-to-floor height of the facility, and allows for easy organization and modification of these systems. Exposed castellated beams allow for the flow of light (natural or bulb) through the webs of the beams providing greater indoor environments.

Castellated Beam Advantages:

- Castellated steel members are lightweight and structurally sound.
- Castellated steel members, like wide flange framing, can be painted, galvanized or fire protected.
- Castellated beams provide lower floor-to-floor height by passing ductwork and utilities through openings rather than under the beam.
- Castellated steel members, like wide flange framing, provide a bright and open look for added feeling of safety.
- Steel construction (both castellated and wide flange framing) has the benefit of ease and speed of erection.

Designing Castellated Shapes

The theory behind the castellated members is increasing the member's flexural strength without increasing its weight. The castellation process increases the depth of the beam, thus increasing the flexural strength of the beam. When designing castellated members, there are three additional conditions that must be evaluated by the structural engineer:

- Vierendeel Bending
- Shear (both vertically through the opening and horizontally through the web post)
- Web Post Buckling

Fabrication

Castellated beams have two web opening geometries; hexagonal and cellular. The fabrication process for castellated members can be performed easily by today's more automated fabrication shops. The sections are created by cutting a standard wide-flange shape in a zig-zag pattern along the web, separating the member into two halves. The two halves (which can originate from two different parent wide flange sizes) are then welded at the web posts to create the castellated member. And during the creation of these members, camber can be fabricated into the cutting/welding of the member.

If hexagonal castellated beams are chosen and corrosion protection is required, it is recommended that a high-performance coating system be utilized rather than galvanizing. This decreases the chances of cracks forming at the edges of the hexagonal openings during the hot-dip galvanization process.

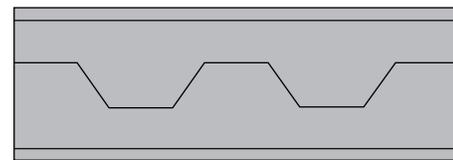
Nomenclature

The general nomenclature for castellated and cellular beams indicates the shape type, the approximate shape depth, and the approximate weight of the shape per linear foot. Castellated beams are represented by a CB prefix, while cellular beams are represented by LB. The number representations are similar to those of standard wide-flange structural steel sections. For example if the root beam for the top portion of the castellated (CB) or cellular beam (LB) is a W21×44 and the root beam for the bottom portion is a W21×57, then the castellated and cellular beam call outs would be CB30×44/57 and LB30×44/57, respectively. The first number represents the approximate depth of the section and the second pair of numbers provides the approximate weight of the root beams used for the top and bottom section (top/bottom).

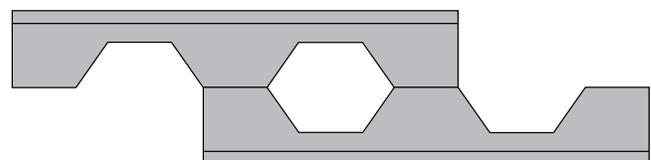
(An AISC Design Guide for castellated and cellular beams will be available in the near future!)

Reference:

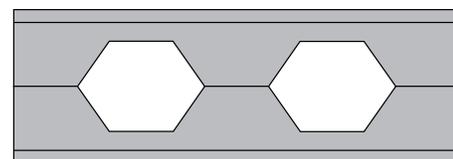
Design of Welded Structures, by Omer W. Blodgett



Cut



Stagger



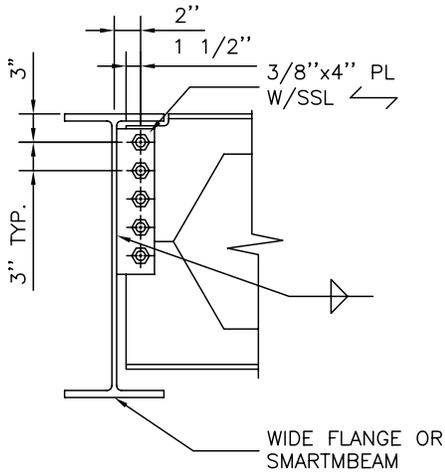
Weld



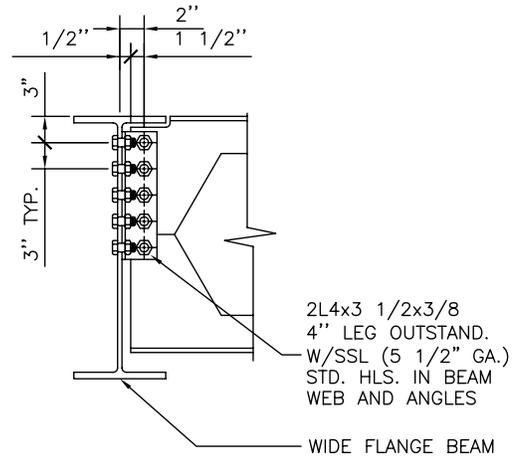
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STANDARD DETAILS FOR CASTELLATED BEAMS

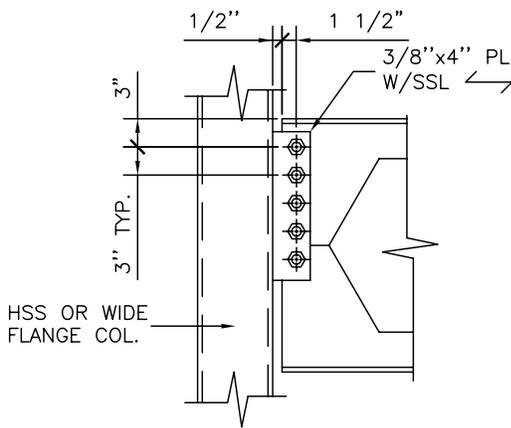
Below are four typical castellated beam connections
(details courtesy of CMC Steel Products)



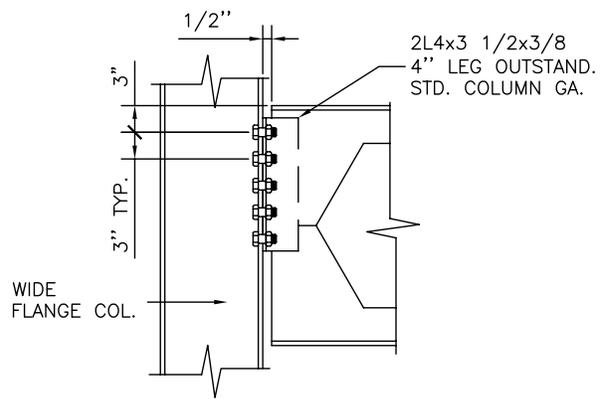
Beam-to-Beam
Shear Tab Conx.



Beam-to-Beam Bolted-
Bolted Clip Ang. Conx.



Beam-to-Column
Shear Tab Conx.



Beam-to-Column Bolted-
Welded Clip Ang. Conx.



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BUILDING INFORMATION MODELING

Building Information Modeling

Building Information Modeling (BIM) is the process of generating and managing a building database in a graphic, multi-dimensional building information model (also abbreviated BIM). The BIM can be used for the entire life cycle of a building project and can contain items that include building geometry, spatial relationships, geographic information, sizes and quantities of building components, and energy system information.

The BIM process requires a great deal of advanced planning and early involvement prior to construction, which in turn helps to eliminate time-consuming design and field issues, materials savings, earlier occupation, and lower up-front costs. The BIM process and model can be advantageous in a variety of ways for almost all parties involved in the construction process:

Owner

BIM allows an owner to capture facilities lifecycle data, reducing maintenance cost over the lifecycle of the building.

Architect/Engineer/Detailer

The Building Information Model can provide for a more accurate steel tonnage, resulting in foundation savings. The BIM model allows design teams to view complicated configurations and connections in 3D. The BIM process also reduces requests-for-information (RFIs) and change orders by identifying collisions and interferences virtually on the model before they ever become issues in the field.

Fabricator

BIM can streamline the entire structural steel fabrication process. Today's high-tech fabrication shops can upload electronic information directly into fabrication equipment without having to convert 2D drawings into different formats. The BIM model can provide for a more accurate steel tonnage, resulting in more accurate estimating/bidding and material savings.

Erector

Erection considerations can be handled before the foundation has been poured. Representations of construction equipment can be placed on the model to allow the erection team to evaluate site conditions and site scheduling. And with collisions and interferences evaluated on the model, time-consuming field modifications and repairs are almost eliminated. Therefore, using the BIM process results in a compressed schedule and faster erection time.

Specialty Contractor

The BIM process enhances scheduling of all subcontractors on the project. With BIM, the subcontractors will know which phase of their work can begin, and the conditions of the construction site they can expect prior to the start of their work. Also, collisions between systems (MEP, HVAC, specialty equipment, etc.) and the structural steel can be evaluated prior to construction, almost eliminating field re-routes or fixes; resulting in a compressed schedule and faster erection time.

Interoperability

The structural steel industry remains a leader in the use of BIM technology—having been using it since before the term 'BIM' was even introduced. Back in 1998, AISC recognized the advantages in cost and schedule that could be gained if different disciplines using different software tools could readily share and access each other's data. AISC's efforts in this area have led to industry wide adoption and acceptance of this method of collaborative project delivery with various methods of exchanging data between different disciplines available today. To learn more visit www.aisc.org/integration.



Photo courtesy of Magnusson Klemencic Associates



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THE HEALTHCARE STRUCTURE PROTOTYPE II

Further Support

Once the conceptual solution was completed, the owner and design team were able to visualize and comprehend castellated structural steel beams as a viable option for their project. To help the owner address his concerns regarding the price and speed of construction, the AISC Regional Engineer passed the conceptual solution onto an AISC Member Fabricator member who was familiar with castellated beam fabrication and erection. The AISC Member Fabricator invited the owner and design team to a tour of his nearby facility to give the owner and design team a chance to visually see the castellation process. The owner and design team were impressed by the speed of the process, and appreciated the time that the fabricator took to address their concerns. After the tour, the AISC Member Fabricator developed an estimate and schedule based on the information provided in the conceptual solution.

Delivering the Message

With the SSC's conceptual solution and the AISC Member Fabricator's initial estimate and schedule, the owner and design team were able to discuss how structural steel met the original project goals, and provided advantages that exceeded their expectations, including:

- A system that meets the vibration criteria for the unique serviceability requirements for sensitive equipment and procedures
- A system that easily accommodates the significant medical mechanical and electrical requirements
- Lower soft costs and earlier revenue generation due to decreased schedule when compared to other building materials
- A system that provides for the adaptability of area usage throughout the life of the structure

The owner and each member of the design team agreed that the castellated structural steel beam option provided more benefits than the traditional structural steel framing system as well as other building materials. The architect and owner were pleased to know that the AISC Steel Solutions Center would provide a high level of technical assistance throughout the life of their project. They voiced their agreement that "there is always a solution in steel!"



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St. Louis, MO
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THE HEALTHCARE STRUCTURE PROTOTYPE II

Postscript

This story is being repeated at the Steel Solutions Center on a daily basis. Project decision makers are reaching out to AISC Regional Engineers and the SSC for new ideas to solve their project challenges. The SSC has resources to help you throughout the life of your project. The SSC works with everyone involved with the construction industry including mills, service centers, fabricators, engineers, architects, general contractors, and code officials. The SSC can offer solutions that provide reduced foundation weight and cost, increased speed of erection, and help with seismic lateral resisting systems. The SSC has prepared and provided tools that help all parties involved to effectively communicate the benefits of steel to their clients and partners. The SSC provides a win-win outcome for everyone involved, and best of all, it is a free service!

What should you do next?

You've invested the time to examine this prototype—a conceptual solution for the castellated composite framing system in a healthcare project. Ask yourself if this system might be beneficial for your next project. When you start to approach your next project, contact your local steel fabricator, AISC Regional Engineer, or call/email the Steel Solutions Center directly to discuss what benefits a steel solution can provide to your project.

There's always a solution in steel.



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