Modeling for Integrated Structural Design

Discussion

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At the dawn of the information age, it is essential that we be able to aggregate knowledge and data and navigate based on patterns.
“Insanity is doing the same thing over and over again and expecting different results”

Albert Einstein,
German born American Physicist
1879-1955

Corollary 1: If you want the same results, do the same thing.
Corollary 2: If you want something better, do something different
Where We Are Headed

- Design/Construction Industry
  - HiDef BIM
  - Functional IPD
  - Virtual Design and Construction (VDC) – utilize HiDef BIM to visualize, analyze, coordinate, and evaluate different design and construction alternatives

- Structural Engineering
  - Performance-Based Design (PBD) of all building systems
  - Performance Based Earthquake Engineering beyond life safety to eliminate sacrificial structures and control losses
Our Process

We use integrated or "interleaved" methods to design structures in steel, light gage (CFMS), wood, and concrete, as the SEOR member of design-build teams by creating fabrication-level structural BIMs starting in concept design and working through to acceptance of the built systems by the owner. We coordinate our structural BIM with the BIMs of the architect and other important design and construction partners, such as HVAC. We integrate our BIM with the contractors global BIM for use in planning and organizing construction activities. Our BIM has been integrated with facility management programs to support life cycle processes. (after John Kunz)
BIM: Building Information Model

**BIM**
- Graphical Representation
  - Graphics
  - Renderings
- Approximate/Design Intent
- Concept to Design
- Clash-Checking

**HiDef BIM**
- Database of Information
  - Knowledge
  - Heuristics
- Shop Drawing
  - Level Detail
- Concept to Facilities
- Virtual Design & Construction

------ GIGO Effect ------

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Structural Engineers and Builders

Modeling for Integrated Structural Design 2012-02-21
Victor Sanvido, Ph.D.
Senior VP Southland (MEP)

- Nothing is too small to model
- Uses BIM to facilitate prefabrication
- 33% reduction in rough-in costs
- Reduction in safety mod ratio from 0.68 to less than 0.5 (industry average 1.0)
HiDef BIM

• High Definition BIM (HiDef BIM) incorporates shop drawing level detail into the design model (AIA LOD = 5)

• There is only one BIM model, and it is used for all life cycle processes. During one short interval in the life cycle – design-construction – the model is used to produce shop drawings and support both design and construction processes.

• This requires explicit consideration of and provision for, means, methods, and sequences during the design phase.

• This is possible today in structural engineering
Ft. Bliss Headquarter Building @ El Paso, TX
Curtain wall details
Our Software

We use Tekla Structures because

- It is the software of choice for preparing structural steel shop drawings and rebar shop drawings.
- It has an external database that is scalable offering potential for long term “vision”
- It has efficient memory management requiring 1/10 the file size of competing software which means we can integrate our models as a normal part of our process
- It is IFC compliant
Anchor Bolts

- 5 – 1” Anchor Bolts Embedded 40”
- Transfers Overturning Tension to Foundation Walls
To date we have used Tekla to:

- Model concrete, rebar, structural steel, wood, light gage
- Produce shop drawings for steel, light gage, rebar
- Coordinate construction sequences
- Facilitate the design & construction of innovative high performance structures
- Perform “in model” shop drawing review and work on the same model as the steel detailer with model remotely located in the cloud
- Store structural behavior attributes such as member forces and proprietary data in external database accessible through model
Garden Entry Truss

- No Visible Connections
Our Design Process

- Modeling is integral to our design process. Our engineers develop the model simultaneously with doing the structural analysis and design. Controlling loads are stored as UDA’s in the model. Members are classified based on structural function.

- We export geometry for global analyses. Most of the projects we do are special and require significant modeling effort after export. We do not use “all in one” software such as RAM or ETABS because they cannot handle our “custom” structures, we do not like the designs they produce for “typical” structures, and we find the presentation of engineering methodology and results to be less than transparent.

- Regardless of material, we try to model construction level detail so all of our details can be obtained as views of the model – minimal or no CAD details to augment the model.
End Connections

- Two Trusses with Steel Knife Plates
- Recessed & Plugged Bolts
Software Used by Team Mates

- Majority of our architectural clients use Revit
- Majority of our MEP team mates use Revit
- MEP subcontractors use special purpose software generally compatible with Autodesk through DXF or as add-on to AutoCAD 3D
- BIM coordinators/facilitators, including general contractors, tend to use NAVIS. There is a move toward Tekla for structures, curtain walls, and light gage framing because of the detailing capability and integration with Trimble.
- Majority of steel fabricators use Tekla or SDS2 for shop drawings
- Tekla is the only software used for accurate 3D rebar modeling
These are screen shots of the structural design model which is being used for steel shop drawings, rebar shop drawings (by EOR), and light gage stud framing shop drawings with EOR assist.
Our Coordination Process

- Team mates send Revit or IFC models which we use as reference models in Tekla during design.

- For dimensional control, we prefer 2D plans and elevations which we also reference into the same Tekla models.

- We export our model to IFC and import it to Revit. We send our team mates either Revit or IFC.

- We are moving toward Tekla BIMsight for hosting the global integrated model in the cloud. BIMsight offers “model organizer” for team coordination, communication, and documentation in a “cloud based” application.

- We use coordination checklists and “hot lists”
MEP Coordination

- Example: Structure near Mechanical Wells
Our Communication Process

• We try to push our model into the field down to the level of the foremen. If we can hook the superintendent on looking at the model, we’re home free. Otherwise we’re dead in the water.

• Architects rarely inform us of changes. They send the model and expect us to catch changes.

• Architectural Revit models rarely show sufficient detail to establish critical dimensions such as edge of slabs, eave/gutter details, etc. Such dimensions are the source of most of the coordination glitches. Much of the architectural detail is still generated in a 2D CAD drawing.

• Contract documents and permits are still based on 2D drawings for the most part.
The model is available to anyone with web access. It can be password protected.

Users are able to cut multiple sections simultaneously, zoom, pan, and rotate.

Tekla Web Model
Process Challenges with HiDef BIM

• We cannot afford to put all the detail in the model on day one. We need to build into the process a way to accommodate model evolution from concepts to construction that communicates the needed level of detail at each stage of design, along with critical or enabling details, while waiting until

• When a detail is put in the model, it cannot be a placeholder to be coordinated later. It must be the detail that will be used in construction.
VIRTUAL REALITY

2ND LEVEL DECK REBAR INSTALLED
Our Quality Control Process

• Fundamentally a qualitative rather than quantitative

• Starts with a narrative containing a functional description of the structure, the design criteria, the architectural constraints/objectives, the construction constraints, and the project context constraints (schedule, weather, geography, market, etc.) Based on this, one or more potential structural systems are hypothesized and a program for investigation and proportioning outlined along with preliminary evaluations.

• Daily oversight and discussion with principal/SEOR

• Periodic audit of production/QC checklists

• Periodic review and discussion with outside expert

• Final quality control check (red, yellow, green), checklists
USC School of Cinema Phase II Building Components

- Panelized light gauge roof with steel support structure
- Metal deck on steel trusses
- Rotating concrete wall exterior
- Soldier piles
- Acoustically isolated light gauge rooms
- Temporary bracing within stair & elevator walls
- Stairs
- Rebar (not shown)
Our Production Control Process

- Starts with narrative
- Drawing list
- Calculation table of contents
- Calculation task list (20% of total production budget)
- Modeling task list (30% of total production budget)
- Drawing task list (30% of total production budget)
- Coordination list (10% of total production budget)
- QC task list (10% of total production budget)
- Hot list
Challenges: Supporting a Cable Supported Glass Wall System

Casino Hollywood – Toledo, OH
Glass Walls

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Enabling Details in Roof Framing

Casino Hollywood – Toledo, OH
Glass Walls

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Our Construction Administration Process

• Master the construction schedule and budget

• Maintain project logs: RFI, SSK, Shop Drawings target instant turn around

• Hot list

• Get to know construction personnel (superintendents & foremen key structural subs – call daily during periods of peak activity to find out what the short term plan is, what is working well, what is not working well.)

• Ferret out potential pitfalls

• Proactively engage other team members to clear obstacles that could affect schedule
USC School of Cinematic arts – Phase 3 Status as of 2/21/2012
Stay Tuned

- Metrics – is everyone happy? Are we beating schedule? Are we beating budget? Have we given the architect more than he/she wants? Is the structure elegant? Are we turning things around quickly?

- Budgets – We make money as an office, not by projects

- Representing - Function, Form, Behavior
Comparison of planned and actual schedules for structural frame on USC School of Cinema Phase II, Building B:

- Planned: Start 11/24/08 Finish 12/25/09 – Duration 391 days
- Actual: Start 11/24/08 Finish 8/31/09 – Duration 275 days

The use of detailed construction model, produced by the design team, for design coordination, shop drawings, and field coordination saved 116 days, or 30% of the schedule.
Michael P. Cannistraro, P.E., LEED AP
Vice President of Engineering
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Functional IPD

- fIPD: Incorporating detailed construction knowledge and planning into the design
  - Means, methods, and sequencing
  - Enabling details
  - Prefabrication
  - Precision
HiDef BIM

This is a disruptive technology

• The design/construction processes must change to get maximum benefit from the technology.
• Scope shifts from construction to design
• Construction knowledge must be deployed to support design – we pull the knowledge forward in the process
Denver Health Center (Martino & Luth, Denver)
• Structural design
• Rebar model and shop drawings
• Exterior architectural light gage model and shop drawings
Objective of Our Design Process

Our objective is to produce - as the deliverable product of the design - a model with sufficient detail and data to facilitate Lean Construction and Functional Integrated Project Delivery today, using technology that is scalable to support Life Cycle Facility Management processes in the near future.
Conventional Practice

Contract documents reflect a concept design that is based on no particular construction sequence or means and methods,

IPD with HiDef BIM

The SEOR produces a complete design predicated on the most efficient construction sequence with structure topography and details tailored to optimize construction efficiency, economy, and quality, complete with construction aids and/or temporary structures included. Knowing the details of both the design and construction facilitates true lean construction – getting exactly the right resources in exactly the right place at exactly the right time.
Panelized Light Gage Roof
- Decreases Schedule
- Less Off Ground Work
- Acoustical Details Included
- Plywood, LG Studs 12” OC, Insulation, 2 Layers of ceiling Gyp Board

Savings:
- roof finished in 3 days
- 3 weeks exterior
- 3 weeks interior
- eliminated scaffolding
Panelized Rebar Cages

- Decreased Schedule (with EOR detailing)
  - Phase 1 – 6 weeks
  - Phase 2 – 15 weeks (30% schedule)
- Saves Space On Site

Rebar hoops 4” O.C. in slit plates require precision in prefabrication & placing

50 ft x 10 ft Panel - 4 tons - 15 min
Conventional Practice

Fixed price is an estimate based on incomplete details. Subcontractors have to cover risk in price. Final quantities aren’t known until after shop drawings. Final price is adjusted through change order process based on revised estimates of concept drawings.

IPD with HiDef BIM

Unit price is based on exact quantities in the model and adjusted based on actual quantities delivered. (RE: Denver Health Project) This saves all of the overhead of the RFI and change order process.
Denver Health Center – Rebar model and shop drawings
DD quantity – 375 tons – used to sign a unit cost contract
Shop drawings quantity detailed – 365 tons (incl. accessories, -1.9% from DD)
Final delivered quantity - 372 tons (-0.8% from DD, +2.5% from detailed)
Isle of Capri – Cape Girardeau

Rebar modeling and Shop Drawings by EOR accelerated the schedule and resulted in higher quality end product. 2000 yd. pour with 250 tons of rebar starting at 7 pm 2 weeks after award of concrete contract. Photo at noon on day of pour.
**Conventional Practice**

Construction sequence is determined by superintendent long after contract is awarded and detailed construction means and methods by the foreman of the trade involved. Quite often the details of the design have to be amended by the RFI process to tune the design to the eventual means and methods.

**IPD with HiDef BIM**

Construction sequence on which the design is based is included with the contract documents providing a reliable starting point for the contractor’s logistical planning. All of the detailing that is necessary to support the sequence – including any temporary structures – is included in the design.
Livermore Performing Arts Center

Construction sequence 3D Tekla visualization construction steps 1-4, concrete substructure and partial superstructure
Livermore Performing Arts Center

Construction sequence 3D Tekla visualization steps 5-8 at concept – steel & facade

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Livermore Performing Arts Center– Roof truss with temporary construction bracing
LIVERMORE – Building Section
with temporary construction columns under cantilever
USC School of Cinema Phase III Building Components

- Panelized light gauge roof with steel support structure
- Metal deck on steel trusses
- Rotating concrete wall exterior
- Soldier piles
- Stairs
- Temporary bracing within stair & elevator walls supports stairs during construction and is left in as redundant lateral system
- Acoustically isolated light gauge rooms
- Rebar (not shown)
Conventional Practice
The structural steel and rebar detailers have to interpret the SEOR’s intent in preparing complete shop drawings. Any question are resolved using the RFI process. The shop drawings have to be submitted to the SEOR to verify that the intent has been faithfully captured. Drawings are marked up by hand or manually in PDF and iterated until a clean set is produced. The process takes months.

IPD with HiDef BIM
The SEOR produces shop drawings that are, by definition, consistent with the design intent. The shop drawings can be furnished to the supplier at the time the contract is awarded. (RE: Cape Girardeau, Denver Health, USC, and Toledo projects)
Challenge: 10’ Rouge fill & fast schedule

Enabling Concepts

• Single pile foundations
• Prefabricated 5-piece cages detailed for quick install.
Conventional Practice
Changes are suggested by the owner or contractor, redesign is performed by the design team, a new shop drawing and RFI process is begun, sketches may be issued. The process is time consuming and error prone, particularly because the structure is typically under construction while the balance of the design disciplines are completing their work.

IPD with HiDef BIM
The SEOR is privy to both the design and construction processes and can flag potential changes that will conflict with planned construction activities. Changes are made to both the documents and the shop drawings at the same time. Revised shop drawings are issued to the contractor for construction minimizing or eliminating any delay. Change orders are based on delivered quantities as detailed on the shop drawings.
Denver Health Center – Exterior architectural light gage model and shop drawings
Conventional Practice
The process is cumbersome, fraught with opportunities for miscommunication, conflict, and abuse.

IPD with HiDef BIM
The process is set up around the need to efficiently manage change while maintaining a productive construction operation. Design IS the process of managing change until the optimum design is arrived at. In modern projects, the structure always goes first, so managing change is essential to the art of structural engineering. The best way to manage change is to minimize the length of the supply chain.
Case Studies
USC School of Cinematic Arts – Phases 1 - 3

- PBD: Repairable Structure
  - Slit shear plates act as fuses
- HiDef BIM: Rebar Detailing
  - Rebar shop drawings created from model
  - Part of base scope contract
  - Kickoff meeting with rebar fabricator, rebar foreman, formwork, GC and architect
Rebar layouts were standardized with minimum 4#8 ea. side to facilitate panelizing. Cages were assembled without window openings for stiffness and tolerances. Boundary elements allowed for tolerance in opening. Openings were cut and trimmed after installing panels.
Panelized Rebar Cages

- Decreases Schedule (with EOR detailing)
  - Phase 1 – 6 weeks
  - Phase 2 – 15 weeks (30% schedule)
- Saves Space On Site

Rebar Hoops 4” O.C. in Slit Plates Require Precision in Prefabrication & Placing

50 ft x 10 ft Panel - 2 tons - 15 min
HiDef BIM facilitates the incorporation of the enabling details for PBEE within the context of an aggressive fast-tracked schedule.
Shear is transferred to the foundation wall by a 2”x5” bar that bears on (2) 1 ½” plates separated by 1” of EPS to allow rotation anchored to the concrete on each side of the joint by welded dowels.
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USC CineArt II

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Phase 3 - Multiple-Purpose Cinema Building:

3 stories plus basement

Seismically-rotating concrete shear walls

Repairable structure

Accelerated construction sequence designed into structure
USC School of Cinema Phase II Building Components

Panelized light gauge roof with steel support structure

Metal deck on steel trusses

Rotating concrete wall exterior

Soldier piles

Stairs

Temporary bracing within stair & elevator walls

Acoustically isolated light gauge rooms

Rebar (not shown)
Isle of Capri - Cape Girardeau

- PBD: Repairable Structure
  - Slit shear plates act as fuses
  - Self-restoring, post-tensioned rocking frame
- HiDef BIM: Steel Detailing
  - EOR produced rebar shop drawings directly from Tekla design model
  - EOR produced steel shop drawings directly from Tekla design model.
  - Misc. metal shop drawings modeled with the structural steel and produced directly from Tekla design model.
160,000 sf casino near New Madrid fault, high seismic, long span over independent floating barge, complex architectural theming elements.
Isle of Capri, Cape Girardeau, Missouri
Self-centering post tensioned rocking frames with fused moment trusses HiDef BIM level of detail

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Roof over floating precast/CIP/composite barge in CIP basin
Rebar modeling and Shop Drawings by EOR accelerates the schedule and results in higher quality end product. 2000 yd pour with 250 tons of rebar starting at 7 pm 2 weeks after award of concrete contract. Photo at noon.
HiDef BIM level of detail. FF=50 slab (actual 70) poured without incident over 11 hour period
Structural ceiling grid at 12’x12’ provides seismic anchorage within 4 ft of acoustical ceiling and serves as anchorage structure for MEP and architectural features

HiDef BIM architectural systems ceiling and ID support
Isle of Capri Cape Girardeau – Phase 3  Status as of 1/20/2012
HiDef  BIM architectural systems ceiling and ID support
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Thank You!
Isle of Capri, Cape Girardeau, Missouri
Self-centering post tensioned rocking frames with fused moment trusses HiDef BIM level of detail

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2012-02-21
Panelized light gauge roof with steel support structure
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USC School of Cinema Phase II Building Components

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