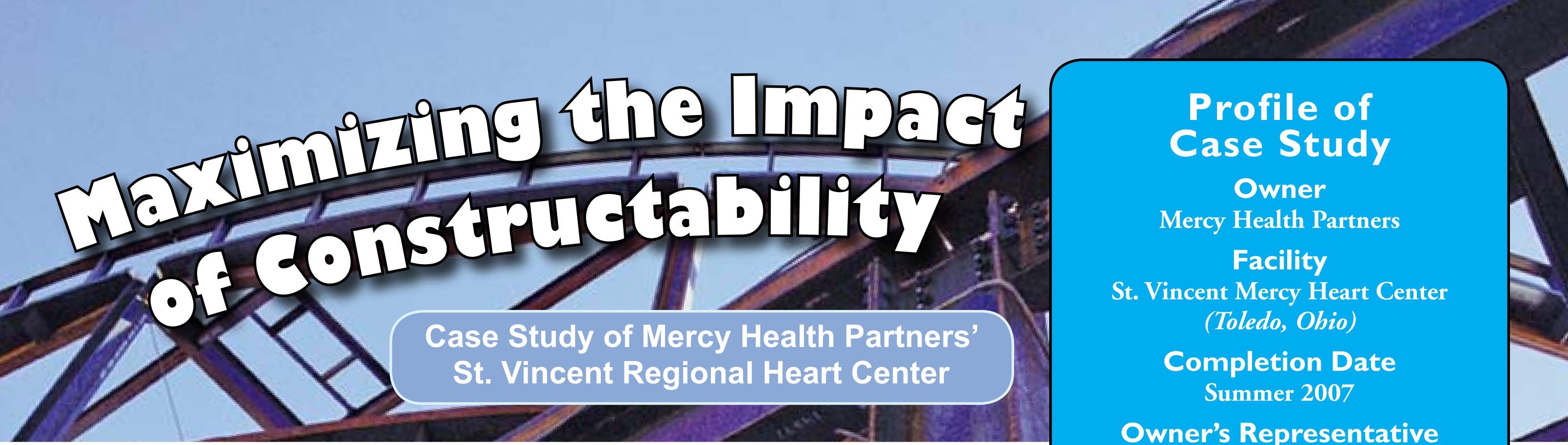

Maximizing the Impact of Constructability

Case Study of Mercy Health Partners' St. Vincent Regional Heart Center

By David I. Ruby, P.E., S.E., SECB and Jay Ruby, P.E.

This article is the third in a series on Constructability. In the first two articles, Constructability was defined and the stages of Constructability outlined. The impact of integrating this philosophy is maximized when it is initiated at the onset of a project, during the planning and conceptual design phases. The case study reviewed here features the process for accomplishing this, and presents the tremendous impact that this process delivered for Mercy Health Partners at their new regional heart center in Toledo, Ohio.

Case Study: St. Vincent Mercy Heart Center

Using Constructability principles, the Mercy Heart Center Design/Build team successfully completed the structural steel erection for the new Regional Heart Center in Toledo, Ohio by implementing a unique structural steel frame in record time, with lower costs than the conventional Design/Bid/Build (D/B/B) method could ever have achieved. Design of the four-story, 144,000 square foot facility conceived by the Mercy Health Partners began in January 2005 with the initial architectural concept drawings. Erection of the main steel framing was completed in October 2005 — ten months from architectural concept to final bolt-up.

Typical Members of the Constructability Design Team

- o Architect
- o Structural Engineer
- o Mechanical Engineer
- o Civil Engineer
- o Geotechnical Engineer
- o Owner or Owner's Representative
- o General Contractor
- o Steel Fabricator / Erector
- o Constructability Consultant

Step 1: Design Team Formation

Constructability involves the process of thinking through the complete project prior to beginning the actual design. It requires consideration of the entire construction process, beginning in the conceptual design stage.

Constructability usually requires that the Owner go beyond conventional approaches to project execution by expanding front-end planning and investing additional money to allow the design team the time and effort to address the interrelationship of materials, equipment and the construction trades. It is the Owner who initiates and provides this opportunity for thoughtful initial design decisions, and these initial design decisions establish the principles and the fundamentals that will influence the entire design and construction process, and ultimately the quality of the constructed project.

"This delivery method is better and faster than any other method we've ever used."

George Karagiorge
Director of Facilities
Mercy Health Partners

To benefit from Constructability as a design philosophy, the Owner (or other entity at risk) should seek to engage a construction professional in the planning and concept stages of a project. Such an infusion of construction knowledge and experience expands the decision matrix and fosters many more alternatives, facilitating more informed initial design decisions. Adding construction expertise to the design process delivers more accurate and up-to-date cost and material information, recognizes conflicts of trades, addresses material and skill availability and provides for *continuous* value engineering input (not only at the milestones of significant design completion). In addition, design documents, subcontractor qualifications, site constraints, weather impact and schedule concerns can be evaluated and incorporated into the design during the early stages, up to and including design development.

The construction professional as a member of the design team assists in reviewing alternate framing schemes, fundamental design ideas and concepts, potential cost and schedule impact of design options and serves as a sounding board for the entire design team, as well as the Owner, while addressing the construction process. Research by the Construction Industry Institute (*Constructability Improvement During Conceptual Planning*, Source Document 4, March 1986) indicates that this involvement drives cost reductions between 6 and 23 percent and benefit/cost ratios of up to 10 to 1, in addition to significant reductions in the project schedule. Addition of steel construction experience early in the design process for the Mercy Heart Center resulted in significant savings in the structural steel costs for the building.

Profile of Case Study

Owner
Mercy Health Partners

Facility
St. Vincent Mercy Heart Center
(Toledo, Ohio)

Completion Date
Summer 2007

Owner's Representative
George Karagiorge

Construction Manager
The Lathrop Company
(Maumee, OH)

Structural Engineer of Record
Ruby+Associates, PC
(Farmington Hills, MI)

Steel Fabricator
Art Iron, Inc.
(Toledo, OH)

Steel Erector
Gurtzweiler
(Toledo, OH)

Architect
Martell Associates
Healthcare Architects, Inc.
(Toledo, OH)

Mechanical Engineer
DJRM
(Toledo, OH)

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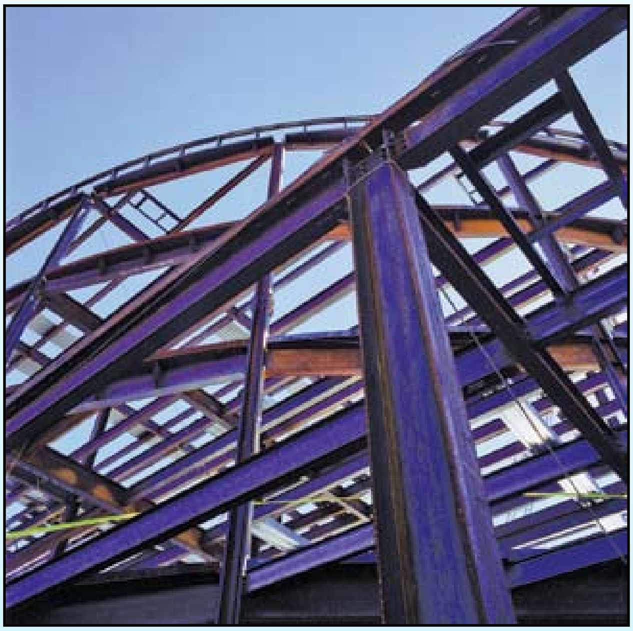
The Mercy Heart Center design team included a structural steel fabricator and a Structural Engineer of Record (SER)/Constructability Consultant, as well as the typical team members. The Architect, Mechanical Engineer (ME) and SER/Constructability Consultant worked hand-in-hand in the development of bay spacing, framing schemes, floor-to-floor heights and the location and nature of the lateral load-resisting system. The fabricator provided input on material availability, preferred practice and schedule impact; and the General Contractor, Geotechnical Engineer and the SER/Constructability Consultant jointly developed the foundation and subgrade framing schemes.

Step 2: Data Gathering and Recognizing Constraints

In a traditional Design/Bid/Build project, the role of the SER may be limited to completing the design of a structure as defined by the Architect, often with minimal involvement during concept development and minimal opportunity to fully understand or to influence the final design concept. This may lead to unnecessary cost and schedule implications for the project. Inserting construction knowledge and expertise can avoid such excesses, but only when this expertise is engaged in the planning and design teams, and project constraints are addressed early in the design process.



The lateral load resisting system chosen by the Structural Engineer and endorsed by the fabricator consisted of field welded moment frames in both directions, maximizing flexibility for space utilization and simplifying shop drawing preparation and approval. The structural steel frame was designed and fabricated with simple framing, using similar members, allowing the fabricator to standardize the fabrication process. Connections were designed based on fabricator/erector preferences and other economic factors.

As an active team member, the SER assists with initial building development, bay spacing or lateral support element placement, and evaluation of framing options to maximize interior space and maintain space use flexibility. When doing this, the SER incorporates:

- o Site conditions and constraints
- o Building Code Requirements
- o Owner's program, wants and needs
- o Proposed building usage and access
- o Architectural considerations

All such design decisions impact the project cost and schedule; knowing the structural considerations (and their related cost ramifications) during the initial planning and design process provides the opportunity for the exploration and identification of options, facilitating better, informed decisions.

While this is the role that the SER plays during project planning and design, the Constructability Consultant adds another dimension — knowledge of the construction process and fabrication and installation expertise. This knowledge and experience was a major contributor to the success of Mercy Heart Center design team.

The Mercy Heart Center is a new building added to an existing medical campus. The new facility included two wings, one 4-story and one 1-story with a basement. The existing campus was to continue in service without disruption during construction of the new facility.

During the initial project planning meetings, the design team learned that the Mercy Heart Center was landlocked and suggested that Mercy Health Partners consider future expansion possibilities during facility design to minimize expansion costs later. The Geotechnical Engineer predicted minimum bearing capacity for shallow foundations for both the 1-story and the 4-story wings. The SER/Constructability Consultant recommended consideration of enlarged deep foundations for the 1-story wing, designed to accommodate future expansion, since the cost to increase the size of the deep foundations would be minimal and deep foundations were required for the basement. The general contractor developed the confirming cost and schedule data, and Mercy Health Partners proceeded with this inexpensive means to accommodate the potential future expansion.

The framing option evaluation must consider the relative costs of options and schedule impact given:

o Architectural requirements
- **Architectural features**
- **Integration – structure/architecture**

o Fabrication considerations
- **Connection options**
- **Material availability**
- **Shipping and receiving**
- **Site lay down and yard area**
- **Maximum size, weight and/or length**

o Construction considerations
- **Site considerations**
  - **Access**
  - **Lay down area**
  - **Trade coordination**
  - **Security**
  - **Work constraints or restrictions**
- **Equipment availability**
- **Labor availability and overtime required to staff the project**

Step 3: Structural Program Development

The determination of the appropriate framing system for a structure drives the lower boundary of the economics and constructability that can be realized as the design progresses.

During the framing option evaluation for the Mercy Heart Center, the SER/Constructability Consultant, Fabricator and General Contractor studied the impact of future expansion for the 1-story wing. The team developed the costs for designing and building today's structure to accommodate future expansion plans, considering material and fabrication requirements. Given the data developed, Mercy chose to have the 1-story structure designed to accommodate an additional three stories. The columns were extended and prepared for future splices, and connection angles were attached to the girder beams, facilitating minimal disruption when the expansion is performed.

All of these upfront design decisions proved to be very prudent. The "future" expansion was ultimately completed as the original construction project was underway. This was done without impact to the overall construction schedule because the design/construction team had made accommodations for it in the original design.

Note: This project was designed and fabricated during the period when steel was subject to surcharge pricing and delivery allocation. Therefore, the cost implications of over-ordering steel were severe, and the fabricator had additional pressure to accurately estimate facility steel quantities.

Step 4: Design process

The Mercy Heart Center design team juggled multiple considerations: the floor uses, operating and prep rooms, intensive care, recovery and examination rooms and the circulation of the new facility. In addition, the team accommodated needs for future expansion in establishing the bay spacing and finalizing the lateral load resisting scheme. This forward thinking was put to the test when Mercy Health Partners moved the third floor operating rooms of the 4-story wing to the second floor of the 1-story wing well into the project. The expansion of the 1-story wing and the relocation of the operating rooms were accomplished with minimal design impact.

The project delivery schedule on the project also was compressed, which impacted the design process. Material was ordered using the structural model, prior to completion of final design check and the design of the connections. The lateral load-resisting system chosen by the SER and endorsed by the fabricator consisted of field welded moment frames in both directions. This scheme provided maximum flexibility for space utilization, simplified shop drawing preparation and the approval process, and allowed the fabricator to standardize the fabrication process:

- o Columns, although spliced where necessary, remained the same size for the full height of the column,
- o Girder beams generally remained the same size,
- o Typical moment connections were detailed with standardized extended shear plates,
- o Filler beams were dropped two inches to eliminate copes and framed with single angles, and
- o The connection design was performed by the SER based on fabricator/erector preferences and other economic factors.

The shop drawings were prepared using the SDS2 computer detailing program. Through the AISC CIS/2, the SER's model output was imported by the detailer into SDS2. The detailer then assigned the connection attributes based on the SER's connection design and the shop drawings were prepared with minimal coordination issues.

During the design process, the SER considers:

- o **Framing**
  - ▪ **Material Availability (shapes, grades, sizes)**
  - ▪ **Fabrication**
    - • **Types of connections**
    - • **Modular or sub-assemblies**
    - • **Camber**
    - • **Superelevation**
    - • **Maximum size, weight and/or length**
  - ▪ **Construction**
    - • **Types of connections**
    - • **Modular of sub-assemblies**
    - • **Special installation considerations**
    - • **Camber**
    - • **Superelevation**
    - • **Maximum size, weight and/or length**
- o **Member Selection**
- o **Detail Development**
- o **Connection Design**

Step 5: Design completion

Contract Bid Documents

Without experience, "one does not know what one does not know." The problem with experience is that it takes so long to acquire. Therefore, involving a Constructability Consultant in the preparation of the Contract Bid Documents delivers tremendous benefits to the Owner. Coordination begins with the Architect and the SER and other design disciplines, and continues among all disciplines as the bid packages are developed.

The Contract Bid Documents should clearly explain the Owner's vision, objectives and goals, outline the design criteria for the structure and contain sufficient information for a qualified steel contractor to properly price the structure, and upon award, to build the structure according to the assumptions made at the time of bidding. Sufficient information should be provided within the documents to allow the sharing of the risks and rewards for creating the structure.

Using Constructability principles, the Mercy Heart Center Design/Build team shaved 16 weeks from the schedule and 140 tons of steel from the structure of the four-story, 144,000 square foot facility.

Bid package development should define:

- o Structural assumptions and requirements
- o Special installation conditions or considerations
- o Special fabrication or installation tolerances
- o Project-specific and site-specific Specifications and Special Conditions

The specifications and the drawings should clearly differentiate between the separate segments of the industry. That way the individual contractors will be able to clearly define the scope of work upon which to quote, and ultimately, to perform. Team work is an essential element of construction. The ideal structure from a constructor's view point will allow each trade to perform the work in an efficient, orderly manner and leave the jobsite never to return. This is a concept that is attainable on most projects with proper planning. The SER should review the nature of the structure and its lateral-load resisting system with the Owner's representative (Construction Manager, General Contractor) to facilitate a properly planned and sequenced project.

Installation Process

While planning and scheduling are extremely important in saving money and time, sequence of construction is the key to implementation of these, and this is driven by the execution of Step 2. In structural steel, like manufacturing, the most efficient process is "just in time" delivery of material. The objective is to minimize the handling of the structural steel, allowing sections to be fabricated, delivered to the site, and erected in sequence. During erection, the crane progresses from one end of the building to the other, setting each piece of steel in sequence — with no comeback work. After the material is set by the raising gang, the plumbing and detail gangs bolt, plumb, weld, etc. the structure in the same sequence. The metal deck and shear studs are installed closely behind the detail gang, followed by placing the concrete slab. The other trades follow with everyone working the project plan, on schedule and within budget.

During construction, sequencing was extremely complex. The site was very tight, with no lay down or storage areas, and minimal space for the crane and for receiving material. The structure had to be built using the just-in-time delivery method. Construction expertise during the planning stages facilitated execution of this critical aspect of the project.

For this to happen, much planning is required, focusing on the construction sequence. Everyone on the Design Team and the Construction Team must plan their work, and then work the plan. Adequate access roads must be available throughout the jobsite for equipment to operate, adequate on-site storage must be available to facilitate just in time delivery of materials, and labor and equipment must be available to meet project needs.

During the construction of Mercy's Heart Center, this was expertly demonstrated. The site was very tight, with no lay down or storage areas and minimal space for the crane and for receiving material. The structure had to be built utilizing the just-in-time delivery method. The structural steel frame was designed and fabricated with simple framing, using similar members, and connections that could be quickly and safely installed to minimize equipment and raising gang hours.

The SER/Constructability Consultant accomplished this by providing the fabricator with a preliminary design with member size options shown in lieu of specific sizes (in Step 2). The fabricator grouped member sizes based on mill rolling requirements, cost, shop fabrication practice and the building installation schedule. The members were grouped as columns, girders, filler beams and base plates. The SER's computer model was revised using the grouped member sizes, reanalyzed to account for any additional stiffness and issued to the fabricator for construction.

Coordination among the trades extended beyond the foundations and structural steel:

- The design of the light-gauge cold-formed exterior wall system was designed to be compatible with the shop installed slab edge angle. The exterior wall system was designed and detailed with adjustable connections that accounted for the plumbness of the structural steel and any variation in floor elevation.
- Areas of the metal deck were left open to provide access to the basement for delivery and installation of the masonry partition walls.
- The pedestrian bridge between the Mercy Heart Center and an existing parking garage was fully assembled, with the floor and roof deck to be installed in one piece; however, because of the geometry, the bridge lift was eccentric. The SER analyzed the lift and determined that the addition of load to one end would allow the bridge assembly to be lifted in a level position the first time it was pitched.

Facing a very tight construction schedule, Mercy Health Partners incorporated a Structural Engineer and Fabricator/Erector into the planning team. Design began in January 2005 with the initial architectural concept drawings. Erection of the main steel framing was completed in October 2005 - ten months from architectural concept to final bolt-up. Mission accomplished.

Final Step: Conclusion

Mercy Health Partners is an advocate for innovative designs and creative thinking to drive the ever-changing healthcare industry. For years, Mercy has partnered with seasoned hospital contractors to build a construction team to optimize project budgets and schedules.

Mercy's Heart Center project was the first time Mercy partnered with a Structural Engineer and Fabricator/Erector. As the Owner's representative, George Karagiorge faced a very tight construction schedule. With the structural steel designer and the fabricator involved from the beginning of the design, the team incorporated "Constructability" concepts to streamline fabrication and expedite erection, delivering a better-designed structure in less time, for less money.▪

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Just The Facts

Design/Build Method	Design/Bid/Build Method
Design Time (10) weeks	Design Time (10) weeks
Bid / Estimate Time (0) weeks	Bid / Estimate Time (4) weeks
Award Time (0) weeks	Award Time (1) week
Prepare ABM (1) day	Prepare ABM (3) weeks
Order Material (1) week	Order Material (1) week
Detail Shop Drawings (6) weeks	Detail Shop Drawings (8) weeks
Approval Review Time (1) week	Approval Review Time (3) weeks
Incorporate Design Changes (1) week	Incorporate Design Changes (4) weeks
Fabricate Steel (8) weeks	Fabricate Steel (9) weeks
Erect Steel (8) weeks	Erect Steel (9) weeks
Total Duration - 35 weeks & 1 day	Total Duration - 52 weeks
Real Time Schedule Savings – 17 weeks	
Dollars & Sense	
$2,345,000.00	$2,800,000.00
$16.28 / SF	$19.44 / SF
772 Tons	910 Tons
$3,037.57 / Ton	**$3,076.92 / Ton**