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Special Feature

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Steel-structure Technologies for Earthquake and Tsunami Safety

Triggered by the Great East Japan Earthquake of 2011, the Japan Iron and Steel Federation (JISF) prepared a brochure titled "Earthquake and Tsunami Safety of Steel-structure Buildings and Application of Steel Products," via which JISF promotes proposals to society pertaining to the construction of buildings with enhanced earthquake and tsunami safety and to the application of structural steel products that are useful in the construction of those buildings.

In this special feature, national initiatives to secure earthquake and tsunami safety and the steel-structure technologies that support safety are introduced in line with the objectives of the brochure, together with the design of tsunami evacuation buildings and their practical examples under the following three themes on pages 1 to 14:

- Initiatives for establishing steel-structure technologies to secure earthquake and tsunami safety
- Basic particulars in the structural design of tsunami evacuation buildings
- Practical examples of tsunami evacuation facilities employing steel structures

Initiatives for Establishing Steel-structure Technologies for Earthquake and Tsunami Safety

Committee on Building Construction and Committee on Overseas Market Promotion
The Japan Iron and Steel Federation

Earthquake Disasters and Initiatives for Establishing Steel-structure Technologies to Secure Earthquake and Tsunami Safety

In Japan, steel structures account for about 30~40% of the total floor area in new building construction starts by structural method, showing an extremely high rate of steel-structure application compared to steel-structure applications in foreign nations. When examining the floor area of steel-structure building construction starts by building height, low- and medium-rise buildings with five stories or lower account for more than 90%. Given this situation, in order to build safe and reliable towns, it is necessary to supply steel products that will help to secure the quality of steel-structure building frames and their resultant seismic resistance.

Earthquake Damage to Steel Structures and Promoted Countermeasures

In the Great Hanshin-Awaji Earthquake of 1995, while it can be said that the New Seismic Design Code established in 1981 was practically proven valid, certain damage occurred in steel-frame structures, in which connection fractures caused by inferior welding and other damages were found in several steel-structure buildings (Photo 1). The 2000 revision of the Building Stan-

Fracture of weld at column end due to inferior welding

Fracture at beam end that occurred prior to its sufficient deformation *

Fracture of brace connection *

Fracture of anchor bolts of column base to cause dislocation of column *

Photo 1 Damages of steel-frame structures in the Great Hanshin-Awaji Earthquake of 1995
(*Photos: Report on Damages to Steel Building Structures in the 1995 Hanshin-Awaji Earthquake, Steel Committee of Kinki Branch, Architectural Institute of Japan)

dard Law of Japan, reflecting lessons from the earthquake thus obtained, established new structural methods for joints and connections and added new specifications for steel applications.

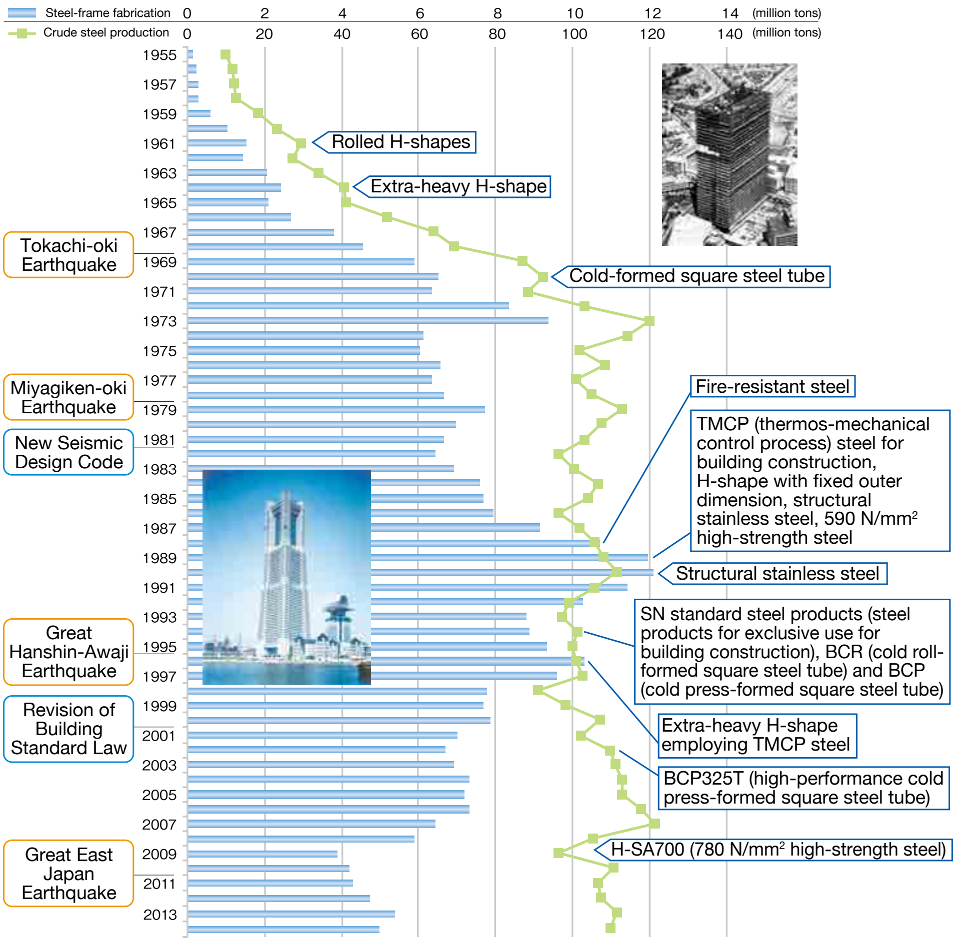
In such situations, the Japanese steel industry has successively put on the market new structural steel products: SN (new structure) standard steel products (steel products exclusively used for building construction), BCR (cold roll-formed square steel tube) and BCP (cold press-formed square steel tube), high-performance TMCP (thermo-mechanical control process) steel and 590 N/mm^2 steel that meet the needs of seismic design; and H-shape with fixed outer dimension, low-yield point steel and fire-resistant steel that conform to diversifying building design methods (Fig. 1).

Then, in the Great East Japan Earthquake of 2011, steel structures suffered damage due to both earthquakes and tsunamis. In the earthquake, while buckling and fracturing of the bracing members and damage to the joints of reinforced-concrete members occurred, there was no noteworthy observation of damage to columns, beams or other major structural members. However, damage was found in the ceilings, exterior members and other non-structural steel members used in gymnasiums and theaters. To mitigate such damage, a technical standard was established that prevents the falling of ceiling members.

The effects of the Great East Japan Earthquake reached the Osaka Prefectural Government Sakishima Office Building, more than 700 km away from the disaster-stricken area of the earthquake. To that end, examinations were promoted of countermeasure against long-period seismic motions.

Among the tsunami-induced damage of the Great East Japan Earthquake, movement, washout, overturning and other similar damages occurred in steel-structure buildings as well as in reinforced-concrete and other buildings. Meanwhile, many examples were observed of the steel framing being left intact in spite of the collapse and washout of exterior members during the tsunami attack. (Refer to Photo 2) The lessons from this damage were reflected in the temporary guidelines for the design of tsunami evacuation buildings prepared by the government agency, on which additional studies are currently being conducted.

Fig. 1 Production of Steel Frames and Development of New Steel Products in Japan




Ceiling members fell due to earthquakes.


While exterior members were washed out, the building framing remained intact.


While exterior members were washed out and fracture of brace was found, the building structure remained intact.


While studs caused deformation due to collision of drifts, the building framing remained intact.

Photo 2 Earthquake- and tsunami-induced damages to steel-structure buildings in Great East Japan Earthquake

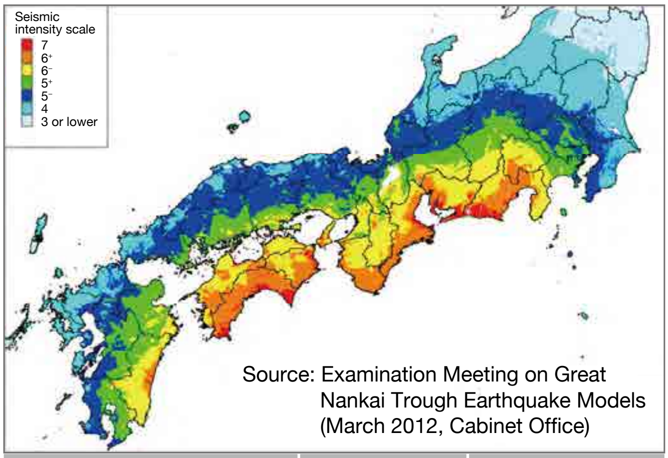
(Photos: Surveys of Great East Japan Earthquake in 2011 (Preliminary Report)—National Institute for Land and Infrastructure Management (Data No. 636), Ministry of Land, Infrastructure, Transport and Tourism; and Building Research Institute (Data No. 132))

Countermeasures against Disasters Forecasted to Occur in Future Great Earthquakes

In the future, several earthquakes are forecasted to occur in various regions of Japan. In order to mitigate the disasters that will be caused by these earthquakes, the Central Disaster Management Council of the Cabinet Office is promoting various response measures. The Council sets the protection of people's lives as its first priority based on the lessons learned from the Great East Japan Earthquake. The Council also estimates the levels of seismic motions and tsunamis that are forecasted to occur in future Nankai Trough Earthquake (Fig. 2), Tokyo Inland Earthquake and other mega-class earthquakes and the scale of the resulting disasters in order to reexamine countermeasures against such mega-class earthquakes.

In a report on the huge Nankai Trough Earthquake that is forecasted to occur in the near future, it is reported that disaster-mitigation effects will be brought about by promoting various disaster-prevention measures. Specifically, it is estimated that the number of completely-destroyed houses due to seismic vibrations will be reduced by about 40% in cases when the current rate of seismic-resistant housing construction at about 80% will be raised to 90%, and that the number of deaths due to tsunamis will be reduced by a maximum of about 90% in cases when early tsunami evacuation is successfully completed and tsunami evacuation buildings are effectively utilized.

Fig. 2 Profile of Strong Seismic Intensity Scales in the Great Nankai Trough Earthquake Forecasted to Occur in the Near Future



Source: Examination Meeting on Great Nankai Trough Earthquake Models (March 2012, Cabinet Office)

Attacked area	Current estimate (Cabinet Office, 2012)	Past estimate (Central Disaster Management Council, 2003)
Seismic intensity scale 6^- or high	About 71,000 km^2	About 24,000 km^2
Seismic intensity scale 6^+ or high	About 29,000 km^2	About 6,000 km^2
Seismic intensity scale 7	About 4,000 km^2	About 400 km^2

Seismic Designs in the Building Standard Law of Japan and Mechanical Properties Required for Steel Products

New Seismic Design Code

In the New Seismic Design Code introduced in the Building Standard Law and enforced in 1981, seismic design is to be done by checking seismic resistance of buildings according to two levels of seismic motions and scales (medium-scale earthquakes and great earthquakes). For medium-scale earthquakes (seismic intensity scale of 5^- on the seven-stage seismic intensity scale of the Japan Meteorological Agency), the aim of the New Seismic Design Code lies in that buildings do not suffer damage and that the structural members remain within their elastic range; for great earthquakes (seismic intensity scale of 6^+), the aim of the New Seismic Design Code lies in that building collapse is prevented in order to protect human life while a certain level of damage is allowed to occur in the structural members.

In particular, the New Seismic Design Code has been established based on the idea that during great earthquakes, damage to steel structural members is allowed (plasticization of structural mem-

Fig. 3 Energy Absorption during Great Earthquakes

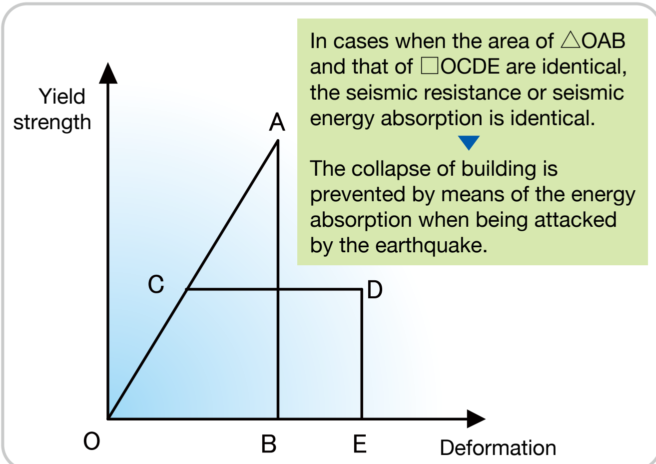


Fig. 4 Effects of Yield Point Deviation on Plasticization of Structural Members

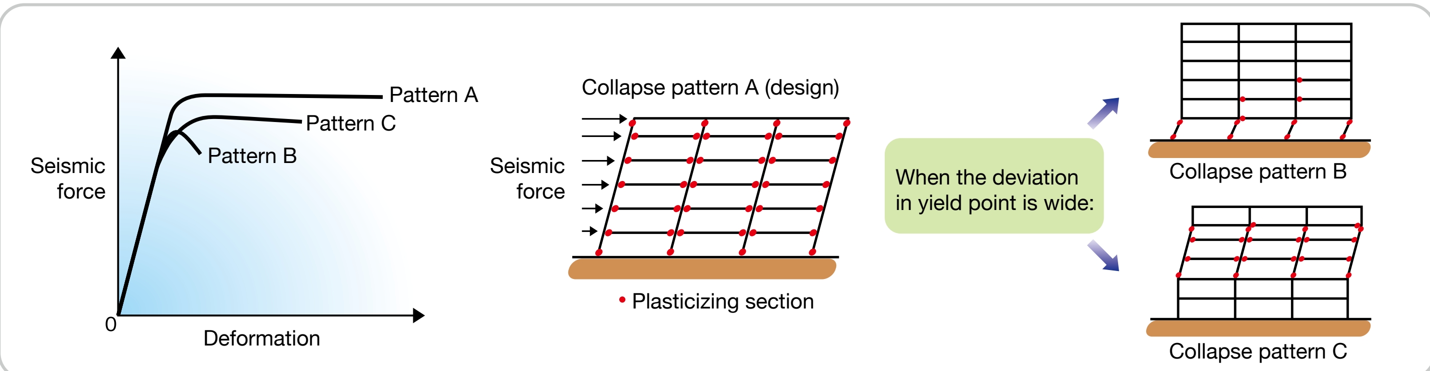
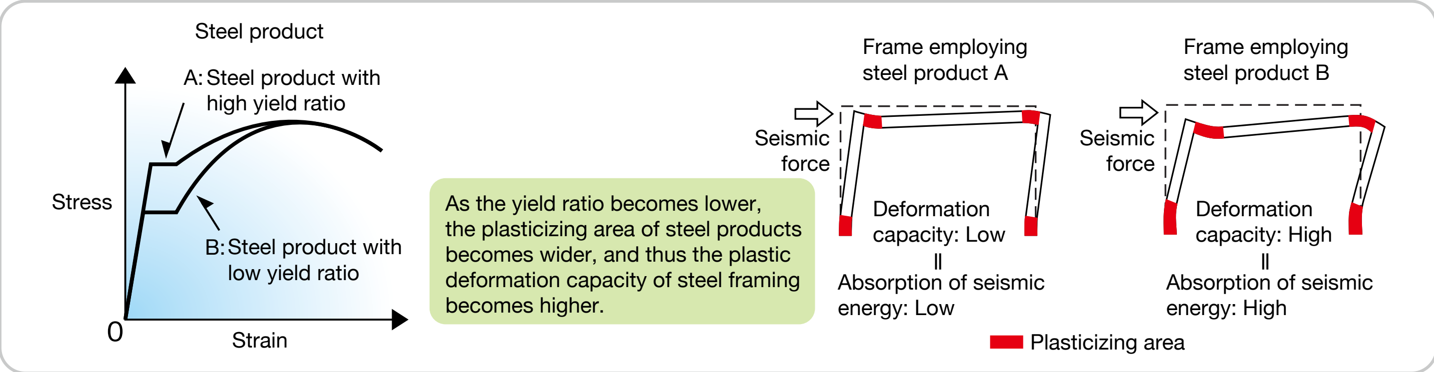


Fig. 5 Effects of Yield Ratio on Plastic Deformation Capacity of Structural Members



bers) but the collapse of buildings is prevented by absorbing the seismic energy through the ductile deformation of structural members (Fig. 3).

As regards steel-frame structures, specifications and detail design methods to prevent buckling and fracturing of joints are incorporated in the New Seismic Design Code so that the plastic deformation capacity originally possessed by the steel framing can be fully demonstrated.

Seismic Design of Steel-frame Buildings and Steel Products Applied

The New Seismic Design Code provides that the stress occurring in the steel members is designed to be maintained at a level lower than the yield point so that damage to the steel framing can be prevented during small- and medium-scale earthquakes, and that during great earthquakes building collapse is prevented by absorbing the seismic energy through the ductile deformation of structural members.

In order to attain the goal, structural steel products are required to possess a yield point and tensile strength higher than the commonly specified values. In addition, the following performances are required for steel products:

Firstly: Although the plasticizing parts are designed to be located in the targeted zones at a design stage, there are cases in which unexpected members plasticize or members that should plasticize remain non-plasticized because of large deviations in the yield point of the steel products, and accordingly the framing does not enter into the designed stage. In order to solve this problem, it is necessary to suppress the range of yield point deviation by setting the upper limit for the yield point as well as its lower limit. (Refer to Fig. 4)

Secondly: Generally the steel framing is designed to able to treat with seismic loads by utilizing the large deformation

Table 1 Mechanical Properties in JIS G3136 Rolled Steels for Building Structures (Reference: Corresponding specifications in EN, ASTM and JIS)

Designation	Yield point or strength	Tensile strength (N/mm²)	Yield ratio (%)	Elongation (%)	Charpy impact energy (J)
EN 10025-2 S355J0/J2	(16<t≦40 mm) Min. 345 (40<t≦63 mm) Min. 335 (63<t≦80 mm) Min. 325 (80<t≦100 mm) Min. 315	(t≦100 mm) Min. 470 Max. 630	–	(t≦40 mm) Min. 22 (40<t≦63 mm) Min. 21 (63<t≦100 mm) Min. 20 *Proportional test piece	(S355J0) 0°C/Min. 27 (S355J2) -20°C/Min. 27
JIS G3106 SM490B/C	(16<t≦40 mm) Min. 315 (40<t≦100 mm) Min. 295	Min. 490 Max. 610	–	(16<t≦50 mm) JIS # 1A: Min. 21 (40 mm<t) JIS # 4: Min. 23	(SM490B) 0°C/Min. 27 (SM490C) 0°C/Min. 47
JIS G3136 SN490B/C*	(16≦t≦40 mm) Min. 325 Max. 445 (40≦t≦100 mm) Min. 295 Max. 415	Min. 490 Max. 610	Max. 80	(16<t≦50 mm) JIS # 1A: Min. 21 (40 mm<t) JIS # 4: Min. 23	0°C/Min. 27
ASTM A572 Gr. 50	Min. 345	Min. 450	–	ASTM 8": Min. 18	–

*Through-thickness property of Z25 is specified.

Table 2 Chemical Composition in JIS G3136 Rolled Steels for Building Structures (Reference: Corresponding specifications in EN, ASTM and JIS)

Designation	Chemical composition (%)							
	C	Si	Mn	P	S	N	Cu	Ceq**
EN 10025-2 S355J0/J2	(16<t≦40 mm) Max. 0.20 (40 mm<t) Max. 0.22	Max. 0.55	Max. 1.60	(S355J0) Max. 0.03 (S355J2) Max. 0.025	(S355J0) Max. 0.03 (S355J2) Max. 0.025	(S355J0) Max. 0.012 (S355J2) –	Max. 0.55	(t≦30 mm) Max. 0.45 (30<t≦150 mm) Max. 0.47
JIS G3106 SM490B/C	(t≦50 mm) Max. 0.18 (50 mm<t) (B) Max. 0.20 (C) Max. 0.18	Max. 0.55	Max. 1.65	Max. 0.035	Max. 0.035	–	–	–
JIS G3136 SN490B/C	(t≦50 mm) Max. 0.18 (50 mm<t) Max. 0.20	Max. 0.55	Max. 1.65	(SN490B) Max. 0.030 (SN490C) Max. 0.020	(SN490B) Max. 0.015 (SN490C) Max. 0.008	–	–	(t≦40 mm) Max. 0.44 (40 mm<t) Max. 0.46
ASTM A572 Gr. 50	Max. 0.23	Max. 0.40	Max. 1.35	Max. 0.040	Max. 0.050	–	–	–

**Weldability index
EN Ceq=C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15
JIS Ceq=C+Mn/6+Si/24+Ni/40+Cr/5+Mo/4+V/14

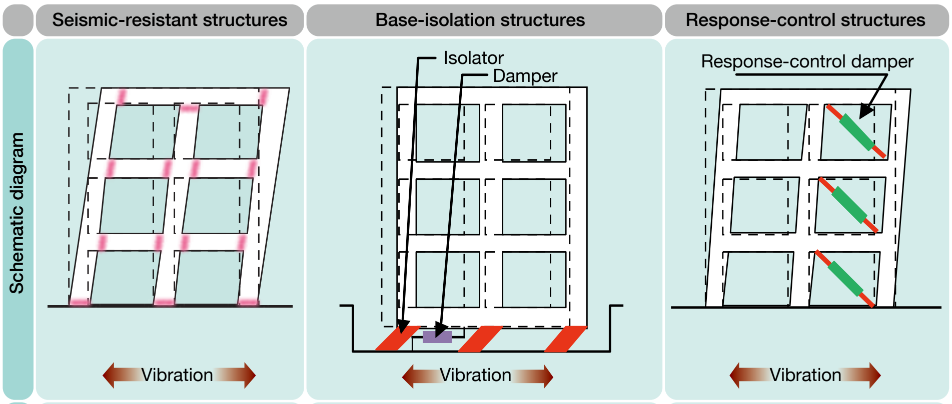
capacity of steel members, but the plasticizing area of part of steel framing members becomes narrow in the case when the yield ratio (ratio of yield strength to tensile strength) is high, and accordingly the sufficient and expected deformation capacity of members and framing cannot be displayed. To overcome this drawback, it is necessary to set the upper limit for the yield ratio of steel products. (Refer to Fig. 5)

As a steel product that meets not only the above-mentioned requirements but also has favorable weldability, the SN (new structure) steel product was standardized in JIS in 1994. It is specified as JIS G3136 (Rolled Steels for Building Structures) that is applied exclusively for building construction. The kind of steel products available in SN steel products are plates, strips, shapes and flat steels, for which two levels of strength are set: 400 N/mm^2 and 490 N/mm^2. (Refer to Tables 1 and 2)

◆

The concept mentioned above describes the technical manner to secure the performances required for steel products used in seismic design and for seismic-resistant structures as well. In addition to seismic-resistant structures, new aseismic structural types called base-isolation structures and response-control structures have increasingly been applied. When applying such new structural types, it has become possible to widely reduce the damage to structural members such as columns and beams even during great earthquakes. (Fig. 6)

Fig. 6 Seismic-resistant, Base-isolation and Response-control Structures



	Seismic-resistant structures	Base-isolation structures	Response-control structures
Features	During great earthquakes, the seismic energy is absorbed by allowing damage to the building frame in order to prevent collapse of the entire building from occurring.	Structures in which isolators (laminated rubber) and dampers are installed between the building structure and the foundation structure. Vibrations of the building structure during earthquakes are greatly mitigated by making the building's natural period longer by introducing isolators and by improving the damping performance of the building by the use of damping devices.	Structures in which response-control dampers (buckling-restraint braces etc.) are installed in the building structure. Vibrations of the building are mitigated and damage to columns and beams is also mitigated solely by absorbing the seismic energy by the use of dampers.

Design Standards for Tsunami Evacuation Buildings and Proposal for Tsunami-resistant Steel Structures

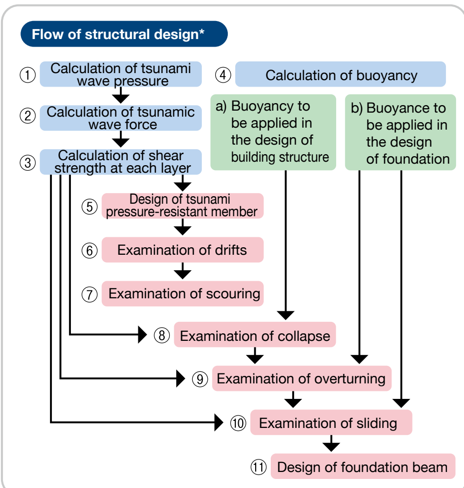
Guidelines for Structural Design of Tsunami Evacuation Buildings

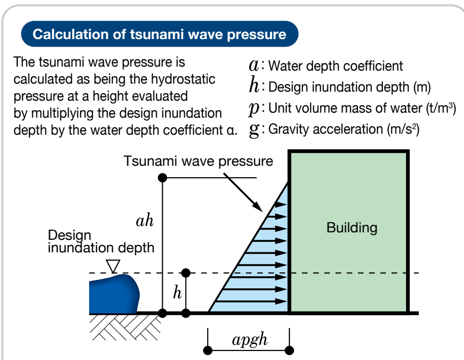
As regards tsunami evacuation buildings, the *Guidelines concerning Tsunami Evacuation Buildings* was presented by the Cabinet Office in 2005. Then, based on survey results of the disasters that occurred in the Great East Japan Earthquake of 2011, the technical standards for tsunami evacuation buildings were established—temporary guidelines (Notification No. 1318 of the Ministry of Land, Infrastructure, Transport and Tourism in 2011), and a separate attachment (New Guidelines: Notification No. 2570 of Director-General of Housing Bureau, Ministry of Land, Infrastructure, Transport and Tourism in 2011).

In these technical standards, the restrictions by applicable structural type that were limited to the reinforced-concrete structures and steel-reinforced concrete composite structures in the above-mentioned Cabinet Office's Guidelines were abolished, and the performance specifications required for tsunami evacuation buildings were clarified. These performance specifications now cover steel structures in addition to reinforced-concrete structures and steel-reinforced concrete composite structures.

Further, in computing the tsunami wave pressure and force, a wave-force reduction coefficient was introduced that facilitates the rational assessment of external forces conforming with the practical conditions of structural plans, such as whether or not a barrier is installed in the peripheral area of a building or if a pilotis structure is adopted for the building. At the same time, in order to enforce the stricter examinations of the structural calculations that are made to prevent overturning and sliding of buildings during tsunamis, the buoyancy of buildings was recommended to be taken into account. (Refer to Fig. 7)

Fig. 7 Structural Design Method for Tsunami Evacuation Buildings





	Barriers reside in-between		No installation of barriers
Distance from coast of sea, river, etc.	500 m or longer	500 m or shorter	Not applicable
Water depth coefficient α	1.5	2	3

*Examples of design of tsunami evacuation buildings based on the *New Guidelines* are published in the following website:
The Japan Building Disaster Prevention Association: Opening of "Commentary on Structural Requirements for Tsunami Evacuation Buildings and Other Structures"
http://www.kenchiku-bosai.or.jp/seismic/tsunami_text.html

Proposal of Tsunami-resistant Steel Structures

To cope with emerging needs, the Japan Iron and Steel Federation is promoting proposals to construct various types of facilities employing "New Structural System Buildings Employing Innovative Structural Materials" that can withstand huge tsunamis and were initially designed and developed with the aim of preventing damage to building structures even when attacked by a great earthquake of a seismic intensity scale of 7 (Fig. 8). The intended application of "New Structural System Buildings" ranges from town block facilities, restoration housing and distribution centers to disaster-prevention bases to be built by the use of the pilotis structures employing concrete-filled steel tubes (Fig. 9).

Fig. 8 "New Structural System Buildings Employing Innovative Structural Materials"

1) No damage even when attacked by an earthquake with a seismic intensity scale of 7

- Avoiding plasticization of building framing by the use of high-strength steel H-SA700 having a tensile strength twice that of conventional steel and response-control mechanism as well
- Maintaining the main structural section intact when attacked by an earthquake with a seismic intensity scale of 7 so as to protect human life and to secure continued business operations after experiencing a disaster

2) Structural planning to resist to huge tsunamis

- Securing the structural safety against huge tsunamis and their backwashes by means of the "New Structural System Buildings"
- Enhanced tsunami measures, reduced tsunami pressure by minimizing the column size and reduced number of columns and raising an entire town block by the use of high-strength steel framing

3) Buildings with longer service life

- Flexibility to allow future change in planning by adopting a skeleton-infill (SI) design, in which a building structure and its exterior-interior structures and equipment are designed as separate structures, as well as by adopting large spanning for framing structure
- Easy restoration of damaged buildings by adopting the exterior/interior members and equipment design in which these members and equipment are designed to be renewed

4) Resources savings

- Realization of environmentally-friendly buildings by adopting high strength steel, which can lead to the reduction in the total weight of steel framing and in CO_2 emissions
- Easy reuse and recycling of steel products by adopting SI design

Important facilities on raised town block

In order to protect the building from great earthquakes and huge tsunamis, the entire town block is raised, in which the upper area accommodates high-function administrative and reginal disaster-prevention functions, and the lower area houses a parking lot and rental space

Restoration housing on raised town block

Raised town block is developed using "New Structural System Buildings Employing Innovative Structural Materials," in which the lower area houses existing commercial and business facilities as well as newly-located commercial facilities, and the upper area accommodates multi-storied residential buildings constructed as they encircle a refuge square.

Distribution center

Distribution center with mixed three-dimensional arrangement of plants and offices capitalizing on high ceiling heights and large spans and with floors that are easily accessible by cars using two ramps

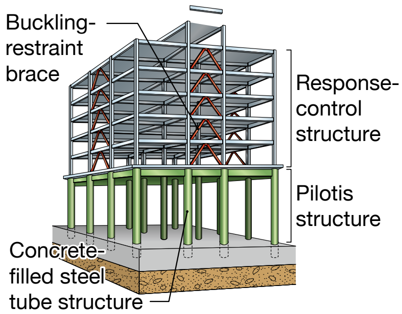
Fig. 9 Proposal of Tsunami Evacuation Facilities Employing Steel Structures

Tsunami evacuation tower

- Realization of lightweight building frame with high seismic and tsunami resistance that is enabled by the use of square steel tube-H shape structures
- Tower framing, configuration and height that conform to tsunami height (inundation depth) and the number of evacuees

Building serving as disaster-prevention building

- Adopting a pilotis structure with a height surpassing the assumed tsunami height to avoid tsunamis thrust
- Adopting CFT columns with high yield strength and rigidity
- Adopting response-control structures in which buckling-restraint braces are installed so as to improve the seismic-resistant performance of buildings
- Lightweight buildings by the use of steel structures that can result in less seismic force applied to pilotis structures



■ "Building National Resilience" Initiatives and the Japanese Steel Industry

Many great earthquakes such as the Great East Japan Earthquake of 2011 have occurred in Japan, causing serious damages nationwide. Based on the experience of these earthquakes, the Japan Iron and Steel Federation has promoted surveys and research on steel structures conducive to securing earthquake and tsunami safety under tie-ups with related industrial organizations. As seen in serious accidents represented by the ceiling collapse on the Chuo Expressway in December 2012, social infrastructures in Japan are facing the problem of ongoing superannuation. In order to meet such situations, the "Building National Resilience" initiative is becoming a pressing task for Japan.

By capitalizing on the steel-structure technologies thus far fostered in the Japanese steel industry and enhancing cooperative relations with related organizations, the Japan Iron and Steel Federation is promoting contributions to the establishment of countermeasures against earthquake, tsunami and other natural disasters and to the "Building National Resilience" initiatives being tackled by national and local governments. ■

Basic Particulars in Structural Design of Tsunami Evacuation Buildings

by Kenzo Taga, Professor, Kobe University

Kenzo Taga: After graduating from Osaka University, he entered Nikken Sekkei Ltd. in 1979. He assumed his current position as Professor, Graduate School of Engineering, Kobe University in 2011. Among the major works in which he was involved are Terminal Building of Kansai International Airport, Kobe Daimaru Department Store, Kansai Electric Power Building and Osaka Lawyers' Hall.

The Great East Japan Earthquake that occurred March 11, 2011 was a mega earthquake with a magnitude of 9.0.

While the damage to buildings due to seismic motion was comparatively little, most of the damage to human life and buildings was brought about by the tsunamis, which clearly displayed their destructive and terror-inducing power. Steel-structure buildings suffered diverse damages from the tsunamis—collapse, overturning, scouring, the loss of exterior and interior members due to water flow and many others (Photos 1~5).

Triggered by these damages, the Institute of Industrial Science of The University of Tokyo and the Building Research Institute began surveys and research on tsunami loads, which led to a working out of temporary guidelines for the design of tsunami evacuation buildings in November 2011 by the Ministry of Land, Infrastructure, Transport and Tourism. These were the *Temporary Guidelines concerning Structural Requirements for Tsunami Evacuation Buildings Based on Tsunami-induced Building Damages in the Great East Japan Earthquake (New Guidelines)*, a separate attachment of *Additional Knowledge (Technical Advice) concerning Design Methods for Buildings That Are Structurally Safe against Tsunamis*[1]. Information on the design of tsunami evacuation buildings thus released has been given to local governments via the Ministry.

In the *Guidelines concerning Tsunami Evacuation Buildings* (released by the Cabinet Office in June 2005), the tsunami load (the force and pressure working on a building due to tsunami) is uniformly set at the hydrostatic pressure three times the inundation depth. However, it has recently been assessed that the tsunami load is reduced by whether or not shelter exists and that it differs depending on the distance from the coast or a river, and thus the tsunami load thereby established has rationally been modified.

Tsunami Loads

The horizontal load adopted in the structural design of buildings is generally composed of the seismic load and the wind load. At first, the feature of tsunami loads is examined in comparison with that of seismic load and wind load.

Photo 1 Steel-structure building destroyed by tsunamis

Photo 2 Steel-structure building with which drifts (ship) collided

Photo 3 Building that overturned due to tsunamis

Photo 4 Building that inclined due to scouring

Photo 5 Steel-structure building where exterior and interior members were washed away by tsunamis

- Any seismic, wind or tsunami load is a dynamic loading effect, and in structural design, they are substituted for the equivalent static load to allow simple design work.
- The seismic force is an inertial force and is largely affected by the mass. On the other hand, it can be said that the wind and the tsunami, called the liquid force, are largely affected by the size of the tsunami pressure-receiving area and the configuration of the buildings. Accordingly, when the tsunami load is examined in a comparison of the horizontal load that is dominant for low- and medium-rise buildings, it is easily assumed that the effect of the tsunami load will become larger for lightweight steel structures than for heavyweight reinforced-concrete structures. As the design inundation depth becomes deeper, the effect of the horizontal load due to buoyancy and tsunamis on a building becomes larger. To cope with such a trend, there seem to be increasing cases in which non-tsunami pressure-resistant members (members that are subjected directly to tsunami wave pressure and are expected to break) are arranged as exterior members and a pilotis structure is adopted as a practical measure to mitigate the effect of tsunami loads.
- As the story height increases, the seismic load and the wind load become high. But the tsunami load is assessed using the equivalent hydrostatic pressure that becomes larger as the story height lowers. If the total horizontal load is identical, it can be understood that the overturning moment due to the tsunami load is relatively small. In cases when a pilotis structure is adopted at the first-story, it can be conceived that the tsunami load can greatly be reduced and the pilotis structure can efficiently work as a countermeasure against sliding. In this way, effective and appropriate measures to mitigate the tsunami load can be taken by understanding the feature of the height-direction tsunami load distribution profile. Meanwhile, as regards the effect of drifts, it is necessary to make separate examinations.

In the following, an outline of a quantitative assessment of tsunami loads is shown by quoting from the *New Guidelines*.

Fig. 1 Tsunami Wave Pressure

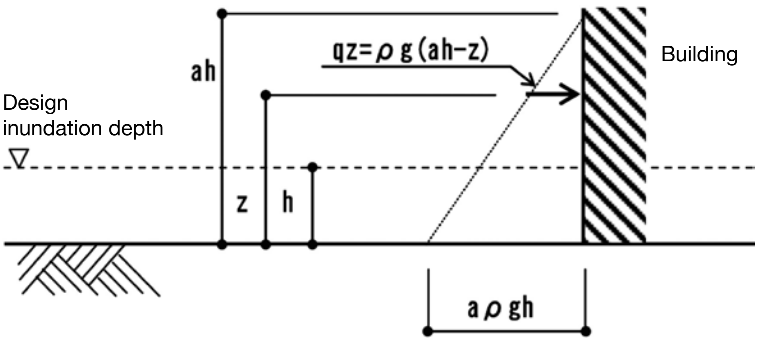
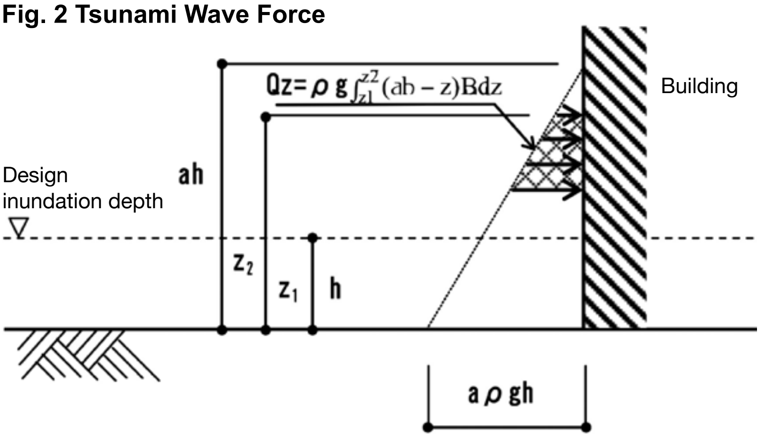


Fig. 2 Tsunami Wave Force



• Tsunami Wave Pressures

The tsunami wave pressure shall be the hydrostatic pressure distribution obtained by multiplying the design inundation depth by the water depth coefficient *a*, and it is specified that the numerical value 3 conventionally applied is basically adopted as the water depth coefficient; the numerical value 2 can be adopted in cases where an effective shelter is installed; and the value 1.5 can be adopted in cases where the structure is separated from the coast or a river by 500 m or more. (Refer to Fig. 1)

From the standpoint of convenience for design work, it is specified that the tsunami load is assessed by use of the equivalent hydrostatic pressure. Meanwhile, in the *Recommendations for Loads on Buildings (2015)* of the Architectural Institute of Japan, a chapter pertaining to the tsunami load is newly provided where the tsunami load that works on a building is classified into three conditions depending on the time-dependent change in which the tsunami works on the building: tsunami load on the tsunami tip section, that on the non-tip section, and that at the still water stage, and the method is shown in which the tsunami load is calculated from the inundation depth and the velocity in these three conditions.

• Tsunami Wave Forces

The tsunami wave force is calculated by integrating the tsunamic wave pressure on the tsunami wave force-receiving area.

The running-direction tsunami wave force for use for structural design is calculated by assuming that the tsunami wave pressure shown in the tsunami wave pressure calculation formula simultaneously occurs and integrating the tsunamic wave pressure on the tsunami wave force-receiving area. (Refer to Fig. 2)

• Reduction of Tsunami Wave Force due to Openings

In cases when openings are provided that are composed of structural members to be destroyed by the tsunami wave pressure (non-tsunami pressure-resistant members), the tsunami wave pressure can be reduced to a range that does not fall short of 70% of the tsunami wave force calculated in the case of no provision of openings.

- **Effect of a Pilotis Structure on Reduction of Tsunami Loads**

As regards a pilotis structure, the tsunami wave loads can be calculated on the condition that the tsunami wave pressure works only on columns, beams and other tsunami pressure-resistant members of the pilotis structure.

- **Directions of Tsunami Horizontal Loads**

It is assumed that the horizontal load of tsunamis occurs from every direction. However, in the case when the running direction of tsunamis can be assumed from the forecasted inundation distribution profile obtained by means of simulations and the configuration of coastal lines, this shall not apply to the above-mentioned assumption. Further, depending on the actual tsunami conditions, the tsunami horizontal load is examined by taking into account the effect of tsunami backwashes.

- **Buoyancy**

While the buoyancy generated by tsunamis basically corresponds to the buoyancy of the volume of the building section that is inundated, it can be calculated by taking into account the water flowing-in from the opening in conformity with the rise of the water level. Meanwhile, in cases when the flowing-in of tsunamis into a building's interior is unclear, it is accepted as desirable that the safer design be made by taking into account at the stage of design of structural framings the buoyancy that is calculated on the condition that water will flow into the building's interior, and at the stage of discussion about the overturning and sliding of buildings the buoyancy that corresponds to the submerged building volume (including the volume of the inner space). (Refer to Fig. 3)

Basic Concepts for Structural Design of Tsunami Evacuation Buildings

- **Design of Tsunami Pressure-resistant and Non-tsunami Pressure-resistant Members**

In the structural planning of buildings resistant to tsunami load, the tsunami pressure-resistant members (members that are subjected directly to tsunami wave pressure and designed not to break) and the non-tsunami pressure-resistant members (members that are subjected directly to tsunami wave pressure and expected to break) are clearly distinguished from each other, and then arranged in the building structure.

The strength of tsunami pressure-resistant members is designed so that the strength does not reach the ultimate strength even when attacked by tsunamis and that the tsunami wave force received by the member can surely been transferred to the structural framing. Further, care should be taken to the water cutting-off performance of each member if the need arises.

It is tolerated that non-tsunami pressure-resistant members can break with no damage to the structural framing.

- **Design of Structural Framing**

It is confirmed that the horizontal strength of the structural framing exceeds the horizontal load of tsunamis in every direction and at each story. Further, the strength of tsunami pressure-resistant members that also serve as the member of structural framing is designed so that the strength does not reach the ultimate strength vis-à-vis not only the tsunami load but also the load that combines other loads when the need arises.

- **Examinations of Overturning and Sliding**

It is confirmed that the building will not overturn or slide due to the tsunami load, taking into account its buoyancy and dead weight (for the piling foundation, the pull-out force does not surpass the pull-out resistance.)

- **Scouring**

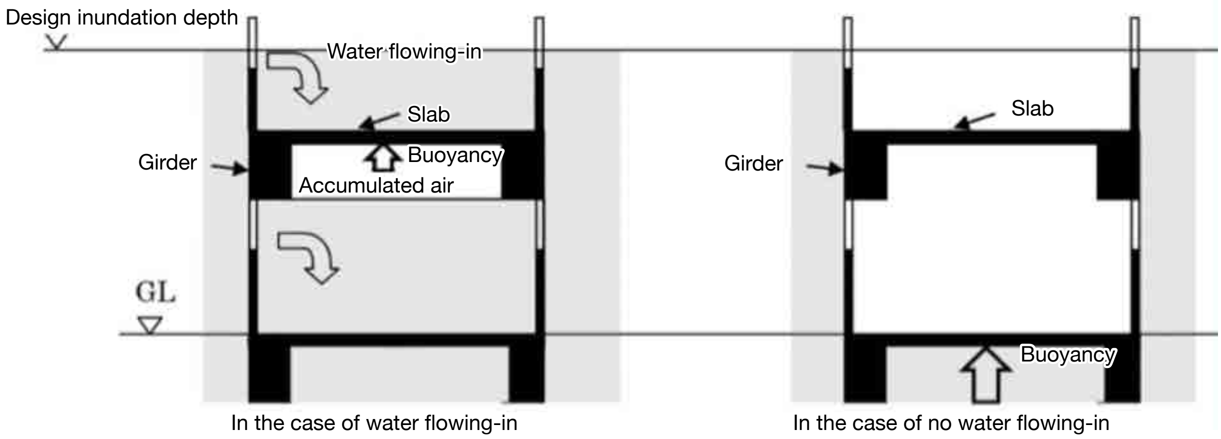
A pile foundation is adopted by taking into account the occurrence of scouring, or in the case of adopting a spread foundation, measures are taken that prevent tilting of the foundation due to scouring.

- **Collision of Drifts**

Taking into account the damage that occurs due to the collision of drifts, it is confirmed that the structurally important sections do not collapse due to the collision of drifts, or that, even if some columns and bearing walls are damaged due to the collision of drifts, the entire building structure does not collapse.

Research is underway on the assessment of the collision force of drifts on buildings, and thus it is currently difficult to precisely calculate the collision force of every kind of drift. Further, in order to confirm that a building does not collapse due to the collision of drifts, it will be necessary to assume not only the kind, amount, size, configuration, weight, collision speed and collision direction of the drifts that will collide with the building but also the building section that is collided by drifts; but in most cases, it will generally be difficult to assume such diverse collision factors. To these ends, it will be important to construct buildings with sufficient redundancy so that an entire building structure does not easily collapse by separately adding a structure that protects the building periphery section or even when the peripheral section causes local collapse. (Refer to Fig. 4)

Fig. 3 Concept for Buoyancy



Directions in Tsunami-resistant Design Employing Steel Structures

The ratio of tsunami load to horizontal strength, required in seismic design, is highly likely to become larger for a lightweight steel structure than for a heavyweight reinforced-concrete structure.

The essential factor in the design of a steel-structure tsunami evacuation building is that such a building be appropriately planned and designed after gaining a full understanding of the features peculiar to the lightweight steel structures mentioned above.

• Horizontal Resistance

In seismic design in Japan, the allowable stress design for temporary loading is adopted for a medium-scale earthquake, and the ultimate strength design for a great earthquake. In this way, both elastic design and elasto-plastic design are generally adopted in the seismic design depending on the load level. The elastic design means that the building structure returns to its original state with no damage after an earthquake, and the elasto-plastic design allows such conditions as the occurrence of damage and residual deformation in a building.

In cases when the plastic design is adopted to treat tsunamis, there is a high possibility that structural safety after an earthquake and against aftershocks cannot be retained. To remedy such a situation, one effective countermeasure is that the horizontal load-bearing capacity of a building is raised by applying ultra-high strength steel products in order to improve the steel-structure building's resistance to the seismic load and the tsunami load. (Refer to Fig. 5)

• Buoyancy and Measures for the Overturning and Sliding of Buildings

If the water does not penetrate into the building, the buoyancy that corresponds to the building volume will work on the building. Further, in cases when a building is inundated through its exterior wall and open sections, if air accumulates in the section surrounded by beams and slabs, the buoyancy corresponding to the accumulated air works on the building. To this end, in contrast to a heavyweight reinforced-concrete structure, a lightweight steel structure is apt to float, and thus overturning and sliding are likely to occur.

To improve such a situation, it is feasible that the inundation level of the building is structured using the pilotis system and that the building finishing members are forcibly collapsed to cause inundation in order to reduce the buoyancy as much as possible. It has been known from past earthquake damage examples that, when the rigidity and strength of a pilotis structure become insufficient in terms of seismic design, the building suffers concentrated damages. Accordingly, due care should be paid to the adoption of a pilotis structure in seismic design. In cases when a pilotis structure is adopted as a countermeasure against tsunamis, the most important precondition is of course to secure sufficient seismic resistance.

When applying a steel structure in the construction of tsunami evacuation buildings, if the column bases and connections are appropriately designed, the advantageous toughness peculiar to steel products is fully demonstrated. In addition, steel structural members are slim, and in terms of the tsunami pressure-receiving area, an important element in seismic resistance, the area of steel bracing is smaller than that of a reinforced-concrete bearing wall, which allows the reduction of the tsunami load itself. To this end, it is feasible that steel pilotis structures effective in tsunami-resistant structural design are easily put into practical use.

As far as the overturning and sliding of buildings due to tsunamis are concerned, a countermeasure can be conceived in which steel piles are used. As a measure to prevent overturning in particular, it will be appropriate to adopt steel piles having high pull-out resistance. ■

Fig. 4 Collision of Drifts

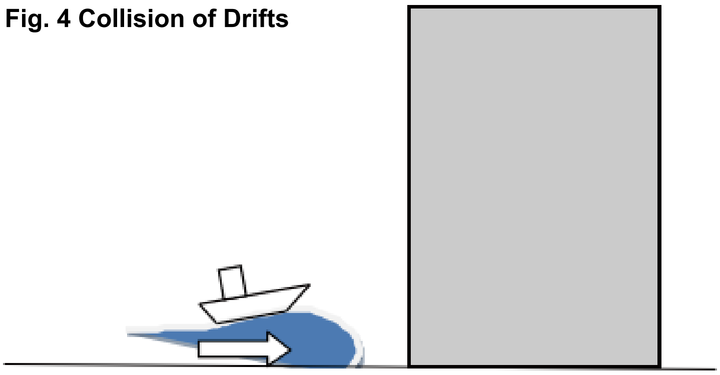
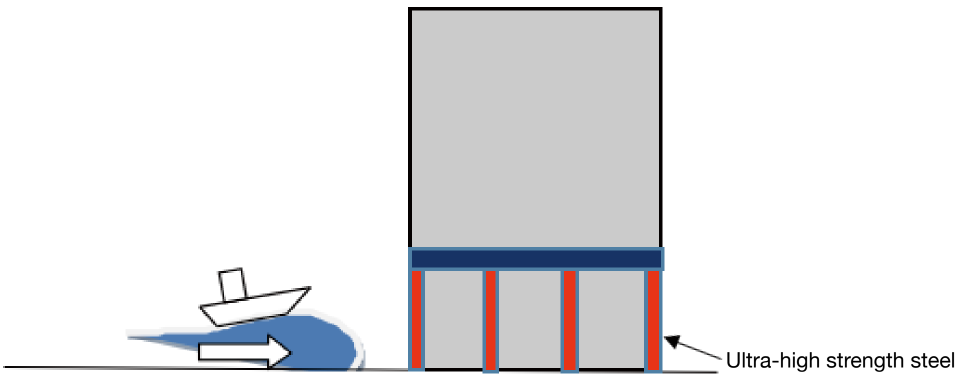


Fig. 5 Image of Application of Ultra-high Strength Steel



Reference

1) Additional Knowledge (Technical Advice) concerning Design Methods for Buildings That Are Structurally Safe against Tsunamis: Notification No. 2570 of Director-General of Housing Bureau, Ministry of Land, Infrastructure, Transport and Tourism (November 17, 2011) (Separate attachment)
Temporary Guidelines concerning Structural Requirements for Tsunami Evacuation Buildings Based on Tsunami-induced Building Damages in the Great East Japan Earthquake (New Guidelines)

Improvement of Tsunami Evacuation Facilities in Sendai City

by Masaru Fukurai
Disaster Prevention Planning Section, City of Sendai Crisis Management Department

Huge Tsunamis Attack Sendai City

In the Great East Japan Earthquake of 2011, huge tsunamis with a maximum height of 7.1 m attacked the coastal area of Sendai City in Miyagi Prefecture. They inundated an area of more than 45 km^2 and caused a heavy loss of life amounting to more than 700 victims (Photos 1 and 2).

Having learned from such tsunami disasters, the Sendai City Office has been tasked with the mission "how to protect human life from tsunamis," setting it as a major pillar of the city's reconstruction plan. Under the concept of a multi-faceted defense, diverse countermeasures against tsunamis are being promoted in Sendai City. Among the hardware measures are:

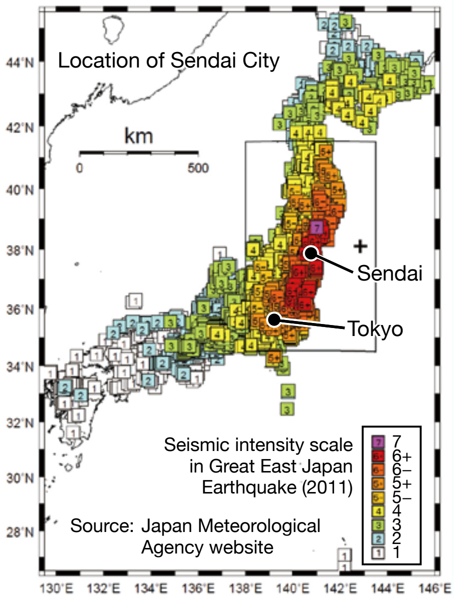
- Improvement of coastal and river banks and of coastal disaster-prevention forests
- Measures to control tsunami disasters by raising road levels
- Improvement of tsunami evacuation towers and other evacuation places and evacuation routes so that citizens can smoothly evacuate from tsunami attacks
- Mass movement of residential areas with a high risk of suffering a tsunami disaster

In addition, an evacuation plan by area has been worked out, and repeated training exercises for tsunami evacuation have been implemented (Photo 3), thereby promoting comprehensive countermeasures against tsunamis in terms of both hardware and software.

Building Plan for Tsunami Evacuation Facilities in Sendai City

As one of these tsunami countermeasures, the Sendai City Office plans to build new tsunami evacuation facilities in 13 different locations so that citizens living in the coastal area can escape a tsunami by foot. Specifically, the plans call for the construction of tsunami evacuation towers at 6 sites, evacuation buildings attached to the volunteer fire corps branch station at 5 sites, and evacuation stairs to the rooftops of 2 existing primary and junior high-school buildings.

In the improvement of these new tsunami evacuation facilities, it was necessary to take diverse factors into account—the wide flat area and relative unavailability of high-rise buildings to be used for evacuation peculiar to Sendai City, and the time required for the tsunamis to arrive. To that end, a committee has been established that is comprised of learned persons and representatives of the residents in coastal areas. A full examination has been made regarding evacuation methods and evacuation facility requirements that would allow for the quick and sure evacuation of citizens, which has led to the establishment of the tsunami evacuation facility standards of Sendai City.



Further, exchanges of opinion with local residents have repeatedly been made, and the proposed opinions have been carefully examined one by one. The results thus obtained have been fully reflected in the improvements of the tsunami evacuation facilities—installation of exterior walls as a countermeasure against cold weather and the provision of ramps to be used for aged persons and wheelchair users to safely evacuate.

Photo 1 In the Great East Japan Earthquake, huge damage was brought about by tsunamis, not by seismic forces.

Photo 2 Tsunami attacked condition at the Arahama Primary School, where 350 people were forced to evacuate

Photo 3 Tsunami evacuation training for citizens has been repeatedly implemented in Sendai City.

Photo 5 A study tour to the Nakano 5-chome Tsunami Evacuation Tower was conducted during the UN World Conference on Disaster Risk Reduction (2015 Sendai Japan)

Full-scale Tsunami Evacuation Tower

The Nakano 5-chome Tsunami Evacuation Tower, the first of its kind constructed in Sendai City, is a two-story steel-structure tower. It has a total floor area of 398 m^2, is equipped with exterior stairways and ramps and is capable of accommodating 300 persons during tsunami evacuation in the interior section of the second floor (6.6 m aboveground) and on the rooftop (9.9 m aboveground). The tower is designed as a rigid structure that can withstand ground liquefaction caused by earthquakes, the wave force of tsunamis and the collision of tsunami drifts. (Refer to Photo 4 and Fig. 1)

The second-floor evacuation space is designed as an enclosed floor surrounded with exterior walls and covered with a roof, taking into account the possibility of hypothermia during intense cold, thus containing necessary countermeasures against the cold. Inside the room, partitioned accordion curtains have been installed so that privacy can be assured. Further, at both sides of the room, retractable benches have been arranged to meet the need for a long-term stay. As countermeasures against power failure, it is now possible to generate electricity employing solar power panels installed on the rooftop and a cassette gas-type power generator.

In order to meet the need for a stay of about 24 hours, emergency provisions, drinking water, gas stoves, blankets, simple toilet devices and other necessities have been stocked in the tower. In addition, in order to secure communications during a disaster, an emergency wireless set for use for disaster-prevention administration has been installed.

Tsunami Evacuation Tower Gains Much Attention

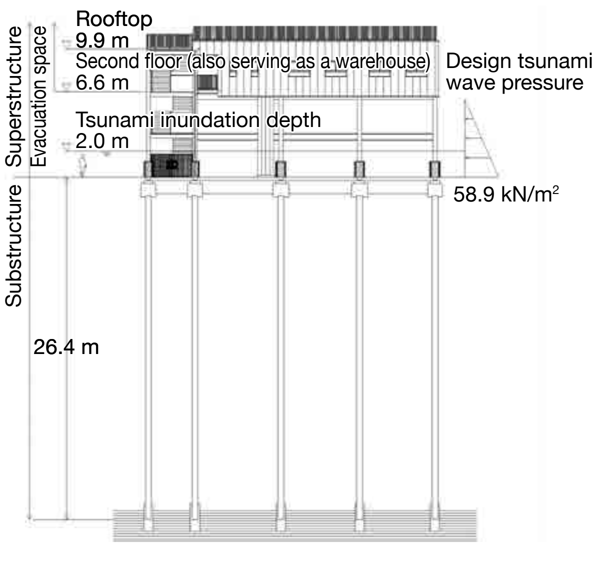
A visit was made to the Nakano 5-chome Tsunami Evacuation Tower as part of a study tour during the UN World Conference on Disaster Risk Reduction (2015 Sendai Japan) held in March 2015 (Photo 5). The tower has attracted much attention not only in Japan but abroad, and many interested persons visit the tower for observation. The Sendai City Office not only introduces this tower as an effective means to prevent tsunami disasters that was developed based on lessons learned from the Great East Japan Earthquake, but also is highlighting the importance of tsunami evacuation during earthquakes.

♦♦♦

Firmly establishing the Nakano 5-chome Tsunami Evacuation Tower as a landmark for tsunami evacuation, we at the Sendai City Office are promoting measures to disseminate an alarming message regarding tsunami disasters—they are likely to occur again in the future and many more lives must be protected from future tsunami attacks. ■

Photo 4 Two-story steel structure Nakano 5-chome Tsunami Evacuation Tower developed and constructed in Sendai City

Fig. 1 Elevation of Nakano 5-chome Tsunami Evacuation Tower



Framing-type and Simple Multi-use Building-type Tsunami Evacuation Facilities

Nippon Steel & Sumikin Metal Products Co., Ltd.

In Japan, huge earthquakes such as the Tokai Earthquake, Tonankai Earthquake and Nankai Earthquake are forecasted to occur in the near future. Given this situation, improvements of tsunami evacuation facilities started in 2004 in Shizuoka Prefecture, Mie Prefecture, Wakayama Prefecture, Tokushima Prefecture and other prefectures that are likely to suffer tsunamis associated with such large-scale earthquakes. Further, triggered by the Great East Japan Earthquake of 2011, improvements of tsunami evacuation facilities are being promoted nationwide.

Tsunami Evacuation Facility of the Steel Tube Column-H Shape Structure Type

In the Great East Japan Earthquake, the Sendai Works of Nippon Steel & Sumikin Metal Products Co., Ltd. was attacked by tsunamis, and it took nearly one year to resume operations of the tsunami-damaged works. During this process, employees proposed to construct a full-scale tsunami evacuation facility at the works. To this end, based on the latest national design guidelines for tsunami evacuation facilities—*Additional Knowledge (Technical Advice) concerning Design Methods for Buildings That Are Structurally Safe against Tsunamis*—and the request of employees who experienced the tsunamis, the company has promoted the development of tsunami evacuation towers. The latest development is a tsunami evacuation tower that uses columns employing square steel tubes and beams employing H-shapes (Photo 1) for its structural members; members that remained intact even after being subjected to the attack of past tsunamis.

Since 2012, improvements have been made to the tsunami evacuation towers based on the tower thus far developed, and this has led to the construction of a total of 20 towers (including a tower installed at the company's Sendai Works) as of March 2016.

Safety and Security Required for Tsunami Evacuation Towers

Needless to say, it is necessary for tsunami evacuation towers to possess a high level of structural safety that can indisputably resist both seismic motions and tsunamis. Specifically, it is required for these towers to provide not only measures to treat the common horizontal force (wave force) of tsunamis but also countermeasures against drifts, overturning, sliding and scouring that are peculiar to tsunami. That is, it is important to secure the safety of both the aboveground structure and the underground structure.

Further, from the aspect of tower safety, it is indispensable to provide such measures as:

- Rapid, sure evacuation of evacuees from the ground to the evacuation floor
- Prevention of evacuees falling from the evacuation floor
- Responsiveness to the receipt of unforeseen evacuees

In addition, once people evacuate from a tsunami, it is highly likely that they will need to stay in the evacuation tower for a certain period, during which due care must be paid to security and to safety, including:

- Securing protection against rain/wind and heat/cold during their stay
- Mitigating uneasiness about darkness at night and loss of communications
- Securing water and food stockpiles

Framing-type and Multi-use Tsunami Evacuation Facilities

Various types of tsunami evacuation facilities can be constructed depending on the number, age and sex of the target evacuees, site conditions, residents' requests, construction budget and other terms. When examining the recent record of construction, tsunami evacuation facilities are undergoing the following evolution, along with an expansion of the area requiring those evacuation facilities and an increasing need for more effective utilization:

- Framing-type evacuation towers without a roof or walls to be built in warm areas→Evacuation towers with roof and walls to be fixedly built in cold areas in Tohoku and other regions→Simple, multi-use evacuation buildings to be built based on the evacuation tower

Because the Nakano 5-chome Tsunami Evacuation Tower that was completed in Sendai City and introduced on the previous pages is a tsunami evacuation tower with roof and walls, three examples of representative framing-type tsunami evacuation towers and simple, multi-use tsunami evacuation buildings are introduced in the following:

Steel tube column-H-shape structure in which square steel tube is used for column and H-shape for beam

• Mihominami Tsunami Evacuation Tower (Framing Type)

This tower was constructed in Miho, Shizuoka Prefecture. It is a two-story steel-structure tsunami evacuation tower having an evacuation floor of 370 m^2 on its roof where about 740 persons can evacuate. Because the construction site is located in a park with ponds and trees and over underground piping, the tower is designed as three independent structures: a structure that supports the evacuation space, a structure that supports the stairway and a structure that supports the slope. The square steel tubes used for the columns are 300×300 mm with a plate thickness of 19 mm, their lower limit for yield point is 295 N/mm^2 and they are filled with concrete. The tsunami evacuation tower is open and used as an observation tower in normal times.

Design condition		Accommodation capacity	
Design inundation depth	3.0 m	Evacuation area	370 m^2
Water depth coefficient	3.0	Accommodation	740 persons

• Sonochiku Tsunami Evacuation Tower (Framing Type)

This tower was constructed in Gobo, Wakayama Prefecture. It is a three-story steel-structure tsunami evacuation tower having an evacuation floor of 450 m^2 on the third story and roof where about 800 persons can evacuate. Taking into account the site configuration, the tower is designed as a structure having an octagonal-shape plane configuration, and the slope is arranged around the periphery. The square steel tubes used for the columns are 450×450 mm with a plate thickness of 22 mm, and have a lower limit for yield point of 295 N/mm^2. The tower is designed so that the evacuees can approach the tower via the park and the neighboring road.

Design condition		Accommodation capacity	
Design inundation depth	5.0 m	Evacuation area	450 m^2
Water depth coefficient	3.0	Accommodation	800 persons

• Sangochiku Tsunami Disaster-prevention Center (Simple, Multi-use Building Type)

This building was constructed in Toyohashi, Aichi Prefecture. It is a two-story steel-structure tsunami evacuation building having an evacuation floor of 240 m^2 on the roof where about 300 persons can evacuate. A parking lot is provided on the first story, and a living area on the second story. The building is designed so that it can be used as an assembly hall during normal times and its rooftop can be used as an evacuation site during emergencies. The square steel tubes used for the columns are 300×300 mm with a plate thickness of 12 mm, for which a high-strength steel product having a lower limit for yield point of 365 N/mm^2 is adopted.

Design condition		Accommodation capacity	
Design inundation depth	1.2 m	Evacuation area	240 m^2
Water depth coefficient	1.5	Accommodation	300 persons

Kunimi Town Office Building —New Restoration Center Designed on Wood-Steel Hybrid Structures—

JR East Design Corporation

The new Kunimi Town Office Building in Fukushima Prefecture is the first of the local government office buildings that were damaged by the Great East Japan Earthquake (2011) to be rebuilt. This new building, which serves as the earthquake disaster restoration center for mountain-encircled Kunimi Town, contains all the elements for reconstruction that were desired by the town's citizens and those involved in construction. It is a bright, warm, relaxing space that was brought about by the extensive use of local wood and that capitalized on "local wood-laminated hybrid member of the steel product built-in type."

Town Office Building That Merges into Surrounding Landscaping

The old Kunimi Town Office Building was completely demolished and rendered unserviceable by the Great East Japan Earthquake. Since then, the Cultural Hall of Kunimi Town has been substituted as a temporary replacement of the town office building, which required urgent new construction. The site chosen for construction of the new building is open and level and commands a beautiful view of the surrounding mountain range. To this end, the new building was designed so that it shows an architectural image of the forest that blends with the surrounding beautiful scenery; further the architectural designers aimed at realizing a town office building that offers a gentle atmosphere and is encircled with wood that is locally produced for local consumption. (Refer to Photo 1)

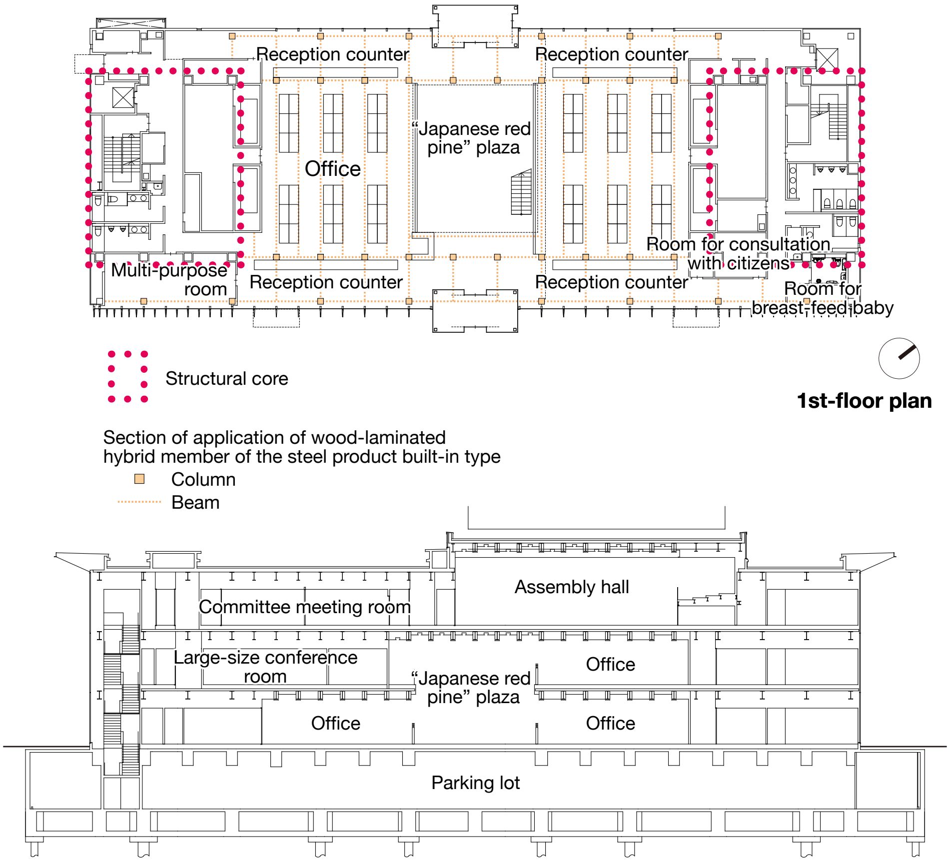
Meanwhile, legal requirements call for the construction of new town office buildings to be fire-proof, and this resulted in a careful examination of how to use wood compatibly in fire-proof buildings. At this stage, JR East Design Corporation noticed that it had previously employed a structural design method that uses wood for the fire protection of steel frames. And, based on this, it designed

Photo 1 New Kunimi Town Office Building built capitalizing on the strengths peculiar to wood and steel

the frame of the new building using this method while at the same time aiming to realize a building space with exposed framing that is extensively covered with wood. Further, the building was structurally integrated into the surrounding landscape by promoting a structural feature—the building's wood-covered interior space could be seen from the outside through the glass façade.

To this end, the goal targeted by these design approaches was to "realize a town office building that would serve as a site where many citizens could get together."

Fig. 1 Plan and Section of Kunimi Town Office Building



Realization of a Wood-based Space with Built-in Steel Frames

The town office building has a rectangular 55×20 m shape. Two rows of columns are installed in the longitudinal direction of the peripheral area of the building. In the center section, the columns are arranged at a span of 13 m, which allows provision in the 1st and 2nd stories of a spacious office space with flexible options for use. Reception counters and small rooms are arranged in the sections sandwiched by the two rows of columns, which are called "veranda zones in contrast to the large area of the center section. Located in the large space of the 3rd story is an assembly hall and in the north-side veranda zone an observatory lobby is arranged. (Refer to Fig. 1)

While the space appears to be a wood-framed structure, it is actually structured by the use of steel framing with wood framing used as fire protection for the steel. Specifically, the building frame is composed of wood-laminated hybrid member of the steel product built-in type in which the wood members are laminated to the steel members as fire-proofing materials. These fire protection mem-

Fig. 2 Wood-laminated Hybrid Member of the Steel Product Built-in Type (Column and Beam)

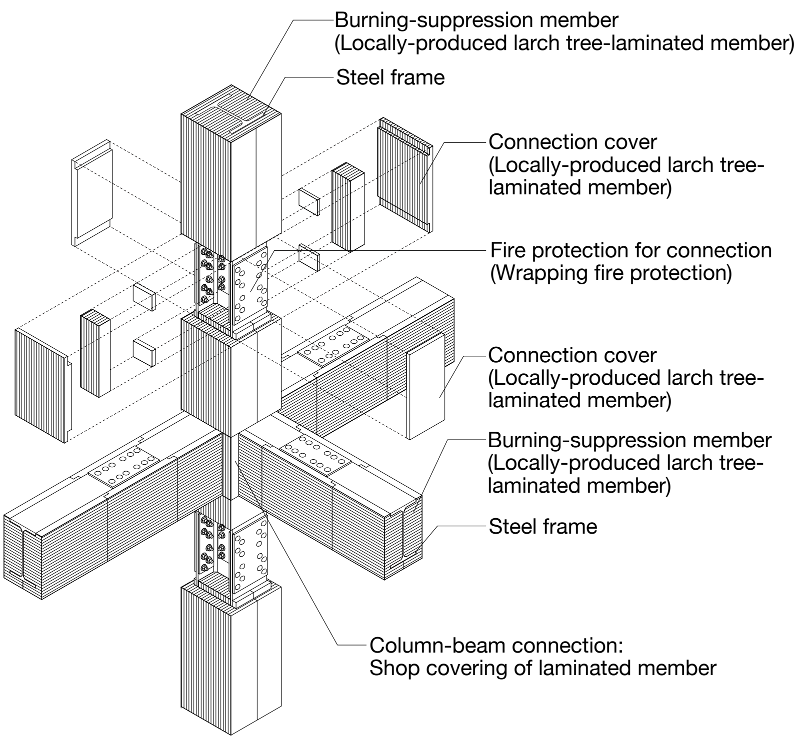
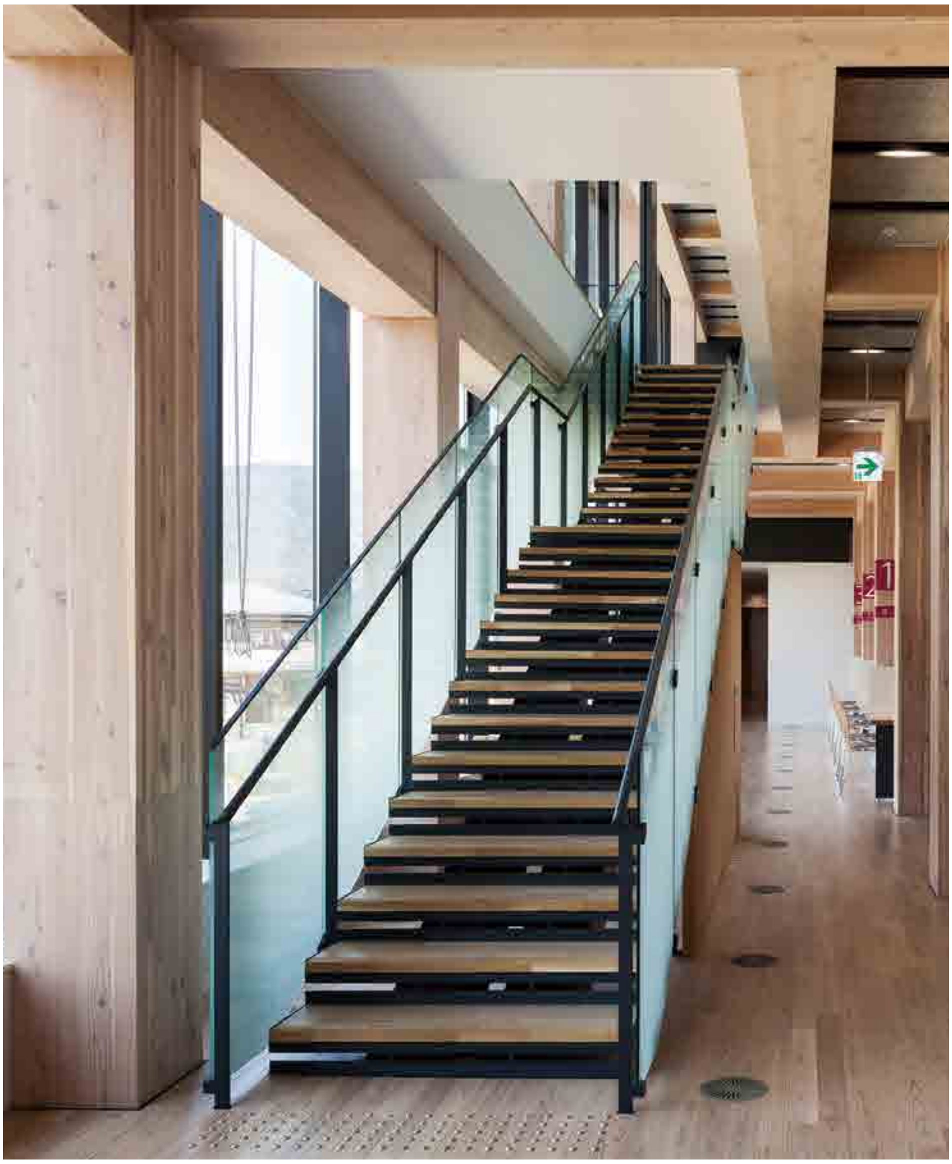


Photo 2 Wood-laminated hybrid member of the steel product built-in type

bers have obtained approval as structural members from the Ministry of Infrastructure, Land, Transport and Tourism. With this method of fire protection, the wood laminated members function to suppress burning of the steel framing. That is, the wood fire protection suppresses the rise of the temperature in the steel framing during a fire, and when a fire is extinguished, the wood fire protection protects the steel framing from the fire due to its self-extinguishing property. Laminated Japanese larch trees are used in the burning suppression members. H-shape steel products (300×300 mm) are applied for the columns of the wood-steel hybrid sections. (Refer to Photo 2 and Fig. 2)



Photos 3 and 4 Stairways: Highlighted application of steel products

Stairways—Structures of Steel Design

While the warmth offered by wood is pursued in the design of the town office building, the application of steel is highlighted in the stairway of the atrium and in the stairway to the 3rd-story observation lobby. Although it is troublesome to structurally highlight the application of steel, it can clearly be seen in the stairway sections. In other words, the stairways are exactly of steel design.

As imaged in the architectural design, diverse measures were incorporated so that the heavy steel of the stairways looks as light as possible. While H-shape steel members are used in the stairway girders, both sides of the H-shapes are closed employing steel plates to provide a square box shape. Two H-shape stairway girders under the stairway center are placed close together to realize a compact structure, and both sides of the stairway steps are cantilevered from the stairway girder. In this way, a lighter-weight image of the steel stairway structure was pursued in the design stage. (Photos 3 and 4)

Full Consideration of the Environment and Preparations for Disasters

A pellet boiler is adopted for air-conditioning, and hardened wood chips are used as a heat source to produce biomass energy. Ignition of the chips requires only a small amount of electricity, and carbon dioxide emissions are suppressed by means of carbon neutralization. Because pellets (fuel) produced in Iwaki in Fukushima Prefecture are used, the pellet boiler air-conditioning system can be seen as an environmentally conscious technology in terms of using locally produced wood materials.

Because the building exterior is of glass façade construction, citizens expressed some anxiety that it would be hot in the summer and cold in the winter. To wipe away such anxieties, wooden louvers for cutting off sunlight were adopted to improve the heat-insulation performance of the exterior wall and Low-E pair glass with high heat-insulation performance was also adopted. Further, the building is planned so that the veranda zones work as heat-insulation zones for the large spaces at the building's center, which successfully lessens the heat burden of such a wide working space.

The recycling of rainwater and the use of solar power generation have been introduced, and thus, even when the regular electricity supply stops, building operations can be sustained for at least three days by using emergency power generators and the solar power generation system.

Underground Space for Both Car Parking and Temporarily Receiving Refugees during a Disaster

It has been said that places of refuge were insufficient within the Kunimi Town area during past disasters and in the Great East Japan Earthquake. For that reason, a plan was submitted at the project proposal stage that parking be provided in the basement, which would be used for the parking of public-use cars in normal times and as a place of temporary refuge in emergencies. Manhole emergency lavatories can be prepared in the basement. As a result, a plan was finally accepted that allows for the evacuation of citizens. (Fig. 3)

Focusing only on the Strengths of Steel and Wood

Still the strong point of steel framing is that it allows for the construction of large spaces and atrium structures. This performance of steel cannot be substituted by wooden construction. Above all, the construction of fire-proof buildings employing wooden structures is very difficult in terms of both cost and the current technological level.

As a result, the current hybrid construction method focusing on the strong points peculiar to the wood or steel members is highly rated—wood materials being used as finishing members and steel frames as structural members. Further, steel frames are reliable in making the spans between columns larger and in securing considerable space volume. (Refer to Photo 5)

Currently, only comparatively small-size H-shapes are adopted in the steel frames of hybrid wood-steel members. However, when we count that it might become feasible to obtain ministerial approval for hybrid members that use square steel tubes or H-shapes with a constant outer web depth, expectations are high for the promising development of building methods employing "local wood-laminated hybrid member of the steel product built-in type."

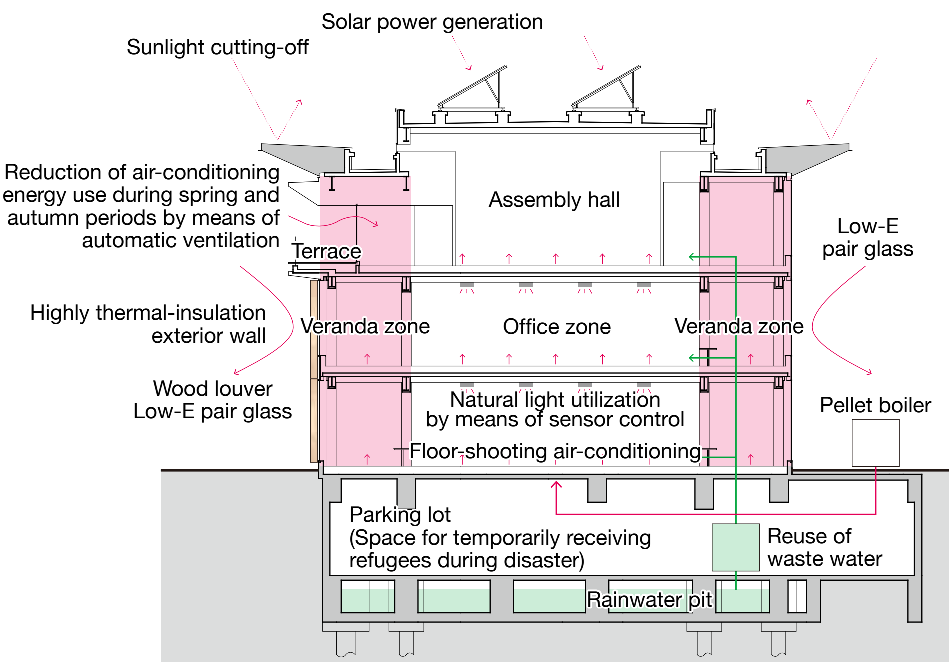
(Photos and figures: Courtesy of JR East Design Corporation) ■

Outline of Kunimi Town Office Building

- Location: Kumini Town, Date, Fukushima Prefecture
- Project owner: Kunimi Town Office
- Application: Town office building
- Building site: 1,500.43 m^2
- Building area: 4,833.39 m^2
- Structural type: Steel frame structure, partly steel-reinforced concrete structure
- No. of stories: 1 basement, 3 stories aboveground, 1 penthouse
- Maximum building height: 15,500 mm
- Structural design: JR East Design Corporation, Tabata Architect & Design Office
- Construction: Joint venture of Ando, Hazama, Andogumi and Sakuma Kogyo
- Design period: August 2012~August 2013
- Construction term: September 2013~April 2015

Photo 5 Adoption of wood-steel hybrid structure realizes a large space with a texture like a wooden structure.

Fig. 3 Schematic Diagram for Environmental Plan



Two Programs for the Steel Industry Cooperation Program of the Japan-Thailand EPA

The Japan Iron and Steel Federation (JISF) in collaboration with the Iron and Steel Institute of Thailand (ISIT) held two programs. These programs were planned as part of government-initiated projects pursuant to the Japan-Thailand Economic Partnership Agreement (EPA).

Newly Recruited and Young Engineer Training Program

The Newly Recruited and Young Engineer Training Program was held for one week in Osaka in September 2016. The main aim of the program is for "newly recruited and young Thai engineers to get necessary and indispensable basic knowledge." A total of 20 Thai engineers participated in the program in which lectures titled "Bars and Rods Special Course" were delivered and visits were made to related steel plants. The program was the second following one held in 2015.

Seminar on CO2 Emissions Evaluation Method

A program was held for four days starting from July 4, 2016 in Bangkok, Thailand with the aim of establishing a CO2 emissions evaluation method in the Thai steel industry. In this program, guidance on a CO2 emissions evaluation method was given to ISIT staff and related persons in the Thai steel industry and government agencies. In addition, the program included the demonstration of CO2 emissions data collection and an evaluation method during the visit to an electric furnace steelmaker.

Steel Structure Conference in Cambodia for 2016

The Japan Iron and Steel Federation will hold a conference titled "Recent Technologies for Steel Structures 2016" in Phnom-Penh, Cambodia on December 9, 2016. It will be jointly held by the Ministry of Public Works and Transport of Cambodia and the Institute of Technology of Cambodia, and will be supported by the Embassy of Japan in Cambodia, JICA Cambodia Office, JETRO PHNOMPENH and the Japanese Business Association of Cambodia.

In the conference, three professors from Japan will participate to deliver lectures in the field of steel construction:

- Dr. Osamu Kiyomiya (lecture on port and harbor facilities)
- Dr. Yoshiaki Okui (steel bridges)
- Dr. Yasushi Uematsu (building construction)

Further, two lecturers from Cambodia will participate in the conference by delivering lectures. Subsequently, the Small Group Session of the conference is scheduled to be held with the participation of key persons from both nations. This conference will be the fourth in the series, following those held in 2012, 2014 and 2015.

Steel Structure Conference for 2015

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