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STEEL CONSTRUCTION TODAY & TOMORROW

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繫

【 *k e i* 】

"繫 (*kei, tsuna-gu*)" in Japanese, or "connect" in English

The purpose of BIM (building information modeling) and CIM (construction information modeling) is originally to connect the information required for every process of a construction project from design and construction to maintenance. How to effectively apply BIM and CIM is featured in Issue No. 47.

Special Issue: Japanese Society of Steel Construction

Commendations for Outstanding Achievements in 2015

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Special Feature: BIM and CIM

Special Feature: Stainless Steel

Published Jointly by

The Japan Iron and Steel Federation

JSSC Japanese Society of Steel Construction

Nhat Tan Bridge

Prize winners: Joint Venture of IHI Infrastructure Systems Co., Ltd. and Sumitomo Mitsui Construction Co., Ltd.

Nhat Tan Bridge is a new route from Noi Bai International Airport to downtown in Hanoi, Vietnam. The main bridge section is a 1500 m long, 6-span cable stayed bridge with 8 traffic lanes. This multiple span cable stayed bridge is the first application in Southeast Asia and a very rare type in the world. A general view and cross-section of the main bridge are shown in Fig. 1.

Steel pipe sheet pile (SPSP) was adopted for the foundation of pylons with a total weight of steel pipe equal to 14,200 tons. Total weight of anchorage box and steel girder is around 15,000 tons. New prefabricated parallel wire strands are used for stay cable. Total number of stay cable is 220 and total weight of stay cables is approximately 1,800 tons.

The architectural and structural design was undertaken by the consortium of Chodai Co., Ltd. and Nippon Engineering Consultants Co., Ltd. (NE) in association with Transport Engineering Design Incorporated (TEDI).

The construction was undertaken by the Joint Venture of IHI Infrastructure Systems Co., Ltd. (IIS) and Sumitomo Mitsui Construction Co., Ltd. (SMCC), wherein the lead JV partner is IIS.

General Construction Method

The main bridge across and over the 1.0 km wide river plays an important role as navigation route, so that any construction method that occupies the river (such as construction bent on river) was not allowed. Therefore, inclined bent method is adopted around each pylon and balanced cantilever construction method was adopted in the remaining parts including side span of bridge as shown in Photos 1 and 2, respectively. Side span usually is constructed in advance with use of bent, so application of cantilever erection into whole span in large scale of multiple span stay cable bridge would be the first challenge of its kind in the world.

Steel Pipe Sheet Pile (SPSP) Foundation

The foundation for the five pylons that support the main bridge was done using SPSP foundation method. This is a technology developed in Japan that shortens the time needed for construction compared to conventional methods and strengthens the bridge against earthquake and soft ground. This technology was adopted for the first time in Southeast

Fig. 1 General View/Cross-Section of Main Bridge

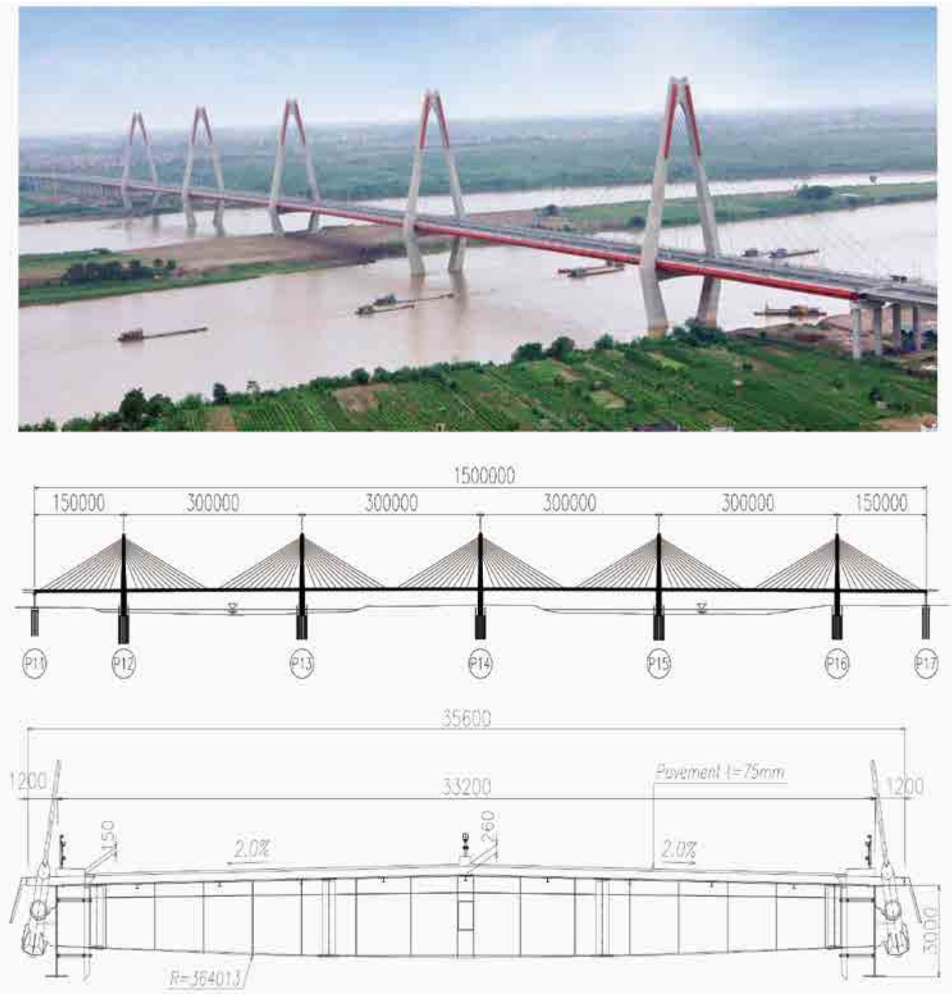



Photo 1 View of construction by inclined bent


Photo 2 View of construction by cantilever erection


Photo 3 SPSP installation

Asia and was completed successfully. Photo 3 shows SPSP installation.

SPSP foundation method was newly adapted as one of standards of foundation system (TCVN9246: 2012) in Vietnam.

Step Analysis and Geometry Control

• Step Analysis

In order to confirm the structural integrity of the bridge during erection, forward step analysis was performed. It is a noticeable point on this model that fishbone model with two separate beam elements representing the steel girders and concrete deck slab was applied, thereby, it realizes effective modeling of creep and shrinkage on concrete deck that are much closer to actual creep and shrinkage as well as easy modeling of composite and non-composite section effect on girders. (Refer to Fig. 2)

• Geometry Control

During cantilever erection, it was necessary to predict the effects of any adjustments made at each erection stage on the geometry at bridge completion. Construction stage results were used as target values for comparison during stay cable tensioning works.

Fabrication errors on edge girder, anchor box and stay cable were considered and the targets were adjusted accordingly.

A system that incorporated all of the above was developed and applied for the installation and adjustments of all stay cables. Comparison of the target Girder displacement (analysis) and actual Girder displacement after calibrated is shown in Fig. 3.

Structural Steel Fabrication Works

Structural steel fabrication was conducted in three factories as shown in Table 1 and more than 50% was done by IHI Infrastructure Asia Co., Ltd (IIA). IIA is a subsidiary company of IHI Corporation with fabrication shop in Hai Phong, Vietnam. (Refer to Photo 4)

Table 1 Steel Fabrication Summary

IHI Aichi (Japan)	2,500 tons
IHI Infrastructure Asia Co., Ltd. (IIA) (Vietnam)	7,885 tons
Mitsui Thang Long Steel Construction Co., Ltd. (MTSC) (Vietnam)	4,000 tons

Photo 4 Steel fabrication works

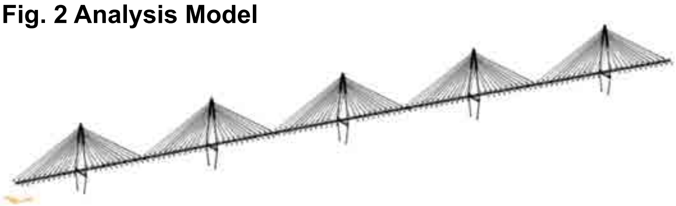
Photo 5 Night view of Nhat Tan Bridge

To ensure high quality, Vietnamese fabrication supervisors had a 3-4 months training in IHI Aichi factory in Japan, and during the fabrication works, Japanese supervisors were mobilized in each fabrication stage.

Also, during the fabrication works, factory visits and inspections were conducted and high quality steel fabricated in Vietnam was produced, which is a proof of another successful transfer of technology from Japan to Vietnam.

As a result, the quality and workmanship of steel fabrication in IIA are the same as steel fabricated in Japan.

Fig. 2 Analysis Model



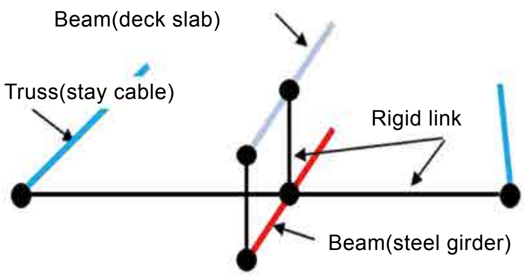
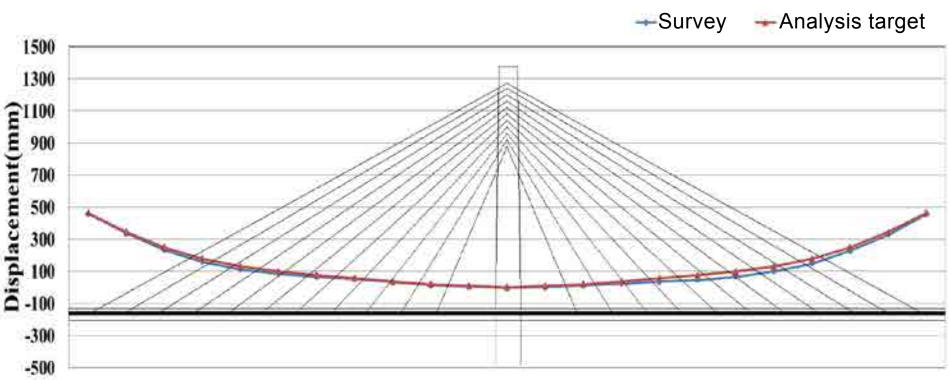


Fig. 3 Comparison of Target and Actual Girder Displacement during Cantilever Erection



Nhat Tan Bridge — A Famous Landmark in Hanoi

With the use of structural steel, the construction period was shortened by 4 months compared with the Original Master Schedule on superstructure part. Therefore, this shows in Vietnam and all over the world the advantage of using structural steel in bridge construction and other construction works.

Nhat Tan Bridge, which was constructed using mostly structural steel, has become a famous landmark in Hanoi and is considered one of the most scenic bridges in Vietnam especially when the different colors of lights directed at the pylons are illuminated at night (Photo 5). ■

—Outstanding Achievement Award

Ribbon Chapel

Prize winners: Hiroshi Nakamura, Hiroshi Nakamura & NAP Co., Ltd., Ikuhide Shibata, Arup, and Yuzo Minoda, NIPPON STEEL & SUMIKIN ENGINEERING CO., LTD.

The Ribbon Chapel is a wedding venue located on the grounds of a resort hotel in Hiroshima, Japan. Inspired by a flying ribbon, two curved staircases encircle the exterior of the chapel, a steel structure 15.4 m in height and with an area of 72 m², meeting at a rooftop platform overlooking the Seto Inland Sea. The staircases start at different locations before ascending and becoming one at the top, symbolizing two paths ending in marriage. The structure can be regarded as a coil spring that twists and expands outward while moving up and down with pressure from above but unlike a typical coil, the architect's design is free form.

Fig. 1 Structural Concept Model

The curved free-form 3D design with the 'floating' staircases presented unprecedented challenges to realize in construction and steel fabrication in both cost and schedule. Hence the geometry was redefined as a combination of 88 two-dimensional curved steel pieces, each with a maximum variation allowance of 10 mm to create a 3D free form.

The structural challenges included:

- Providing support without impacting the aesthetics
- Coping with vibration and seismic activity
- Managing the displacement under the structure's own weight

The chapel spirals up a cliff overlooking the sea

Our solution to stabilize the movement was to connect four points in four directions where the two stairways cross paths. This created a 3-dimensional bracing system to resist horizontal forces and a basic structural concept of hoops to restrain the outward swell with the two staircases providing mutual horizontal support to each other. Steel posts 100 mm in diameter were installed to support the vertical load. The posts only support the inner spiral, while the outer spiral is coupled to the inner spiral in the form of an overhang. (Refer to Figs. 1 and 2)

Secondly, since the Ribbon Chapel is located in an earthquake zone, a Base Isolation System was installed to reduce seismic forces and to increase durability of the building so that it would not be necessary to modify the form, system, regulations or material specification to ensure a stable and safe building but still preserve the original design intent. Furthermore, there were three points on the outer spiral where the floor's natural vibration frequency

Ribbon Chapel

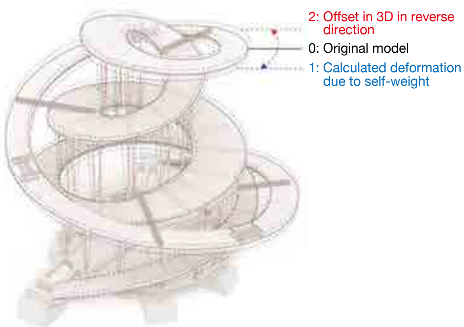
was under 8 Hz, which led to concerns about footfall-induced vibration. Therefore, to ensure visitor comfort, three cantilever-type Tuned Mass Dampers were installed to reduce floor vibration.

The third challenge was the displacement by self weight from the desired location when constructed. It was foreseen that when the falsework was removed after completion of construction, the building would undergo a maximum of 32 mm in rotational displacement, causing the vertical support posts to lean.

Our solutions were:

- Shaping the steel to take into account the effect of the calculated deformation and the offset in 3D
- Add a 3D concave offset to absorb the vertical support post movement. The support posts were deliberately slanted during construction by the same degree of rotational displacement, but in the reverse direction. As a result, after the completion of construction the posts would 'twist' back to vertical. (Refer to Fig. 3)

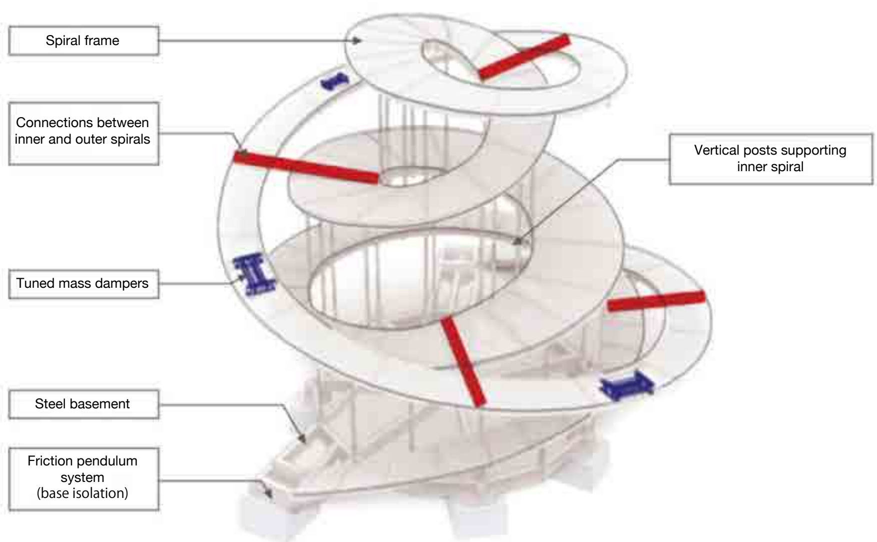
Fig. 3 3D Concave Offset to Absorb the Vertical Support Post Movement



We used real world applications as innovative solutions to realize this concept. We believe this is the only structural system of its kind in the world. The total design including a durable structural system and simplified fabrication methods is ecological, cost and time efficient. It's an iconic double purposed design, that is a wedding chapel and also an observatory, which continues to entice increased numbers of new visitors yearly. It's small but displays our cutting-edge design and creativity.

(Written by Ikuhide Shibata, Arup)■

Fig. 2 Structural Components of Ribbon Chapel



—Outstanding Achievement Award

Nippon Life Marunouchi Garden Tower

Prize winners: Satoru Nagase, Isao Kanayama and Yasuo Kagami, Nikkken Sekkei Ltd.; and Toru Takahashi and Yoshiyuki Tanaka, Obayashi Corporation

Nippon Life Marunouchi Garden Tower is a 115 m high office building located near the imperial palace at the center of Tokyo. The impressive building façade is a part of structural and architectural elements. Also it is environmentally sun-shading device to reduce heat inputs. Structural solution taking advantage of multifarious steel has integrated architectural, structural and environmental design.

Design Requirements for Structure

—Expansive column-less office space with a good view
—Façade design with vertical impression
—High seismic resistant capacity
—Sustainability design with LEED (Leadership in Energy & Environmental Design) Certified Gold

Structural Design Solutions

—Structure composed of core and perimeter moment-resistant frame
—27.5 m long beam connecting core and perimeter frame to support office floor
—Façade design by exposed steel columns of perimeter frame
—Seismic response control design
—Fire performance-based design for steel
—Use of recycled steel for sustainability design

Structural System

• Composite Steel Structures

Gravity load of office space of 64.8 m × 27.5 m is supported by 27.5 m long steel beams connecting columns in core and perimeter frame. RHS and CHS steel columns are filled with high strength concrete of Grade Fc60 and Fc80. The 27.5 m long H-section beams are stiffened by partially filled concrete to improve floor vibration performances.

• Horizontal Response Control

—Vibration energy-absorbing devices

Combined hysteretic and viscous energy-dissipating vibration control system using both buckling-restraint braces and wall-type dampers in core is used in order to reduce responses due to earthquakes and winds.

—Seismic damage control device

Column-type metallic dampers with the low yield point steel to control seismic damages of perimeter frame are used. Combined two column-type dampers and twin-columns to support gravity load are placed alternately and connected by perimeter beams to constitute the moment-resistant frame.

Structural Material Right Selection in the Right Place

• Steel Grade

Yield points of primary steel used for columns and beams are 325, 385, 440 N/mm^2 which are selected considering design forces and structural roles. The steel plate used for both buckling-restraint braces and perimeter column-type metallic dampers has a low yield point of 225 N/mm^2.

• Composite Columns and Beams

Concrete with high compressive strength of 60 and 80 N/mm^2 is used for composite columns and 27.5 m long beams to support gravity loads efficiently.

• Recycled Steel for Sustainability

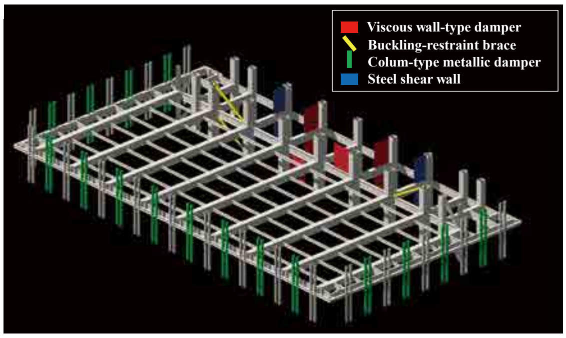
Recycled steel with a yield point of 235 and 325 N/mm^2 is widely for beams and also was evaluated on LEED certification.

Steel Fabrication and Site Erection

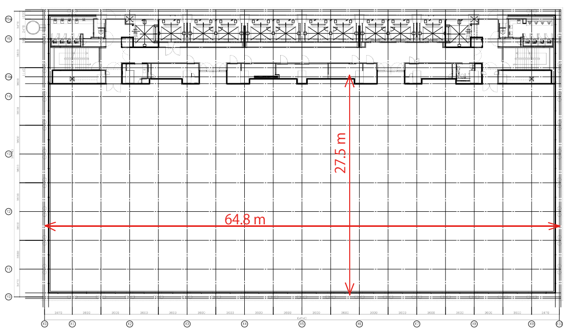
High construction accuracy for shop fabrication and site erection was obtained and it contributed to realize the architecturally, structurally and environmentally integrated design. ■

Building appearance

Perimeter column



Main structure CG



Typical office floor plan

—Outstanding Achievement Award

Yomiuri Shimbun Tokyo Headquarters Building

Prize winners: Yuichi Koitabashi, Seiya Kimura and Yasuo Kagami, Nikken Sekkei Ltd.; and Shimizu Corporation

In the plans for the Yomiuri Shimbun Tokyo Headquarters Building, the following original ideas, devices and advanced measures were incorporated to handle the various tasks involved in the design and construction. These ideas led to an architecture that contributes to the development and diffusion of steel structures.

- **Securement of high seismic resistance—Retention of the building main frame in its elastic range and maintenance of its function as a newspaper headquarters building during near-source region and other great earthquakes**

High-strength steel products were used for the columns (SA440C and TMCP385B grades) and girders, and "energy-absorbing response-control structures for specified floors" were adopted that offer a high energy absorption efficiency, an efficiency that is more than three times that of the response-control structures of common high-rise buildings.

- **A plan to reduce the aftershock tremors that follow long-period seismic motions or great earthquakes**

The active mass damper (AMD) was installed on the rooftop that can handle a floor response acceleration of 2~200 gals. This was done in order to structure a mechanism for mitigating not only wind-induced vibration but also the aftershock tremors that follow earthquakes.

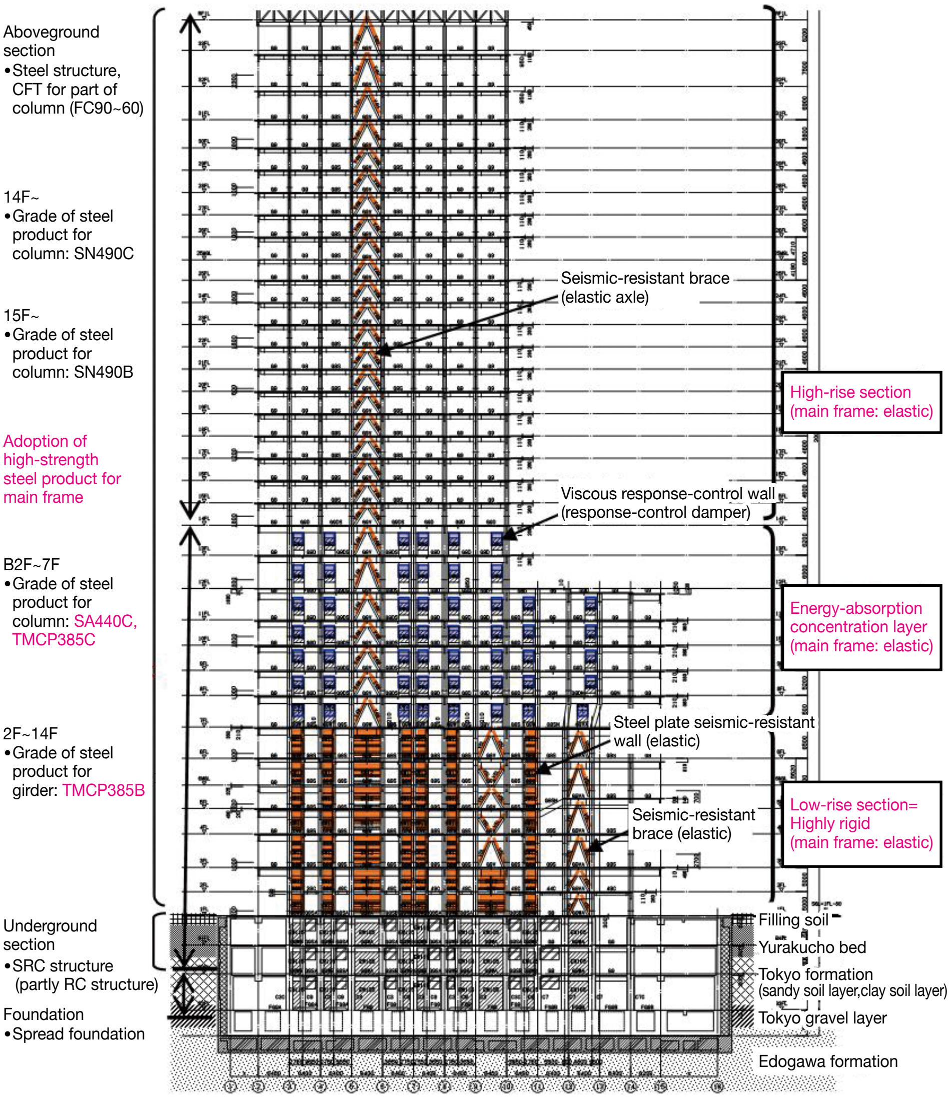
- **Measures to prevent building collapse even during an unexpected mega earthquake that is even more severe than a great earthquake**

Among the measures taken were: the development and adoption of beam-end web local buckling and stiffening details with high plastic deformation capacity and the implementation of diverse welding tests for the high-strength steel column-girder weld connections. These tests are designed to find the welding conditions for obtaining high Charpy impact strength and to reflect such conditions in member manufacture and installation.

- **Measures to prolong building service life and to mitigate environmental loads**

Among the measures taken were: the monitoring of response-control and seismic-resistant members by means of floor response acceleration and displacement measurements; the adoption of a pair of large-span suspension cable trusses employing double-wall Low-E glass to realize a spacious atrium façade with a higher heat reduction efficiency; and the partial utilization of existing former headquarters building structures for the earth-retaining walls and the bearing stratum of the new building, in order to reduce the discharge of waste materials and surplus soil and the usage of earth-retaining and other temporary construction steel products. ■

Structural Outline




Full view


Spacious atrium façade

—Thesis Award

Reinforcement Design for Existing Non-conforming Steel Buildings Using STKR Columns

Prize winners: Yuji Koetaka, Kyoto University and Tatsuya Nakano, Utsunomiya University

Yuji Koetaka

1999: Graduated from Graduate School of Engineering, Osaka University
1999: Entered Taisei Corporation
2001: Assistant Professor, Kyoto University
2007: Lecturer, Osaka Institute of Technology
2011: Associate Professor, Graduate School Engineering, Kyoto University

Tatsuya Nakano

2003: Finished Doctoral Course, Graduate School of Engineering, Utsunomiya University
2003: Assistant Professor, Utsunomiya University
2013: Associate Professor, Utsunomiya University

In the revision of the Building Standard Law of Japan in 2007, a new provision was added in which the column overdesign factor was set at 1.5 or more for steel buildings using cold-formed square steel tubes as the columns. This study targets existing steel buildings that cannot satisfy the above-mentioned factor and use the STKR-grade square steel tube as the columns.

The attainments of this study are compiled in three theses, in which the calculation formula of the full plastic moment of columns after reinforcement is proposed, targeting four kinds of reinforcement methods as shown in Fig. 1. The elasto-plastic behavior, strength and plastic deformation capacity of columns after reinforcement have been confirmed by means of loading tests. In addition, the validity of the equations used in the calculations is confirmed based on the test results, and the conditions for demonstrating the full plastic moment are made clear. Outlines of the three theses are introduced below:

In the first thesis, reinforcement methods that use steel plate or angle steel are targeted. The reinforcing effect was mainly examined of the dimension of the reinforcing members and the number of column surfaces on which the reinforcing members are installed. In addition, the reinforcement height and the necessary conditions to weld the reinforcing members were grasped. When using angle steel for reinforcement, it is necessary to install the reinforcing members on all surfaces of the columns. Meanwhile, when using steel plate for reinforcement, it is possible to select optional surfaces of the columns.

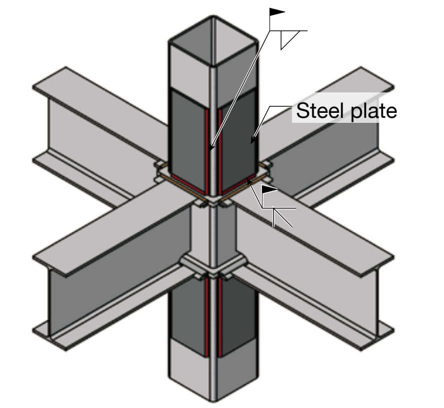
In the second thesis, a reinforcement method that combines the use of both steel plate and PC bars is targeted. In the test, the separation between the floor slab and the fastening steel plate due to the elongation of PC bars and the out-of-deformation of the fastening steel plate due to its yield are observed preceding plasticity of a column. Based on these test results, the method to calculate the strength of the stiffening section was established in order to propose a design method that ensures the full plastic moment of the column after reinforcement.

In the third thesis, reinforcement by wrapping mortar around the column is targeted. The main examination was to grasp the necessary conditions, such as the number and thickness of the shear cotters, to demonstrate the full plastic moment of columns after reinforcement.

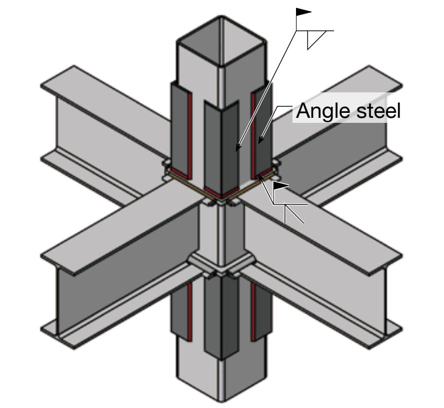
Concrete floor slabs are not removed if either the reinforcement by the combined use of steel plate and PC bars or the reinforcement by wrapping is applied.

This study was conducted under the auspices of the Building Standard Maintenance Promotion Program by the Ministry of Land, Infrastructure, Transport and Tourism in Japan. We express our sincere gratitude to whom it may concern. ■

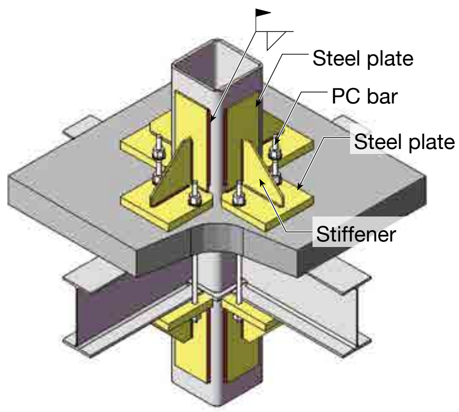
Fig. 1 Methods of Reinforcement of STKR Column



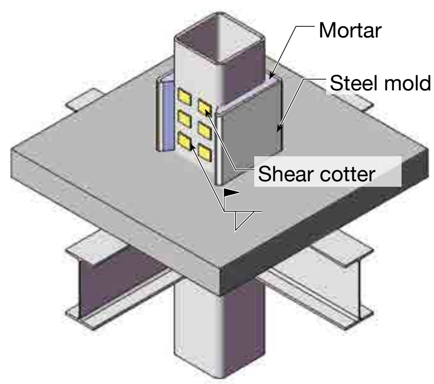
(a) Reinforcement by steel plates



(b) Reinforcement by angle steels



(c) Reinforcement by steel plates and PC bars



(d) Reinforcement by wrapping

—Thesis Award

A Study on Use of the Effective Notch Stress Method to Prevent Root Fatigue Failure in Out-of-plane Gusset Welded Joints with Ground Toes

Prize winners: Takeshi Mori, Hosei University; Toshimitsu Suzuki, Tohru Oomae, Takahiro Murakami and Junichi Ikoshi, Japan Bridge Association

Takeshi Mori

1980: Finished master course, Graduate School, Tokyo Metropolitan University
1982~1990: Assistant, Tokyo Institute of Technology
1990: Assistant Professor, Hosei University
1996: Professor, Hosei University
Currently: Professor, Faculty of Engineering and Design, Hosei University

In out-of-plane gusset welded joints that are used where main girders intersect with cross beams on steel plate girder bridges, fatigue failure in most cases originates in boxing weld toes that have high concentrations of stress. However, in cases when the weld toe is finished by the use of a grinder to improve fatigue strength, there are instances when the fatigue failure will originate at the weld root, rather than the weld toe.

In the current study, in order to establish a method to prevent root fatigue failure in out-of-plane gusset joints with weld toes finished to about 5 mm, fatigue tests and finite element stress analyses were conducted on model test specimens; further, the parametric finite element stress analyses were conducted with the thicknesses of the main plate and the gussets set as variables.

In the fatigue tests, five kinds of test specimens were adopted with each having a different weld toe finish, weld penetration depth and welding leg length. In the analysis of these five test specimens, the stress concentrations at the root tip and the finished weld toe were compared using the effective notch stress method, which is regarded as able to account for peculiarities in root tip configurations. The analysis shows that use of the effective notch stress method as proposed in the current study is effective in examining fatigue failure initiation points.

Furthermore, the three-dimensional elastic finite element stress analyses were conducted using as parameters the thickness of the main plate girder and the gussets, weld size, weld configuration and the weld penetration depth in the longitudinal direction of the gussets and the through-thickness direction of the plate, thereby clarifying the effect of these parameters on the effective notch stress of the weld root and toe.

The results of this study confirm the appropriateness of the Recommendations specified by the Japanese Society of Steel Construction in its guidelines for preventing root fatigue failure: "the welding depth in the longitudinal direction of the gusset end should exceed twice that of the main plate thickness." In this regard, the current study presents this practical result—the effective notch stress of the weld root is about 70% of that at the weld toe. ■

Fig. 1 Configuration and Dimension of Test Specimen

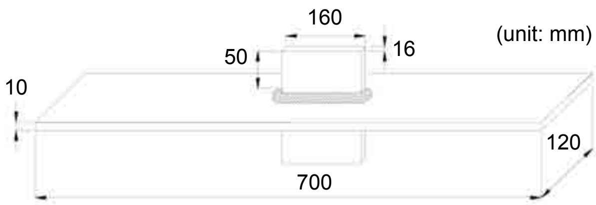


Fig. 2 Fatigue Failure Surface with Beach Mark

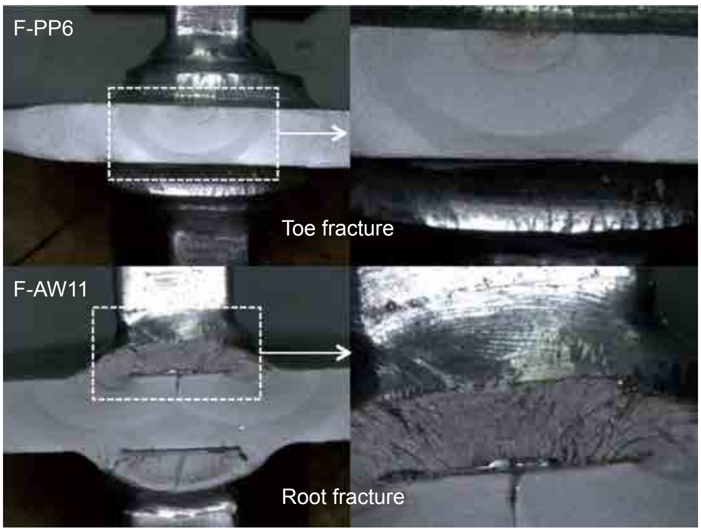
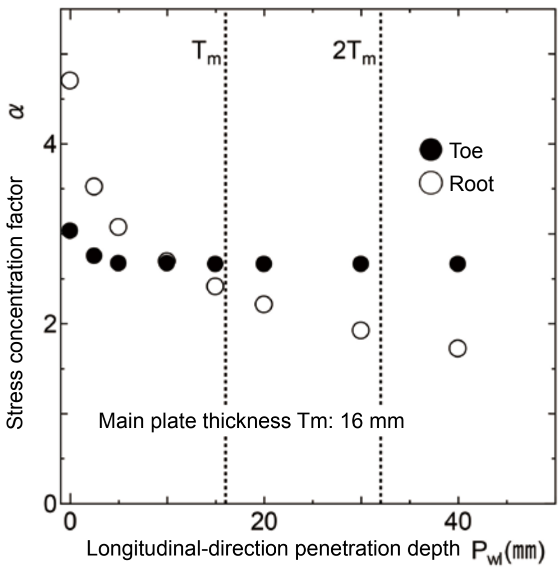


Fig. 3 Relation between Stress Concentration Factor and Weld Penetration Depth



Looking ahead to the ongoing reduction in birth rate and to the aging of society in Japan, new changes are being called for in every aspect of construction from design and construction to maintenance and repair, in order to further promote resource/energy/labor savings and to enhance work efficiency. BIM (building information modeling) and CIM (construction information modeling) are expected to work as the nucleus for attaining this goal. BIM has already been put into trial use in many practical projects, and the full-scale application of CIM (BIM for infrastructure) started in 2012.

In light of this situation, Issue No. 47 features the current application of BIM and CIM and their future tasks in the following four cases:

- BIM in architectural and structural designs
- Expectations for the wider application of BIM in steel-frame construction
- Application of three-dimensional bridge product modeling towards the strategic maintenance of steel bridges
- CIM trial application project

Special Feature: BIM and CIM—Building Information Modeling (1)

BIM in Architectural and Structural Designs

by Tomohiko Yamanashi, Nikken Sekkei Ltd.

From Productivity Improvement to Design Quality Improvement

Originally, BIM (building information modeling) was a "tool for productivity improvement" that was developed under the influence of the design and production processes in automobiles and aircraft. In the field of building construction, BIM was developed with the main aim of improving productivity in construction. More specifically, it was developed on the concept of reducing reworking in the construction process by preparing, at the design stage, a highly consistent three-dimensional digital model in a virtual three-dimensional space in computers, instead of preparing two-dimensional drawings on paper.

While BIM was developed from such a concept, it has become clear that diverse merits derive from using BIM even in the design process. Most reworking at the design stage is caused by various factors, such as a lack of understanding by the client of the design proper when entering into the latter stage of the design work, non-attainment of the expected design performance, excessive initial cost, and inconsistency between the architectural structure and the equipment.

In order to hurdle these factors, BIM is greatly helpful in capitalizing on design visualization, various BIM-applied simulations, and the real-time grasping of required tonnages by the use of BIM. To this end, it has become clear that BIM can serve as a tool that improves quality in the design process.

Given this situation, Nikken Sekkei considers BIM as a trump card in "improving design quality" and is promoting the company-wide application of BIM. (Refer to Photo 1 and Fig.1: Lazona Kawasaki Toshiba Building)

"Configuration" and "Phenomenon" in Architectural Design

The merits obtained from the use of BIM in building design can be roughly classified by two terms: "configuration" and "phenomenon."

It can safely be said that the principal merit in using BIM in architectural design lies in that when BIM is applied, the building structure that is originally three-dimensional can be designed straight-forwardly as three-dimensional. This merit may be seen as a benefit derived from BIM's capability to handle

Fig. 1 BIM integrated drawing at basic design stage of Lazona Kawasaki Toshiba Building

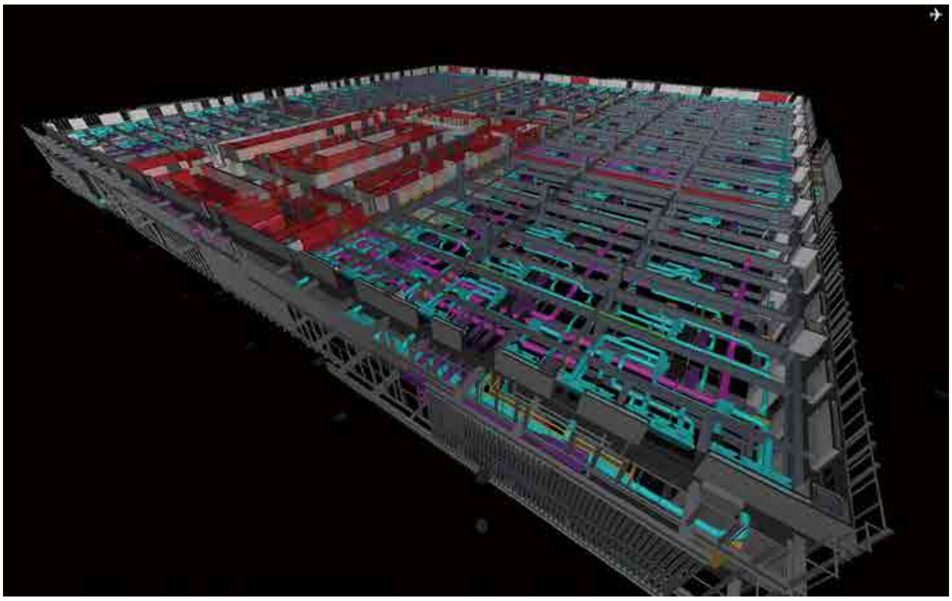


Photo 1 Lazona Kawasaki Toshiba Building

the “configuration.” (Refer to Photo 2 and Fig.2: Hoki Museum)

Compared to the case of relying on two-dimensional design, mutual understanding among the design team members is outstandingly promoted by the use of BIM. On top of this, the presentation by means of perspective drawings and videos prepared by the use of BIM is very helpful in promoting the client’s understanding of design. In addition, the clash detection of consistency among design, structure and equipment can be visually and electronically confirmed at the design stage by preparing an integrated model in which the BIM-based columns, beams and other structural members and the BIM-based ducts and other equipment are piled on the architectural BIM. In the integrated model, the structural members are three-dimensionally input, and therefore approximate tonnages can be calculated nearly on a real-time basis. Because the architectural design of a building is the handling of the “configuration,” the predominance of BIM is surely obvious because a BIM design can be promoted in a manner similar to the way that plastic models are assembled in a virtual three-dimensional space on computers.

It can be said that a secondary merit of BIM in architectural design is the availability of various simulations that employ BIM’s three-dimensional models. This merit is, so to speak, the capability of BIM to handle var-

Fig. 2 BIM of Hoki Museum

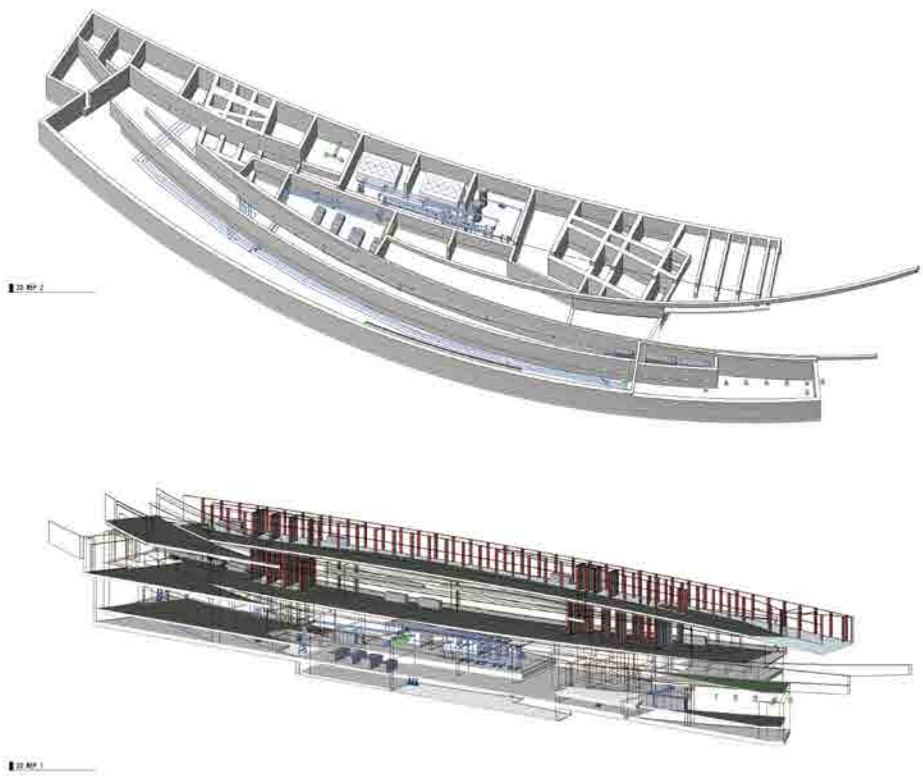


Photo 2 Hoki Museum

Fig. 3 Simulation by use of BIM of *On the water*

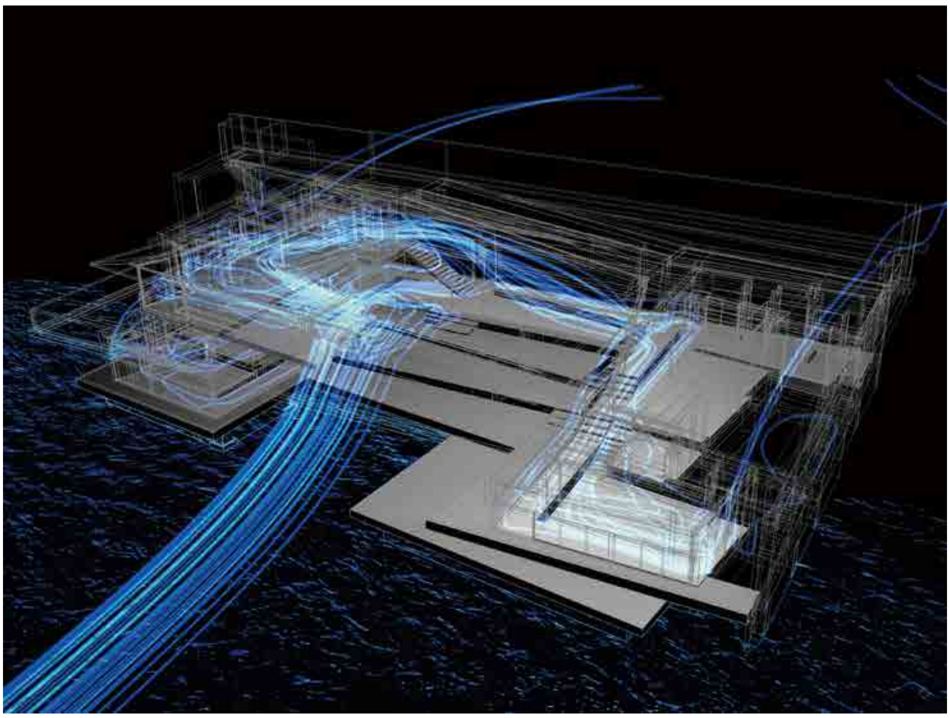


Photo 3 *On the water*

ious physical conditions occurring inside the building, that is, the "phenomena."

When mentioning simulations that handle the typical phenomena in building design, the simulation of airflow and the thermal environment by means of computer fluid dynamics (CFD) can be cited. Formerly, it required more time to prepare the three-dimensional digital model that was used for simulation than it did to prepare the simulation itself. Currently, because the design itself is made by means of BIM, CFD has become easier to apply, and thus it is now easy to feed back the results obtained in CFD to the design, which has led to the improvement of design quality. (Refer to Photo 3 and Fig.3: *On the water*)

The common application of simulations pertaining to the light and sound environments has started due to the diffusion of not only CFD but BIM; and, as a result we really feel in our routine design work that the application of BIM has led to an improvement of design quality.

"Configuration" and "Phenomena" in Structural Design

In the field of structures, the tasks involved in the "configuration," or analytical line segments, and the "phenomena," or structural calculation and analysis, had already been treated on computers prior to the introduction of BIM. Nikken Sekkei has noticed this and has linked several structure-related software applications to digital images, which has promoted BIM in structural design all at once.

In this situation, it was the software to connect the company's in-house structure analysis program and the BIM structural software that was first developed. Capitalizing on this software, the BIM structure is automatically prepared from the numerical and member information that the analysis line segment retains on the structural analysis program. When the detailed beam- and slab-level information is given on BIM, a list of the various structural members and framing elevations can be nearly automatically drawn. The linkage of both the "phenomena" on the analysis program and the "configuration" on the design drawing offers a great merit when taking quality into account in structural design. (Refer to Photo 4 and Fig. 4: No. 1 Building of Toho Gakuen Chofu Campus)

Further, in the design of stadiums and other similar facilities in which complicated structural configurations are adopted and structural members are used in an exposed form (used as they are), the building shape (configuration in architectural design) and the analysis line segment (configuration in structural design) have simultaneously been modelled by three-dimensional CAD that can handle free configurations. In this approach, the building configuration is sent to the architectural design BIM, which is linked to the phenomena handled by the various environmental simulations. And, as a result, it is now possible to link the analysis line segment with the phenomena handled by the structure analysis program. To this end, the application of BIM showed rapid progress in the field of structural design.

"Behaviors" and "Lifecycle"

As introduced above, the application of BIM in architectural and structural designs at Nikken Sekkei started from configuration, and its application has been expanded to include the phenomena that occur in the configuration. The main goal targeted here has been to improve the design quality. In the future, it is expected that BIM will target productivity improvement, an original scheme of BIM, in collaboration with the construction BIM that is attaining steady development nearly in parallel with BIM in architectural and structural design.

In addition, we think it necessary in the field of design that the "behavior" of people occurring in a building be incorporated in the sphere of BIM. In this regard, it is expected that the combination of BIM with artificial intelligence will be promoted. Further, it is an important task that BIM play a beneficial role for the client and for society, the final user of BIM. To this end, we consider that the application of BIM should be promoted in the field of facility management (FA) and other building lifecycle issues. ■

Fig. 4 BIM of No. 1 Building of Toho Gakuen Chofu Campus

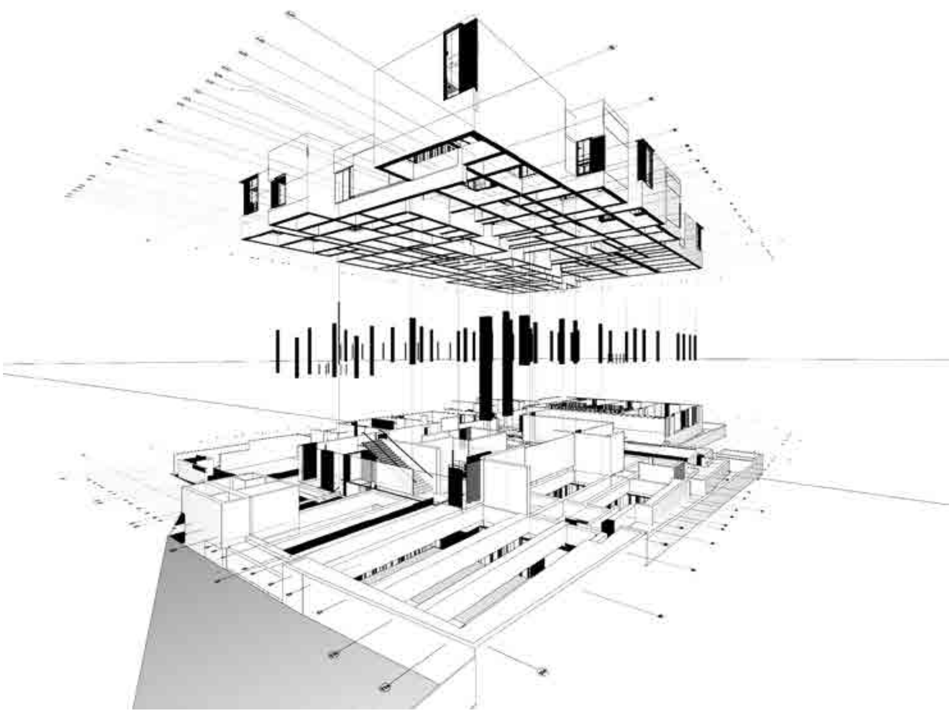


Photo 4 No. 1 Building of Toho Gakuen Chofu Campus

Expectations for the Wider Application of BIM in Steel-frame Construction

by Hiromitsu Sone, Japan Federation of Construction Contractors

The BIM subcommittee of the Japan Federation of Construction Contractors[1] published in December 2014 a handbook titled "What's Construction BIM—Handbook for the Collaboration of General Contractors and Subcontractors," which was the first manual in Japan for applying BIM (building information modeling) at the construction phase. It includes many figures and illustrations so that even beginners can easily read the Handbook and enhance their understanding of BIM (Photo 1).

Photo 1 "What's Construction BIM—Handbook for the Collaboration of General Contractors and Subcontractors"

In common construction projects, the general contractor prepares execution drawings based on the design document simultaneously with the start of construction, and the subcontractor also prepares shop drawings, based on the design and execution drawings, that is used for manufacturing the structural members at the shop. During this course, the need arises for the general contractor and the subcontractor to efficiently promote coordination to the diverse drawings between them by means of BIM.

In this situation, the Handbook has made clear various procedures of how to apply BIM so that the general contractor and the subcontractor can mutually gain merits derived from the use of BIM at the construction phase (hereinafter referred to as the construction BIM).

Photo 2 Fixing of ceiling inside equipment and coordination of steel-frame sleeves

Construction BIM

It has been said that, in cases when BIM is not used in the integrated process from design and construction to maintenance, its application merits cannot be demonstrated. However, the Handbook clearly shows that, even when BIM is applied only from the construction phase, the parties concerned can obtain sure merits. Among those specific merits obtained are:

- Acceleration of consensus process in project stakeholders
- Clash detection and detailed design confirmation
- Examination of constructability and construction simulation
- Productivity improvement in generation of drawings
- Efficiency improvement in approval of drawings
- Description of the cost breakdown

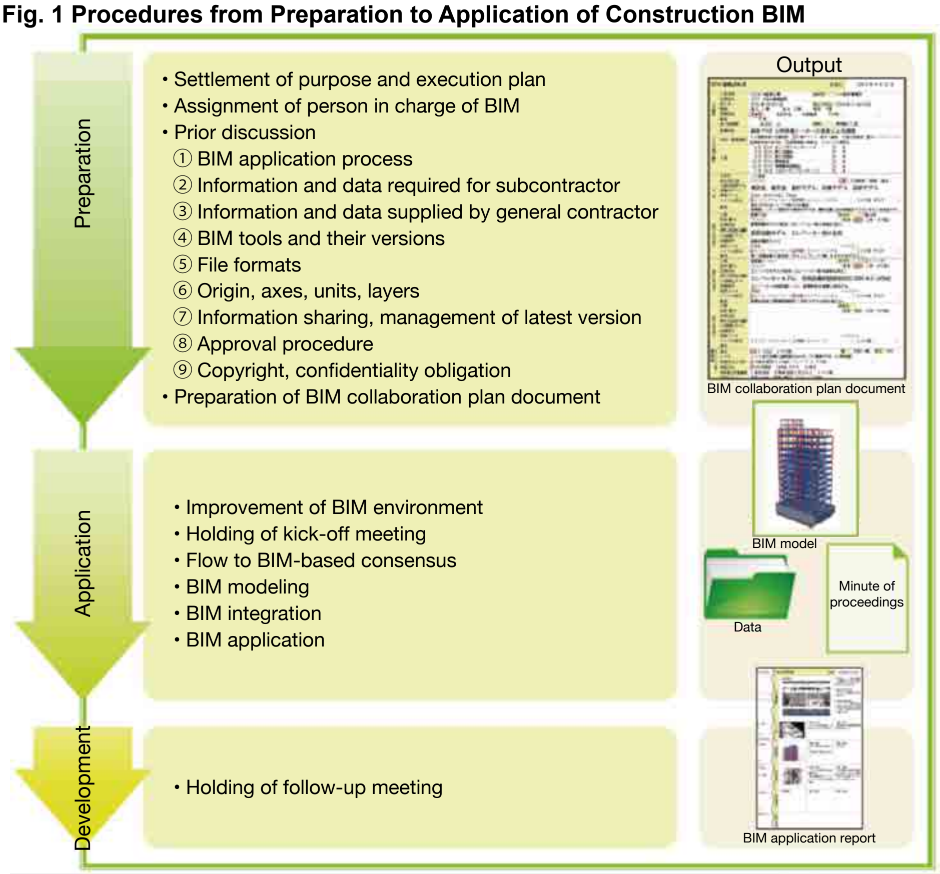
High Expectation for BIM Application in Steel-frame Construction

The content of the Handbook details the following items:

- What is targeted in BIM?
- Procedure for successful application of BIM (Fig. 1)
- Construction BIM by trades of construction work
- Application of BIM at the level of shop drawings in steel-frame office building construction
- Outline and main points of successful application of construction BIM being promoted by the general contractor and the subcontractor
- List of effects derived from BIM application, and sample of BIM format

In the list of BIM application effects, the work items in which BIM is effective, compared to the examination by use of two-dimensional drawings, are organized by 14 types of construction trades (a total of 109 work items). Of the 109 work items, steel-frame work accounts for 26 (Fig. 2), and thus the steel-frame construction is regarded as the type of construction work for which the highest BIM application effect can be expected.

Fig. 1 Procedures from Preparation to Application of Construction BIM



“BIM-based Consensus” in Steel-frame Construction

In Japan, the shop drawings produced by subcontractors must be approved by a designer and a general contractor before start of construction. When the drawings are replaced by the BIM models, the specific procedures of approval process such as clash detection and productivity evaluation will become easier than ever. However, the drawings are suitable for recording of the approval process and not easily replaced to the BIM models. The Handbook proposes “BIM-based consensus” approach, in which the subcontractor starts production of the drawings after agreement with a designer and a general contractor by using BIM models (Fig.3).

The approach introduced above has already been put into practical use in conjunction with steel-frame manufacture-related works such as an elevator (Fig. 4). In this regard, certain effects have been confirmed—a reduction in the number of drawings prepared for use for examinations that are made up to the stage of obtaining approval by design supervisors, and the mitigation of defects during member connection.

Photo 3 BIM-based consensus of steel-frame members for elevator equipment (red) and steel-frame model (grey)

Further Development of Construction BIM

It is no exaggeration to say that closer tie-ups between general contractors and steel fabricator and other subcontractors hold the key to further development of construction BIM in Japan. The Japan Federation of Construction Contractors plans to widely promote the dissemination of construction BIM application effects not only for general contractors but also steel fabricators and many other subcontractors by holding a seminar[2] to introduce the Handbook and BIM application merits. ■

References

1) Website of Japan Federation of Construction Contractors: http://www.nikkenren.com
2) Texts used at the training course: http://www.nikkenren.com/kenchiku/bim

Fig. 2 Construction BIMs by Type of Construction Works

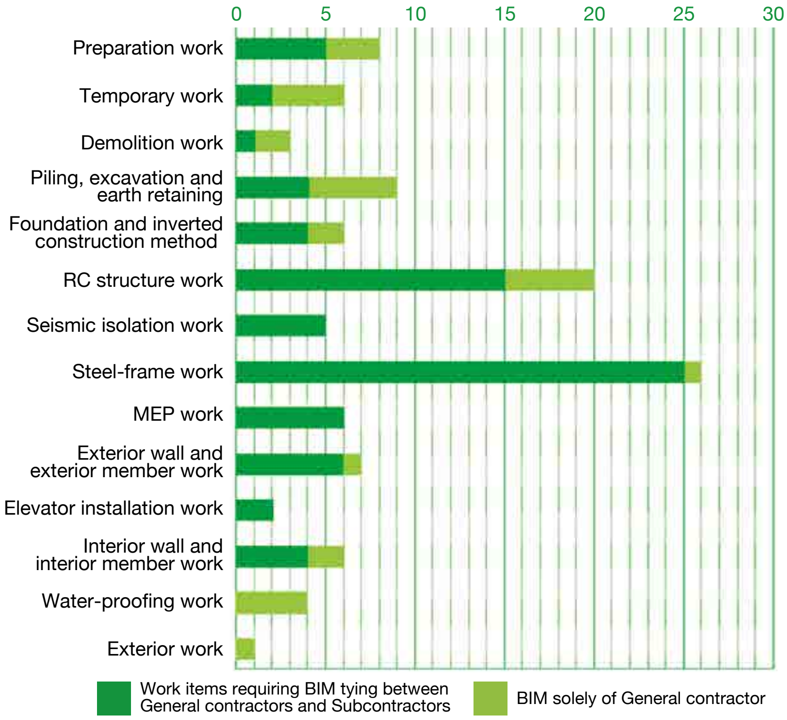


Fig. 3 Formation of BIM-based Consensus

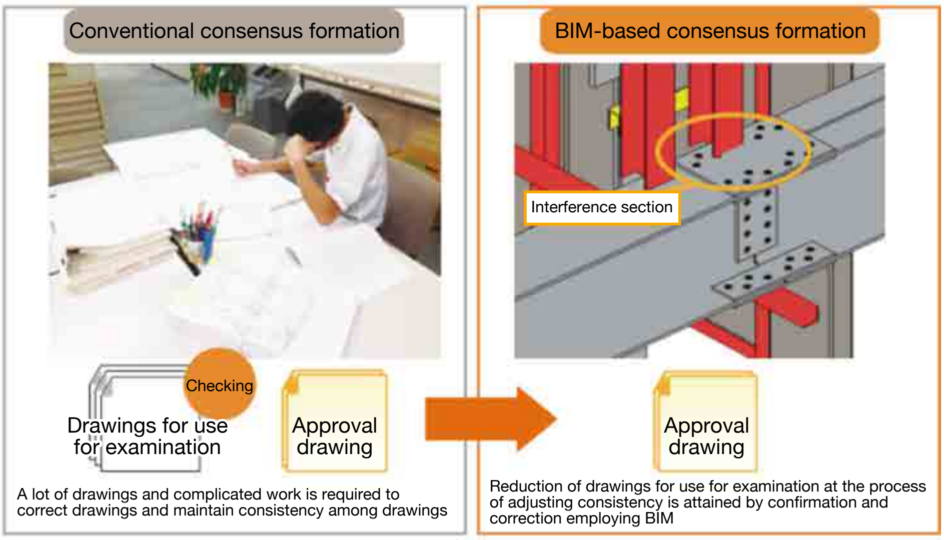
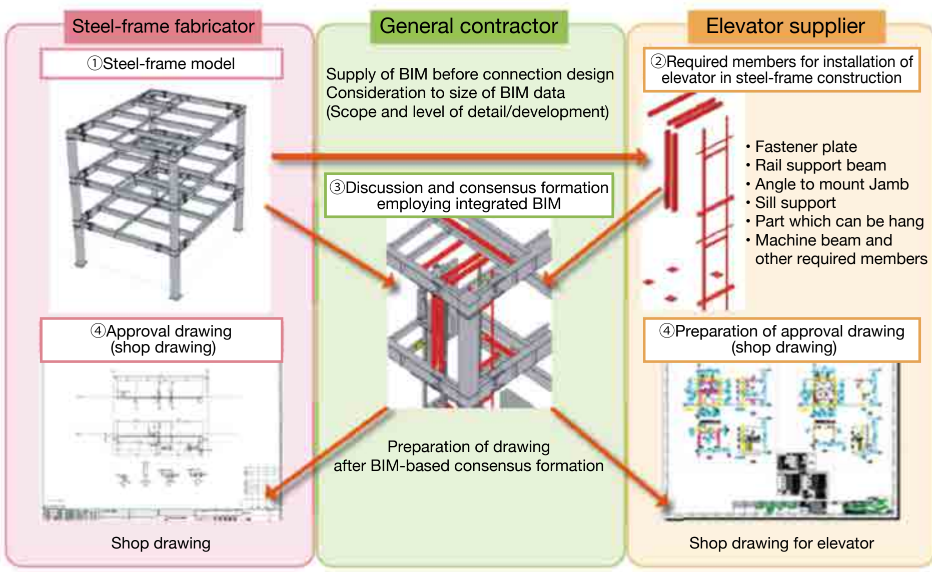


Fig. 4 Procedures for BIM-based Consensus (Example)



Application of Three-dimensional Bridge Product Modeling towards the Strategic Maintenance of Steel Bridges

by Hiroaki Matsushita, Japan Bridge Association

A vast amount of bridge stock is superannuating in Japan. Therefore, how to efficiently maintain this bridge stock in light of restrictions on budgets and human resources is becoming a pressing domestic task.

Given this situation, the introduction of CIM is positively being promoted by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). CIM (construction information modeling) undertakes the integrated control of a project process from survey and planning to design, construction and maintenance on a platform based on 3D-PDM (three-dimensional product modeling). 3D-PDM is a model in which construction information is modelled by adding as attribute information the materials, specifications, performance, tonnage and cost information that are required in the respective processes of the project to a three-dimensional model having the geometrical information.

In this article, the function of steel bridge 3D-PDM is expanded to structure it on a CIM computing platform, and the potential to strategically apply this 3D-PDM for steel bridge maintenance is introduced.

Applications and Future Tasks of Steel Bridge 3D-PDM

Paralleling the promotion of CALS/EC (Continuous Acquisition and Life-cycle Support/ Electronic Commerce) by MLIT in the latter part of the 1990s, 3D-PDM, for example, was developed in the steel bridge industry (Fig. 1) and put into practical use. In spite of the fact that 3D-PDM is available for three-dimensional design, on-site construction and maintenance, its application is currently restricted to the preparation of NC processing information, fabrication documents and other shop-manufacturing information.

Application of 3D-PDM to the Strategic Maintenance of Steel Bridges

The 3D-PDM is used to construct in computers a virtual structure equivalent to an actual bridge from the stage of survey and planning; and, even when specialized knowledge is unavailable, it is easy to visually understand the condition of the structure. To this end, we can expect to enhance the efficiency in the progress of the project, prevent trouble and achieve safety improvements by the integrated use, throughout an entire project process, of project visualization that capitalizes on the overwhelming "ease of understanding" associated with 3D-PDM and of information about a structure unified into 3D-PDM.

Fig. 2 shows an image of 3D-PDM used for the strategic maintenance of bridges. As seen in the figure, the maintenance information, such as inspections, repair/reinforcement history and the structural health monitoring record, is prepared as attribute information, which is consecutively added to the 3D-PDM on which the design, quality and as-built geometry information used during construction is reflected so as to structure the three-dimensional maintenance database for use in strategic maintenance.

Further, in recent years, maintenance technology has made steady development that utilizes ICT technology and three-dimensional measurement technology. To this end, the potential of 3D-PDM is being raised in its application as a tool for the strategic maintenance of steel bridges by linking it with these new technologies.

Application Example for 3D-PDM in Bridge Maintenance

An example of 3D-PDM applied for bridge maintenance is introduced below, in which laser scanner measurements were applied in the periodical inspection of an existing cable-stayed bridge (Fig. 3).

One main feature in the example is that the bridge geometry and stay cable forces of the cable-stayed bridge were measured employing a laser scanner in the periodical inspection. The 3D point cloud data of the bridge thus obtained was analyzed to structure the 3D solid model, and then the 3D-PDM model for maintenance use was prepared. As a result, it has become possible to conduct more efficient and advanced measurements by means of laser scanner measurements, compared to measurements made by conventional methods. Another advantage obtained was, even after measurements were complete, it is easy to confirm the information about the bridge geometry at any optional point of the bridge structure capitalizing on the 3D-PDM thus prepared.

Fig. 1 Outline of Three-dimensional Bridge Product Modeling (Modeler: Symphony)

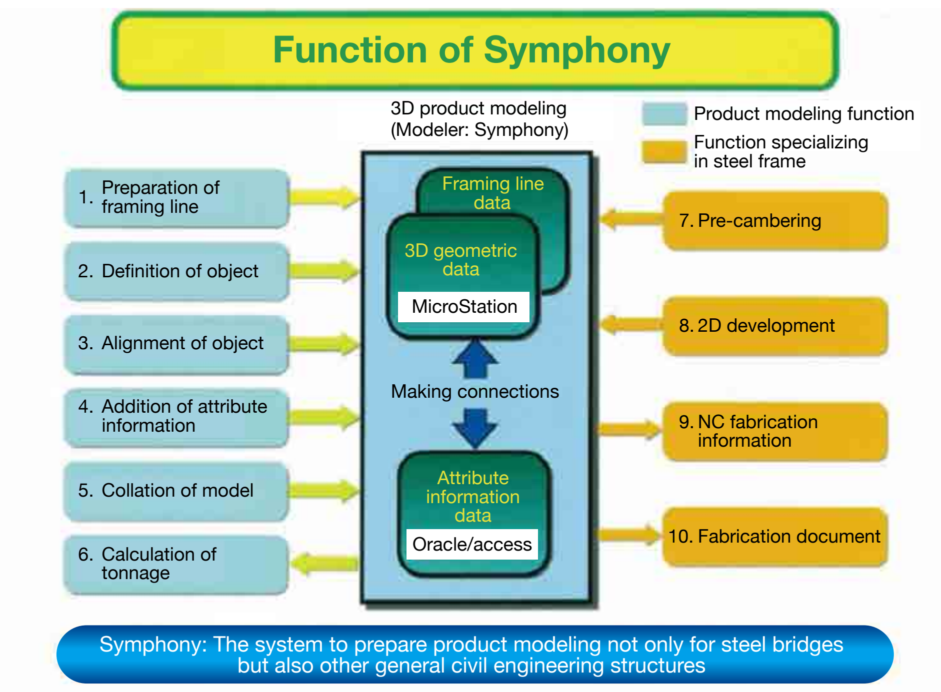
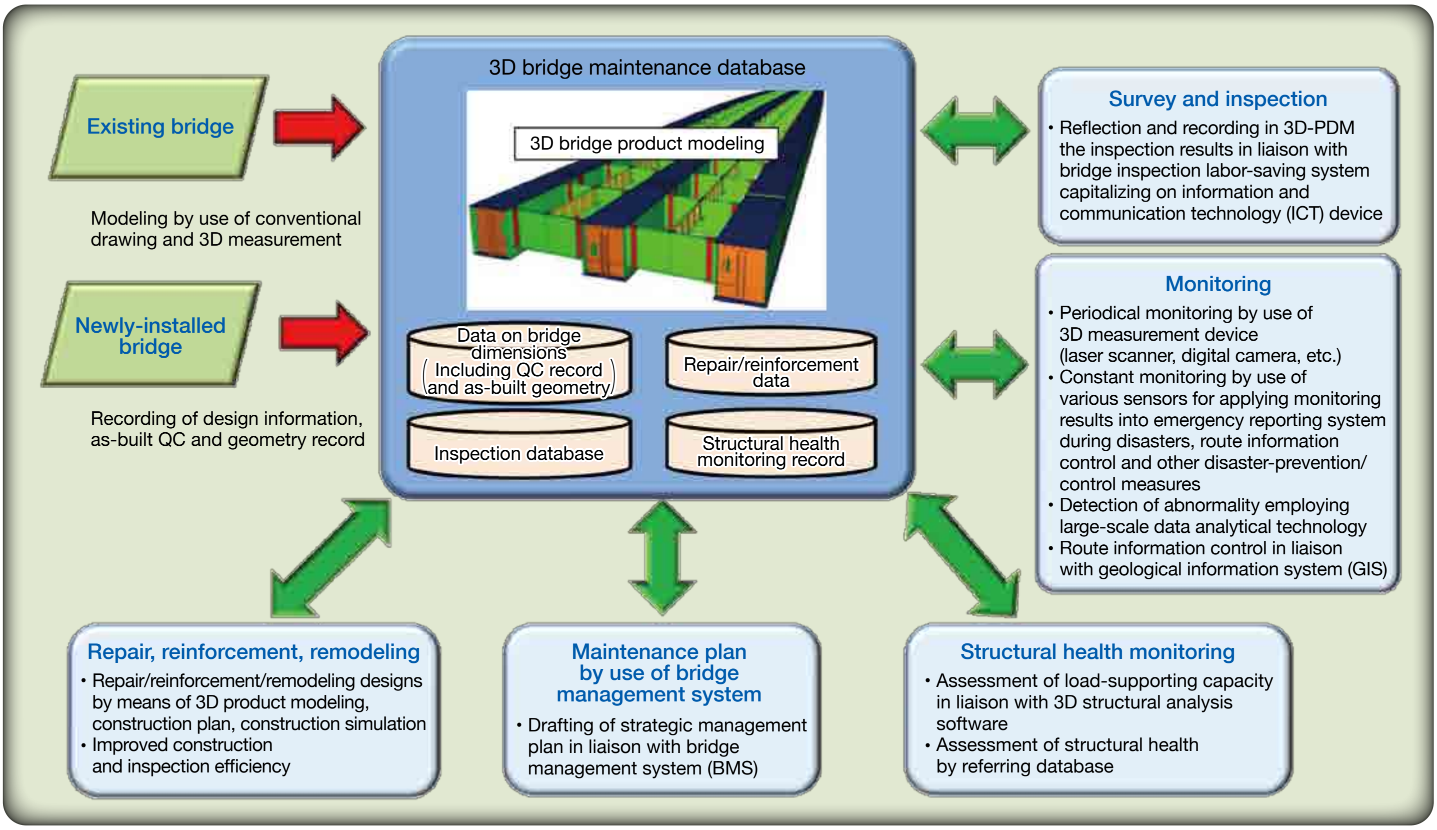


Fig. 2 Application of Three-dimensional Bridge Product Modeling Used for Strategic Maintenance (Image)



Currently there is room for improvement in the accuracy and cost involved in three-dimensional modeling, but the 3D-PDM is regarded as an effective tool for visually understanding the secular changes of bridge structures.

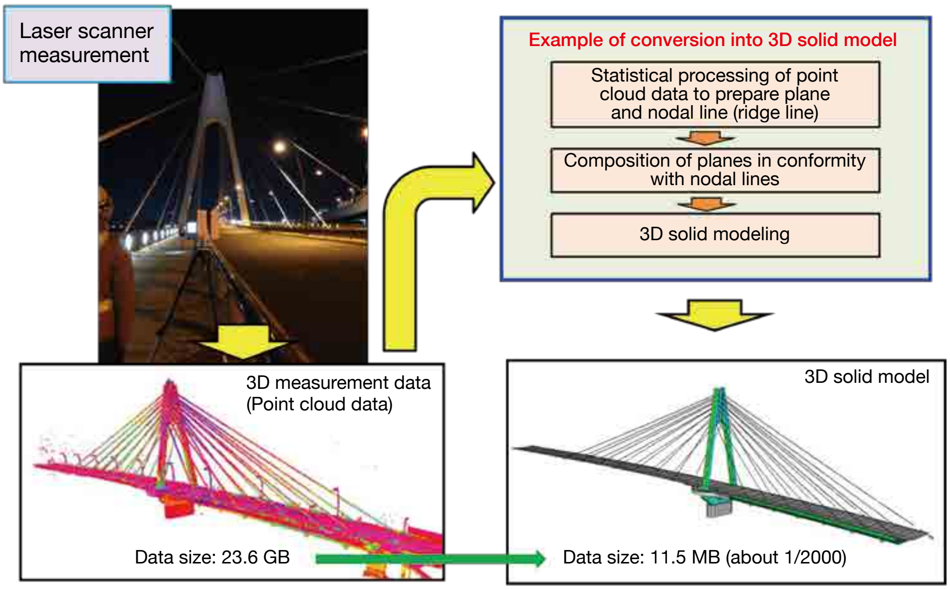
Application Potential of 3D-PDM in Infrastructure Maintenance

In the field of civil engineering, while the steel bridge industry leads all other civil engineering sectors in tackling the introduction of 3D-PDM, its application remains limited to specified areas.

On the other hand, in the construction supervision of steel bridges, ICT technology and three-dimensional measurement technology that have recently shown remarkable development are currently being applied, and the joint use of 3D-PDM with these advanced technologies offers great potential for 3D-PDM to be applied for the strategic maintenance of social infrastructure.

It is expected in the future that capital outlays and technology development to promote 3D-PDM application will be accelerated towards earlier and wider application of CIM. ■

Fig. 3 Laser Scanner Measurement and 3D Modeling Technology



CIM Trial Application Project

by Makoto Nakane, TAKADAKIKO Co., Ltd.

The bridge that is the subject of this article was ordered as a project targeted (requested) for the trial application of CIM (construction information modeling) from the Chugoku Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism. It is a 2-span continuous non-composite steel box girder bridge.

In applying CIM in this project, application validity was examined. As a result, we focused on the following two effective approaches in CIM application: three-dimensional modeling of the main structures and the accessory facilities; and integrated control of the related information on a three-dimensional model. The following article outlines the data preparation procedure for these two approaches and how to apply them.

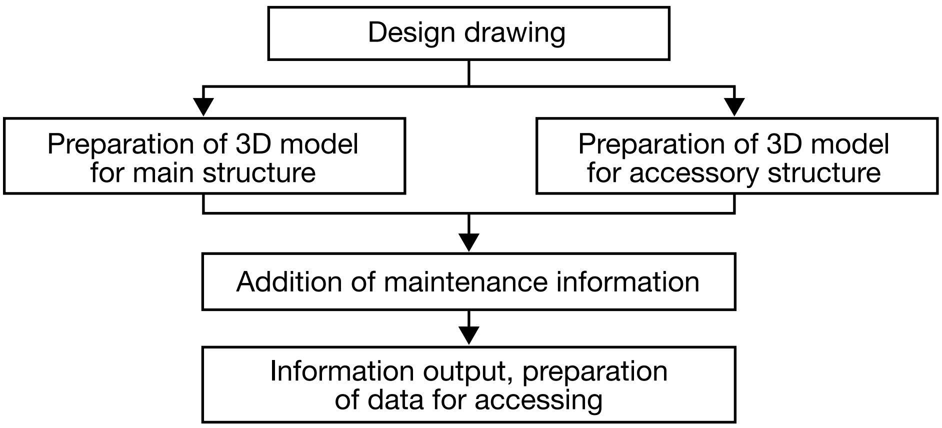
Data Preparation Procedures

At first, a three-dimensional model for the main structures, used for shop manufacture, was prepared based on the design drawings and employing MASTERSON (JIP Techno Science Corporation).

Next, a three-dimensional model for the superstructure inspection platform, superstructure drain devices and other accessory facilities was prepared employing Braz (JIP Techno Science Corporation) that allows for the comparatively easy preparation of three-dimensional models for accessory facilities.

Lastly, AXEL3D (JIP Techno Science Corporation) was used with the aim of accessing the input information, including the main structure three-dimensional model and the accessory facility three-dimensional model. Fig. 1 shows the data preparation procedure.

Fig. 1 Data Preparation Procedures



Three-dimensional Modeling of Main Structures and Accessory Facilities

• Outline

Various issues involved in clash detection between the structural members and the member shop manufacture are verified prior to shop manufacture, by preparing three-dimensional models for the main structures and accessory facilities and visualizing these models.

• Verification of Issues Involved in Shop Manufacture

In the neighborhood of the supporting point of the current bridge, the support point stiffeners, bearing reinforcing ribs, cross beam back-up members of the support point and other members are adjacently arranged. Thus, it was necessary to verify whether or not there existed various issues involved in the shop manufacture, such as member clashes and working space availability. Then, a three-dimensional model for the main structures (Fig. 2) was used to verify these issues, in addition to verification by the use of two-dimensional drawings.

As a result, it was possible to verify that no issues in shop manufacture existed, and shop manufacture of the members was smoothly undertaken.

• Confirmation of Clash Detection between the Main Structures and Accessory Facilities

While clash detection between the main structures and accessory facilities are commonly confirmed employing two-dimensional drawings, it is necessary to confirm clash detection

Fig. 2 Three-dimensional Model for Main Structures

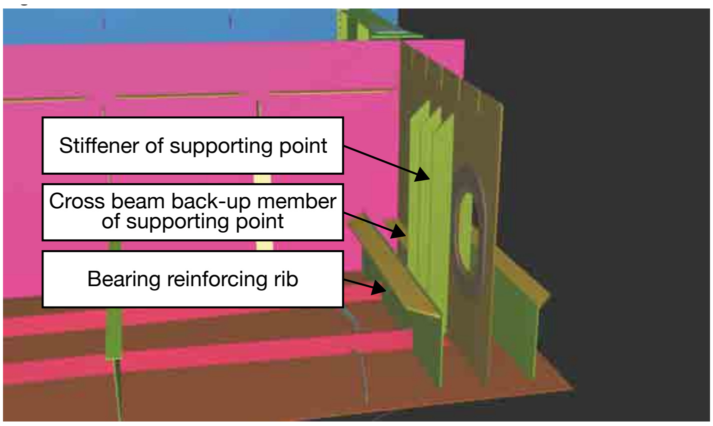
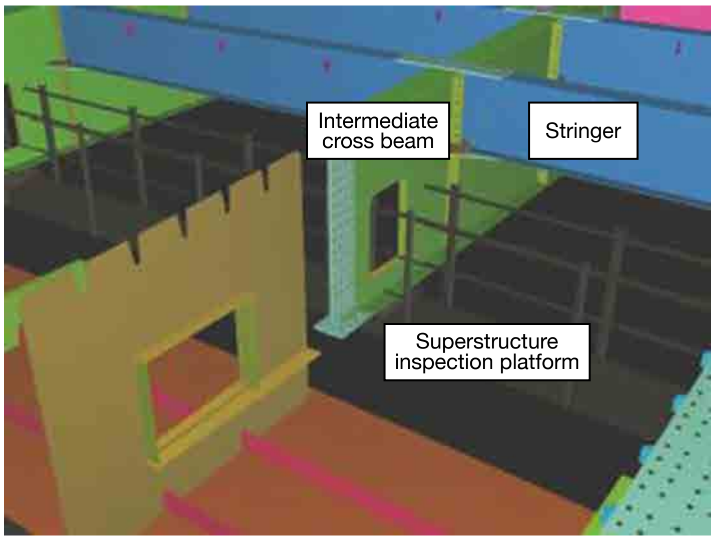


Fig. 3 Three-dimensional Model for Main Structures and Accessory Facilities



by means of three-dimensional visualization. Clash detection between the main structures and accessory facilities was confirmed prior to shop manufacture, employing the three-dimensional models for the main structures and accessory facilities (Fig. 3).

Integrated Control of Information on Three-dimensional Models

• Outline

Diverse kinds of information were added to the three-dimensional model for main structures and accessory facilities so that information required for future maintenance could be confirmed on the display screen. Among the information added were the reaction force of the supporting point, the jack-up stiffener design reaction force and the paint record table in addition to information on the members used for the main structures.

• Integrated Control of Information on Members Used for Main Structures

At the stage of preparing the three-dimensional model for the main structures, it was necessary to input information on the grade and plate thickness of the steel products to be used. To meet this need, the information on the members of the main structures can be displayed on the three-dimensional model (Fig. 4).

In cases when reinforcement of the current bridge arise in the future, the member grade and plate thickness of the reinforcement sections can be confirmed employing the three-dimensional model on the display screen, which is considered to lead to improved work efficiency.

• Integrated Control of Maintenance Information

In addition to information on the members of the main structures, information required for future maintenance was added. As a result, the maintenance information can be confirmed on the three-dimensional model on the display screen (Figs. 5 and 6).

Further, the design conditions, the reaction force of the supporting point, the base-isolation bearing design conditions and the record plate of the bridge were added in the current bridge project as maintenance information in addition to the information shown in Figs. 5 and 6. As a result, the maintenance information can be confirmed in further detail on the three-dimensional model on the display screen.

Trial Application of CIM with Successful Results

In the trial application of CIM in the current bridge project, both the main structures and the accessory facilities were three-dimensionally modeled, which allowed for verification of both the issues involved in the member manufacture and in the clash detection between the main structure and the accessory facilities not only prior to member manufacture but with high accuracy.

Various kinds of necessary information can be confirmed on the display screen by implementing the integrated control of information on the three-dimensional model, which is considered greatly helpful in future maintenance.

Future tasks for examination in promoting CIM application in bridge construction are the following: what level of maintenance information is added and how effectively maintenance information can be confirmed on a three-dimensional model.

Lastly, we express our sincere thanks to all concerned in the Tottori River and National Highway Office of the Chugoku Regional Development Bureau and the Japanese Society of Steel Construction, who gave kind support and advice in the preparation of the current article. ■

Fig. 5 Maintenance Information (Jack-up Stiffener Design Reaction Force)

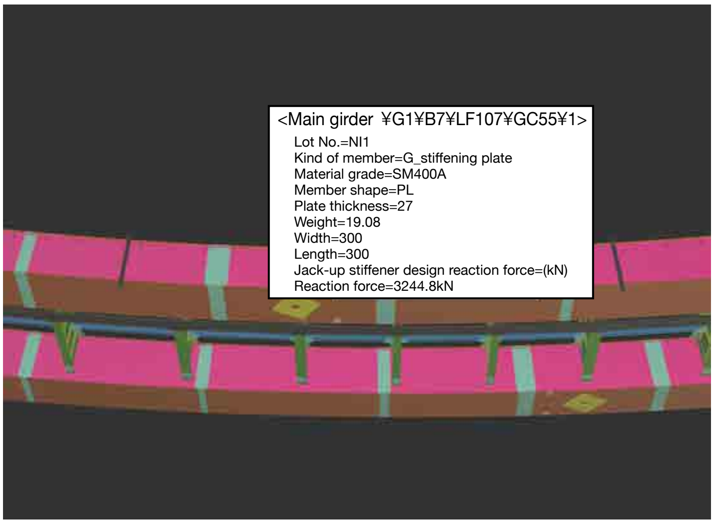


Fig. 4 Information on Members of Main Structures Information on members of main structures

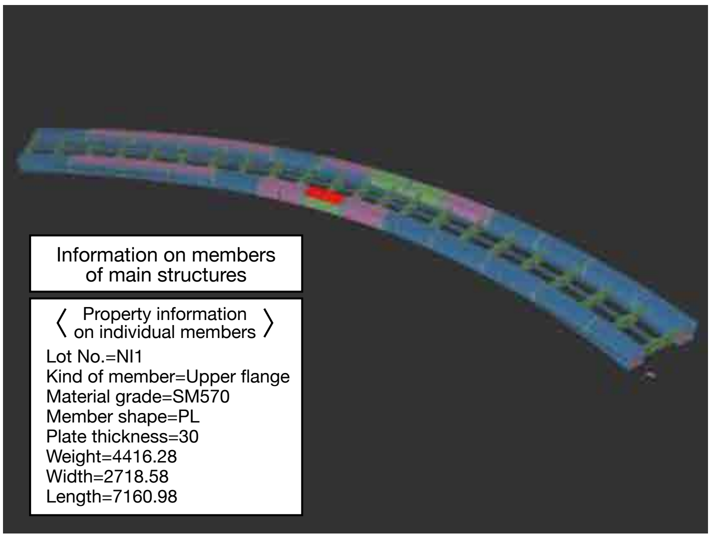
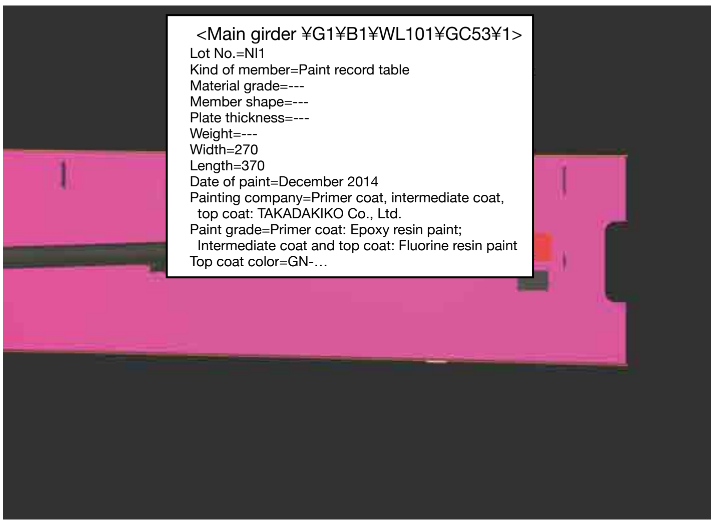


Fig. 6 Maintenance Information (Paint Record Table)



Current Applications of Stainless Steel Structural Materials in Japan

by Yasumi Shimura, Nippon Steel & Sumikin Stainless Steel Corporation

In terms of the amount of stainless steel used in Japan, the construction field ranks third, following automobiles and home appliances/office machines. In construction, stainless steel is widely applied in building walls and roofs and other structural sections requiring corrosion resistance and decorativeness. While most of the stainless steel products applied as structural members are stainless steel sheets, structural members requiring stainless steel plates are showing an increasing trend.

Because the structural safety resistant to earthquakes and corrosion is called for in the use of steel structural members, the design standards have been organized according to their respective fields of application. As regards stainless steel, it is necessary to acquire public recognition pertaining to its safety when used as structural members. Table 1 shows the grades of stainless steel specified in the standards currently applied in the construction field. Meanwhile, even though stainless steel is not specified in these standards, mechanisms employing new structural technologies have been organized by application field, and therefore new types of stainless steel have come into use that capitalize on such mechanisms.

The stainless steel for structural uses is specified in the Japanese Industrial Standards (JIS). In addition, duplex stainless steels SUS821L1, SUS323L and SUS329J3L are specified in various standards (refer to Table 2).

Table 1 Grades of Stainless Steel Specified in Various Standards

Target facilities in construction standards, and building standards	Stainless steel grades
Dam, weir	SUS304, SUS316
Water service (aqueduct)	SUS304, SUS316
Water service (reservoir)	SUS304, SUS316, SUS329J4L
Building Standard Law	SUS304, SUS316, SUS304N2

Table 2 Grades of Duplex Stainless Steel Specified in Various Standards

JIS	ASTM	EN
SUS821L1	S82122	–
SUS323L	S32304	1.4362
SUS329J3L	S32803, S32205	1.4462
SUS329J4L	–	1.4507
SUS327L1	S32750	1.441

Recent Structural Applications of Stainless Steel

The main stainless steel grades thus far applied in construction are SUS304, SUS304N2 and SUS316. However, the structural application of duplex stainless steel is increasing because it offers both high strength and high economic advantage, recent examples of which are introduced below:

• SUS329J3L

In the wall that covers the ventilation opening to the underground shopping center at the Yaesu exit of Tokyo Station, the wall surface is fronted with a thick growth of trees, part of which has stainless steel in exposed form so that the ventilation opening can harmonize with the surrounding landscape design (see Photo 1). Taking into account the effects of the water supply to plants and the rust stains from the railway station and, further, in order to reduce the load on existing underground

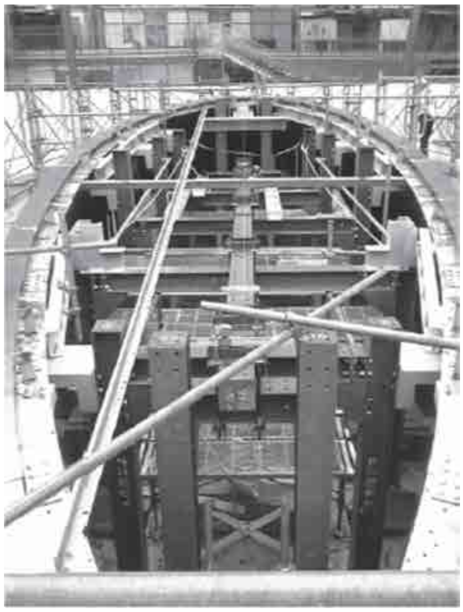


Photo 1 Ventilation opening cover at the Tokyo Station

shopping center structures, high-strength SUS329J3L stainless steel is applied.

• SUS323L

Among river facilities, stainless steel has been applied in dam facilities and floodgates. In recent years in particular, stainless steel has been applied to increase maintenance-free river facilities. Photo 2 shows an example of SUS323L stainless steel for a floodgate. Lighter gate weight attained by the use of high-strength stainless steel allows the downsizing of the winch capacity and the foundation structure. Selection of stainless steel as a structural material is regarded to have brought about extremely high economic efficiency to the entire floodgate structure.

• SUS821L1

As a link in the development of renewable energy, solar power generating equipment is

Photo 2 Floodgate (sluicing outlet)

Photo 3 Solar panel framing

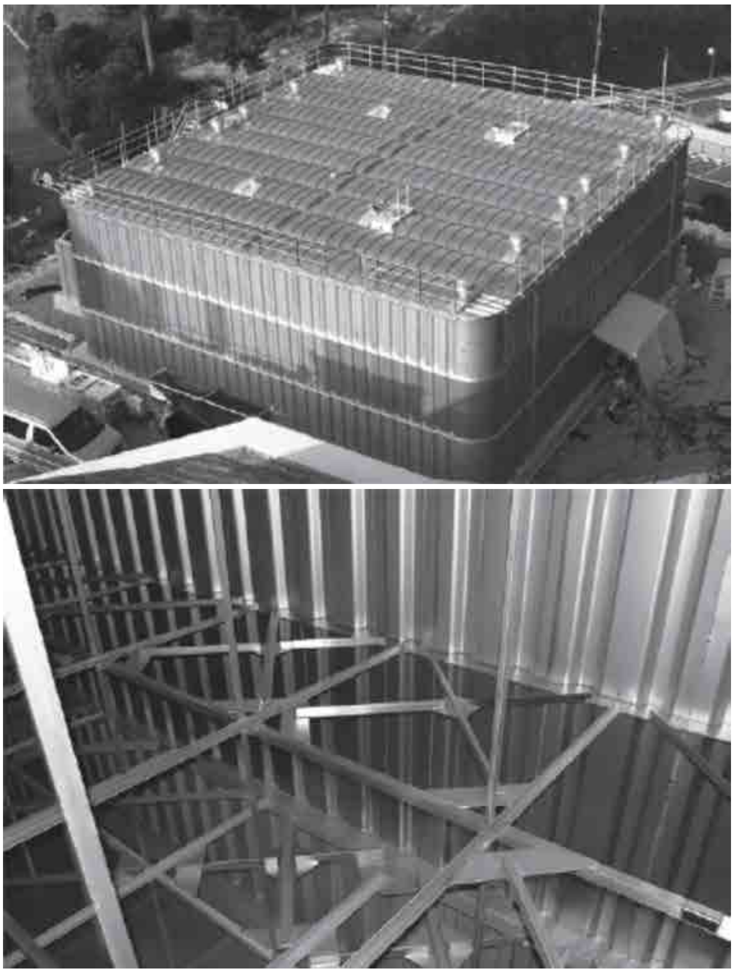


Photo 4 Atami Baien service reservoir

increasingly being built. In this regard, stainless steel has been applied in the framing of solar panels (Photo 3). The thoroughgoing reduction of the weight of the framing members has been attempted by the use of high-strength stainless steel, which has not only led to a reduced construction term due to improved construction efficiency in large sites but has also contributed to the reduction of the entire project cost.

• SUS329J4L

In the tap water supply facility, stainless steel has also been applied. Photo 4 shows the water tank of a service reservoir, for which duplex SUS329J4L stainless steel is used. For the tank in which sterilized tap water is stored and from which sterilized tap water is supplied for drinking purposes, the gas phase part of the tank is required to possess high corrosion resistance, and the suitable material was to be selected based on the exposure test. Hot-rolled SUS329J4L stainless steel shape is also used for the framing inside the water tank.

Growing Application of Duplex Stainless Steel

While stainless steel is more expensive than carbon steel, the demand for stainless steel is increasing in fields in which maintenance-free performance and structural decorativeness are required and in which a reduction in the lifecycle cost is targeted. Duplex stainless steel is a high-strength material and thus allows for the weight reduction of structures. That is, duplex stainless steel is a material that can ensure higher economic rationality, and thus its application is expected to further grow in the future. ■

JSSC Symposium 2015 on Structural Steel Construction, Marking the 50th Anniversary of the JSSC Founding

—"Innovations from Steel Construction!"—

For three days between November 18th and 20th, the 2015 JSSC Symposium on Structural Steel Construction sponsored by the Japanese Society of Steel Construction (JSSC) was held in Tokyo. The symposium held special programs (Parts 1 and 2) entitled "*Innovations from Steel Construction!*" in commemoration of the fiftieth anniversary of the foundation of JSSC.

In Part 1, special lectures that focused on "Standing at the Forefront of Technology—The Challenges of Uncharted Territory," consisted of presentations by researchers working in cutting-edge fields. One was on the commercial use of a space-based solar power station and microwave power transmission, and the other was on an innovative approach that emerged from technological development associated with a space probe launched by the unmanned spacecraft "Hayabusa."

In Part 2, special panel discussions took place under the theme "Steel Construction Alters the Present and Makes the Future," and focused on the latest technology, new developments and technological perspectives in the field of steel construction.

Among the other organized events were: the Academy Session, which was an annual event established as a venue for young engineers to report the results of their studies and research; JSSC commendation for outstanding achievements (refer to pages 1~7) and the prize-winners' commemorative lectures; a symposium under the theme "Progress in Steel Materials and Their Utilization" co-sponsored by the JSSC and the Iron and Steel Institute of Japan; and a "Corporate Panel Display" as a forum for JSSC member companies to promote public recognition of technical and other information.

All these events provided the many participants (totaling over 1,500), including steel structural engineers and researchers, with a valuable place to communicate and interact.

Poster prepared for the 2015 symposium *"Innovations from Steel Construction!"*

Message from Chairman of International Committee

Kuniei Nogami, Chairman, International Committee (Professor, Tokyo Metropolitan University)

Starting with issue No. 26 of *Steel Construction Today & Tomorrow,* published in 2009, our Internal Committee has been responsible for the editorial planning of one of the three issues that are published annually. Since its inauguration, JSSC has conducted wide-ranging activities in the form of surveys, research and technological development aimed at promoting the spread of steel construction and at improving associated technologies, and at the same time it has extended cooperation to related organizations overseas.

This year marks the fiftieth anniversary of the foundation of the Japanese Society of Steel Construction (JSSC). On this occasion, our International Committee has been organizing several important memorial affairs in the 2015 JSSC Symposium on Structural Steel Construction. Looking toward the next fifty years, we will maintain a strong commitment to spurring the spread of steel construction and promoting technological development, while also enhancing our activities for the transmission of related information throughout the world.

As was true in issue No.44, the previous special issue of JSSC for which our committee was responsible, our current issue, No. 47, introduces the excellent works and theses that have received awards of commendation for outstanding achievement in 2015. In addition, this issue features BIM (building information modeling) in building construction and CIM (construction information modeling) in civil engineering, in which the current state of the application of BIM and CIM for design, construction and maintenance in Japan is introduced. It also reports on the JSSC Symposium on Structural Steel Construction held to commemorate the 50th anniversary of JSSC.

The International Committee, while working on multi-faceted responses to the internationalization of steel construction specifications and standards, promotes exchanges of technical information and personnel between Japan and overseas organizations. As one aspect of these operations, we are attempting with this issue to inform our readers of JSSC operations, trends in steel construction, and the technologies and technological developments relevant to the planning, design, and building of steel structures in Japan.

If you wish to obtain more detailed information about the various articles contained in this issue or to receive related technical information, please do not hesitate to contact the JSSC secretariat (info-jssc@jssc.or.jp).

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