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Feature Article

Qualifications for Steel Construction Engineers in Japan

Special Topic

Serial Article: Latest Design of Steel Buildings in Japan (7)

"myu terrace" Brings Economy, Style to Matsuyama Univ. Campus

Published Jointly by

The Japan Iron and Steel Federation

Japanese Society of Steel Construction

Organization for Building Steel Structure Qualification (OBSSQ)

Organization for Building Steel Structure Qualification of the Japanese Society of Steel Construction

Establishment of OBSSQ

In building construction in Japan, the share accounted for by the steel structure is steadily increasing and the role played by the steel structure is becoming more significant.

In such a situation, how to secure the safety of steel-structure buildings and how to appropriately promote quality control in steel structure construction have been discussed in various ways. In particular after the Great Hanshin Awaji Earthquake of 1995, how to secure and improve the quality of steel-structure buildings have become pressing concerns in terms of protecting the lives and property of people.

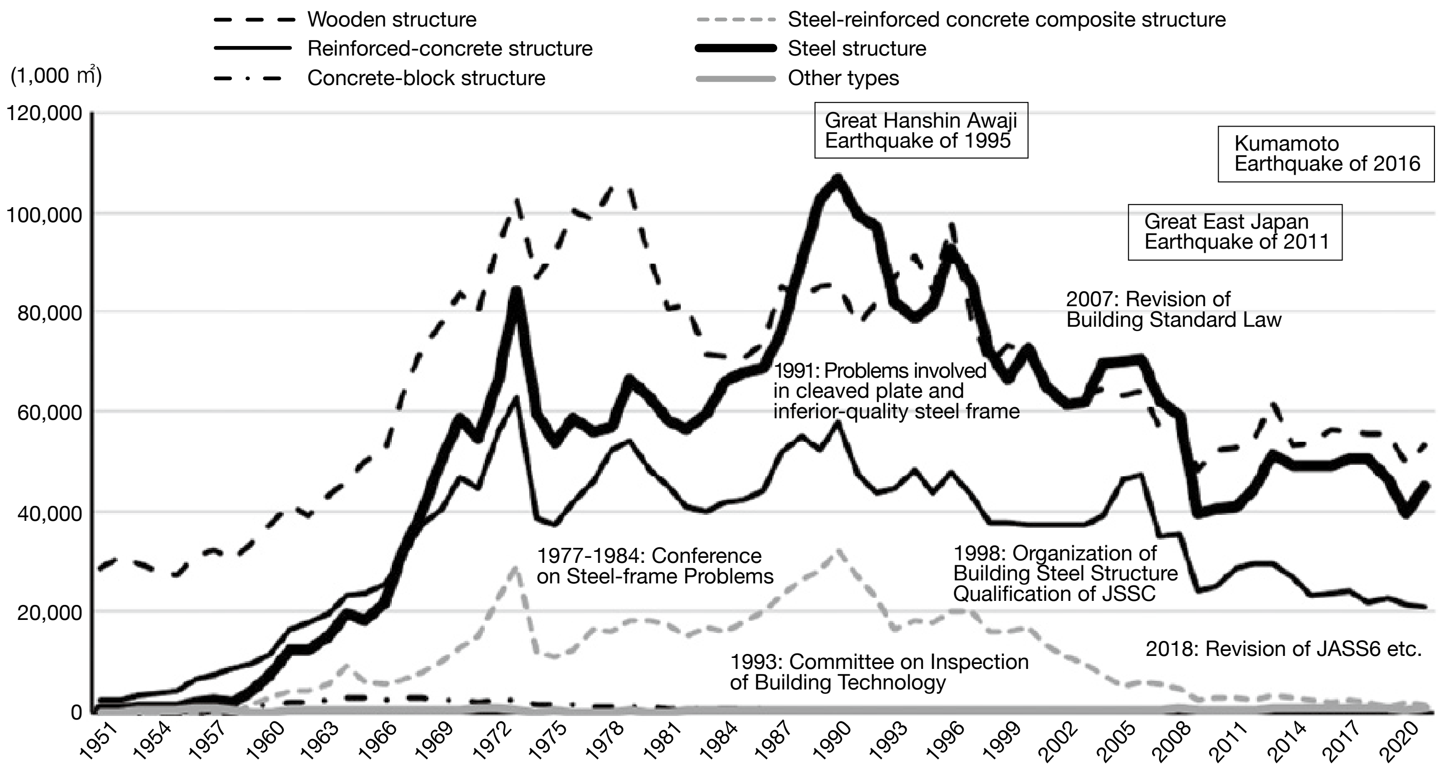
When Japan was in the midst of the bubble economy from the middle of the 1980s to the beginning of the 1990s, as steel structure construction was showing a significant increase, serious problems such as weld defects involved in steel structure construction also became apparent (Fig. 1). At this time, there was particularly excessive media coverage on the problems involved in inferior-quality steel structures, which thus led to a well-known fact among general public. Among the specific issues at that time were the unproper use of steel type, the unproper use of full-penetration welding and fillet welding, the forgery of inspection reports and the two-piece separation of steel plates.

In order to solve these problems, the Technical Committee for Rationalization of Problems in Steel Structural Buildings was established in March 1993 as an advisory committee of the Housing Bureau of the Construction Ministry (currently Ministry of Land, Infrastructure, Transport and Tourism). As a result of various discussions promoted by the committee, the Report on Rationalization of the Problems in Steel Structure Buildings was finally prepared and submitted.

In this report, necessary measures were shown—appropriate quality control of steel products themselves, quality optimization in steel-frame fabrication, improvements in inspection and other improvement measures. Then the situation faced by steel-frame operations were analyzed, which made clear the fact that steel-frame related operations are specialized and subdivided to cover those from upstream to downstream (from steel product manufacturers, distributors and intermediate steel member fabricators to designers, inspection agencies and construction companies). Given these circumstances, the report set out the duty of engineers working in these fields on the basis of process control to be attained by related parties.

In response to this report, the Japanese Society of Steel Construction (JSSC) established the Special Committee for Steel Structures in July 1993, which made comprehensive studies mainly on the current situation of steel structure-related fields, specialized engineers and legal systems over a period of three years. In addition, the Committee discussed the

Fig. 1 Transition in Construction Starts of Floor Areas by Structural Type



measure to secure the quality of steel-structure buildings and the qualification system to secure the quality of engineers working in steel structure construction proposed in the Report.

Given these conditions, the Organization for Building Steel Structure Qualification (OBSSQ) was established within JSSC in July 1996 with the participation of construction-related organizations, experts and administrative agencies, which initiated the System of Qualifications of Quality Control Administrator for Constructional Steel Structure in 1998 as a consensus of steel structure construction-related industries.

Role and Organization of OBSSQ

In order to nurture the engineers engaged in steel structure construction and maintain and improve the quality-control system of plants engaged in stainless steel fabrication and other similar operations, OBSSQ has implemented the qualification and registration of various types of engineers and fabrication plants. Further, in order to promote the fair implementation and operation of qualification systems, OBSSQ has established two organizations with the participation of representatives from related fields—the Administrative Meeting as the supreme deliberative organ of OBSSQ and the Certifying Committee in charge of the qualification and registration of various types of engineers and fabrication plants.

In order to promote the proper operation of the qualification systems for various types of engineers and fabrication plants and as the organization affiliated with the Certifying Committee, two organizations have been established based on the type of qualification to promote their respective operations—the Technical Committee that conducts approvals of training/examination implementation procedures and pass/fail decisions, and the Execution Committee in charge of the preparation of examination texts, preparation of training texts and implementation of training and examination. (Refer to Fig. 2)

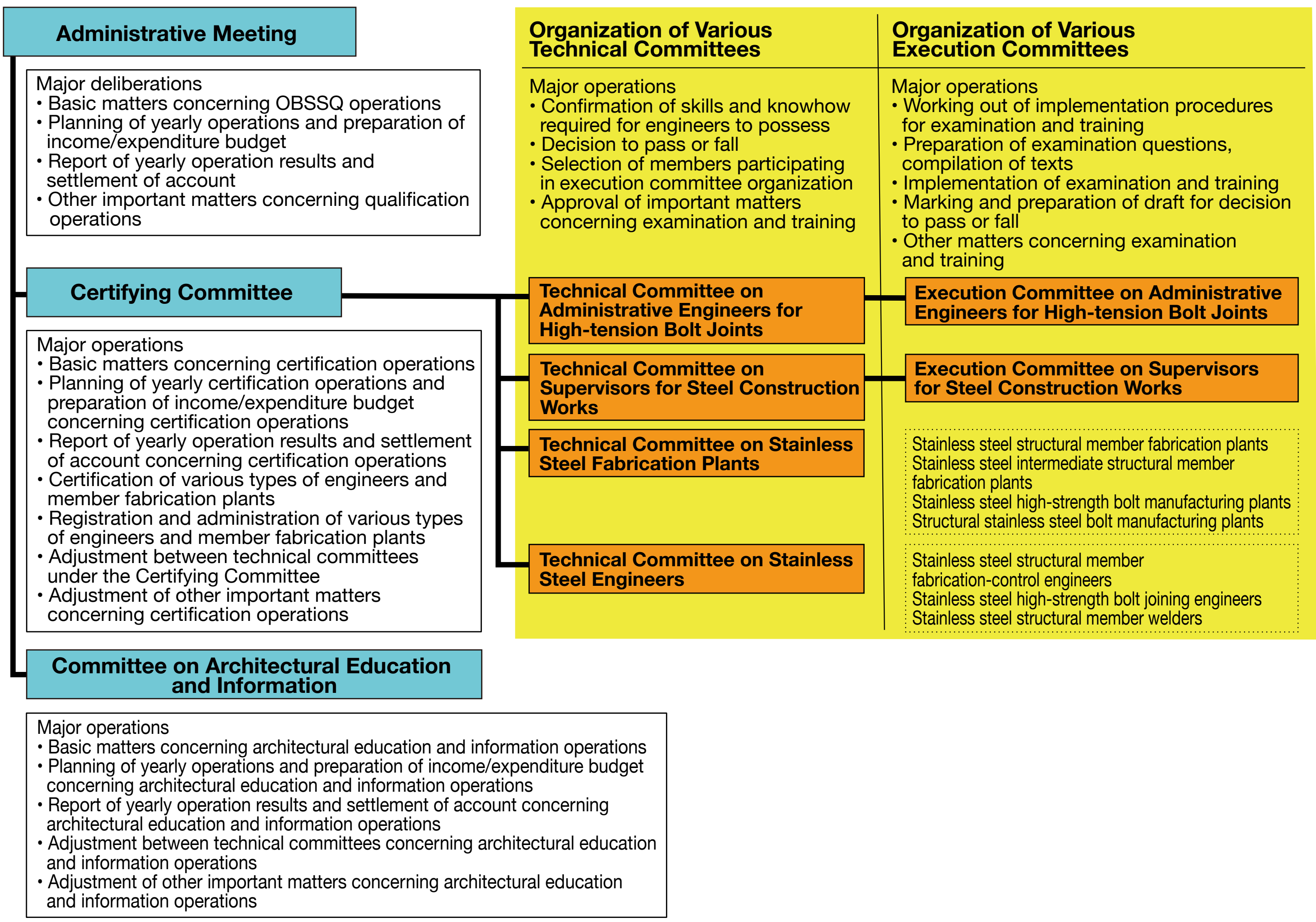
Transition in OBSSQ Operations

OBSSQ started the operation of the Authorization and Registration System for Plants to Manufacture Anchor Bolts for Use for Building Structures in 2005 with the aim of securing the safety of the steel structures used in building construction. (Following the standardization of anchor bolts in the Japanese Industrial Standards, the operation of this System came to an end in 2015.)

In 2006, OBSSQ established the Committee on Architectural Education and Information aiming mainly at furnishing information to qualified individuals registered in OBSSQ. This Committee continues its operations.

In 2008, OBSSQ inaugurated the Committee on the Certification of

Fig. 2 Organization for Building Steel Structure Qualification (OBSSQ)—Organization and Operations



Steel Product Quality. In this Committee, discussions are made on the concepts, steps and methods for confirming and guaranteeing the quality of steel products in practical use.

Following the merger of JSSC and the Stainless-Steel Building Association of Japan in 2010, OBSSQ has also become responsible for the operation and implementation of the qualification of stainless steel-related engineers and fabrication plants that had previously been managed by the Association.

In 2019, the two qualifications of "building steel structure inspection engineers" and "building steel structure UST engineers," for which OBSSQ had been responsible for integrated management since its establishment, were transferred to the newly-established Steel-fabrication Engineers Education Center.

Qualification of Engineers and Fabrication Plants

Currently, OBSSQ operates the qualification shown in the table below:

Growing Role of OBSSQ-qualified Engineers

When constructing steel-structure buildings, various types of engineers qualified and registered by OBSSQ are specified as the steel structure-specialized engineers by the project owners, construction managers, general contractors and administrative organs.

A manual, the Guidelines on Building Construction Supervision (editorial supervisor: the Ministry of Land, Infrastructure, Transport and Tourism), has been prepared for use as the common specifications in building construction, in which the Administrative Engineers for High-tension Bolt Joints and the Supervisors for Steel Construction Works qualified by OBSSQ are specified as the construction supervision engineers required for steel structure construction. In this way, OBSSQ qualification is well utilized.

The guidelines prepared by the Tokyo Metropolitan Government show that it is desirable to appoint Supervisors for Steel Construction Works to be in charge of acceptance inspections in steel structure construction. Further, the comments of design companies show the participation of OBSSQ-qualified engineers in construction projects. In this way, OBSSQ-qualified engineers are playing an active part in the field of practical steel structure construction.

Expectations are high for OBSSQ-qualified engineers not only to play a growing part but to contribute toward the improvement of quality control in steel structure construction.

Qualification of engineers	No. of qualified persons
Supervisor for steel construction works	8,434
Administrative engineer for high-tension bolt joint	8,083
Administrative engineer for stainless steel member fabrication	38
Engineer for stainless steel structure high-tension bolt joining	100
Welder for stainless steel structure	37
Total of qualified persons	16,696

Qualification of fabrication plants	No. of qualified plants
Stainless steel structure fabrication plant	5
Stainless steel intermediate member fabrication plant	2
Stainless steel high-strength bolt manufacturing plant	5
Structural stainless steel bolt manufacturing plant	4
Total of qualified plants	16

Application of steel structure construction shows steady increase in building construction in Japan.

Supervisors for Steel Construction Works

Organization for Building Steel Structure Qualification of the Japanese Society of Steel Construction

Establishment of Supervisors for Steel Construction Works

The so-called "qualification system for supervisors for steel structure construction" originated in the activities of the Specialized Subcommittee on Steel Structures of the Building Contractors Society (BCS)—currently the Japan Federation of Construction Contractors. In the period from the end of the 1980s to the beginning of the 1990s, the quality issues involved in steel structure construction occurred frequently. Based on careful review of these issues, the Specialized Subcommittee on Steel Structures considered it necessary to raise the quality of engineers in charge of steel structure construction who are working at construction sites of general contractors, and in 1993 voluntarily started to hold a course for the training of supervisors for steel structure construction.

Initially, BCS held the training course with a target of 5,000 participants from BCS member general contractors, but this target was cleared at an early stage. In addition, it was required that the above-mentioned qualification system not only target BCS member general contractors but also function as an open qualification system. As a result, it was decided that the "qualification system for supervisors for steel structure construction" be transferred to the Organization for Building Steel Structure Qualification (OBSSQ) of the Japanese Society of Steel Construction.

In 1998, the qualification system was transferred from BCS to the OBSSQ of JSSC, and this system has been operated as the Qualification System for Supervisors for Steel Construction Works since then. Most of the engineers qualified under this system cover those working in general contractors, but the qualification field has been expanded to include those working in fabricators in charge of steel frame manufacture. As of April 2022, a total of 8,434 engineers are registered as qualified supervisors under this system. (Refer to Figs. 1 and 2)

Fig. 1 Itemized Fields in the Application of New Steel-structure Construction Supervisors in 2021

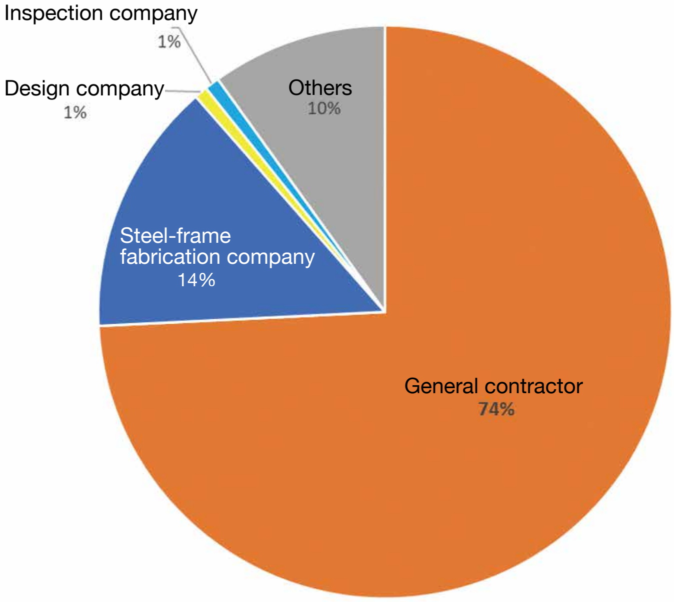
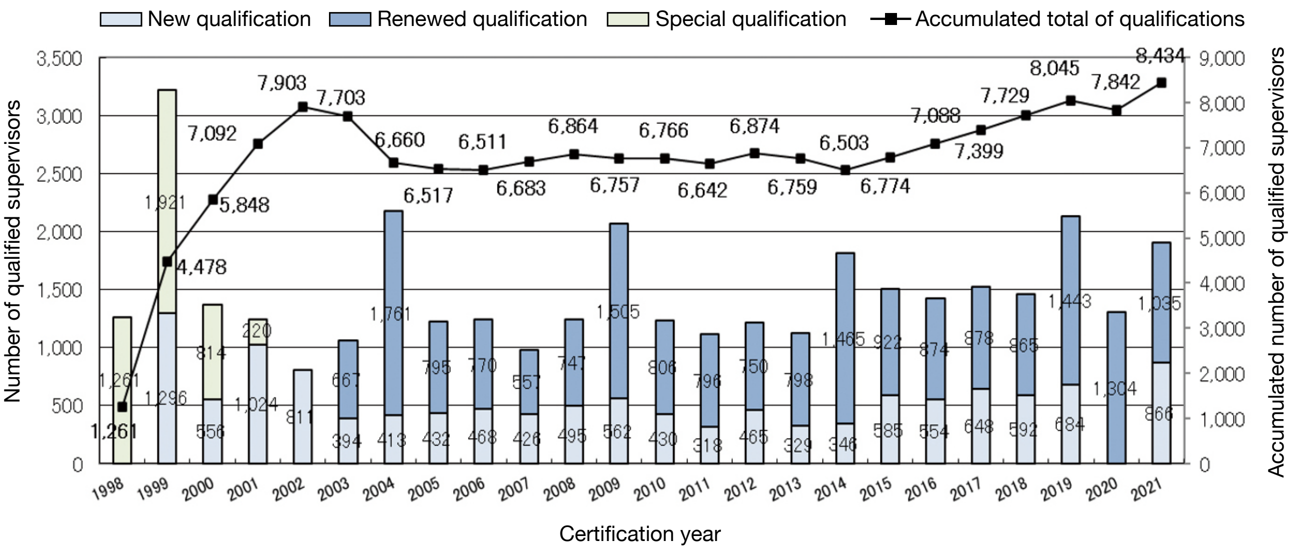


Fig. 2 Transition in the Number of Supervisors for Steel Construction Works



Role of Supervisors for Steel Construction Works

Supervisors for steel construction works are positioned as a qualified engineer who has the capability with which the quality and operation controls can be undertaken in an integrated manner—from the planning of steel structure construction to the completion of the building. In steel structure construction, while qualified engineers in various specialized fields such as high-strength bolt fastening, welding and inspection play an important role, the supervisor for steel construction works is not a qualified engineer working in such specialized fields but assumes the role of a generalist who undertakes the integrated control of wide-ranging operations involved in building construction.

Specific operations involved in steel structure construction covers a wide range of fields—from instruction and guidance at the stage of ordering steel-structure fabrications prior to the delivery of fabricated steel frames to the construction site to the inspection of fabricated steel frames covering acceptance inspection, the proper control of all on-site construction operations, erection control and the preparation of details for various operations in steel structure construction. The supervisor for steel construction works possesses the capability to instruct these operations to on-site workers, and thus is playing diverse roles in various aspects in practical steel structure construction.

Procedures to Acquire Qualification

In order to acquire qualification as a supervisor for steel construction works, it is required to attend the training course and to pass an examination to be held afterwards. Further, in the case of newly taking an examination, it is required to meet the number of years of practical work experience. More specifically, it is stipulated that "those who wish to newly take an examination not only are engaged in design, construction supervision or construction operations but also have three years or more of experience in the supervision/management of practical steel-structure construction. Although the years of experience was five years or more until 2020, the chance for newly taking an examination was expanded with the aim of further improving on-site supervision operations with the participation of qualified supervisors.

The training course has typically been held nationwide using a face-to-face system, but in the current situation of COVID-19, videotaped lectures are delivered on an on-demand basis, and trainees can view the videotaped lectures as many times as necessary. The lectures in the training course are delivered by expert lecturers with extensive experience as an engineer working for a general contractor (Table 1).

The textbook used in the training course explains in details the key factors that should be taken into account by engineers in charge of construction while following the respective stages from planning to completion. (Refer to the Appendix) This textbook is of course used as teaching materials in the training course and for examination, but it can also be used as a manual in the case of issues faced at actual construction sites.

After viewing the videotaped lectures, candidates for examination take a practical examination at a venue, where the examination date, time and place are specified in advance. Examination questions are adapted to practical construction conditions and are prepared by people working for general contractors and having a thorough knowledge of construction sites. Efforts are also made to foster knowledge through examination.

Renewal of Qualifications

The period of validity of qualifications has been settled at five years. Qualifications can then be renewed by completing the renewal procedure before the expiration of its term. In order to renew qualifications, it is required to attend the training course and take a renewal examination.

As for the lecture content in the training course, OBSSQ asks for university professors involved in steel structure construction nationwide and experts with a thorough knowledge of practical building construction to deliver keynote lectures on the content of latest studies so as to further brush up the knowledge on steel structure construction. Those who attend the lectures can freely view videotaped lectures.

Then, after viewing the required videotaped lecture, a written examination is held. In the examination, it is required for the qualification renewal candidate to look at photos showing defects in steel-structure construction that

Table 1 Outline of Lecture Programs Used for the Qualification Examination for New Supervisors for Steel Construction Works (Qualification Examination in 2022)

- Videotape viewing period: August 8 to October 25, 2002
- Examination date: September 3 to October 25, 2022

Lecture title	Time (min)
Program 1: • Objective of Lectures • Planning of Steel Structure Construction	About 65
Program 2 • Steel-frame Fabrication Control and Acceptance Inspection	About 75
Program 3 • On-site Execution Control of Steel Structure Construction	About 100
New supervisor: Written examination	50

Table 2 A List of Titles of Keynote Lectures for Supervisors for Steel Construction Works (Renewal of Qualification) in 2022

Symbol	Lecture title
P 1-1	Past Huge-scale Disasters and Safety and Security
P 1-2	Outline of Preventive Rules for Disorders Caused by Specified Chemical Substances and Countermeasures against Disorders
P 1-3	Treatment of Hot-dop Zinc Coating (Basics, Design and Phenomenon)
P 1-4	Disasters of Steel-structure Buildings in the Great Hanshin Awaji Earthquake (Jan. 1, 1995) and Subsequent Moves
P 1-5	Seismic Forces in Future Mega-scale Earthquakes and Examples of Countermeasure to Be Provided for Steel Structures
P 1-6	Trends in Seismic Design of Buildings Employing Steel Products
P 1-7	Design and Construction of Buildings Employing High-strength Steel Products
P 1-8	Dynamical Performance of Beam-end Connection of Steel Structures Employing Prefabricated Weld Built-up H-shapes
P 1-9	Blowholes Caused by Corrosion-protection Agents for Exclusive Use for Grooves

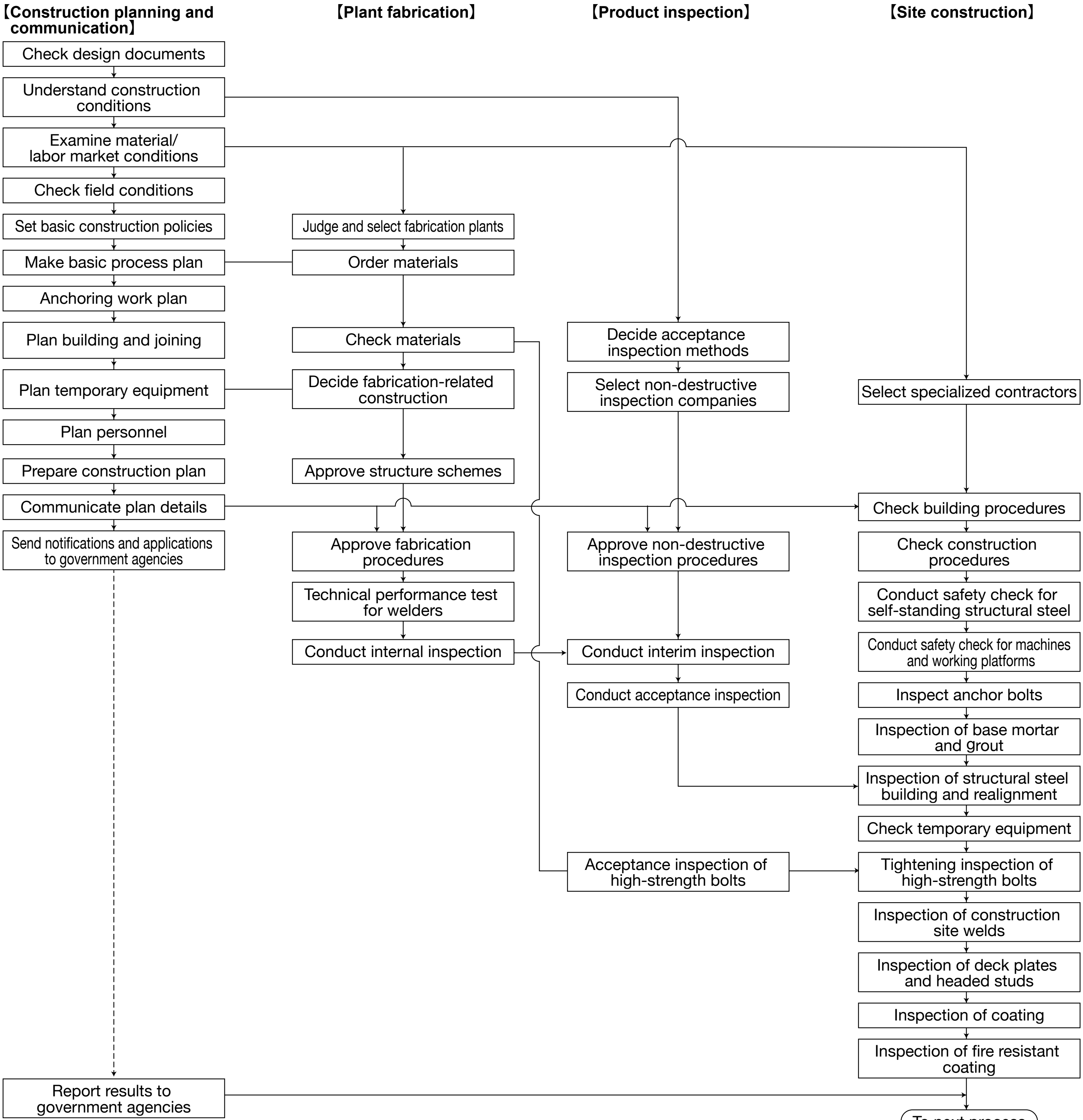
may occur at the construction site and then to describe the details of the defect and their preventive measures, through which OBSSQ also works to firmly establish their knowledge and improve their capability to treat defects and other construction-related problems occurring at the construction site. (Refer to Table 2)

Towards Raising the Level of Supervisors

As stated above, supervisors for steel construction works play an important role in the improvement of quality control in steel structure construction. In order to nurture the supervisors appropriate for this purpose, JSSC promotes the development of human resources by gathering together the experience and knowledge of top-level engineers of general contractors and experts, and plans to continue its utmost efforts for raising the level of the content of training programs while at the same time accurately meeting the current circumstances faced by steel structure construction.

(Appendix)

• Flow of Supervision of Steel Structure Construction (draft)



Source: Technical Recommendations for Steel Construction for Buildings: Part 2 Guide to Erection and Construction in Site, Architectural Institute of Japan

Supervisors for Steel Construction Works —Qualification Exam Textbook—

Organization for Building Steel Structure Qualification of the Japanese Society of Steel Construction

Aim of the Textbook

The *Supervisors for Steel Construction Works—Qualification Exam Textbook,* published by the Organization for Building Steel Structure Qualification (OBSSQ), has been prepared for those who newly attend lectures and take an entrance examination relating to supervisors for steel construction works, and as materials for use for continued learning for those who renew their supervisor qualifications.

In the compilation of this textbook, many experts from diverse fields have participated—university, public and private research organizations, related industry associations, design companies and general contractors (refer to the Editorial Committee in the Appendix).

The "supervisor for steel construction works" is a qualified engineer who can supervise a series of processes involved in steel structure construction—from the preparation of construction plans to the completion of construction works (refer to Flow of Supervision of Steel Structure Construction on the previous page). The textbook is composed of content in conformity with the major goals of developing human resources for new supervisors and further upgrading the quality of steel structure construction by brushing up the know-how of qualified supervisors for steel construction works.

Outline of the Textbook

The textbook is composed of six chapters.

• Chapter 1

Description of advance confirmation items (confirmation of specifications, etc.) prior to working out the construction plan to be required at the stage of preparing the steel structure construction and key factors to be confirmed at the stage of working out the practical construction plan

• Chapter 2

Comments on the selection of steel-frame fabrication plants (fabricators) and related construction companies, description of how to confirm whether or not the selected fabricator has the necessary capability to manufacture steel-frame members while securing the design quality specified in the documents of the design in which the selected fabricator participates

• Chapter 3

Preparation of steel member fabrication procedures, UST flaw detection and other member inspection procedures, confirmation of design documents and welders and explanation of various tests

• Chapter 4

Confirmation of specific factors involved in interim inspection, member fabrication-stage inspection and acceptance inspection with practical photos, detailed explanation to confirm the conditions pertaining to cutting, groove processing, drilling and assembly

• Chapter 5

Extensive explanation of specific confirmation points at practical steel-structure construction sites—erection method and erection process control, confirmation of crane and other equipment and safe operations, measures to secure worker safety, position/dimension/configuration of anchor bolts and base mortar, erection and plumbing correction of steel frames, acceptance/on-site bolting/inspection of high-strength bolts, on-site qualified welders, control of welding heat inputs and pass-to-pass temperatures, inspection of welds

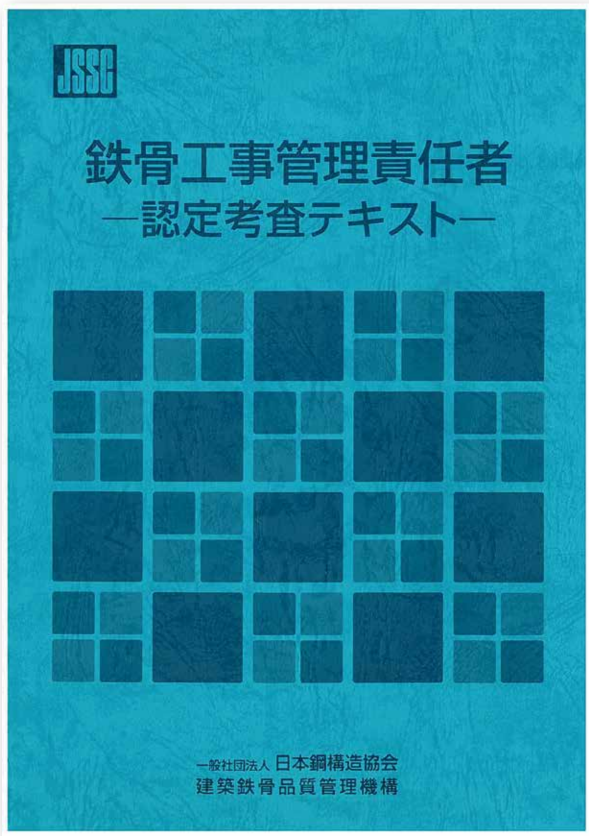
• Chapter 6

Description of control points on deck plate erection, corrosion-protection coating (heavy-duty corrosion-protection coating and galvanizing), and fire-protection coating

(For more details, refer to Table of Contents in the Appendix)

English-version Textbook

The purpose of publishing an English version of the textbook lies in the dissemination of information on steel-structure technologies in Japan, particularly steel-structure construction supervising systems and methods, through which it is expected for these systems and methods to be diffused overseas. Meanwhile, because construction environments and conditions differ in each country, it is hoped that the textbook will be helpful for you as a reference to Japanese examples.



Japanese version of *Supervisors for Steel Construction Works—Qualification Exam Textbook*

(Appendix)

Supervisors for Steel Construction Works
—Qualification Exam Textbook—

• Editorial Committee and Committee Members of the Organization for Building Steel Structure Qualification

List of Members of Specialized Committee on Supervisors for Steel Construction Works (FY2022)

Title	Name	Affiliation/Role	Affiliation
Chairman	Kikuo Ikarashi	Architecture Professor, School of Environment and Society, Tokyo Institute of Technology	Japanese Society of Steel Construction
Member	Takashi Hasegawa	Senior Researcher, Structural Research Group	Building Research Institute
	Makoto Karasawa	Kanou Structural Design	Japan Federation of Architects and Building Engineers Associations
	Takao Sonobe	SPC Design, Inc.	Japan Structural Consultants Association
	Toru Shima	Toda Corporation Architectural construction technical director, architectural construction supervision division	Japan Federation of Construction Contractors
	Kenkou Kawai	Nishimatsu Construction Co., Ltd., main building projects division Chief of Structural Design Department	Japan Construction Industry Association
	Yasuo Shoji	Deputy Director-General and Technical Director	Japan Steel Constructors Association
	Hiroyuki Shinmura	Manager of Technology Department	Japan Steel Fabricators Association
	Masanori Mori	Takenaka Corporation Technology Department, Tokyo Head Office	Chairman of the Structural Steel Construction Manager Executive Committee

List of Members of Execution Committee on Supervisors for Steel Construction Works (FY2022)

Title	Name	Affiliation/Role	Affiliation
Chairman	Masanori Mori	Takenaka Corporation Technology Department, Tokyo Head Office	Japan Federation of Construction Contractors
Vice Chairman	Kenzo Morioka	Sumitomo Mitsui Construction Co., Ltd. General Manager of Building Technology Department, Head Office of Construction	Japan Federation of Construction Contractors
Member	Akira Inubushi	Shimizu Corporation Lead Examiner, Production Technology Office, Construction Administration Office	Japan Federation of Construction Contractors
	Toru Shima	Toda Corporation Architectural Construction Technical Director, Architectural Construction Supervision Division	Japan Federation of Construction Contractors
	Akihiro Endo	Construction Technology Division, Construction Administration Office, Kajima Corporation General Manager of Technology Consulting Group	Japan Federation of Construction Contractors
	Hirokazu Tanaka	Okumura Corporation, East Japan Branch Construction Design Department, Division 2	Japan Construction Industry Association
	Makoto Karasawa	Kano Structural Design	Japan Structural Consultants Association
	Takao Sonobe	SPC Design, Inc.	Japan Federation of Architects and Building Engineers Associations

List of Members of Textbook Committee on Supervisors for Steel Construction Works (FY2022)

Title	Name	Affiliation/Role
Chairman	Kenzo Morioka	Sumitomo Mitsui Construction Co., Ltd General Manager of Building Technology Department, Head Office of Construction
Member	Akira Inubushi	Shimizu Corporation Lead Examiner, Production Technology Office, Construction Administration Office
	Makoto Sugiyama	AXS Satow Inc. Technology Office, Inspection Supervision, Construction Manager, Technical Leader
	Kiyohide Seki	President, SEG Corporation
	Kazumasa Doi	Sumitomo Mitsui Construction Co., Ltd. Project Engineer, Structural Design Division, Head Office of Construction
	Satoshi Fujiwara	Maeda Corporation Chief Engineer, Construction Technology Department, Construction Office

• Table of Contents (draft)

• Excerption from *Supervisors for Steel Construction Works—Qualification Exam Textbook* (draft)

Chapter 1 Basics of structural steel construction

1.1 Construction management

1.1.1 Characteristics of structural steel construction

Structural steel construction is a type of construction that forms the central frame of buildings. Hence, it forms the base of construction work and has a significant effect on the construction of other parts and on the process as a whole. Furthermore, since the basic framework is formed to create the basic dimensions of each part, careful consideration and reliable construction are required. In addition, high-strength bolt and weld joining is important elements in forming the frame and have a significant effect on structural performance.

It is important to fully understand these characteristics and tackle the construction plan and management of structural steel construction.

Photo 1.1.1 Article on issues of defective structural steel

1.1.2 The importance of construction management

In recent years, construction management in the construction industry has shifted from results management, which puts importance on experience and intuition, to process management, which focuses on quality assurance. In other words, production management has become widely known as a production system for achieving quality, construction time, safety, and economic efficiency.

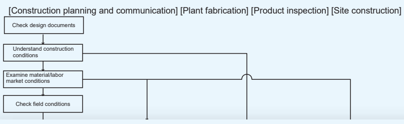
Under these circumstances, structural steel construction managers need to select the optimal construction method based on design documents, create the construction plan, and manage the construction.

Construction management centers around the structural steel construction manager, who is responsible for the architectural construction, and it is important that the fabricator supplying the components and the specialized contractor responsible for the construction work together.

The following is an overview of construction management:

1. Understanding the construction details from design documents
2. Understanding the construction conditions
3. Examining the materials and labor market conditions
4. Setting basic construction policies
5. Form a construction plan
6. Preparation and communication of the construction plan
7. Forming contracts with the fabricator and specialized contractor
8. Coordinating the plan, fabrication, and construction
9. Forming and implementing the management plan during construction
10. Checking and reporting results

Below is a chronological flowchart of the stages of construction management in structural steel construction—construction planning and communication, plant fabrication, product inspection, and site construction.



2.1.3 Examining plants

The plant selected through documents will be inspected in person and decided as the appropriate structural steel factory for the construction work. The items in the plant examination are as follows.

(1) Document screening

1. Check of plant approval: Whether there is a grade or ISO, plant size, quality control system, company's internal standards, production equipment and machinery, inspection and recording with quality control tables
2. Production capacity and stockpile per month
3. Past results: Structural steel material types, maximum weight and plate thickness, special structures
4. Managers and welders: Qualifications and number of people
5. Subcontracting management conditions

(2) Factory screening

1. Management positions: Management positions, quality control policies, etc. of the president, plant manager, and managers
2. Plant's stockpile conditions
3. Work environment: Production equipment and machines (suitability to the construction work), tidiness and safety management conditions, communication of instructions, self-inspection conditions, etc. for the processes and operations
4. Production conditions: Material management, cutting, and processing in other properties, assembly and welding management conditions, friction surface treatment conditions, use of robots and jigs, etc.
5. Product placement: Sizes, handling and placement of structural steel products, coating conditions, safety methods, etc.

Check how the materials (cut board, formed steel, etc.) are placed in the material storage area. Identify each material by construction and structural steel material type as shown in photo 2.1.1, and check that they are organized.

Photo 2.1.1 Material storage area conditions (good)

Since there are limits on the possible sizes of production equipment machines for cutting and processing, it is important to not only check that the machines are there, but also that they are suitable for the construction work by looking at the machines in person as shown in photo 2.1.2. It is also important to verify the capacity of crane and other lifting devices (photo 2.1.3).

Photo 2.1.2 Checking production equipment machinery

Photo 2.1.3 Checking cranes' lifting capacities

The drilling and groove processing machines (photo 2.1.4) also have limits on processing sizes, so check whether they can be adapted to the construction work. In particular, when doing site welding on large beams, check whether grooves can be processed for flanges under beams according to the design document. If the processing cannot be done, it is necessary to check whether the gas is cut off by the company or outsourced.

Photo 2.1.4 Checking the groove processing machine

When laser cutting gusset plates and laser drilling high-strength bolt holes, bolt holes, anchor bolt holes, and rebar through holes, make sure that the diameter of the hole including the erosion area has an error of ±0.5 mm or less.

20 Chapter 2 Selecting structural steel factories and related construction companies

Seismic Evaluation of Building Frames Using SN Steel

by Muslinang Moestopo
Associate Professor, Bandung Institute of Technology
Vice Chair of Design Technical Committee, Indonesian Society of Steel Construction

Muslinang Moestopo: He received his Bachelor Degree in Civil Engineering from Bandung Institute of Technology, Indonesia in 1985, and MSEM and Ph.D from University of Wisconsin, USA respectively in 1989 and 1994. He currently serves as Associate Professor at Bandung Institute of Technology and concurrently as Vice Chair of the Technical Design Committee of the Indonesian Society of Steel Construction (ISSC).

This article presents a result of joint research project between Japanese Society of Steel Construction, The Japan Iron and Steel Federation, and Indonesian Society of Steel Construction.

Needs for Higher Seismic Performance Steel

The need for reliable seismic resistant structures is indispensable for earthquake prone area such as Indonesia. The Indonesian seismic resistant building codes have been updated since 2002, including the seismic provisions for structural steel buildings. The recent codes are the adoption of some U.S. building codes, i.e. Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE 7-16), Specification for Structural Steel Buildings (AISC 360-10), and Seismic Provisions for Structural Steel Buildings (AISC 341-10). The codes will be updated following the revision of the U.S. building codes. In addition to the code compliance, the need for a higher performance steel material is also essential to secure the performance of seismic resistant structure as stated in recent Codes.

Evaluation of Structural Performances of SN490B and SS400

A study has been conducted to evaluate the use of SN490B steel in the design of four-story office buildings in soft-soil at Bandung, West-Java, according to Indonesian Steel Seismic Building Codes. Two identical structural frames were analyzed, using SN490B and commonly used SS400 steels, respectively. The frame model and data of the building are shown in Figure 1 and Table 1. The building design parameters are determined based on the Indonesian Seismic Loading Code (SNI 1726: 2019), as shown in Table 2.

Table 2 Seismic Design Parameter

Risk category	II
Importance factor	1.0
SD_S	0.6987 g
SD_1	0.6415 g
Seismic design category	D
Response modification coefficient, R	8
Overstrength factor, Ω_o	3
Deflection amplification factor, Cd	5.5
Redundancy factor, ρ	1.0
Drift limit	2.5 %

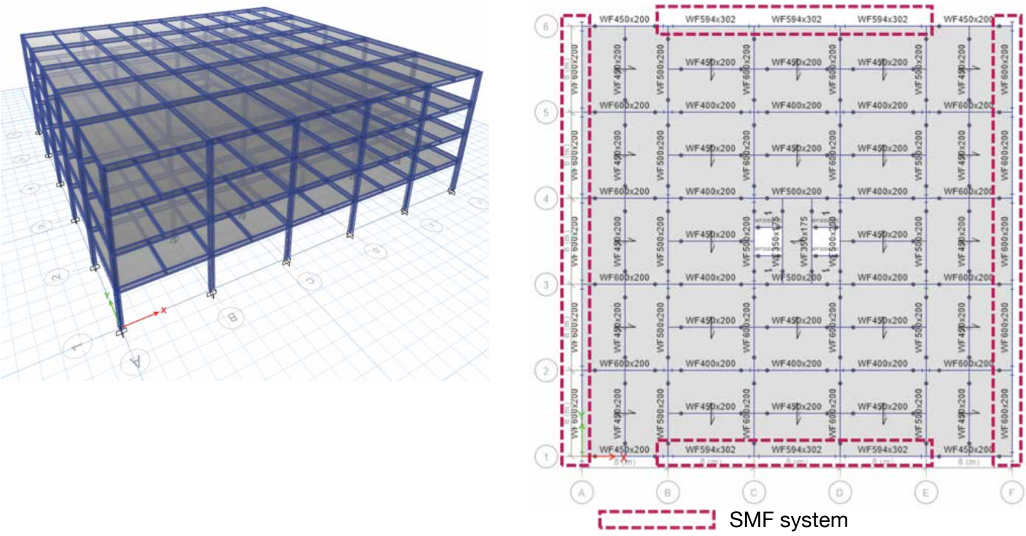
Table 1 Data of Steel Building

Dimension	Typical 4-story (40 m × 40 m, 5 × 8 m in each direction)		
Steel materials		SS400*	SN490**
	Yield stress, Fy, MPa	235	325
	Tensile strength, Fu, MPa	400	490
Sectional member	Wide flange		
Seismic resisting system	Special moment frames on building perimeter		
Gravity resisting system	Gravity frames on building interior		
Building irregularity	No (vertical and horizontal)		
Building standards	SNI 1726: 2019, SNI 1729: 2015, SNI 7860: 2015, equivalent to ASCE 7-16 (seismic part), AISC 360-10, AISC 341-10		

*JIS (Japanese Industrial Standards) G3101: SS400 (rolled steels for general structure)
**JIS (Japanese Industrial Standards) G3136: SN490 (rolled steels for building structure)

Figure 1 Structural Model of 4-story Office Building

(a) 3D model **(b) Typical plan**



Preliminary design was proposed for both frame models using the wide-flange sections. The structural analysis for the seismic loading combination, i.e. 1.2 dead load + 1.0 live load + 1.0 earthquake, governed the design of beam elements. Due to the requirement for highly ductile member, the use of available beam sections in special moment frames resulted in less "demand-capacity ratio" (DCR) than beam elements in gravity frames, for both SS and SN frames.

The capacity design was conducted to determine the dimension of columns that are parts of special moment frames according to the Seismic Provisions for Structural Steel Buildings (SNI 7860:2015). Since the provision only specifies the Ry value (= expected yield stress/specified yield stress) for ASTM steels, the design assumed Ry = 1.5 for SS400 and Ry = 1.338 for SN490B, which corresponds to the Ry values for ASTM A36 and data from AIJ Proceeding (2015): *"Statistical Study on Mechanical Properties and Chemical Compositions of SN Steels."* This Ry value is critical in the design stage as well as in the analysis of structural performance.

Higher Performance of SN490B Steel

The design for the two buildings showed that the SN frame provided smaller sections of beams and columns due to its higher yield stress (1.3 times higher than yield stress of the SS400) and lower Ry value. Tables 3 and 4 show the DCR of special moment frames and gravity frames, respectively. The seismic requirement for the drift limit of 2.5% required heavier column sections so that the DCR for special moment frame of SN steel could not be maximized. On other hand, the DCR for the gravity frames of both SS and SN steels can be maximized since they were leaning columns that are not part of lateral force resisting system with its stringent slenderness limit.

Figure 2 shows the interstory drift of both frames. The drift requirement eventually prevents to maximize the DCR of special moment frames, especially for SN frame. In other words, the advantages of using SN490B will be more evident for building design which is not governed by the drift limit.

The design for the two frames shows that the SN frame provides 12.81 % less weight of columns and beams than the SS frame (Table 5).

Table 5 Structural Steel Weight

Element	Weight (kg)	
	SS400	SN490B
Column	95,726	82,061
Beam	171,962	149,747
Sub-beam	57,251	51,491
Total	324,939	283,299
Deviation		41,639 (12.81 %)

Figure 2 Interstory Drift

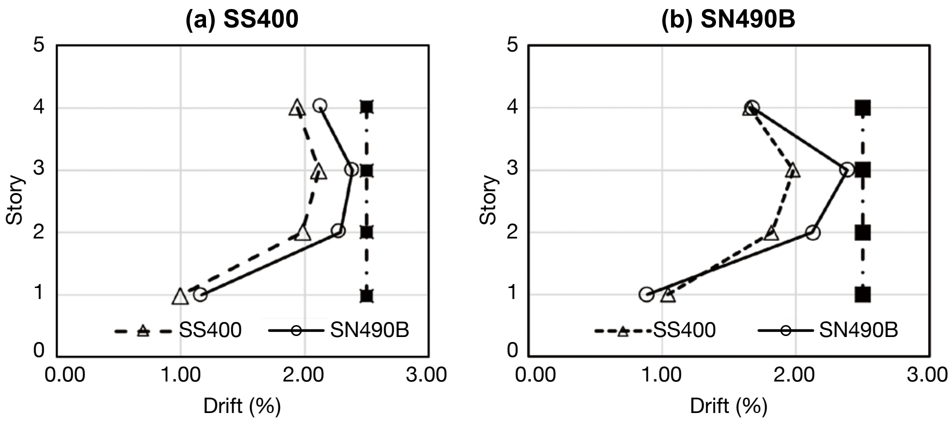


Table 3 DCR for Special Moment Frames

Story	Element	SS400		SN490B	
4F	Column	WF500x200	0.198	WF500x200	0.153
	Beam	WF400x200	0.788	WF350x175	0.878
	Beam	WF450x200	0.843	WF400x200	0.776
3F	Column	WF588x300	0.294	WF600x200	0.394
	Beam	WF400x200	0.954	WF400x200	0.801
	Beam	WF450x200	0.865	WF450x200	0.846
	Beam	WF500x200	0.910	WF500x200	0.888
	Beam	WF600x200	0.902		
2F	Column	WF588x300	0.510	WF588x300	0.384
	Beam	WF400x200	0.954	WF400x200	0.801
	Beam	WF450x200	0.865	WF450x200	0.846
	Beam	WF500x200	0.910	WF500x200	0.888
	Beam	WF600x200	0.902		
IF	Column	WF700x300	0.821	WF588x300	0.738
	Beam	WF400x200	0.954	WF400x200	0.819
	Beam	WF450x200	0.882	WF450x200	0.846
	Beam	WF500x200	0.910	WF500x200	0.888
	Beam	WF600x200	0.902		

Table 4 DCR for Gravity Frames

Story	Element	SS400		SN490B	
4F	Column	WF500x200	0.197	WF500x200	0.152
	Beam	WF400x200	0.788	WF350x I75	0.878
	Beam	WF450x200	0.843	WF400x200	0.776
3F	Column	WF588x300	0.293	WF600x200	0.394
	Beam	WF400x200	0.954	WF400x200	0.801
	Beam	WF450x200	0.865	WF450x200	0.846
	Beam	WF500x200	0.910	WF500x200	0.888
	Beam	WF600x200	0.902		
2F	Column	WF588x300	0.509	WF588x300	0.399
	Beam	WF400x200	0.954	WF400x200	0.801
	Beam	WF450x200	0.865	WF450x200	0.846
	Beam	WF500x200	0.910	WF500x200	0.888
	Beam	WF600x200	0.902		
IF	Column	WF700x300	0.811	WF588x300	0.686
	Beam	WF400x200	0.954	WF400x200	0.819
	Beam	WF450x200	0.882	WF450x200	0.846
	Beam	WF500x200	0.910	WF500x200	0.888
	Beam	WF600x200	0.902		

This number is expected to be higher for building with more effective lateral displacement resisting system (e.q. braced frames, dual system with shear wall), since the design is not governed by the drift limit, so that the DCR of structural members (e.q. beam, column, bracing) could be maximized.

A non-linear static push over analysis was conducted to evaluate the performance of the two frames using the backbone of plastic hinge model with its parameters according to ASCE 41-17 (Section 9.4: *Steel Moment Frames*) as shown in Figure 3. The performance of structure was also determined according to acceptance criteria stated in Section 7.6: *Alternate Modeling Parameters and Acceptance Criteria*. Figure 4 shows the illustration of acceptance criteria that includes Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP).

The result of push-over analysis in Figures 5 (a) and (b) shows the good performance of SN frame in addition to its advantage in steel weight, as compared to SS frame. The performance points of SN frame in both X and Y directions and of SS frame in Y-direction indicate Immediate Occupancy, while the performance point of SS frame in X-direction indicates Life Safety.

The higher overstrength as well as the higher ductility of SN frame in X-direction and Y-direction are supported by a good plastic hinge formation. Figures 6 and 7 show the plastic hinge formation at the final step in SS frame and SN frame, respectively. The red dot indicates the strength loss on the elements (represented by point D in the plastic hinge model in Figure 3). The strength loss on beam elements is identified in SN frame, and not on column elements as in SS frame. The use of stronger column of a slightly heavier section in the SN frame is expected to prevent building collapse by still maintaining the less structural weight than the SS frame.

Furthermore, the good plastic hinge formation results in a higher capacity of dissipated energy (Figure 8), which indicates a better seismic performance. The good performance of SN frame could be further improved, i.e. by the use of larger sections, which leads to less DCR and slightly heavier structure, but still provides a considerably lighter structure than the SS frame.

Additional Application Advantages of SN490B Steel

More advantages of using the SN490B steel have been well recognized as follows:

- Limitation of upper yield stress to ensure the final collapse mechanism of frames as it assumed at design stage;
- Restrict yield ratio (yield stress to tensile strength) to 0.80 or lower, to provide better over-strength capacity;
- Limitation of fracture toughness index higher than 27 Joule at 0°C to provide better weldability for better performance of connection; and
- Limits the carbon, phosphorus, sulphur, and specified weld cracking sensitivity composition, to secure the weldability, workability and resistance to through-thickness cracking.

Figure 3 Plastic Hinge Model (ASCE 41-17)

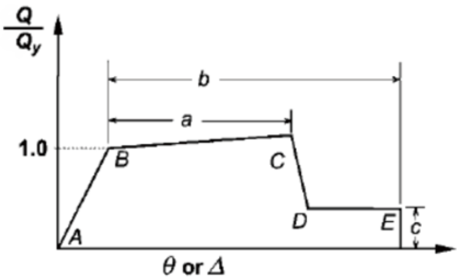


Figure 4 Acceptance Criteria Illustration (ASCE 41-17)

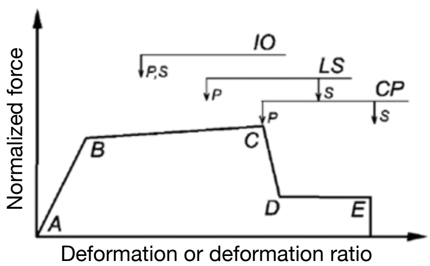
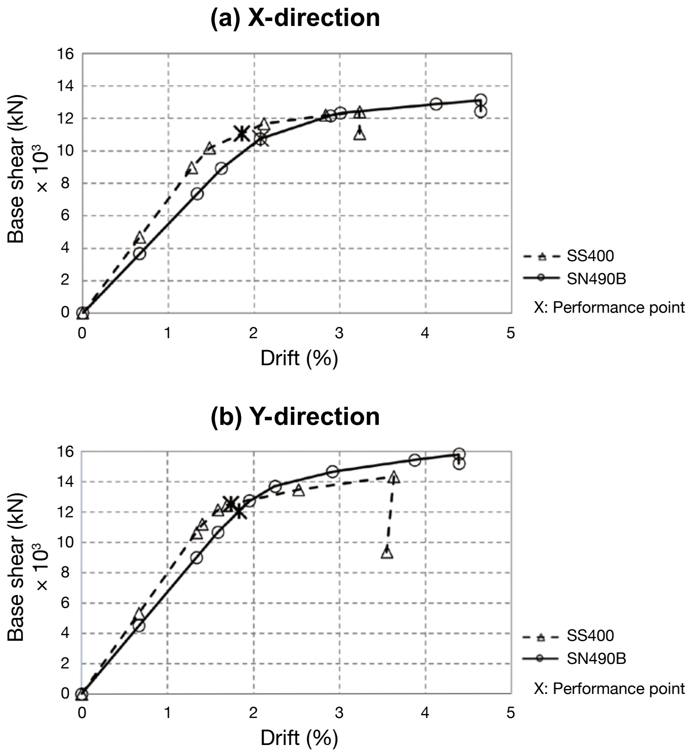


Figure 5 Push over for SS and SN Frames



Conclusion

1. Design of two identical buildings (using SS400 steel and SN490B steel) with special moment frames has been provided according to the recent Indonesia Seismic Building Codes. The design shows the advantages of the SN frame in steel weight due to its higher yield stress and lower Ry value, and this advantage could be more apparent when the design of building structure is governed by the strength limit, not by the drift limit.
2. The result of the non-linear static push over analysis of both design frames shows that the SN frame exhibits: (1) less structural stiffness; (2) higher structural strength; (3) more ductile structure; (4) better structural performance; (5) better energy dissipation capacity; and (6) better plastic hinge formation that prevents a sudden collapse due to column failure.
3. From the viewpoint of risk assessment for building due to earthquake occurrence, the use of SN490B steel with a smaller variation of yield point ensures the structure that will perform much closer to the design performance which was determined for the building. This indeed will increase the performance of the building in protecting the human live and social assets.

Figure 6 Plastic Hinge Formation at the Final Loading Step for SS Frame

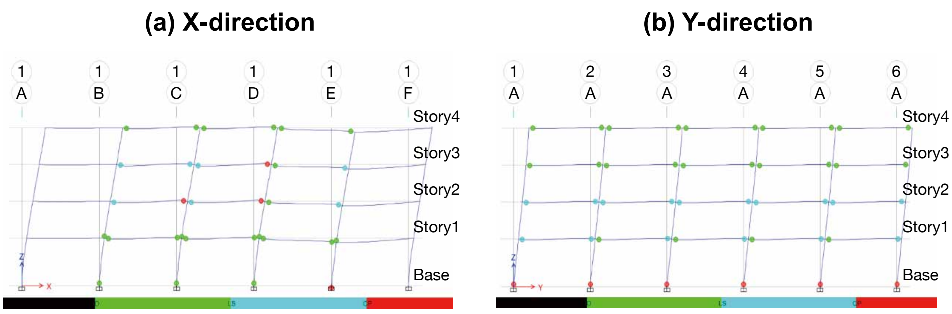


Figure 7 Plastic Hinge Formation at the Final Loading Step for SN Frame

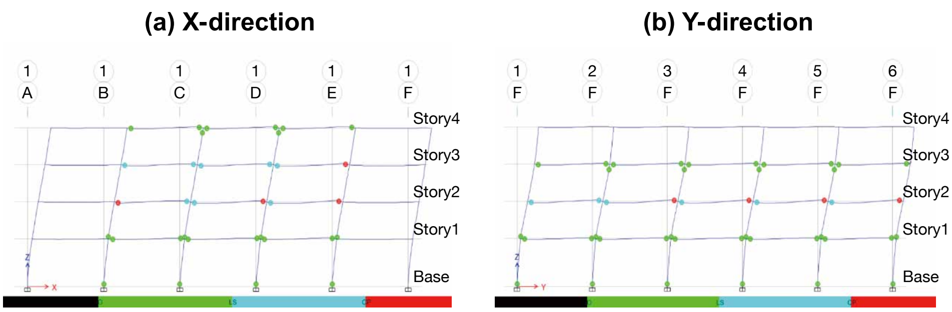
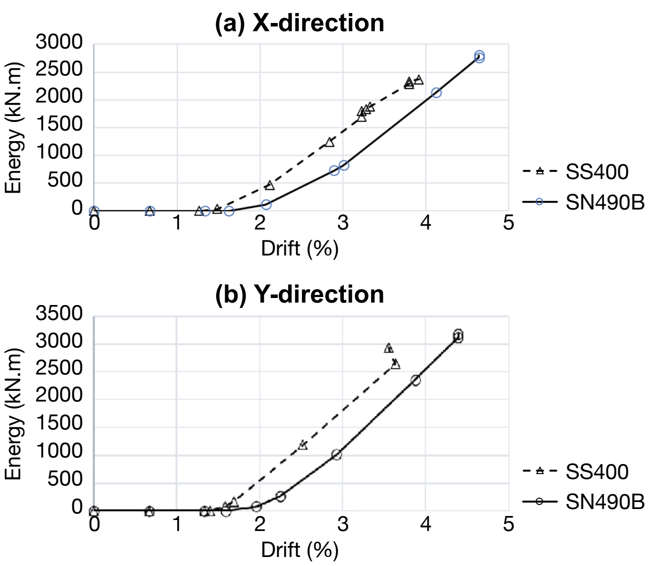


Figure 8 Dissipated Energy of SS and SN Frames



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1) American Society of Civil Engineers (2017), *Seismic Evaluation and Retrofit of Existing Buildings*, ASCE/SEI 41-17.
2) Architectural Institute of Japan (2015) Proceeding: *"Statistical Study on Mechanical Properties and Chemical Compositions of SN Steels"*.
3) National Standardization Agency (2019), *Seismic Loading for Structural Building and non-Building* (In Indonesian), SNI 1726-2019.
4) National Standardization Agency (2019), *Specification for Structural Steel Buildings* (In Indonesian), SNI 1729-2015.
5) National Standardization Agency (2019), *Seismic Provisions for Structural Steel Buildings* (In Indonesian), SNI 7860-2015.

"myu terrace" Brings Economy, Style to Matsuyama Univ. Campus

—Steel Structure, Lightweight Roof Highlight Popular Transparent Social Spot—

Nikken Sekkei Ltd.

"myu terrace" is an outdoor lounge-like building constructed at Matsuyama University's Bunkyo Campus in Ehime Prefecture, Japan. Rectangular-shaped steel hollow framings are aligned at the high ceiling of the structure's wall-free space, where they bear both x- and y-axis seismic forces. They support a large roof spanning the entire building (see Photo 1).

As a project, myu terrace has been well received, as it has reduced the costs and terms of construction through the reuse of a pre-existing underground foundation. It also serves environmental preservation goals.

360-degree Accessibility

A semi-outdoor space, the terrace was newly built in a vacant lot where the former No. 1 school building had been located, at the center of the Bunkyo Campus. A popular gathering site, it was nevertheless seen as a somewhat hard to access facility.

After careful study, we took the somewhat dramatic step of building an architecture without an enclosure or defined entrance points positioned between the architecture and the landscape. We aimed to realize a comfortable space to serve groups of students

Photo 1 Full view of myu terrace

as well as individuals (refer to Figs. 1 and 2).

Utilizing the Existing Foundation

The decision to demolish the site's No. 1 school building created a dilemma: how to dispose of its underground foundation? Its 4.5 m depth and central location posed foreseeable concerns related to noise and safety. In order to avoid this, it was decided to leave the foundation intact. Reusing the existing foundation had two benefits in reducing in both demolition and new construction costs.

Select sections of the foundation were ultimately demolished, however, and in the sections for which new elements were needed, additional measures were taken to reinforce the entire foundation. Joint bars were used to integrate the new and old foundation structures. Rectangular steel framings were then loaded onto the reinforced foundation, which supports the large roof and the second-floor terrace.

A steel structure was deemed more appropriate than an RC structure due to the weight savings, and because it would allow for a high degree of stiffness design flexibility. As the existing foundation also had a structure of RC, compression tests were performed after drawing out its core and redesigning it.

Well-balanced Framing

The rectangular-shaped framings were arranged in different directions to improve myu terrace's seismic resistance. They bear identical sheer force in both x- and y-axis directions (see Photo 2). Further, they were arranged so that they complement each other to work effectively with a minimum number of units.

Because the fixing level is high for both the lower and upper sides of the framings, even framings with low depth and thin wall thickness can suppress structural deformation.

From an orthogonal perspective, the framing is T-shaped. To address this situation, the structural design was made so that both rectangular and T-shaped framings could demonstrate identical stiffness by improving the former's sectional configuration. Ultimately, a highly efficient building structure was realized in which horizontal force is borne by any of the framings.

Fig. 1 Perspective View of the Sectional Structure of myu terrace

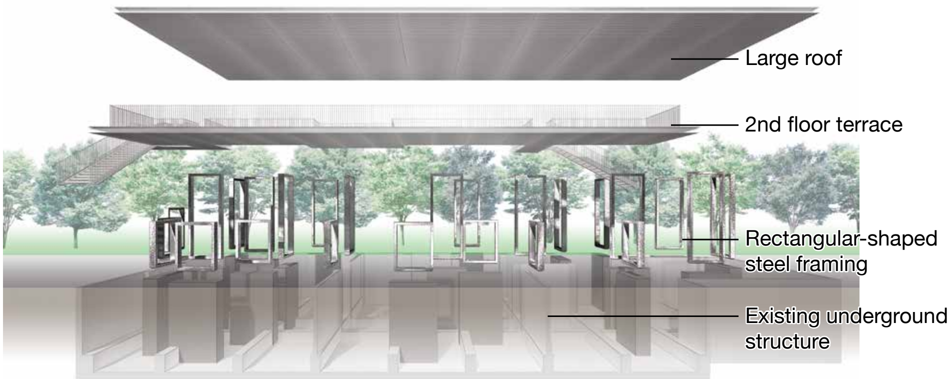
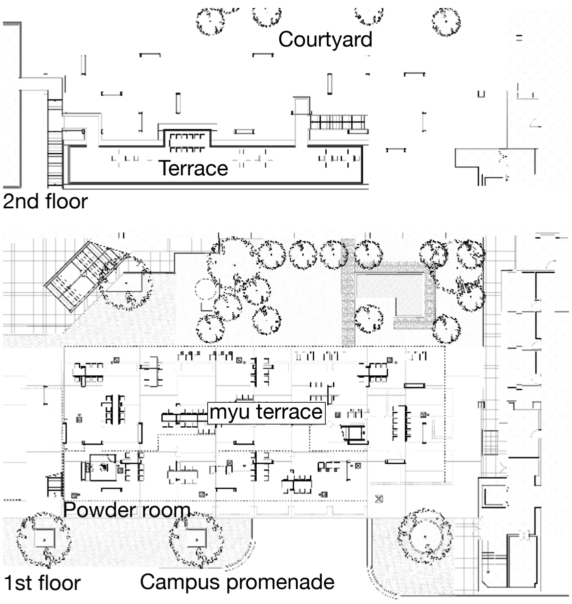


Fig. 2 Plane Drawing of myu terrace



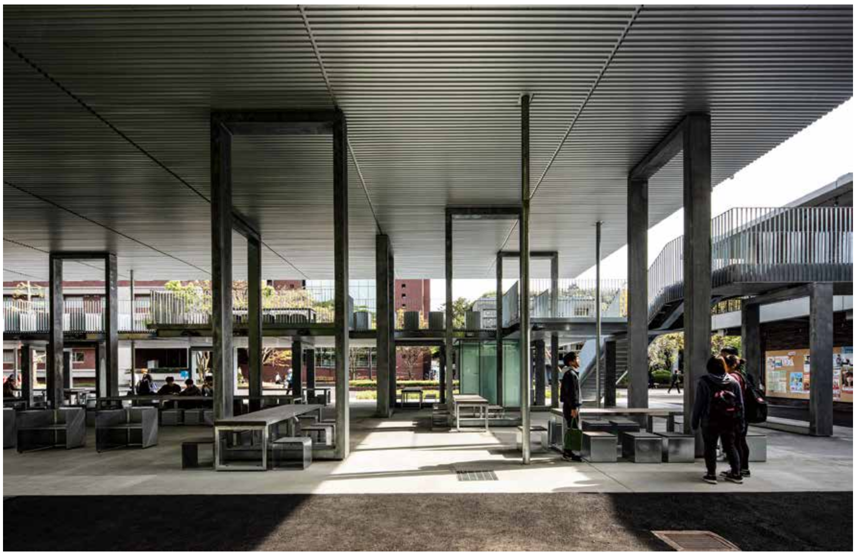


Photo 2 Arrangement of rectangular-shaped steel framings in x- and y-directions

While there are sections in which the span between framings seems wide, the basic span between them (12 m or less) was maintained, with their random arrangement aimed at enhancing comfort (see Photo 2 and Fig. 3).

The respective height dimensions for myu terrace were set at 5.4 m (overall), 2.6 m (ceiling-to-intermediate terrace), and at 2.4 m (terrace-to-large roof ceiling). The logic behind these dimensions was two-fold. First, it was thought best not to exceed the height of the neighboring two-story classroom building. Secondly, higher heights may threaten the sense of intimacy (or "human scale") felt by students on and below the terrace (see Fig. 4).

The columns of the rectangular shaped framings are composed of welded, built-up box columns. Box-shaped H-shapes covered with plates are used as beams. The visible weld of the built-up box columns was grinder-finished to yield a solid, seamless impression.

As to the framings' configuration, we envisioned an image akin to a picture frame with torn out scenes of student social exchange. Rather than pillars, for example, this kind of structure better served our expectations that myu terrace would become a memorable space for its users.

One featured aspect in the arrangement of the rectangular-shaped framings is that upper beams are not built into the ceiling. This owed to concept of making the configuration look more aesthetic by "floating" the framing slightly apart from the ceiling. This idea was applied to the bottom of the structure as well, where the framing is set apart from the floor slab by about 2 cm (see Fig. 5). The base of the frame is otherwise securely fastened using anchor bolts.

Parallel, cross-shaped steel beams are arranged on the rectangular shaped framing (Photo 3), across which the aluminum-zinc (Al-Zn) alloy-coated steel sheet roof has been laid.

We intended to make the roof look light in order to emphasize the rectangular-shaped framing. To do this, the ceilings of both the terrace and the large roof were covered with Al-Zn sheets.

The keystone plate (a folded steel plate using an Al-Zn sheet) was applied as a ceiling member and to the eaves. Identical structural members were also used in render a lightweight appearance to the roof.

Fig. 3 Plane, Elevation and Cross Section Drawings of myu terrace

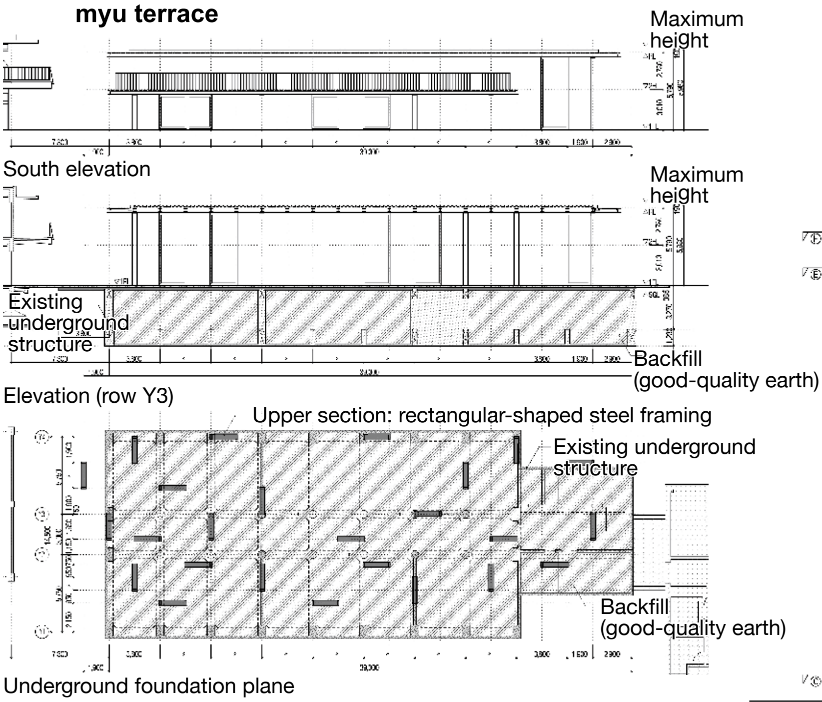


Fig. 4 Rectangular Drawing of myu terrace

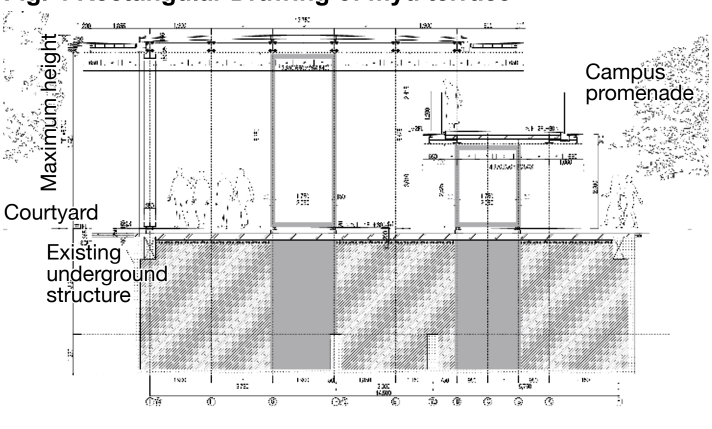
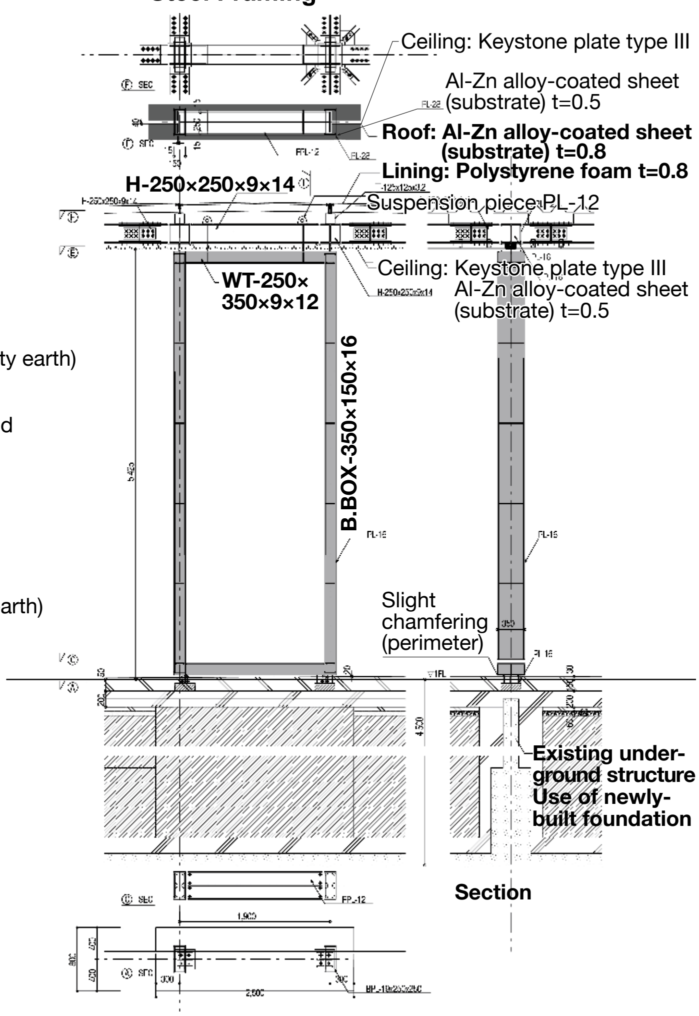


Fig. 5 Detail of Rectangular-shaped Steel Framing



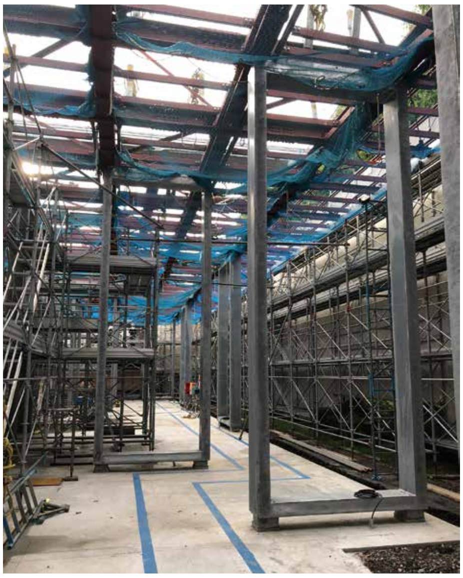


Photo 3 Parallel cross-shaped framing loads on rectangular-shaped steel framing

Galvanizing the Steel Framings

Steel framings were galvanized and displayed without decoration, as we wanted visitors to be able to enjoy the texture and surface alterations imparted by the galvanizing process. Careful discussions were held about the process itself, from the dipping of framings into the chemical bath to removing the zinc, etc (Photo 5).

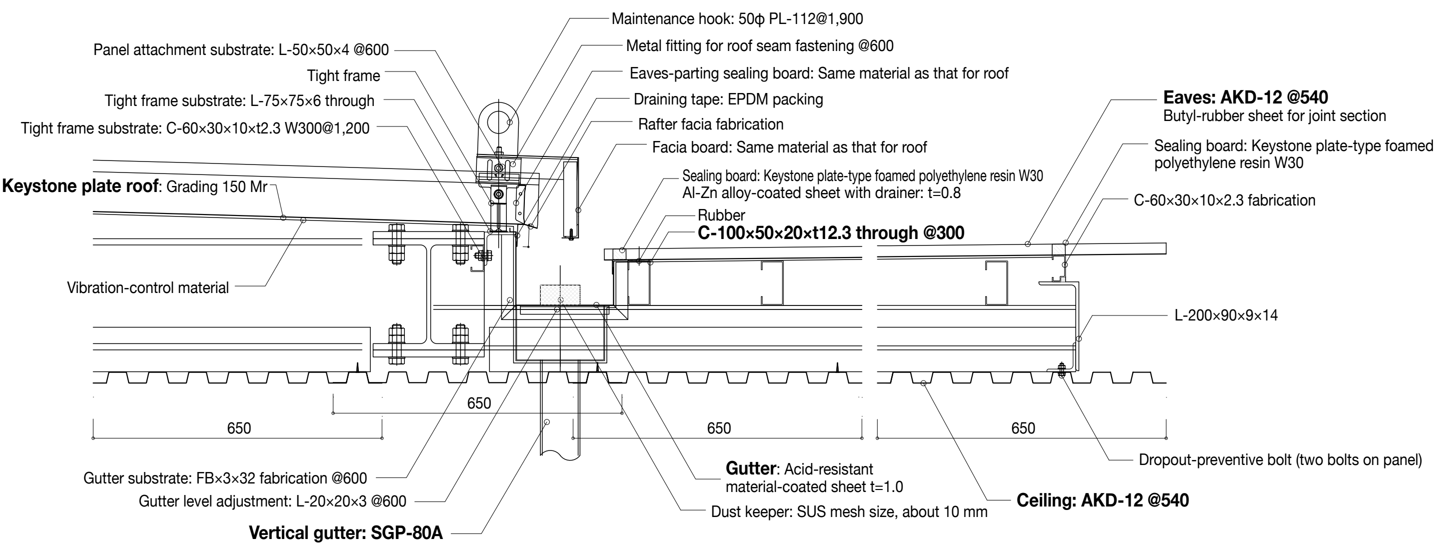
For example, while some streaking of the zinc coating remained on framings after the process was completed, we saw this as more interesting than a “clean” finish. All of the ceilings and handrails were galvanized. Steel is extensively used in myu terrace’s structural members, with no decorative treatment.

Photo 5 Lifting of rectangular-shaped steel framing from galvanizing bath

The eaves were also designed to account for rainwater. While the keystone plate used for the roof was arranged in a parallel direction, the plate used for the eaves was oriented 90° to the long side. This was due to the eaves’ added function as a rain gutter. Rainwater drawn through the eaves is collected in the vertical downpipe installed under the roof (see Photo 4 and Fig. 6).

Photo 4 View of 2nd floor terrace from the classroom building: The direction of the recessed sections of the eaves changes in long-side and short-side directions.

Fig. 6 Detailed Sectional Drawings of Roof and Eaves



Natural Light for the 2F Terrace

Natural light received on the second-floor terrace is reflected upward, illuminating the ceiling of the large roof. This lighting system is based on the use of a "light shelf" to reflect daylight into the building to softly brighten the entire structure. As a result, myu terrace needs no artificial lighting during daytime hours (Photo 6).

On windy and rainy days when rainwater can fall diagonally, the second-floor terrace serves to block and impede this flow, demonstrating one of its many structural virtues.

After its completion, myu terrace evolved to host diverse social scenes, such as students and friends gathering for lunch and assembling under the roof, etc. Some students use the structure as a "bypass" route. With no glass covering, these attributes are precisely the advantages that myu terrace affords. There are no official restrictions on who or how the facility may be used.

Students use myu terrace in clever fashion, and in more ways than that it was envisioned at the design stage. They gather there to take photos after graduation ceremonies, and use the location as a central facility for school festivals. Although not a large-scale building, we feel that myu terrace serves well as a core site in student life. The Bunkyo Campus is reportedly seeing a rise in visitors, and the building is likely contributing to this phenomenon in multiple ways (see Photo 7).

Perhaps some time in the future, myu terrace will be demolished. It is our hope that its elegant and efficient rectangular-shaped steel framing will remain as the foundation for its successor.

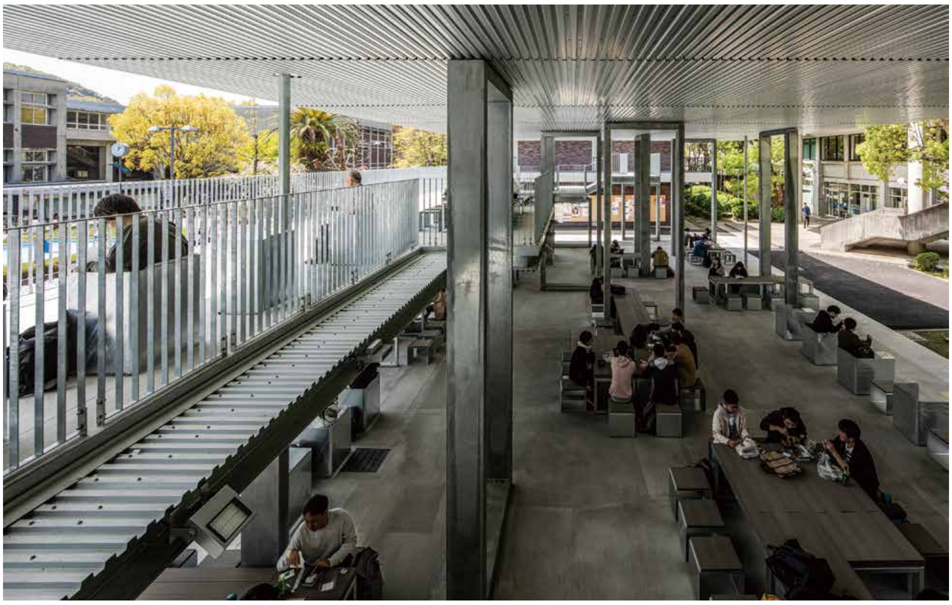


Photo 6 Light expanding through the 2nd floor terrace floor and large roof ceiling

Photo 7 View of myu terrace from promenade

Outline of "myu terrace" at the Bunkyo Campus of Matsuyama University

Location	Bunkyocho, Matsuyama, Ehime Prefecture
Project owner	Matsuyama University
Main application	University facility
Area	Site area: 60,396.00 m^2 Building area: 501.45 m^2 Total floor area: 426.10 m^2
Structural type	Steel structure, mat foundation using existing underground structure
No. of stories	Two
Maximum height	6.21 m
Eave height	5.79 m
Ceiling height	Large roof: 5.4 m 1st floor: 2.6 m; 2nd floor: 2.4 m
Architectural design	Nikken Sekkei Ltd
Structural design	Nikken Sekkei Ltd
Construction	Shimizu Corporation
Design period	June 2017~October 2017
Construction period	December 2017~November 2018

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