3D/ BIM applications toward construction innovation

IDDS & BIM Oneday Seminar
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Outline of Presentation

1. Current state-of-the-art BIM applications

2. Concept of construction innovation by 3D/BIM and related research activities in CIB W78

3. 3D/BIM applications toward construction innovation in building construction projects

4. Future directions of BIM applications toward construction innovation
Concept of Product Model

What is difference with Product Model and BIM?
Product Model: Machine/Production oriented information model?
BIM: Human/Design oriented information model?
Product model for a prefabricated building system

HOLLOW CORE SLAB
ID: slab 02.01
Thickness: 395 mm
Length: 8700 mm
Bearing capacity: 4kN/m²
REINFORCEMENT 01.074
SLAB HOLE 01.023
Former Concept of Component Building

Confirmation process of building Information in design

(1) Building components are recognized as physical objects which information are consistent through whole design stage

(2) Building object information is delivered to users in formal one way. Unified data representation scheme to be selected by user are relevant

Concept of Innovative Construction System

Superstructure Construction System

Computer Integrated Construction System (CIC)

Logistic Management System

Underground Construction System

Site Prefabrication System

Site Information Management System

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(1) Building components are recognized as capsules of information which are flexibly confirmed depending on design development

(2) Building object entities are confirmed not by selection of building components but by designing/engineering of building objects

Automated Construction System

A full-scale implementation of CIC by integrating industrialization, mechanization, automation and information technology

SMART System at Yokohama Nisseki Building (1994-1996)
A CIC Conceptual Model

A strategy for functional integration and decomposition of design/construction to effectively introduce advanced technologies

Integrated Design / Construction Planning System
Optimization of Building System & Construction System planning
Project Simulator

Process Inf.

Project Management System
Multi-Project Control

Product Inf.

Project Database Project Model

Site Automation System
Automated Construction System
Systematized Process Management
Prefabricated Construction System

Factory Automation System
CAD/CAM system Application
Production Management

Logistics Inf.
Former related research activities in CIB W78

1990  Computer Integrated Construction
2nd CIB W78+W74 Seminar, Tokyo (AIJ)

Remarkable Research Topics:
Object-oriented CAD
Object-oriented Project Planning
Object-oriented Database

Remarks:
Many researches proposed specific conceptual models and approaches to CIC

CIB W78 Workshop, Helsinki, Espoo (VTT)

Discussion Topics:
Information reference model for AEC
CIC framework
Discussion on Information reference model for AEC

Real-life object represented by Information represented by Conceptual model

Product

Physical Representation

Product model Reference model Type model

STEP physical files Database Product data model

Conceptual project model Organization model Resource model Process model

Meta-model of information

AEC Information

Domain

Physical representation Modeling language

Semantics Syntax

EXPRESSION IDEF1X NIAM

Domain Information

Abstraction mechanism

Classification Association

Composition/Decomposition

Explanation:
an instance

RATAS BPM ICON GenCON

Explanation:

### CIC Framework

#### Several Options and Strategies of Automation and Integration

<table>
<thead>
<tr>
<th>Dimensions and Levels of Integration</th>
<th>(1) Low Integration</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5) High Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Who?</strong></td>
<td>Individuals</td>
<td>Depts.</td>
<td>Entire Org., Firm</td>
<td>Whole Project Life Cycle</td>
<td>Entire industry</td>
</tr>
<tr>
<td><strong>What?</strong></td>
<td>Data</td>
<td>Models</td>
<td>Knowledge</td>
<td>Goals</td>
<td>All Project Information</td>
</tr>
<tr>
<td><strong>When?</strong></td>
<td>Islands of Automation</td>
<td>Multiple Apps in one Discipline and Phase</td>
<td>Multiple Apps from several Disciplines in one Phase</td>
<td>Multiple Apps from several Disciplines in and Phases</td>
<td>All Apps in Project Delivery Process</td>
</tr>
<tr>
<td><strong>Why?</strong></td>
<td>Survive, Stay in Business</td>
<td>Increase Profit</td>
<td>Increase Market Share</td>
<td>Enter New Market</td>
<td>Create New Market</td>
</tr>
</tbody>
</table>


Development of Integrated Construction Planning by 3D CAD

Major efforts:
- Product/process data modeling based on in-house developed 3D CAD
- 3D construction planning of integrated building/construction system

RC core wall + Steel rigid frame
Yokohama International Passenger Terminal (2002)

Flexible production system for complex structure by 3D CAD

Major efforts:
- 3D modeling of complex structure
- 3D based product design/production planning
- Structural analysis based on construction process
- Application of 3D measurement system
3D data modeling

Geometry Base
line of Girders

Folded-plates

Geometry Data

Girder List
3D based Product Design/Production Planning

Integrated Drawing
Plan
Detail

Design Data

Architecture
2D 3D
Structure
2D 3D
Piping/Equipment
2D 3D

VAD(3D CAD)
(Visual Advanced Design)

3D Model

Analysis/Simulation (VRML)
Visualization (AUTOCAD)
Estimation (Excel)

3D Production Data
Steel Component
Wood deck
Confirmation of Details and Construction Process
Structural Analysis based on Construction Process

3D Data

Structural Model

Construction using setting-beam

Structural analysis reflecting construction process

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Application of 3D Measurement System

Total station

Collimation angle

Distance

Light wave

Target

Measuring points in the erection of folded-plates' blocks
Cocoon Tower (2006-2008)

Visualization of Production/Construction planning by 3D System

Major efforts:
- Production planning
  Extensive utilizations of 3D System in constructability investigations
- Construction planning
  Adaptations of rational and creative construction methods
  (Horizontally-layered Construction System)
- Procurement
  Introduction of new purchasing and ordering methods by standardization and unitization based on 3D system
Construction simulation for erection works

Construction simulation for Specific figure high-rise building by 3D system

Core zone (Concrete filled steel tube)

Exterior zone (Diagonal steel frame)

Confirmation of construction process with 5 days/floor
Standardization of Unitized Curtain Walls

Transportation of curtain-wall components

Height of curtain-wall

Story height

Height of curtain-wall units

Standardization of curtain-wall units

Joint and sealing of curtain-wall units

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Transportation/Installation of unitized exterior curtain walls

Vertical transportation system for unitized exterior curtain walls using elevator space

Installation of unitized exterior curtain walls using balancer
Shimizu Head Quarters (2009-2011)

High-performance Design/Construction system for hybrid structure building by 3D/BIM

Major efforts:
- Application of commercial BIM tool to constructability investigations
- Accuracy improvement of sequence simulation (Real-time simulation)
- Association of process planning with monitoring

RC core wall + Hybrid perimeter frame
Investigation of details and construction process with placing of reinforcement
Material handling/transportation planning

Transportation of PC to stockyard and placing of reinforcement

Goliath crane (20t)

Transportation/ Erection of PC

Layout of temporal facilities and machines at ground floor of the building
Construction Sequence Simulation

Real-time construction process simulation based on standard operation time

Result of construction process simulation

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start crane operation</td>
<td>10:00</td>
<td>11:09</td>
<td>10:43</td>
<td></td>
</tr>
<tr>
<td>Start lifting-up</td>
<td>13:24</td>
<td>10:02</td>
<td>11:11</td>
<td>10:45</td>
</tr>
<tr>
<td>Lifting-up</td>
<td>13:26</td>
<td>10:06</td>
<td>11:12</td>
<td>10:49</td>
</tr>
<tr>
<td>Waiting</td>
<td></td>
<td></td>
<td>11:38</td>
<td></td>
</tr>
<tr>
<td>Rough positioning</td>
<td>10:08</td>
<td>11:39</td>
<td>10:52</td>
<td></td>
</tr>
<tr>
<td>Precise positioning</td>
<td>13:29</td>
<td>10:10</td>
<td>11:43</td>
<td></td>
</tr>
<tr>
<td>Installation</td>
<td>13:38</td>
<td>10:12</td>
<td>11:46</td>
<td></td>
</tr>
<tr>
<td>Form work</td>
<td>13:50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End crane operation</td>
<td>14:03</td>
<td>10:27</td>
<td>11:28</td>
<td>11:04</td>
</tr>
<tr>
<td>Total operating time</td>
<td>39min</td>
<td>27min</td>
<td>50min</td>
<td>21min</td>
</tr>
</tbody>
</table>

Measurement of operation time using full-scale mock-up

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Comparison of sequence simulation and monitoring

Modification of work schedule through comparative analysis of planning data and monitoring data
Concept of technology/knowledge fusion

Manufacturing Industry

Prefabrication Technology
- Industrialization
- Standardization

Automation Technology
- Automated Transportation
- Sensing/Control

Information Technology
- Modeling/Simulation
- Monitoring/Network

Construction Industry

Construction Technology
- Heavyweight Handling
- Site Production/Coordination

New Building/Construction System
- Prefabricated Construction System
- Automated Construction System
- Computer Integrated Construction System
Concept of Industrialization

Defined by ECONOMIC COMMISSION FOR EUROPE, UN (1959)

(i) Continuity of production, implying a steady flow of demand

(ii) Standardization of products

(iii) Integration of the different stages of the whole production process

(iv) A high degree of organization of work

(v) Mechanization to replace manual labor wherever possible

(vi) Research and organized experimentation integrated with production
BIM applications toward Construction Innovation

- Sophistication of collaboration environment with AEC functions by improving production/delivery systems through investigations using BIM

- Promotion of technology and knowledge fusion toward higher level of automation and integration by reviewing BIM as a tool for fusion

- Continuity of research and technology development toward construction innovation by promoting basic research and organized experimentation with CIC based on BIM
References