HD  BIM, PBD, IPD, & VDC
The Future of the AEC Industry

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Santa Clara, California
“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.
GPL/GPLA Role in Industry

- BS, University of Alaska, 1974; MS. Stanford, 1975; Ph.D., Stanford (CIFE), 1991
- Worked for the company that designed the K.C., Hyatt Regency
- We design building structures (some bridges and special structures) and have been doing that since 1976
- Most often sub to architects in traditional design-bid-build
- Licensed in all 50 states and work in many, (Maine, West Virginia, Florida, Ohio, Missouri, Texas, Colorado, Arizona, California, Washington State in past 5 years)
Lean Construction - Four Current Trends that Are Revolutionizing the AEC Industry–

• Performance-Based Design (PBD)
• HiDef BIM (HD BIM)
• Virtual Design & Construction (VDC)
• Integrated Project Delivery (IPD)
“It is no longer reasonable to design structures based solely on the strength approaches contained in current codes. We must focus on performance based design that considers all limit states relevant to the owner and society and pays tribute to life cycle cost considerations.”

January, 1995

Helmut Krawinkler,
Professor Emeritus of Structural Engineering
Stanford University
April 6, 1940 – April 16, 2012
Performance Based Design, PBD

- Engineering performance
- Architectural performance
- Constructability performance
- Sustainability performance
- Facility performance
Performance Base Earthquake Engineering, PBEE 100 year buildings that will survive multiple MCE (Maximum Considered Earthquakes) with repairable structural damage – no more “throw away” buildings.

IOC Cape Girardeau – Self Centering, Post Tensioned Rocking Frames with Replaceable Fuses
BIM: Building Information Model

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

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

GIGO Effect - the use of a “design concept model” for construction documents is obsolete
**HD BIM**

- High Definition BIM (HD BIM) incorporates shop drawing level detail into the design model.

- There is only one HD BIM model, and it is used for all life cycle processes.

- This requires explicit provision for, means, methods, and sequences during the design phase.

- This is done today in some design disciplines, i.e., structural engineering and MEP systems engineering.
HD BIM is a design process utilizing a Building Information Model containing the high level of detail and precision necessary to visualize, design, detail, fabricate, and install all elements of a building | GPLA is the industry leader in structural HD BIM
Definition – VDC

Virtual Design and Construction (VDC) is the management of integrated multi-disciplinary performance models of design-construction projects, including the product (i.e., facilities), work processes and organization of the design - construction - operation team in order to support explicit and public business objectives (CIFE definition)

VDC is the process of utilizing a BIM model to **visualize**, **organize**, and **plan** construction and design activities to **minimize cost and schedule** while **maximizing quality, value, and sustainability**.

**VDC provides the means for making construction more like manufacturing.** This process works best with an HD BIM.
Definition – IPD

**Integrated project delivery (IPD)**, is a collaborative alliance of people, systems, business structures and practices into a process that harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction (AIA Definition)

**Integrated Project Delivery (IPD)** is a process by which owners, designers, and constructors work collaboratively from conception to construction to deliver a project that minimizes the Cost/Value Ratio (CVR) while minimizing the design/construction schedule and maximizing sustainability (GPLA Definition)

To accomplish the multiple objectives of this process, **detailed construction and facility management process knowledge** must be **pulled forward into the design** process and used to **optimize the building in a life cycle context**
OBJECTIVES OF HD BIM & IPD -

• Reduce materials

• Optimize construction sequence

• Reduce schedule

• Reduce labor
REDUCE MATERIALS -

• Design efficiently within context of minimum schedule

• Minimize waste

• Replace “estimates” with actual materials from model
OPTIMIZE CONSTRUCTION SEQUENCE -

- Review construction sequence to reduce critical path
- Maximize opportunities for parallel activities
- Reduce precedence linkage
REDUCE SCHEDULE -

- Maximize automated layout, i.e., MEP hangers
- Maximize opportunities for prefabrication
- Optimize construction sequence
- Optimize activity sequence
REDUCE LABOR -

• Eliminate rework
• Optimize detailed construction labor activities
• Maximize prefabrication
• Eliminate on-site options
• Collaborate with labor to identify and eliminate labor pinch points
HD BIM with IPD... 

... is a revolutionary process and 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

But that isn’t enough, means, methods, and sequences must and will also change to make maximum use of the potential
We have heard anecdotally that some contractors are saving as much as 25% of cost and schedule by applying these principles in their projects.

*Starting the process during design* rather than waiting for construction offers *vastly more potential* for savings.
Key changes in an HD BIM & IPD design/construction process

• Design for construction sequence
• Design for prefabrication
• Design level of detail (SEOR shop drawings)
• Communicating design intent (SEOR shop drawings)
• Estimating and bidding procedures (SEOR shop drawings)
• Interdisciplinary design coordination
• Design/Construction coordination
• Change management (SEOR shop drawings)
Construction Sequence, Prefabrication, and Level of Detail

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

IPD with HD BIM
The SEOR produces a complete design predicated on the most efficient construction sequence tailored to optimize construction efficiency, economy, and quality.

USC SCHOOL OF CINEMA I
Conventional Practice
The rebar detailers have to interpret the SEOR’s intent clarifying with RFI process. The process takes months.

Navy Lodge Coronado Island Rebar Field

IPD with HiDef BIM
The SEOR produces a detailed model that IS the design intent and detail the model can be turned over to the fabricator to produce shop drawings

Rebar Model at Column Drop
Estimating and Bidding

Conventional Practice
Fixed price is an estimate based on incomplete details. Subcontractors have to cover risk in price.

[Image: Denver Health Center Rebar 375/365/372]

IPD with HiDef BIM
Unit price is based on exact quantities in the model and adjusted based on actual quantities delivered.

[Image: Denver Health Center Exterior Wall Studs]
Change Management

Conventional Practice

Changes through RFI and Change Order process. Latency is months

IPD with HiDef BIM

Changes are made to both the documents and the shop drawings at the same time. Change orders are based on delivered quantities. Latency, 7 days.

Casino Hollywood, Toledo, Ohio
Casino Hollywood, Toledo, Ohio

“This project has elevated our BIM experience to a new level. Our superintendent was referring to the latest model on a daily basis. He was able to use an IPAD to bring the web accessed model out to the field and share it with the crew. When the field crew starts asking to view the model, it gets the attention of everyone. Even subcontractors that have never used it before were on board.”

– Ryan Bannister, Rudolph-Libbe, BIM Manager

“Ordinarily, the rebar shop drawings are detailed from documents that are a month old and frequently changing. Keeping the field updated with information is a challenge. On this project, the web model updates were available immediately, so we looked at it every morning before we started work. The shop drawings, coming directly from the EOR, were even better than the model – the best information on the job.”

– Mike Keane, Rudolph-Libbe, General Superintendent
Food for thought . . .

All numbers are estimated:

- % of project cost from labor: 60%
- % of labor hours that are productive “tool time”: < 50%
- % of productive hours that are spent removing previous work: 10%
- % of construction cost spent tracking changes & RFI’s: 5%
- % increase in construction cost due to change orders: 10%
- % of material wasted: 15%

. . . suppose you eliminated the inefficiencies in this process.
Food for thought . . .

All numbers are estimated:

- Potential reduction in field hours through prefab: 75%
- Potential reduction in lost time accidents from prefab: 75%
- Potential reduction in materials through prefabrication: 10%

. . . How much labor could we save if we actually focused our design on that as an objective?
The other IPD – Integrated Process Design . . .

. . . a new process must be designed. It starts with questions:

- “Where are the labor hours being spent?”
- “What percentage of the labor hours are productive?”
- “How can the percentage of productive hours be maximized?”
- “How can the productivity of each hour be maximized?”
- “How can design be changed to optimize construction?”

. . . . . . It’s a manufacturing process applied to construction
Knowledgeable and involved owner, architect, engineers, and contractor are the key. . .

. . . It starts with assembling a high performance team that:

- Designs to minimize the number of labor hours required
- Designs to maximize the productivity of each hour
- Plans the work down to the smallest detail
- Documents in a comprehensive HD BIM design model
- Uses the design model for communicating, coordinating, and controlling the work during construction

. . . no one has done this yet
Case Studies
<table>
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<th>Details</th>
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<tbody>
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<td>Owner</td>
<td>USC</td>
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<tr>
<td>Project Manager</td>
<td>TBD, San Francisco</td>
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<tr>
<td>Architect</td>
<td>Urban Design Group, Dallas</td>
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<tr>
<td>Structural Engineer</td>
<td>GPLA, Santa Clara</td>
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<tr>
<td>MEP Engineers</td>
<td>IBE, Los Angeles (Phases I &amp; II)</td>
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<td>TTG Geotting, San Antonio (Phase III)</td>
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<tr>
<td>GC</td>
<td>Hathaway Dinwiddie (Phases I &amp; II)</td>
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<td>Matt Construction (Phase III)</td>
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<td>Steel Fabricator</td>
<td>Schroeder Iron, Fontana (Phases I &amp; II)</td>
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<td>Olson Steel, Hayward (Phase III)</td>
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<td>Rebar Supplier</td>
<td>CMC</td>
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<td>Metal Framer</td>
<td>Berger Brothers (Phase I)</td>
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<td>Martin Brothers (Phase II)</td>
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<td>KHS&amp;S (Phase III)</td>
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<tr>
<td>SEOR Contract</td>
<td>Fixed Fee to architect for all work</td>
</tr>
</tbody>
</table>
USC School of Cinema Structural Firsts (2006 – 2012)

- PBEE repairable rocking concrete walls for EQ resistance
- Design HD BIM model used for structural steel shops
- Design HD BIM rebar model used for fabrication shop drawings
- Design HD BIM rebar model for shop fabricated assemblies
- Design HD BIM light gage model for architectural walls
- Design HD BIM light gage model for shop drawings for complex prefabricated light gage assemblies
- Integrated design/construction AEC BIM model
- Integrated design/construction AEC BIM model for FM
USC School of Cinema Arch and MEP Firsts (2006 – 2012)

• Full documentation generation from the model

• Finishes and materials embedded in the model

• Design model includes complete description for MEP systems

• Design model includes complete telecommunications and audio video integration

• Prefab for electrical routing and device location

• All layout and location of all system hangers and inserts done prior deck pour

• Reintegration of as built and fabricated systems including configuration modifications into the original design model
USC School of Cinema FM Firsts (2006 – 2012)

- The design model was populated with design data, as built data, and commissioning data
- The design model was used to deliver all as built data tied to an electronic file retrieval system
- Life safety, building management, energy management, and maintenance data were integrated into the design/FM BIM model
- The design/FM model is used to schedule and maintain all building systems
USC School of Cinematic Arts – Phase I
2006 - 2008

• PBD: Repairable Structure
  – Slit shear plates act as fuses
  – Pivoting captive concrete walls

• HD BIM:
  – CAD drawings plus Tekla model to be able to support construction activities
  – Tekla model turned over to fabricator for detailing
  – Rebar modeled and used to coordinate with fabricator’s detailer

• IPD
  – Optimized construction sequence with temporary bracing
PBEE
USC seismic damage control system:
- Concrete substrate for facade
- Ductile linked shear walls
- Pivoting shear panels
- Replaceable steel fuse
Butterfly Slits Shear and Bending Yield at 10% distortion
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.
USC School of Cinematic Arts – Phase II 2009 - 2010

- **PBD: Repairable Structure**
  - Slit shear plates act as fuses
  - Pivoting captive concrete walls

- **HD BIM:**
  - Tekla model turned over to fabricator for detailing
  - Rebar shop drawings created from model as additional service paid by owner

- **IPD**
  - Optimized construction sequence with temporary bracing
  - Steel roof assemblies for fast erection
  - Light gage panelization and details developed collaboratively with supplier
Anchor Bolts

- 5 – 1” Anchor Bolts Embedded 40”
- Transfers Overturning Tension to Foundation Walls
- Steel and concrete in the same model for coordination

USC II

With design HD BIM vs construction HD BIM, you get all the pieces in the same model for coordination during design
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
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.
USC School of Cinematic Arts – Phase III

- **PBD: Repairable Structure**
  - Slit shear plates act as fuses
  - Pivoting captive concrete walls

- **HD BIM:**
  - Tekla model turned over to fabricator for detailing
  - Rebar shop drawings created from model as part of base scope
  - Shop drawings for panelized light gage roof produced by SEOR from Tekla model

- **IPD**
  - “Temporary” bracing put in stair towers
  - Construction kickoff meeting with rebar fabricator, rebar foreman, formwork, GC and architect
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.

Note that the architectural and MEP models are overlaid on the structural model so that coordination between systems occurs continually to design clashes out of the project. This is immeasurably more effective than doing clash detection after the design is complete.
USC III
Wall rebar panel shop drawings from Tekla
Roof panel 3D model from Tekla
Roof panel 3D panels from Tekla
Roof panel shop drawings from Tekla
Prefabriicated Light Gage Roof Panels – Metrics from KHS&S

- 6 deliveries for this job. Approximately 12 panels per truck
- To unload a truck, took 8 men 1 hour. An entire truck was unloaded and erected in under 4 hrs.
- Typical panel took approx. 8-10 minutes to erect. If taken directly off truck, would take 4-5 minutes.
- If delivered on consecutive days, USC roof could have been erected in 5-6 working day. (1.5 weeks). If stick built, not including plywood, estimated to take 1.5 months (Note that if erected off truck, could do 2 trucks per day, 3 days total erection)
- Much safer process. Having 2-3 guys on the roof has much less probability of accident than 10-12 guys
Prefabricated Light Gage Roof Panels – Lessons Learned (from KHS&S)

- “This is the ticket”

- Great process because panels can be built in a controlled area with cheaper, less skilled labor. This is especially given the comprehensive material list with cut lengths and the detailed drawings. “Material list is great. It made all the difference in the world.”

- Would love to have pick points determined on shop drawings and installed in shop. If done, would pick directly off truck for erection.
Prefabricated Light Gage Roof Panels – Lessons Learned (from KHS&S) (cont’d)

• In spite of what was said originally about just needing typical details, full detailing of the break-shape nested tracks would have been better, especially at the complex hip/valley conditions.

• 35 feet is the approximate max length of panel that could easily be handled. If I get a larger, the larger crane size might eat away at savings

• Break shapes should be 14ga or thinner if at all possible, 12ga is hard to screw
USC School of Cinematic Arts – Phase III
Status as of 1/20/2012
Foundation walls and underground utilities almost complete.

USC III
Status as of 2/15/2013
Occupied
USC School of Cinematic Arts – Phase I
Denver Health Pavilion M: A Renaissance in Project Delivery
Denver Health Pavilion M – Denver CO

*Design* Build Team:
- Mortenson Construction
- Heery International Architecture
- Martino & Luth

Four Story + Basement
115,000 Square Feet of Structured Space
Outpatient Dialysis
Outpatient Procedure
Administration
Adolescent Psychiatry
Underground Parking
First Floor ½ Parking
Martino and Luth:

SEOR

Full Structural HiDef BIM Model

3D Rebar Shop Drawings

3D Light Gauge Curtain Wall Shop Drawings

Contracts:

With Heery:

SEOR, Full Structural Model

With Mortenson:

3D Rebar & 3D Light Gauge Shop Drawings
Material Takeoffs at DD

Detailed Structural Model Allows Accurate Estimating

Steel includes Connections

Concrete Planter Boxes and Built Up Column Bases Modeled
3D Rebar Detailing

Rebar Take off At DD

Rebar Bar Lists for Fabrication

Rebar Field Placement Drawings for Rodbusters
Rebar Takeoffs At DD

DD Quantity – 375 Tons – Used to Sign unit price Contract

Shop Drawing Quantity – 365 Tons (-2.6% from DD)

Final Delivered Quantity 372 Tons (-0.8% From DD, +1.9% from Detailed)
**Casino Hollywood, Toledo, Ohio**

400,000 sq ft of casino gaming, offices, and parking on 2 levels and 3100 car, 5 story PT parking garage, $200 million

<table>
<thead>
<tr>
<th>Owner</th>
<th>Penn National Gaming, PA</th>
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<tbody>
<tr>
<td>Architect</td>
<td>Urban Design Group, Atlanta, GA</td>
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<tr>
<td>Interior Designer</td>
<td>Genesis Design, Santa Ana, CA</td>
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<td>Structural Engineer</td>
<td>GPLA, Santa Clara, CA</td>
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<td>MEP Engineers</td>
<td>Concord Atlantic, Atlantic City, NJ</td>
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<tr>
<td>GC</td>
<td>Rudolph Libbe, Toledo, OH</td>
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<td>Steel Fabricator</td>
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<td>Fixed fee to GC for rebar detailing</td>
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</table>
Casino Hollywood – Toledo, OH
Challenge:
10’ Rouge fill & fast schedule. To meet schedule needed 1 pile per column

Enabling Concepts
• 100 ft long piles
• Single pile foundations
• Prefabricated 5-piece cages detailed for quick install.
Casino Hollywood – Toledo, OH
Challenge:
Estimate cable forces and provide structural infrastructure to support them based on early interior design concepts with enough accuracy at DD/Mill Order to avoid costly redesign.

Casino Hollywood – Toledo, OH - Cable Supported Glass Wall System
Enabling Concepts & Details

- Based on required geometric stiffness assume a 13k cable load every 4’
- Provide steel in the roof to resist down forces
- Provide concrete ribs in the raised slab on EPS to resist up forces at floor
- Analyze combined system for deflections
- Coordinate with ID & subcontractor months later (radius off 4”, forces good)
Enabling Details in Roof Framing

Tekla model provided to steel detailer for shop drawings
Casino Hollywood – Toledo, OH - Cable Supported Glass Wall System

Construction Photo

May 7&8, 2013

Gregory P. Luth & Associates
Structural Engineers and Builders

Lean Construction Institute-
HD BIM, PBD, IPD, & VDC
Casino Hollywood
Toledo, Ohio

Design start: July 2010
Fdtn start: September, 2010
Casino open: May, 2012

400,000 sq ft of casino, 3100 car, 5 level, PT parking garage. Construction document phase started July 2010, pile driving started September, 2010. GPLA produced all rebar shop drawings and turned Tekla model over to steel detailer.
### Casino Hollywood, Cape Girardeau, Missouri

35,000 sq ft of casino barge in basin, 200,000 sq. ft. of restaurants and offices on 2 levels restaurant, near New Madrid fault, seismic design category D, $75 million

<table>
<thead>
<tr>
<th>Role</th>
<th>Company/Location</th>
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<tbody>
<tr>
<td>Owner</td>
<td>Isle of Capri, St Louis, MO</td>
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<tr>
<td>Architect</td>
<td>Kuhlmann Design Group, St. Louis, MO</td>
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<tr>
<td>Interior Designer</td>
<td>Kuhlmann Design Group, St. Louis, MO</td>
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<td>Steel Fabricator</td>
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<td>Ambassador Steel, St. Louis, MO</td>
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<td>Vee Jay Cement, St Louis, MO</td>
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<td>Fixed fee to GC for steel detailing</td>
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<td></td>
<td>Fixed fee to GC for misc steel detailing (theming)</td>
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</table>
160,000 sf casino near New Madrid fault, high seismic, long span over independent floating barge, complex architectural theming elements

Beams shown in magenta are from owners stock pile from previous project
Roof over floating precast/CIP/composite barge in CIP basin

- Free-standing light gage rooms on barge – by SEOR
- Accurate Tekla joist model from Millenium
- Precast bulkhead
- CIP keel
- Electrified composite deck
- CIP basin slab & walls

May 7&8, 2013
Isle of Capri Casino Cape
Girardeau, Mo
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 on day of pour.
Encapsulated water stop. Hi Def 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**
Rebar Modeling and Detailing

What is the cost?

Modeling – 0.2 to 0.8 hours per ton
Creating drawings – 0.4 to 1.6 hours per ton

Total with engineers - $70 to $300 per ton

Typical “hand” detailing - $30 - $60 / ton

What are the savings?

Anecdotal evidence: rebar fabricators in the San Francisco area have converted to 3D model-based shop drawings because the re-work it saves in the field more than makes up for the additional cost of modeling
Thank You!