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Current State of Studies of Steel-Concrete Composite Structures

by Junichi Sakai
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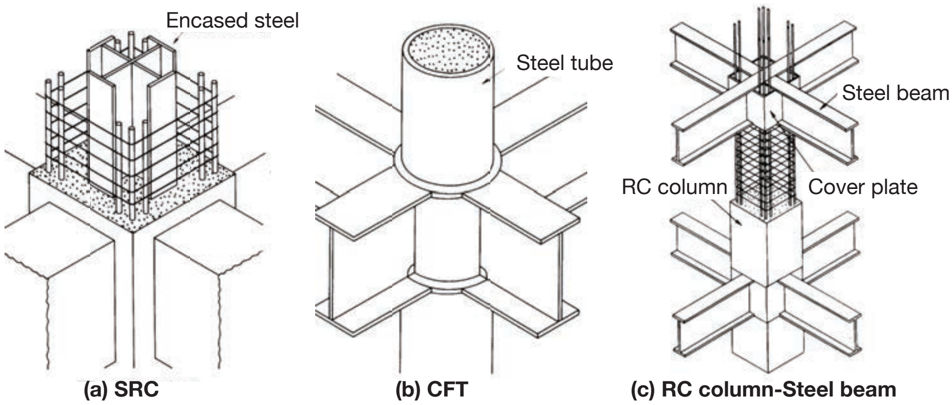
In the following article, the recent trend in studies of steel-concrete composite structures is briefly introduced. In addition, a study is also introduced of a new steel-concrete structure, for which we are promoting the development of studies.

Fig. 1 Typical Steel-Concrete Composite Structures in Use in Japan[1)]



Current State of Studies of Steel-Concrete Composite Structures

The typical steel-concrete composite structures in common use in Japan are of three structures: steel and reinforced concrete (SRC) structures, concrete-filled steel tube (CFT) structures and reinforced concrete column-steel beam (RC+S) mixed structures (Fig. 1). CFT structures are structures that can easily utilize the structural features offered by the composite structure, and CFT structures produced by the use of high-strength steel members have been widely applied in the construction of high-rise buildings. RC+S structures are mixed structures composed of reinforced-concrete columns that offer both high rigidity and economic advantages and steel beams with which the structural span can be made longer, and thus they are extensively applied in the construction of long-span office buildings, commercial facilities and logistics warehouses.

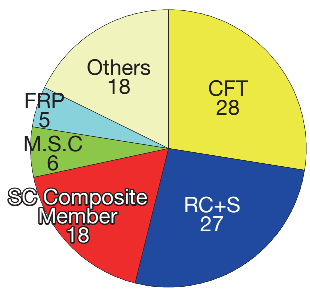
In order to survey the recent trend of studies of steel-concrete composite structures in Japan, an analysis was made of 102 study reports in the field of steel-concrete composite structures published in the Summaries of Technical Papers of the Annual Meeting for FY2018 of the Architectural Institute of Japan (AIJ)[2)]. Fig. 2 shows a breakdown of study reports in the field of steel-concrete composite structures. As shown in the figure, the mainstream in recent studies of steel-concrete composite structures has been on CFT and RC+S structures.

While the content of studies of CFT structure is wide-ranging, the main targets in studies have been placed on the application of super high-strength steel, rectangular-shaped CFT columns, long-period seismic motion, slender columns and built-in steel reinforcement.

In the study of RC+S mixed structures, extensive studies have been made of the effect of grade differences (height direction) in right and left steel beams attached to RC columns and the differences in eccentricities (horizontal direction) of the beam core to the column core that affect the behaviors of connections. Further, studies have been reported on the mixed structures that consist of RC sections in the beam ends and H-shaped steel frame in the middle of the span. In addition, a lot of studies of the attachment of braces have also been reported.

Very few studies have recently been made in the field of SRC structures, and instead of this, the study of steel-concrete (SC) composite structures is increasingly being promoted.

Fig. 2 Breakdown of 102 Study Reports on Steel-Concrete Composite Structures[2)]



CFT: Concrete-filled steel tube
RC+S: Mixed frame of RC column and steel beam
M.S.C.: Mechanical shear connector
FRP: Fiber-reinforced plastics

Total: 102 study reports
(Summaries of Technical Papers of AIJ Annual Meeting for FY2018)

In the field of the study of SC structures, most studies target structural members in which steel reinforcing bars are eliminated from the SRC structure, and studies are actively being promoted on structural members, column-beam connections and seismic-resistant walls composed of concrete encased steel (CES) structures that employ carbon fiber-mixed fiber concrete. In addition, studies are also being promoted on various kinds of SC beams including SC foundation beams and octagonal-section SC columns. Regarding octagonal-section SC columns, an explanation will be made later.

In terms of the number of contributions at the AIJ Annual Meeting for FY2008, while the total number has decreased, it is noted that studies of mechanical shear connectors and fiber-reinforced plastics have tended to increase. In building construction in Japan, the headed stud has been widely applied as the device to transfer the stress between steel and concrete, which however brings about concerns about the increase in the number of headed studs to be applied. To cope with such a situation, studies of the perfobond connectors used in the field of civil engineering have recently been promoted for the field of building construction.

Fig. 3 shows an example of the results of a pressing test conducted by embedding three kinds of mechanical shear connectors into concrete—headed studs, perfobond connectors and new burring connectors[3]. Even for the test specimen prepared by setting the maximum strength of both the headed stud and perfobond connector to an identical level, it can be understood from the test results that the stiffness of the headed stud was low but that of the perfobond connector was high. Further, as can be seen in the figure, both the stiffness and strength of the new burring shear connector employing the burring steel plate are high, and as a result it is expected that the new connector will be put into practical use.

In the field of civil engineering, structures employing fiber-reinforced plastics (FRP) have been constructed, but there are concerns about increasing construction costs attributable to its application. In the field of building construction, its application has been limited only to parts of building structures. However, FRP offers high structural performance such as being lightweight and has high strength and stiffness, and thus its application is considered to grow in the future. Recently, studies and exposure tests have been made for the compression strength of carbon-fiber reinforced plastics (CFRP) members and the application of CFRP in the splice plates of high-strength bolt friction joints.

Among the "others" pertinent study reports shown in Fig. 2 are studies on buckling-restraint braces, composite slabs, and composition with wooden materials and steel pipe pile head joints.

Development Study of Octagonal-section SC Column

Steel and reinforced concrete (SRC) structures are structures that were originally developed in Japan and offer high seismic resistance. However, they require reinforcing bar arrangement and concrete placement in addition to steel-frame fabrication, and as a result, the construction process becomes complex and construction costs tend to rise. Accordingly, while SRC structures are applied to parts of building structures, construction of all SRC-layer building has decreased.

Aiming at further improving seismic resistance and enhancing manpower and labor savings involved in SRC construction, we are promoting the development studies into octagonal-section steel-concrete (SC) columns shown in Fig. 4. A dynamic feature of octagonal-section SC columns lies in that, because concrete surrounded by cruciform steel frame can effectively been confined by the use of steel-frame flanges and webs, the bending resistance and deformation capacity can be enhanced. Specifically, the web of cruciform steel frames is located in the center of the column section, and thus the octagonal section column can resist high compressive axial load and suppress axial contractions. As a result, octagonal-section SC columns show stabilized large deformation behavior. Further, both bending strength and stiffness can easily be adjusted by adjusting the thickness and width of steel-frame flanges.

Fig. 5 shows the conditions of concrete-confined effects obtained by the test in which a uniform compressive load is applied to the octagonal-section concrete. As can be seen in the figure, the compressive strength and deformation capacity of octagonal-section column concrete are improved compared to those of plain concrete (no reinforcement). Because of the limited space for this study report, the method of analysis cannot be mentioned, but it can be understood from the figure that the compressive behavior of concrete can be traced by means of analysis that takes the concrete-confined effect into account[4].

Fig. 6 shows the results of a test in which the constant axial load and cyclic lateral load were applied to octagonal SC columns. It can be seen in the figure that even when the steel-frame dimensions differ one by one, the octagonal column possesses high seismic resistance. The mechanism line in the figure indicates the shear strength of

Fig. 3 Relationship between Load and Slip of Mechanical Shear Connector[3]

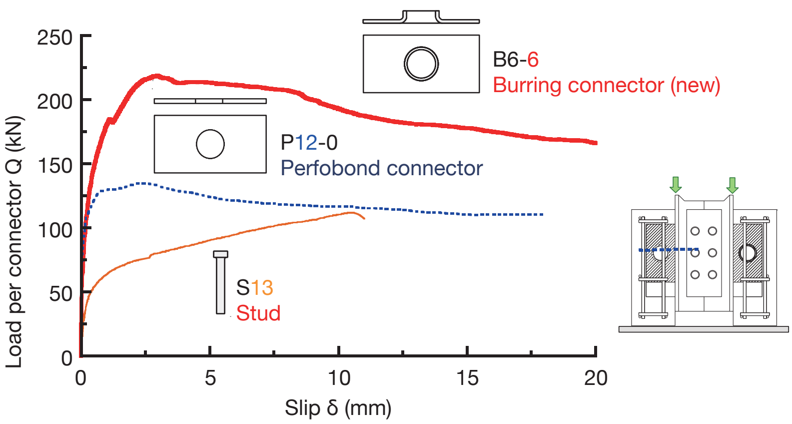
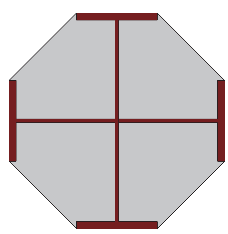


Fig. 4 Cross Section of Octagonal-section SC Column



SC columns in the case when the full plastic moment of the column section, calculated using the yield strength of steel and the compressive strength of concrete, is to be demonstrated on the column head and base. The figure also shows the result of an analysis that takes into account the concrete-confined effect, and it can be said that the test results are precisely evaluated by this analysis.

Fig. 7 shows the column-beam connection of a mixed-framing structure composed of octagonal-section SC columns and steel-frame beams. As shown in the figure, the detail of weld-joining of an exterior diaphragm and vertical stiffener is proposed to confirm the transfer of stress occurring in column-beam connections[5]. Further, two cruciform frame test specimens composed of octagonal-section SC columns and steel-frame beams were prepared, and a test was conducted in which a constant axial load was applied for mixed structures to handle the stress occurring during an earthquake, and then an anti-symmetrical positive/negative alternating cyclic shear load was applied to both ends of the beam. Fig. 8 shows the test results obtained so far.

In the test, the design was made so that attainment to the ultimate strength by column-beam connection precedes that by column and beam in each of these two specimens. One difference between these two specimens is whether or not the vertical stiffener is arranged on the column-beam connection. While both specimens show excellent hysteresis loop in seismic resistance, the diagonal-direction concrete compression

Fig. 5 Concrete-confined Effect of Octagonal-section SC Column Member[4)]

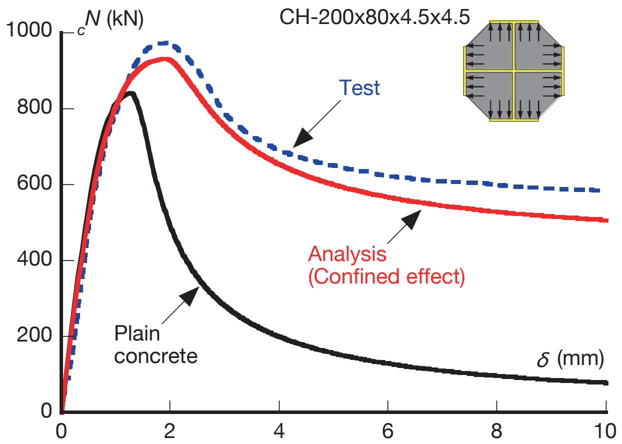
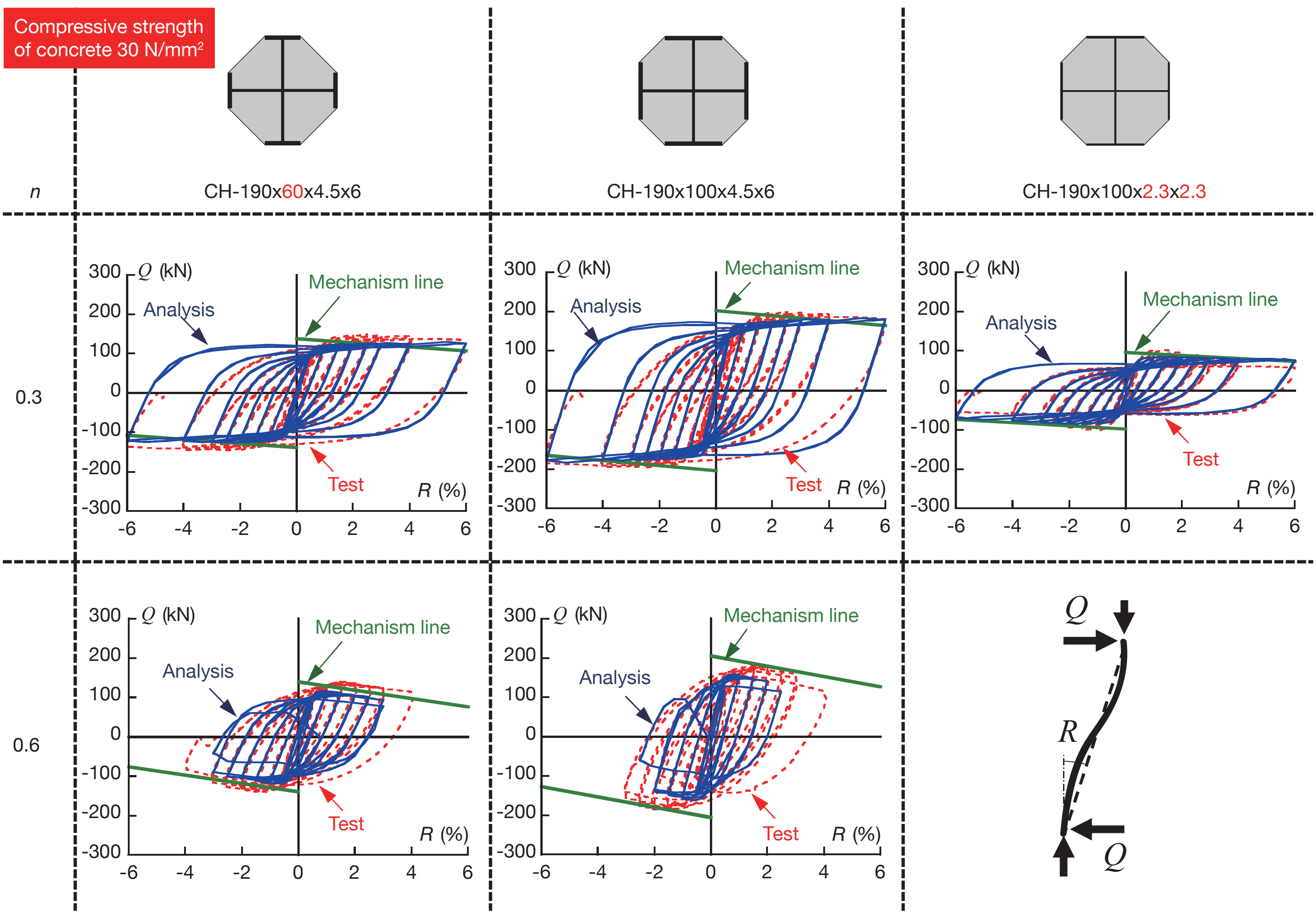


Fig. 6 Relationship between Shear Strength and Rotation Angle of Octagonal-section SC Column Member[4)]



strut is likely to form in the connection panel due to the arrangement of the vertical stiffener, and as a result the shear strength of the connection slightly increases. Further, it has become possible to confirm the effect of vertical stiffener arrangement on the suppression of shear deformation in connections[6].

In the installation of octagonal-section SC columns, reinforcing bar arrangement is not required in terms of construction, and steel-frame flanges can be used as the concrete form, which is considered to lead to simplified construction work. For octagonal-section SC columns, plain concrete is planned to be applied, and the high-level quality control required for the concrete used for CFT structures is not required. To that end, we are examining the application of octagonal-section SC columns in the construction of low- and medium-rise buildings.

High Expectations for Octagonal-section SC Columns

The trend in studies of steel-concrete composite structures in Japan has been analyzed based on the reference literature[2], the results of which are introduced above. The development of studies is proceeding for new octagonal-section SC columns and octagonal column-steel frame mixed structures that are expected to not only allow for both manpower and labor savings but also offer enhanced structural performance. Their structural behavior is also introduced above. ■

Fig. 7 Column-Beam Connection of Mixed Structure Composed of Octagonal-section SC Column and Steel-frame Beam

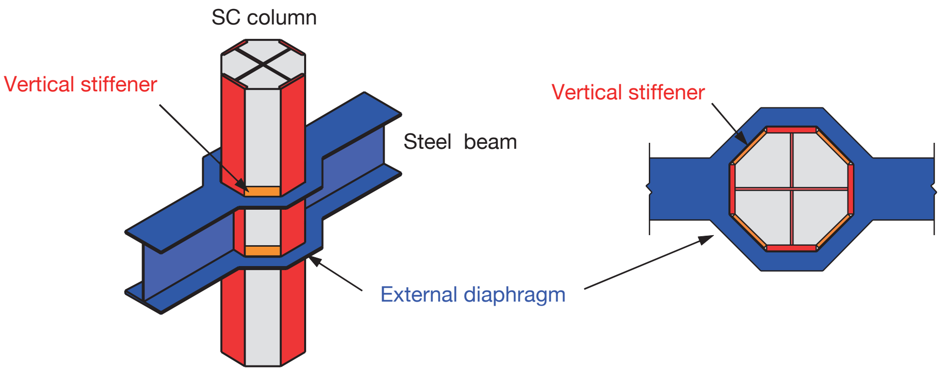
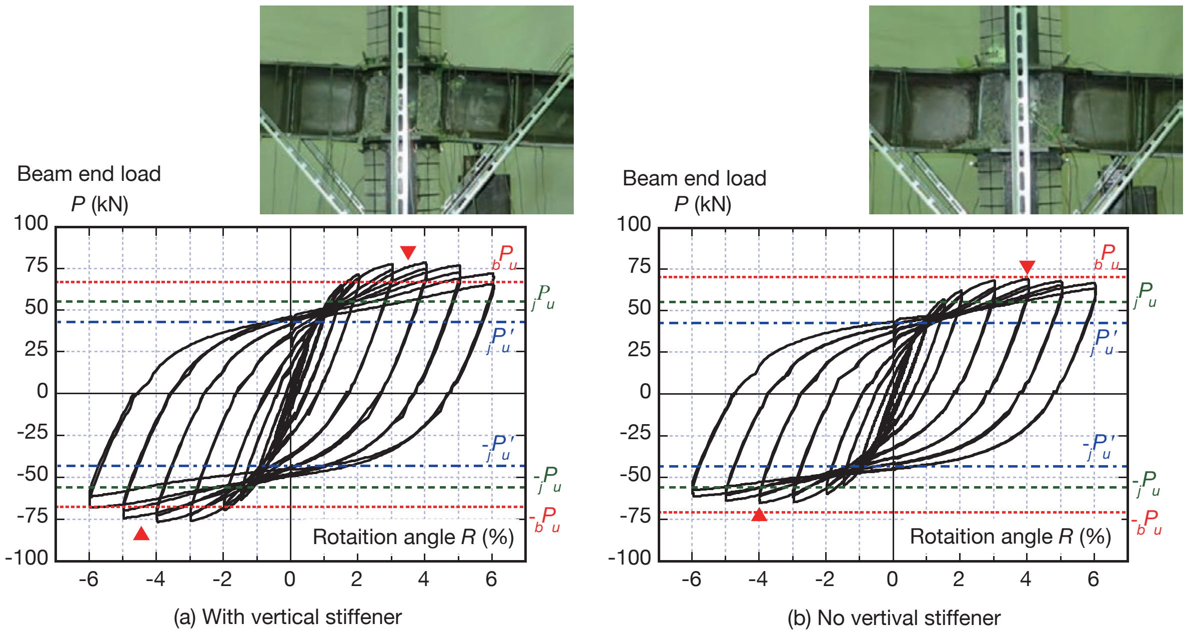


Fig. 8 Relationship between Load and Deformation of Column-Beam Connection Composed of Octagonal-section SC Column and Steel-frame Beam[6]



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Current State of Studies and Research on CFT Structures

by Keigo Tsuda, Emeritus Professor, and Masae Kido, Associate Professor
The University of Kitakyushu

Keigo Tsuda: After finishing the master course at the Graduate School of Kyushu University, he served as research assistant of Kyushu University in 1977 and then as associate professor of Kyushu University. He became professor of the University of Kitakyushu in 2001 and emeritus professor in 2018.

Masae Kido: After finishing the doctoral program at the Graduate School of the University of Kitakyushu, she became lecturer of the University of Kitakyushu in 2007. She assumed her current position as associate professor of the University of Kitakyushu in 2012.

Concrete-filled steel tube (CFT) structures are a kind of steel-concrete composite structure. They feature high structural performance such as high load-carrying capacity and high deformation capacity. In Japan, their application started in the latter part of the 1950s, and CTT structures have widely been used in the construction of a number of high-rise office buildings.

The first study report of CFT structures submitted in Japan was the "Experiment and analytical study on buckling loads of CFT compressive members" prepared by Prof. Shizuo Ban and others in 1956. Then in 1961, a similar report was submitted: "Experiment and analytical study on the centrically loaded CFT slender columns" by Prof. Takeo Naka, Prof. Ben Kato and others. In 1981, Prof. Kenji Sakino reported a doctoral dissertation on CFT structures, a first of its kind in Japan.

In the "Project to Develop New Urban-type Multiple Dwelling Housing System" promoted for five years starting from 1985 by the Ministry of Construction, the CFT structure was adopted as a structural system for high-rise apartment housing. In this regard, an experimental study on beam-column members was conducted to evaluate the performance of the structural system thus adopted. Further, in "Composite and Hybrid Structures," a U.S.-Japan Cooperative Earthquake Engineering Research promoted over five years starting from 1993, the CFT working group was established, and experimental research on the column members and beam-to-column connections of CFT structures was promoted by widely changing the strength of materials and the width-thickness ratio and diameter-thickness ratio of steel tubes.

The recent trends in research and studies on CFT structures are introduced in the following:

Design Guidelines and Application Ranges

Two latest versions of the design guidelines for CFT structures have been published in Japan—*Recommendations for Design and Construction of Concrete Filled Steel Tubular Structures* (2008) by the Architectural Institute of Japan (AIJ) and *Technical Standards and Commentaries for Concrete Filled Steel Tubular Structures* (2012) by the Association of New Urban Housing Technology. In addition, the *Guidebook on Design of Concrete Filled Steel Tubular Structures* for use for young designers and university students has also been published by the Architectural Institute of Japan.

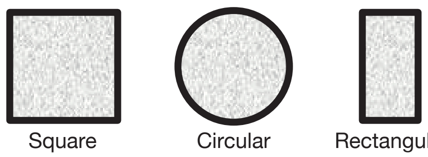
The application range of material strengths for CFT structures specified in the AIJ's *Recommendations for Design and Construction* is set at 18~90 N/mm^2 for the compressive strength of concrete, 590 N/mm^2 or lower for the tensile strength of steel, and 235~440 N/mm^2 for the yield stress of steel tubes (Table 1). The standard section of CFT columns is set to be square and circular (Fig. 1). In addition, experimental studies are being promoted on the application of rectangular CFT columns and the strength and deformation capacity of reinforced-type CFT columns in which steel reinforcing bars are built-in into the steel tube.

Table 1 Requirements for CFT Structures

Compressive strength of concrete*	18～90 N/mm^2
Tensile strength of steel*	Smaller than 590 N/mm^2
Yield stress of steel*	235～440 N/mm^2
Ratio of limiting value of width (diameter) to thickness	1.5 times of AIJ steel standard
Ratio of buckling length to section depth	Not longer than 50 for columns
	Not longer than 30 for beam-columns

* AIJ *Recommendations*

Fig. 1 Cross Sections of CFT Columns



Recent Trends in Studies on CFT Column Members

• Ultimate Strength of Columns Subjected to Axial Loads

In the currently-prevailing AIJ's *Recommendations for Design and Construction of Concrete Filled Steel Tubular Structures*, as shown in Fig. 2, the slenderness parameter of columns subjected to compressive force is examined by selecting the ratio l_k/D of the effective length l_k to the section depth D, and where the ratio is l_k/D=4 or lower, columns within this ratio are defined as short columns, where the ratio is l_k/D=more than 4~12 or lower as intermediate columns, and where the ratio is l_k/D=more than 12 as slender columns, and the design equation is changed depending on the ratio l_k/D selected.

As of now, as the compressive strength evaluation equation for CFT columns, the design equation is proposed that takes the normalized slenderness ratio of steel columns as the slenderness indicator and is based on strength cumulatively added with the buckling strength of both steel and concrete columns with no distinction as short, intermediate and slender columns.

Fig. 3 shows a comparison between the column strength thus proposed and the compressive strength calculated using the AIJ's *Recommendations*. In the figure, ${}_s\sigma_y$ is the yield stress of the steel tube and ${}_c\sigma_B$ the compressive strength of concrete. As shown in Fig. 3, the proposed strength cumulatively added with the buckling strength of both steel and concrete columns well agrees with the buckling strength calculated using AIJ's *Recommendations* in all ranges of normalized slenderness ratios even when the distinction as short, intermediate or slender columns is not applied[1].

• Ultimate Strength of Columns Subjected to Axial Load and Flexural Shear Stress

For columns subjected to both compressive strength and flexural shear stress, the current AIJ's *Recommendations* shows design equations for each of three different types of columns—short, intermediate and slender, as in the case of the design of compressive members. Presently, as with compressive members, the range in which the full plastic moment of column sections can be expected to display in terms of the relation with the normalized slenderness ratio of steel tube column λ_c, the axial load ratio of column n_y and the member end bending moment ratio κ is being examined using Fig. 4 as an analytical model.

That is, in the relational equation of $n_y \cdot \lambda_c^2 = \alpha(1+\kappa)$, when the value of α is 0.05 or lower, it can be understood from the correlation between the bending moment and the axial load vis-à-vis the maximum strength of columns shown in Fig. 5 that the full plastic moment of the CFT column section can be expected to come into play. Currently, the method to evaluate the column strength in the range in which the full plastic moment of the column section cannot be expected is being examined.

As regards the square CFT columns causing shear fracture, there are cases in which fractures occur in the case of a shear span ratio=1 or lower, but it has been known that the square CFT column's hysteresis characteristic for shear fracture is not inferior to the performance in the case of bending fracture. Currently, study is underway on the shear fracture of circular CFT columns.

• Studies on Long-period Seismic Motions

There are concerns about the effect of a great earthquake occurring with the Nankai Trough as an epicentral region on high-rise buildings with a long natural period. Studies on CFT columns to treat long-period seismic motions are currently being promoted. In the Building Standard Maintenance Promotion Project of the Ministry of Land, Infrastructure, Transport and Tourism, examinations were made of the method to verify the safety of CFT columns against long-period seismic motions in 2013[2], in which tests were made pertaining to the case where CFT columns are subjected to constant displacement amplitude cyclic

Fig. 2 Range of Short, Intermediate and Slender Columns

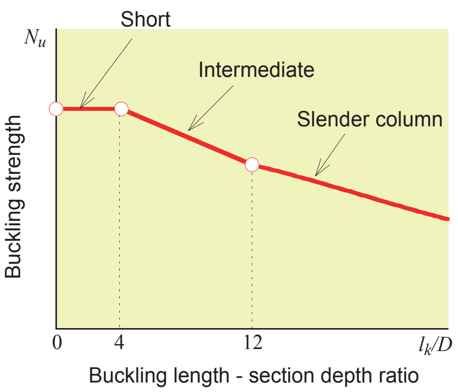


Fig. 3 Column Strength Curves

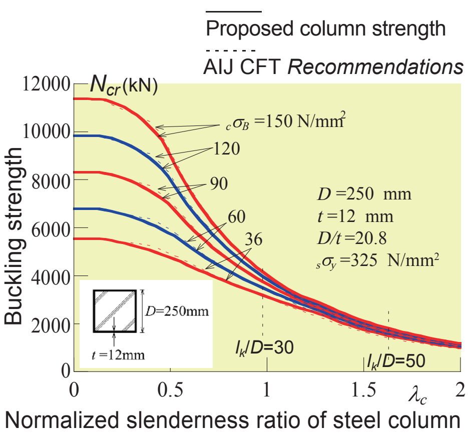


Fig. 4 Loading Conditions and Moment Diagrams

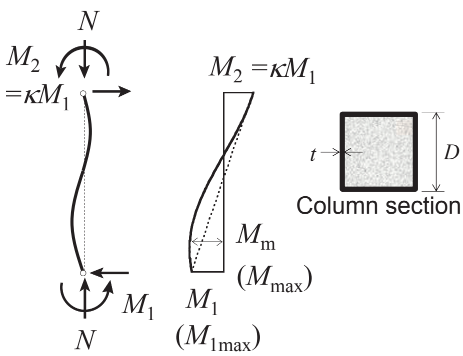
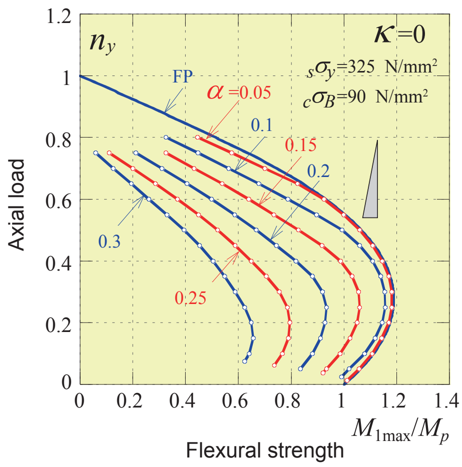


Fig. 5 Column Strength Curves



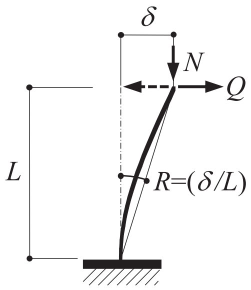
loading under constant or variable axial loads. In addition, based on the capacity obtained from member tests, a procedure has been proposed that evaluates CFT column damage employing seismic response analysis.

Meanwhile, there is high demand to accumulate test data. To meet such a demand, in 2015 the Building Committee of the Japan Iron and Steel Federation entrusted to the Japanese Society of Steel Construction the study on long-term seismic motion, in which the Working Group on Survey and Study on Retained Performance of Column Members against Long-period Seismic Motions was established to promote a three-year study from 2015 to 2017.

As a link with the three-year study, we conducted a number of tests on CFT columns subjected to constant displacement amplitude cyclic loading under constant axial loads by setting as the experimental variable the ratio of effective length to section depth l_k/D, the axial load ratio n_y, the displacement amplitude (rotation angle) R_0, and the sectional shape (square, circular)[3]. Examples of test results thus far obtained are introduced below:

Tests were carried out under the loading condition shown in Fig. 6. Photo 1 shows the CFT column loading apparatus. Fig. 7 shows the relationship between the lateral load and the rotation angle in the following three cases at l_k/D=14: axial load ratio =0.15 and rotation angle=1.5%; axial load ratio =0.3 and rotation angle=1.5%; and axial load ratio =0.6 and rotation angle=1%. The figure

Fig. 6 Loading Conditions



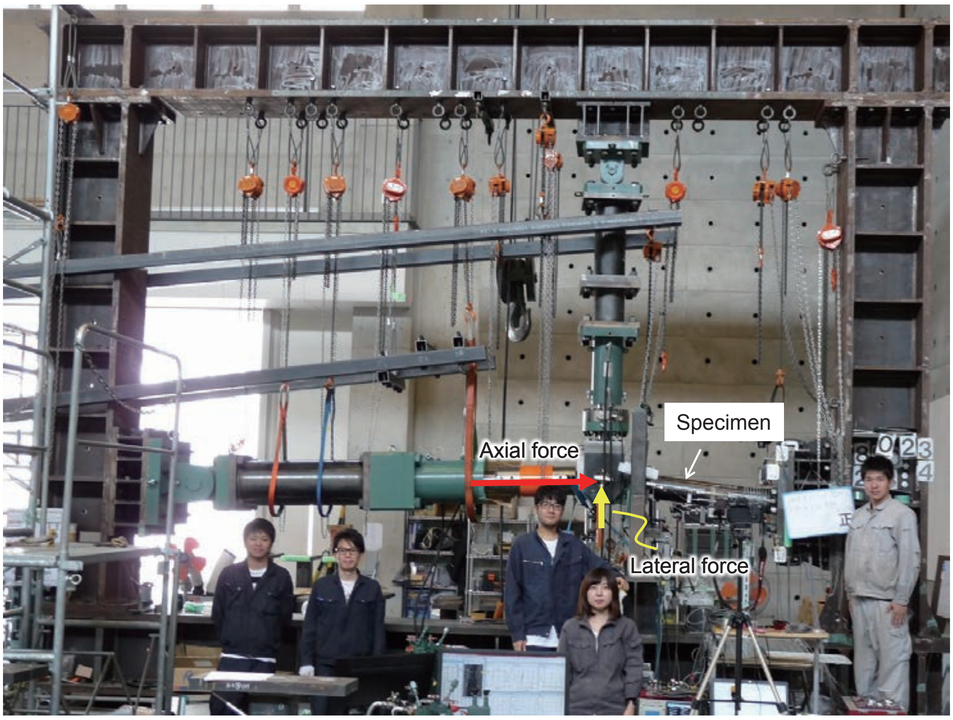
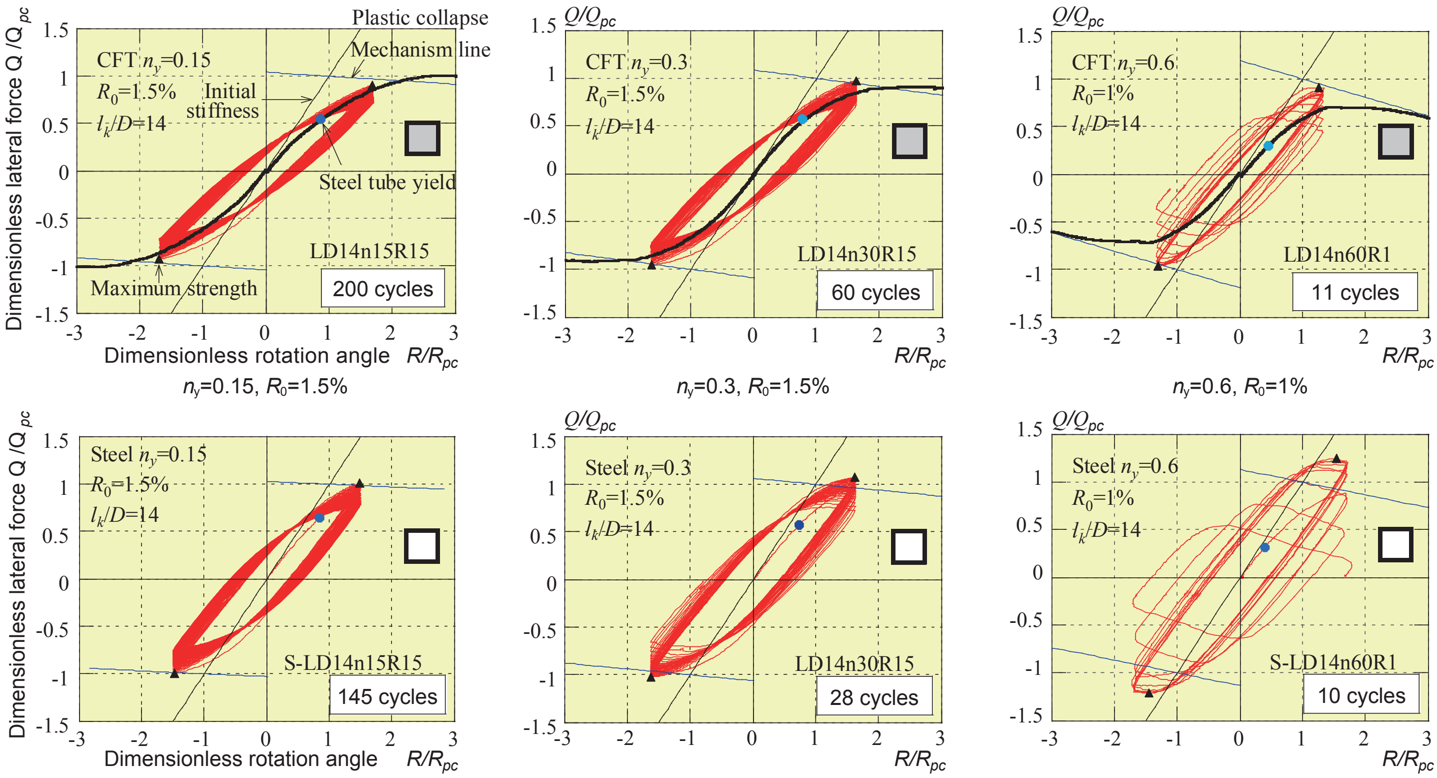


Photo 1 CFT column loading apparatus

Fig. 7 Relationship between Lateral Load and Rotation Angle



n_y=0.15, R_0=1.5% | n_y=0.3, R_0=1.5% | n_y=0.6, R_0=1%

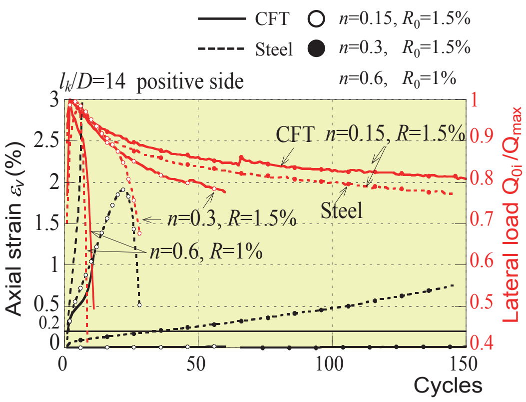
n_y=0.15, R_0=1.5% | n_y=0.3, R_0=1.5% | n_y=0.6, R_0=1%

also shows the case of tests made for hollow steel tube columns. Fig. 8 shows the trend of lateral loads (Q_{0i}/Q_{max}) at the rotation turning point and the trend of axial strain (ε_v%). Photo 2 shows the column base after testing. As the axial load ratio and the displacement amplitude become large, the reduction of the load becomes large. The future plan calls for the proposition of a method to evaluate the strength deterioration performance of CFT columns.

• Studies on Impact Resistance

In the Great East Japan Earthquake that occurred in 2011, building damage caused by tsunamis posed a lot of concern. Because CFT columns can be expected to demonstrate high impact resistance, a method to quantitatively evaluate impact resistance has been developed[4].

Fig. 8 Relationship between the Axial Strain, Lateral Load and the Number of Cycles



• CFT Columns Employing Super High-strength Steel

Tests for CFT column members produced employing super high-strength steel products with tensile strength ratings of 800~1,000 N/mm^2 are underway. In the manufacture of weld built-up box column members, because strict welding conditions are imposed on over-matching welding, studies of CFT members built up by means of under-matching welding are currently being promoted.

Development of CFT Structures with Higher Structural Performance

It is expected that a structural performance evaluation method with high precision will be established for CFT columns that not only are produced employing high-strength steel members beyond the application range of currently-prevailing design standards but also include slender columns having diverse sectional configurations. We expect further development of CFT structures that will offer higher structural performance. ■

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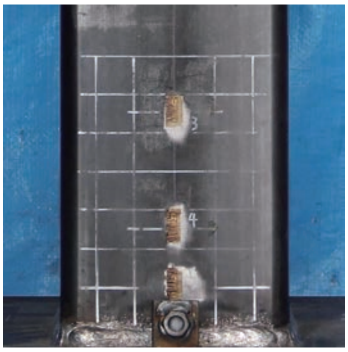
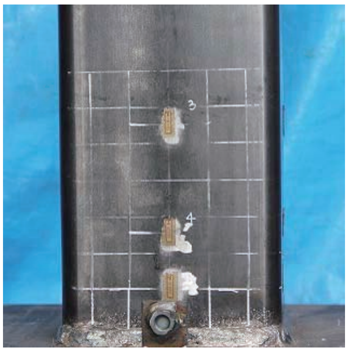


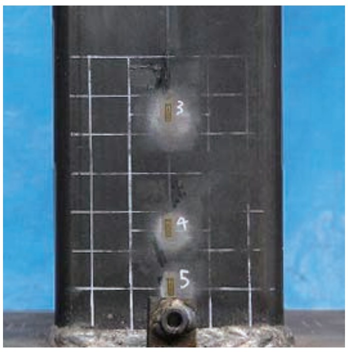
n_y=0.15, R_0=1.5%

n_y=0.3, R_0=1.5%

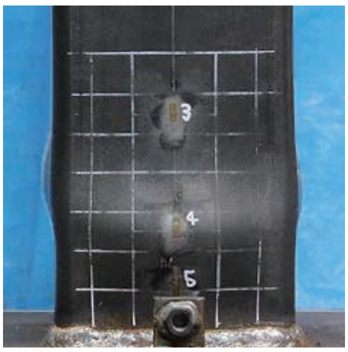


n_y=0.6, R_0=1%

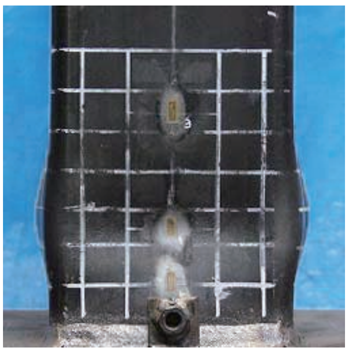
CFT



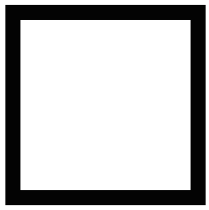
n_y=0.15, R_0=1.5%



n_y=0.3, R_0=1.5%



n_y=0.6, R_0=1%



Steel

Photo 2 Column bases after testing

Potential of Exterior Diaphragm-type Column to Beam Connections

by Tsuyoshi Tanaka
Professor, Kobe University

Tsuyoshi Tanaka: After receiving master's degree at the Graduate School of Engineering, Kobe University, he entered Asanuma Corporation in 1985. He became associate professor at the Kobe University in 1999. He assumed his current position as professor at the Architecture, Faculty of Engineering of Kobe University in 2010. His specialized field covers structural engineering and steel structures.

Exterior Diaphragm-type Column to Beam Connections

Among the methods to connect square or circular steel tube columns and H-shape beams is the exterior diaphragm connection method, which is shown in Fig. 1. In the exterior diaphragm-type column to beam connection, the diaphragm is not arranged inside the closed-section column, but it is arranged as it protrudes over the outer periphery of the column so as to function to transfer the bending stress of the beam to the column.

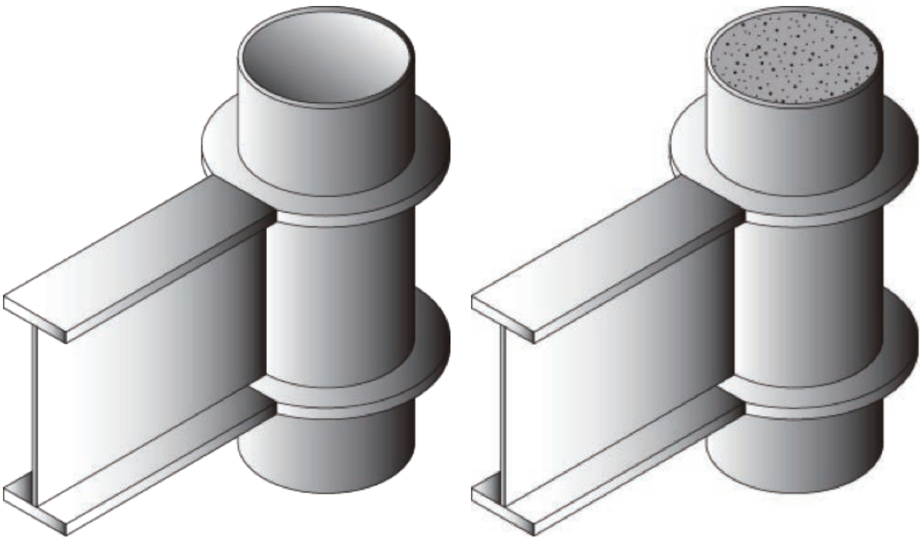
In a through diaphragm-type connection, it is necessary to cut the column at the connecting position and weld-join it. On the other hand, in an exterior diaphragm-type connection, because it is a column penetration type, an application advantage is brought about in which column fabrication is not required.

Meanwhile, in exterior diaphragm-type connections, local deformation (out-of-plane deformation of steel tube wall) occurs at the connections as shown in Fig. 2, and accordingly, in order to secure stiffness and strength of connection, it is necessary to design the details of the shape and dimensions of diaphragms.

Further, in through diaphragm-type connections, it is possible to perform all full penetration welding operations for connections by means of flat position welding, but in exterior diaphragm-type connections, because the welding is performed under conditions in which the column is aligned horizontally in common practice, it is necessary to perform weld-joining of not only column and diaphragm but also diaphragm and beam flange by means of horizontal position welding. Furthermore, as the depth of diaphragm increases, there are cases in which the attachment of exterior members and the securing of piping space are hindered.

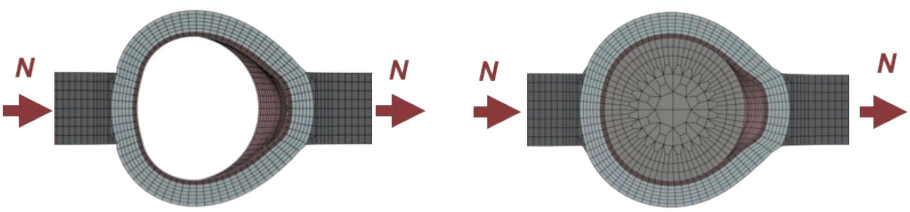
Due to these demerits, through diaphragm-type connections have been adopted extensively in Japan, and currently the application of exterior diaphragm-type connections to practical projects has been limited.

Fig. 1 Column to Beam Connection Stiffened by Exterior Diaphragms



(a) Circular hollow section (CHS) column (b) Concrete-filled steel tube (CFT) column

Fig. 2 Local Deformation at Column to Beam Connection



(a) CHS column (b) CFT column

Higher Strength of Columns and Welding Operations

Recently, high-strength steel products are increasingly been adopted in large-scale building construction projects. In addition, super high-strength steel products with a tensile strength rating of 780 N/mm^2 (H-SA700) have been developed and their practical application has started.

Higher-strength steel products not only keep up with the trend towards the construction of higher-rise and longer-span buildings but also enhance freedom in design. It is expected that higher-strength steel products will contribute towards the creation of affluent architectural spaces and structure that suffers less damage during major earthquakes.

In particular, application of 780 N/mm^2-grade steel products for steel columns in building construction brings about considerable merits. However, when examining the wider application of 780 N/mm^2-grade steel products, weld performance and welding operation are obstacles to its wider application. Guaranteeing the preparation of over-matching weld joints for 780 N/mm^2-grade steel products poses problems such as extreme difficulty in construction and leads directly to high construction costs.

When steel products with a tensile strength of 780 N/mm^2 are used for columns and those of 590 N/mm^2 or lower are used for beams and diaphragms, and further, when the connection is prepared by the use of exterior diaphragms, it becomes unnecessary to weld columns in the preparation of column to beam connections.

Currently in Japan, triggered by a shortage of welders, development of various kinds of robotic welding methods is actively being promoted for use for weld-joining of columns and diaphragms, and as a result, the horizontal position welding of columns and diaphragms by robotics welding is becoming available. To that end, there is a fair possibility of effectively handling tasks involved in the trend for higher strength of columns by the optimum use of exterior diaphragm-type connections.

CFT Columns and Local Deformation

As explained above, because local deformation occurs in exterior diaphragm-type connections, there are cases in which column to beam connections prepared by the use of exterior diaphragms are not accepted as a rigid connection. While local strength is improved by the use of super high-strength steel, local stiffness is not improved. In exterior diaphragm-type connections, diaphragms are not arranged inside the steel tube column, and thus concrete can easily be filled inside the column. Accordingly, suppression of local deformation in column to beam connections can be expected by the use of concrete-filled steel tube (CFT) columns.

Structural Tests

• Test Specimens

The test specimens were prepared by joining circular steel tube columns (○-300×12) manufactured by press-forming 780 N/mm^2-grade steel plates (H-SA700) with 490 N/mm^2-grade H-shape beams (H-400×150×9×16, SN490B) by the use of exterior diaphragms, on which the tests were conducted. Examples of the tests conducted are introduced below:

Fig. 3 shows the structure of column to beam connection specimen. The depth of the diaphragm (SN490B) is h_d=50 mm, and the plate thickness t_d =16 mm. Welding of diaphragms and steel tubes adopted in the test is by grooved fillet welding with a bevel angle of 60° as shown in the figure, and diaphragm and steel tube were weld-joined by means of CO_2 gas shielded arc welding employing welding wire (YGW18) for use for 490 N/mm^2-grade steel.

The tests were conducted for two cases using two specimens: a circular hollow section (CHS) steel tube specimen (TD-16/H) and a concrete-filled steel tube (CFT) specimen (TD-16/C). The design standard strength of filling concrete was set at Fc24, and crushed stone with a maximum size of 20 mm was used for the coarse aggregate.

• Loading and Measurement Methods

As shown in Fig. 4, one end of the circular column is joined to the pin jig, and

Fig. 3 Test Specimen (unit: mm)

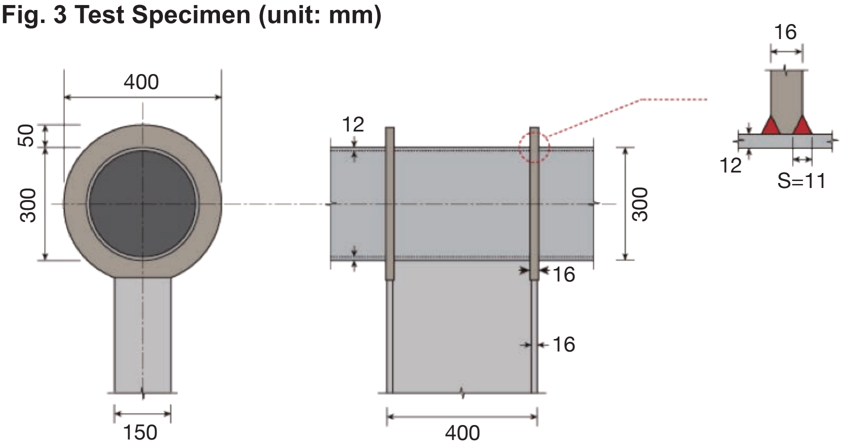
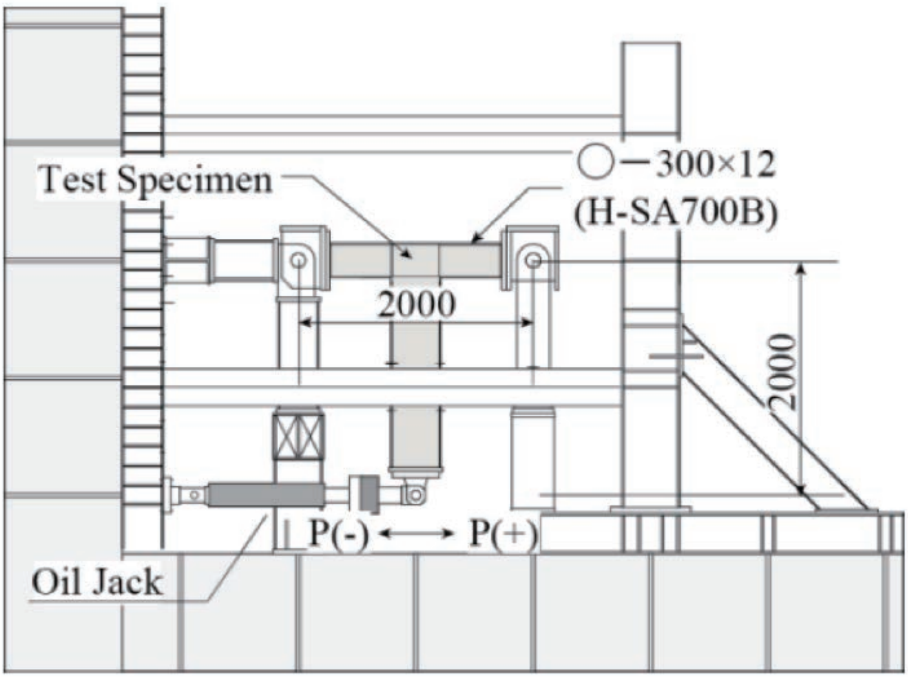


Fig. 4 Specimen and Test Setup



another end to the pin roller jig, to which positive/negative increment cyclic loading is applied using the hydraulic oil jack installed on the beam end.

The displacement transducers are arranged in the vicinity of the connection to measure local deformation ${}_L\theta$, beam deformation ${}_B\theta$ and total deformation ${}_T\theta$ ($={}_L\theta+{}_B\theta$) including both the local and beam deformations shown in Fig. 5.

The loading cycle is set at $\pm{}_B\theta_p$, $\pm 2{}_B\theta_p$, $\pm 4{}_B\theta_p$, $\pm 6{}_B\theta_p$ and $\pm 8{}_B\theta_p$ for ${}_T\theta$ by setting as the standard the elastic deformation angle ${}_B\theta_p$ that corresponds to the beam's full plastic strength ${}_BP_p$, and the cyclic loading mentioned above is twice applied to the specimen respectively.

• Test Results

Fig. 6 shows the relationship between the beam end load P of two specimens and ${}_T\theta$, ${}_L\theta$ and ${}_B\theta$. The broken line in the figure shows the calculated value of the beam's elastic stiffness and the full plastic strength ${}_BP_p$. The progress of the test for each of two specimens is as shown below:

In the specimen TD-16/H of the circular hollow section (CHS) steel tube column, local yielding preceded, but along with the increase in the load applied, plasticization of beam became clear at the loading cycle of $\pm 4{}_B\theta_p$. At the cycle of $\pm 2{}_B\theta_p$, ductile crack-

Fig. 5 Total Beam Deformation ${}_T\theta$, Local Deformation ${}_L\theta$ and Beam Deformation ${}_B\theta$

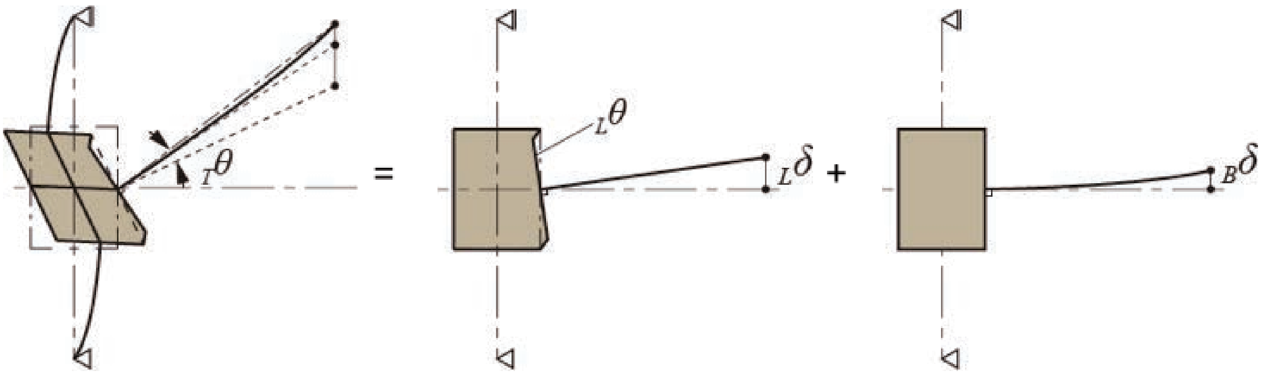
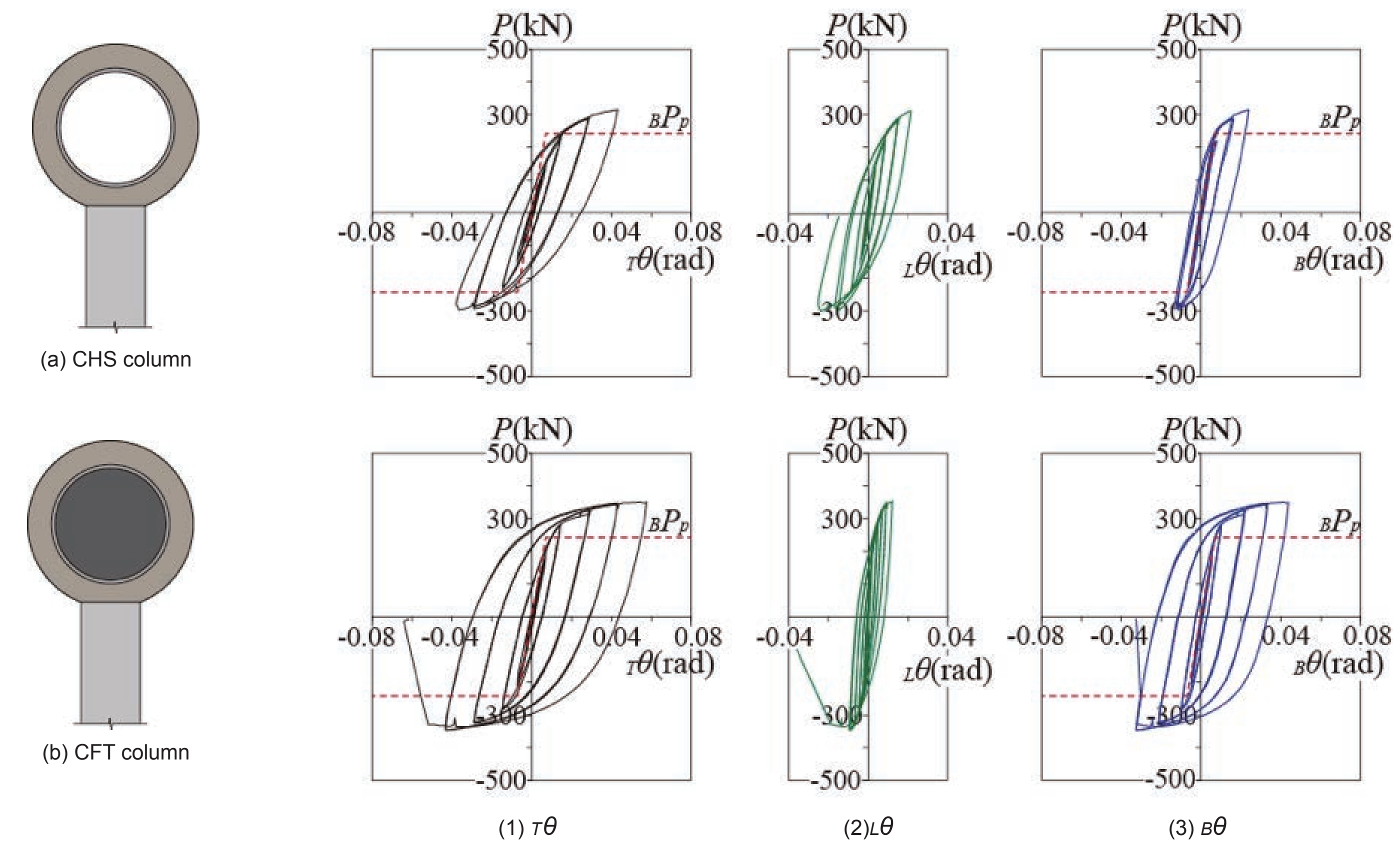


Fig. 6 Load-Deformation Curves



ing occurred at the internal corner section, and at the first cycle of $-6_B\theta_p$, as shown in Fig. 7, this cracking developed diagonally to the diaphragm side to cause a reduction in load-carrying performance.

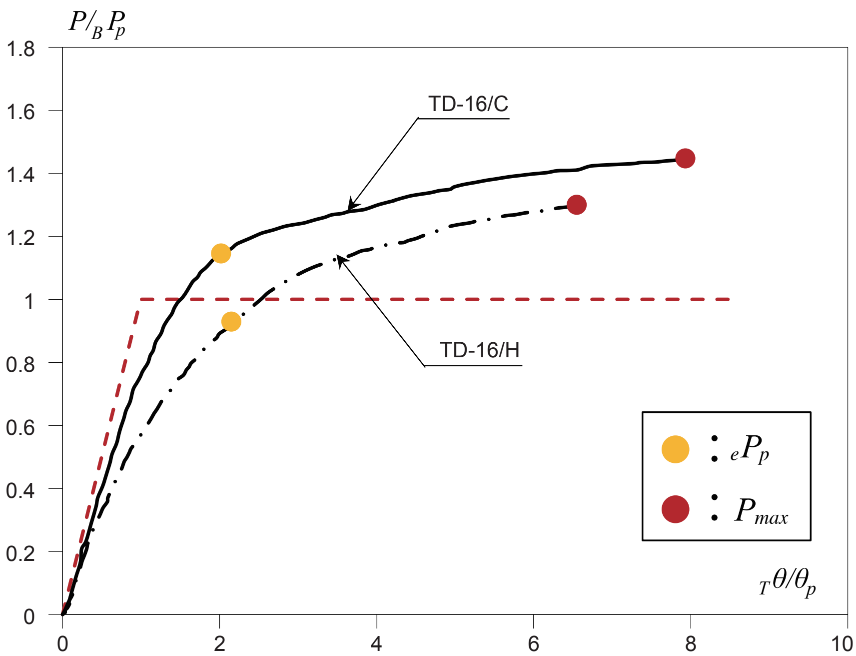
In the specimen TD-16/C of the concrete-filled steel tube (CFT) column, local yielding and beam yielding simultaneously occurred at the loading cycle of $\pm 2_B\theta_p$, but since then the plastic deformation of beam steadily excelled. At the cycle of $\pm 4_B\theta_p$, ductile cracking occurred at the internal corner section, and at the first cycle of $-8_B\theta_p$, after this cracking developed diagonally to the diaphragm side, diaphragm caused a fracture. Meanwhile, local buckling of the beam was observed at the cycle of $\pm 4_B\theta_p$.

When comparing deformation between TD-16/H and TD-16/C, local stiffness of TD-16/C was increased by filling concrete by 1.7 times, and it is known that plasticization of the beam was promoted.

Fig. 8 shows the positive-side skeleton curve in the case in which the $P—_T\theta$ relationship is made dimensionless using $_BP_p$ and $_B\theta_p$. The elastic stiffness in the $P—_T\theta$ relationship reaches a level that falls short of the case of beam end rigid connection by 12% due to concrete filling, and as a result it is known that elasto-plastic behavior and plastic deformation capacity nearly similar to those of the beam-collapse type can be obtained for rigid connection framing.

Fig. 7 Fracture of Diaphragm

Fig. 8 Skelton Curves



Potential Exterior Diaphragm-type CFT Column to Beam Connections

Exterior diaphragm-type connections are the traditional connection system. This type of connection can offer effective solutions in the application of steel tube columns manufactured using super high-strength steel products. In cases when the development and diffusion of robotics flat-position welding will be promoted in the future, I consider it rational to choose exterior diaphragms for column to beam connections. ■

Steel Tubes for Building and CFT Structures

Committee on Overseas Market Promotion, The Japan Iron and Steel Federation

BCR and BCP Standards for Cold-formed Square Steel Tubes

Cold-formed square steel tubes are used mainly as columns in steel-frame building structures in Japan and are one of the most popular steel products for building columns. The manufacturing process takes either of two forms: roll forming (BCR) and press forming (BCP). Fig. 1 shows the manufacturing process.

Neither BCP nor BCR standards are established in the JIS (Japanese Industrial Standards), but listed in MDCR (standards for steel products for construction) established by the Japan Iron and Steel Federation. The steel products specified in these standards are structural members approved by the Ministry of Land, Infrastructure, Transport and Tourism of Japan.

The available size range is 200×6 mm~550×25 mm for BCR and 200×6 mm~1,000×40 mm for BCP.

Chemical composition is shown in Table 1. Mechanical properties are shown in Table 2. BCP235 and BCP325 correspond to SN400 and SN490 respectively, and their mechanical properties such as yield point are the same as those in the JIS SN standard (rolled steels for building structures). Charpy absorption energy is specified at 27J or more at 0ºC for

Table 1 Chemcal Composition of BCR and BCP Materials (%)

Type designation	Material standard	Symbol	Thickness mm Min/Max	C Max	Si Max	Mn Min/Max	P Max	S Max	N[1)] Max	Ceq[2)] Max	Pcm[3)] Max
400 N/mm² grade	MDCR0002-2017	BCR295	6/22	0.20	0.35	/1.40	0.030	0.015	0.006[2)]	0.36	0.26
	MDCR0003-2017	BCP235	6/40	0.20	0.35	0.60 /1.40	0.030	0.015	0.006[2)]	0.36	0.26
		BCP325	6/40	0.18	0.55	/1.60	0.030	0.015	0.006[2)]	0.44	0.29
490 N/mm² grade	MDCR0012-2014	BCP325T	6/40	0.18	0.55	/1.60	0.020	0.005	0.006[2)]	0.44	0.29

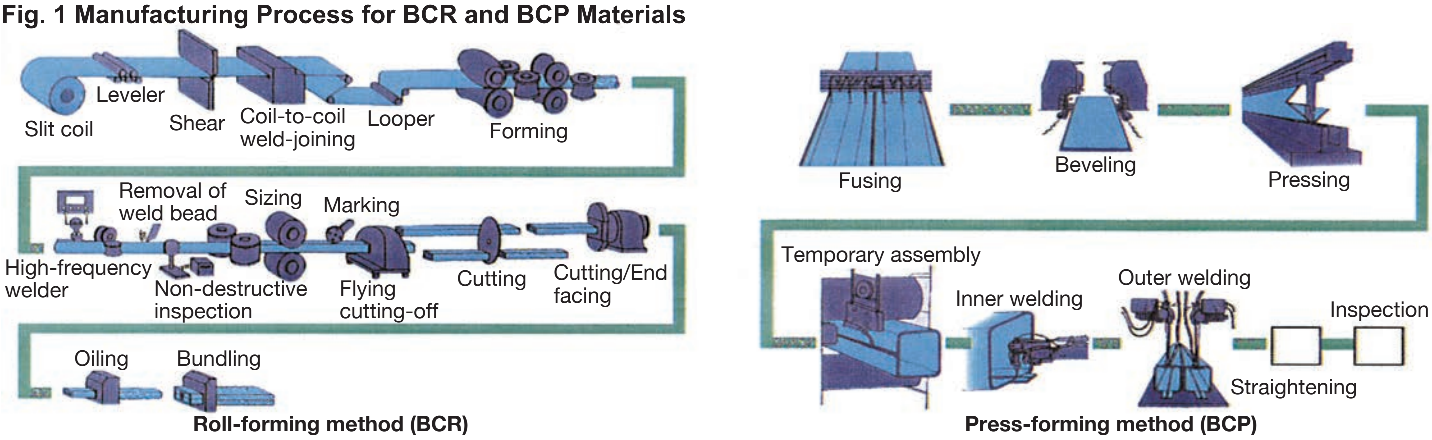
Notes:1) In case when elements to fix N, such as Al, are added and inclusion of solid-solution type N is 0.006% or below, total inclusion of N can be increased up to 0.009%.
2) Ceq = C+Mn/6+Si/24+Ni/40+Cr/5+Mo/4+V/14
3) Pcm = C+Si/30+Mn/20+Cu/20+Ni/60+Cr/20+Mo/15+V/10+5B; Applied in place of Ceq according to the agreement between supplier and purchaser.

Table 2 Mechanical Properties of BCR and BCP Materials

Type designation	Material standard	Symbol	Thickness mm Min/Max	Yield point or strength N/mm²⁾ Min/Max		Tensile strength Min/Max	Yield ratio % Max		Elongation % Min		Charpy impact test; Absorbed energy J Min (0℃)
				t<12 mm	12≤t		t<12 mm	12≤t	t≤16 mm	16<t	
400 N/mm² grade	MDCR0002-2017	BCR295	6/22	295/	295/445	400/550	-	90	23[1)]	27[1)]	27[2)]
	MDCR0003-2017	BCP235	6/40	235/	235/355	400/510	-	80	18	22	27[2)]
		BCP325	6/40	325/	335/445	490/610	-	80	17	21	27[2)]
490 N/mm² grade	MDCR0012-2014	BCP325T	6/40	325/	335/445	490/610	-	80	17	21	70[2), 3)]

Notes:1) JIS No.5 test piece (tube axial direction): No.1A test piece for others
2) Applied for wall thicknesses of over 12 mm and average value of 3 test pieces
3) Applied for both plain/corner parts

Fig. 1 Manufacturing Process for BCR and BCP Materials



wall thicknesses exceeding 12 mm, the same as in the SN standard.

BCP325T, which secures toughness in the bent corners of steel tubes in the BCP standard and allows the same treatment as that in the SN standard, has recently been approved by the Ministry of Land, Infrastructure, Transport and Tourism of Japan.

Steel Plates for Weld Built-up Box Columns

Built-up box columns weld-assembled from steel plates have been used for concrete-filled steel tube (CFT) structures (Fig. 2) in Japan, which are applied in the construction of high-rise buildings because the sectional size of columns is large and exceeds the production range of BCP or BCR. Table 3 shows the mechanical properties of steel plates for building structures.

High-strength steel plates in steel grades, 780 N/mm^2 (H-SA700) and 590 N/mm^2 (SA440), were jointly developed by JISF member companies. The material standards for these products were established by the Japan Iron and Steel Federation and enlisted in the standards H-SA700 and SA440 respectively. Table 4 shows chemical composition of these steel plates. The carbon equivalent (Ceq) is suppressed to a low level to ensure favorable weldability even for the maximum plate thickness of 100 mm.

Especially for SA440, its upper and lower limits for yield strength and tensile strength are specified within a narrow range, and further its yield ratio is specified at max. 80%. Thus, SA440 satisfies a higher level of performance requirements that are essential in securing the seismic resistance of buildings. On the other hand, rather higher yield ratio is specified for H-SA700, and thus it is incorporated in the special design guideline that requires for H-SA700 to be fully in an elastic state even subjected to severe seismic thrusts. ■

Fig. 2 Concrete-filled Steel Tube (CFT) Square Column Structure

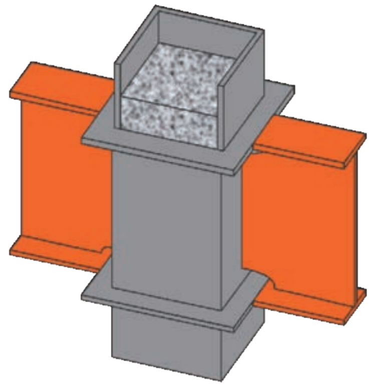


Table 3 Mechanical Properties of Steel Plates for CFTs

Designation	Thickness (mm) Min/Max	Yield point or proof stress: Thickness (mm)	Yield point or proof stress: (N/mm^2) Min/Max	Tensile strength (N/mm^2) Min/Max	Yield ratio (%) Max	Tensile test, Elongation: Thickness (mm)	Tensile test, Elongation: (%)	Tensile test, Elongation: Test specimen	Impact test: Test temp. (°C)	Impact test: Charpy absorbed energy (J) Min	Through-thickness tensile test (%) min: Ave. of 3 tests	Through-thickness tensile test (%) min: Each value
H-SA700A	6/50	-	700/900	780/1000	98	6≤t≤20	16	No.5	0	47[1]	-	-
						20≤t≤50	16	No.4				
							24	No.5				
H-SA700B	6/50	-	700/900	780/1000	98	6≤t≤20	16	No.5	-20	47[1]	-	-
						20≤t≤50	16	No.4				
							24	No.5				
SA440-B Grade 60	19/100	-	440/540	590/740	80	t≤50 40<t	20 26	No.4 No.5	0	47[1]	-	-
SA440-C Grade 60	19/100	-	440/540	590/740	80				0	47[1]	25	15
SN490B (Grade 50)	6/100	t<12 12≤t≤40 40<t	325/ 325/455 295/415	490/610	80	6≤t≤16 16<t≤50 40<t	17 21 23	No.1A No.1A No.4	0	27[1]	-	-
SN490C (Grade 50)	16/100	-	325/455	490/610	80				0	27[1]	25	15

Note:1) Applied for wall thicknesses of over 12 mm and average value of 3 test pieces

Table 4 Chemical Composition of Steel Plates for CFTs (unit: wt%)

Designation	Thickness (mm) Min/Max	C: Thickness (mm)	C: Max	Si: Min/ Max	Mn: Max	P: Max	S: Max	Ceq[1] Max: t≤40	Ceq[1] Max: 40<t≤50	Ceq[1] Max: 50<t	Pcm[2] Max: t≤40	Pcm[2] Max: 40<t≤50	Pcm[2] Max: 50<t
H-SA700A	6/50	-	0.25	/0.55	2.00	0.030	0.015	0.65			0.32		
H-SA700B	6/50	-	0.25	/0.55	2.00	0.025	0.015	0.60			0.30		
SA440-B Grade 60	19/100	-	0.18	/0.55	1.60	0.030	0.008	0.44	0.47		0.28	0.30	
SA440-C Grade 60	19/100	-	0.18	/0.55	1.60	0.020	0.008	0.44	0.47		0.28	0.30	
SN490B (Grade 50)	6/100	t≤50 50<t	0.18 0.20	/0.55	1.60	0.030	0.015	0.44	0.46		0.29		
SN490C (Grade 50)	16/100			/0.55	1.60	0.020	0.008	0.44	0.46		0.29		

Notes:1) Ceq = C+Mn/6+Si/24+Ni/40+Cr/5+Mo/4+V/14

2) Pcm = C+Si/30+Mn/20+Cu/20+Ni/60+Cr/20+Mo/15+V/10+5B; Applied in place of Ceq according to the agreement between supplier and purchaser.

HIRAKATA T-SITE
—Protruding Box Structures Form Expressive Façade and Improve Seismic Resistance—

Takenaka Corporation

The HIRAKATA T-SITE is a proposal-type commercial facility with a combination of floors with diverse kinds of themes, centering on books. It was opened in 2017 in front of the Hirakata Station in Osaka. Its outstanding structural feature is a glass curtainwall that widely opens to the streets and a building appearance that is composed of protruding box construction. A comfortable atrium spreads within the building. (Photo 1)

A variety of advanced devices have been incorporated in order to realize this open space and to enhance the structural strength, among which are the corrugated steel plate seismic-resistant walls and the seismic-resistant box structure. The structural outline of the HIRAKATA T-SITE is introduced in the following:

Towards the Creation of a Relaxing Community Living Room

The HIRAKATA T-SITE was constructed on a site that is located adjacent to a railway station, and is a typical "railway station neighborhood project." In the commercial facilities provided in the building of conventional "railway station neighborhood redevelopment projects," these facilities are behind the commercial facilities in urban centers in terms of product line-up, and further in terms of daily life, their convenience is far inferior to that of mass merchandise outlets and family restaurants operating along major roads. In spite of good access offered by the "railway station neighborhood project" in which many persons pass by as they travel to offices and schools, the attractiveness as a commercial area had been fading.

Under these circumstances, it was required to realize a commercial facility with living value in front of Hirakata Station in which the book street of Tsutaya Books that attracts attention in the DAIKANYAMA T-SITE in Tokyo is posi-

PHOTO: ATSUSHI NAKAMICHI

Photo 1 HIRAKATA T-SITE featuring protruding box structures

Project Outline of HIRAKATA T-SITE

Location: Okahigashicho, Hirakata, Osaka
Project owner: SO-TWO Inc. (representative land owner)
Main applications: Shops, restaurants, banks, parking lots
Area: Site area 2,723.59 m^2; Building area 2,494.07 m^2; Total floor area 17,533.44 m^2
Structure: Steel, partly SRC
No. of story: 1 basement, 9 stories aboveground
Maximum height: 39,830 mm
Architecture, interior: Takenaka Corporation
Interior of TSUTAYA BOOKS: CCC Design Company, Takenaka Corporation
Lighting: Uchihara Creative Lighting Design Inc.
Sign: Nippon Design Center, Inc.
Graphic Art: Hiromura Design Office
Fabric: Studio Akane Moriyama
Construction: JV of Takenaka Corporation and Maeda-gumi
Design term: June 2013~December 2014
Construction term: January 2015~February 2016

tioned as a core facility.

In order to regenerate the railway station neighboring area, we considered that it was not only important for the HIRAKATA T-SITE project to offer attractive content with living value, with a book street as a core facility, but also for the community to be steadily developed there, capitalizing on the living value thus created. In addition, we considered that what is required for producing such values is the creation of the site like a "community living room" into which local citizens freely gather together.

Building Composition

Tsutaya Books has conventionally opened its bookshops in a low-rise building or as a building tenant. The current HIRAKATA T-SITE is a nine-story building-type shop, a first of its kind for Tsutaya Books. As a result, a key point in the plan was how to arrange the book street that connects the upper and lower floors of the building and how to link the book street with other streets. The façade facing the station plaza is finished entirely with a glass wall so that the bustling atmosphere inside the building can be presented to the outside. (Photo 2)

In the HIRAKATA T-SITE building, each living proposal is treated as a volume, which is not piled up straight and vertically but is piled in a shifted form like Jenga. In doing so, a comfortable two-layer atrium space is produced.

PHOTO: TAIZO FURUKAWA

Photo 2 Bustling inside the HIRAKATA T-SITE overflowing into the plaza in front of the station

PHOTO: ATSUSHI NAKAMICHI

Photo 3 Looking down the first-floor atrium entrance from the third floor

On the station front side, seven box structures protrude. Three box structures arranged on the fourth to fifth floors are composed of a two-layer atrium and the exterior walls are finished entirely with a glass curtainwall. The box structure protrudes into the front of the station by up to about 5 m. Its height is about 8.5 m and its width about 7.5 m, and the bookshelf arranged on the wall surface and to a full ceiling height plays a role in connecting the upper and lower floors. (Photo 3)

When viewing a cross-sectional view, the two-layer atriums are arranged in the form of alternate pilings to the side of the station and to the reverse side of the station in order to provide an image as if the inside space of all of the floors are connected. (Fig. 1)

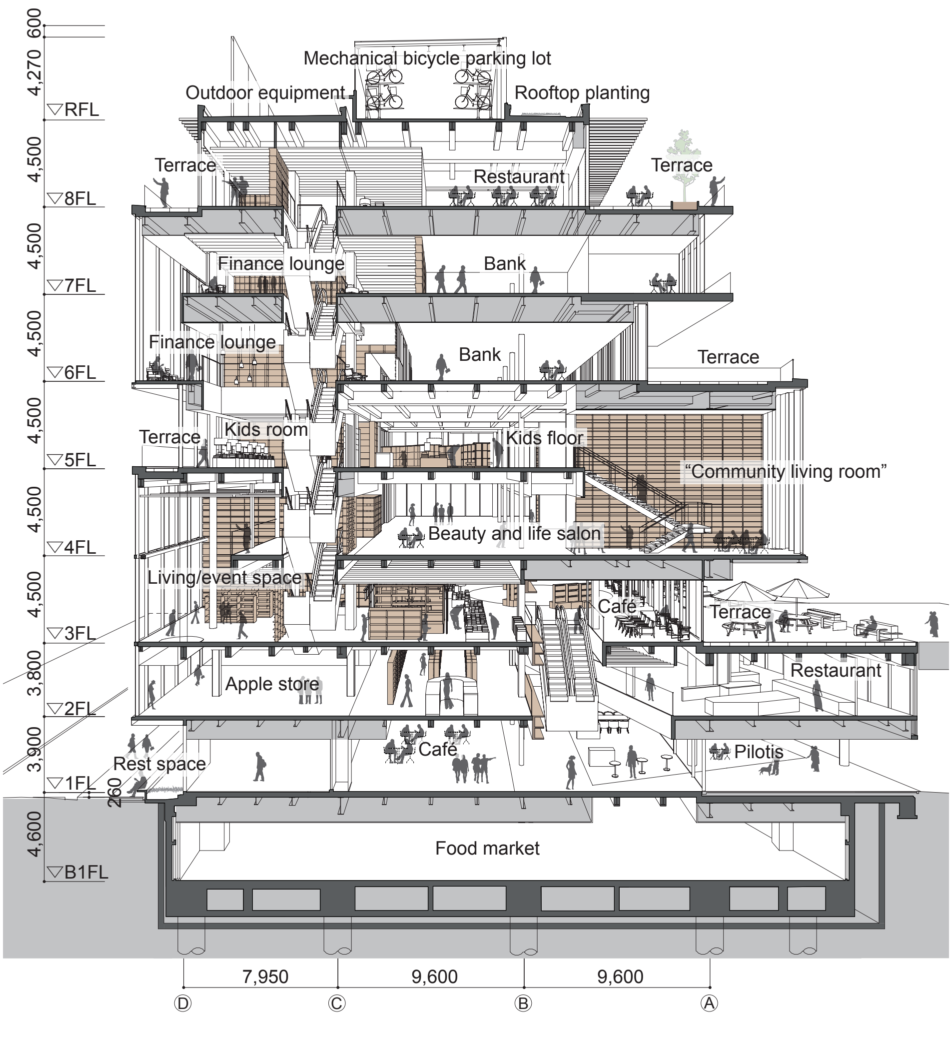
Every atrium is small in scale, but their linkage brings about a sense of integration in construction. The priority in the structural plan of the HIRAKATA T-SITE was for every visitor to feel as if they were in their living room or home wherever they are in the HIRAKATA T-SITE.

Concept of Building Appearance

Generally in the construction of commercial facilities on high-price land, because of the necessity to secure large floor plates that fully occupy the construction site, buildings with flat and wide wall areas tend to be constructed. In the current project, several rooftop terraces appear on the side facing the front of the station due to the alternate piling of the voluminous box structures.

Then, capitalizing on rooftop terraces to be used as play areas for children and a site for restaurants and cafes, we attempted to produce in the front of the station a landscape where people can gather together. In this landscape of gathering together, it is important that the terrace can be seen from the neighboring terrace, that the eyes of people visiting for different purposes can intertwine each other, and that those who are present can feel the presence of each other. If the terraces were arranged in a linear manner along the plaza, such a condition couldn't be brought about. Important here is that clusters of people with identical sympathies in terms of lifestyle can be seen by each other.

Fig. 1 Sectional Drawing



The inside space of the protruding box structures serve as a "community living room," and the outside surface of the box structure plays a role as the wall surface of the plaza in front of the station. That is, the HIRAKATA T-SITE building itself forms part of the plaza in front of the station.

Inside of the Building

Because the main proposal in the project was to "create a relaxing community living room," determining the scale of each building element was important. When the living space, visitor and book are taken into account as the main players, the size of the structural members would become excessively large, and as a result it would be felt that something is wrong. For example, when the size of columns at the book street reaches 600 mm in diameter, the building construction itself lacks structural balance. To solve this problem, we considered that, if the core on the east side and the box structure on the west side were treated as seismic-resistant elements and if the design can be made so that the axial force is borne only by the column, the column diameter could be reduced to 300 mm or less. Finally, a column diameter of 267.4 mm was determined due to the efforts of the structural designers.

Structural Plan

The design concept of the HIRAKATA T-SITE lies in "creating a relaxing community living room." The structural designer understood the concept to be the "creation of a safe space where a sense of security can be obtained." While there are buildings that demonstrate a sense of safety and security by adopting a mega-structure, we considered that such a system was inappropriate for the HIRAKATA T-SITE. When examining the provision of a space that is comfortable and relaxing, it is better not to expose the building structure to the outside. To that end, we considered it desirable not to expose the structural members themselves by adopting thin, slender members.

With regard to structural safety, the client had a high interest in seismic resistance, and it was demanded that the seismic resistance of the HIRAKATA T-SITE be set at 1.25 times that prescribed in the Building Standard Law of Japan. In order to achieve the compatible performance of highly comfortable space and high seismic resistance, it was necessary to prepare a tenacious structural plan that makes optimum use of the narrow space in which the structural members are arranged. An aggregate of devices are incorporated into the construction of the building—for example, in the construction of the façade, in addition to the adoption of slender structural members, some devices are used so that the slender members can demonstrate seismic resistance even in their use as they are.

A main seismic-resistance element adopted was the corrugated steel plate seismic-resistant wall, which was arranged on the core side. While the wall causes plastic deformation during major earthquakes, it is high in fatigue strength, and thus it has a structure to function as a response-control member that absorbs seismic energy.

Seismic-resistant Elements

The corrugated steel plate seismic-resistant wall is arranged on the core side. Meanwhile, in the façade on the station plaza side that widely opens to the outside, nearly no seismic-resistant elements are arranged, which creates the risk of the whole building structure to undergo torsional behavior during earthquakes. To remedy this, we examined whether this eccentricity could be suppressed by making the most of the protruding box structure as a seismic-resistant element. In order for the protruding box structure to demonstrate even a little bit of high rigidity to a seismic force that deforms the box structure to a rhombus shape, the column and beam were inserted into the outer frame panel of the box structure. (Photo 4)

Further, some devices were incorporated to improve the rigidity of the box structure—including the adoption of concrete-filled steel tubes (CFT) for the columns that support the box structure, and an increase in the size of the periphery beams. (Fig. 2)

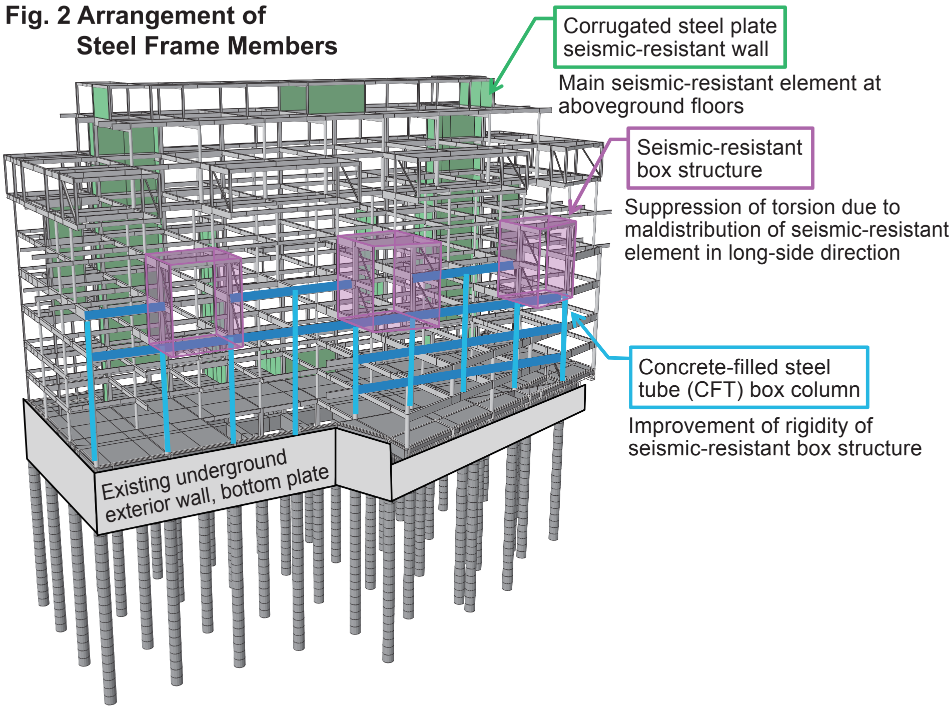
As a result, the eccentricity of the whole building structure was successfully suppressed with no arrangement of braces or other diagonal members in the open surface on the station plaza side but by making optimum use of the box structures.

The aspect width of the outer-frame finishing panel is 400 mm. In order to fit the columns and beams into this width, it was required to suppress the external width of the columns and beams to 300 mm or less for the wall surface and to 330 mm or less for the floor surface. This was an extremely high hurdle in terms of structural design.

PHOTO: TAKENAKA CORPORATION

Photo 4 Steel structure construction

Fig. 2 Arrangement of Steel Frame Members



The aspect width of the panel was important for the box-shaped space of the two-layer box atrium surrounded with books. When the aspect width surpasses 400 mm, this wider size does not fit with the atrium design purpose thereby losing a sense of living. Accordingly, we asked for the structural team to by no means surpass 400 mm.

When only 300 mm was available as the width for arranging the columns, the best that could be done normally was to arrange only the columns that support the box-shaped atrium space. However, in order to improve the safety even slightly, every available device including the column fitting method was incorporated.

Adoption of Seamless Steel Tubes for Columns

It was decided to adopt corner-less round steel tubes as the columns to be arranged in the center of the building because their application not only offers a sense of structural scale but allows for the wider use of available space and brings about no danger to passing visitors. Then, in order to make the size of the tube as thin as possible, heavy-wall seamless steel tubes were selected. The outside diameter was unified to 267.4 mm for use in every floor, and the wall thickness of the steel tube column that support the heaviest weight at the lowest floor was set at 55 mm. Because of its seamless finish, the tubes have no weld beads and thus are structurally fine for use as columns.

In common practice in round steel tube making, steel plates are rounded and weld-joined. When using excessively heavy-wall steel plates to manufacture heavy-wall tubes, it is difficult to bend and weld them together, and thus it is not easy to manufacture steel tube columns with a heavy wall thickness but a slender diameter. On the other hand, the seamless steel tube is manufactured by piecing the center of a defect-free round billet, and thus it can be said that the seamless tube is most suitable for use for columns requiring heavy wall thickness but slender diameter.

The seamless steel tubes with the outside diameter and wall thickness that we wanted to adopt was not available in the normal size range of steelmakers. However, it was confirmed through negotiations with the manufacturer that the specified size could be made available and further advance adjustments were made with a fabricator concerning to the fitting of on-site weld joints of the heavy-wall tubes, which led to successful adoption. (Photos 5~6, Fig. 3)

Among other devices incorporated into the construction of the building was the attachment of commonly-applied H-shapes to commonly-applied square steel tube columns.

Requests for Future Steel Structures

It is considered that the round columns with an outside diameter of 267.4 mm used in the construction of the HIRAKATA T-SITE cannot easily be produced employing reinforced concrete. In other words, it is the steel's attractiveness that can realize the structural section requiring high strength, even by the use of comparatively small-section members. On the other hand, even when applying slender steel members, there are cases in which a slender member prepared so finely may become unexpectedly thick due to fire protection covering—and this would be a disappointment for us. To that end, we strongly desire that an application method be found that makes the most of the slenderness offered by the steel.

In steel products, wide-width or narrow-width H-shapes and I-shapes are freely available, and further specified sizes can be selected from ready-made product line-up. It is possible to produce a weld built-up box steel column used in the current project and also to make the steel members slender. It is another attractiveness of the steel that it can wrestle with applications in the structural sections that allow for the exposed use of the steel itself and are important in terms of design. ■

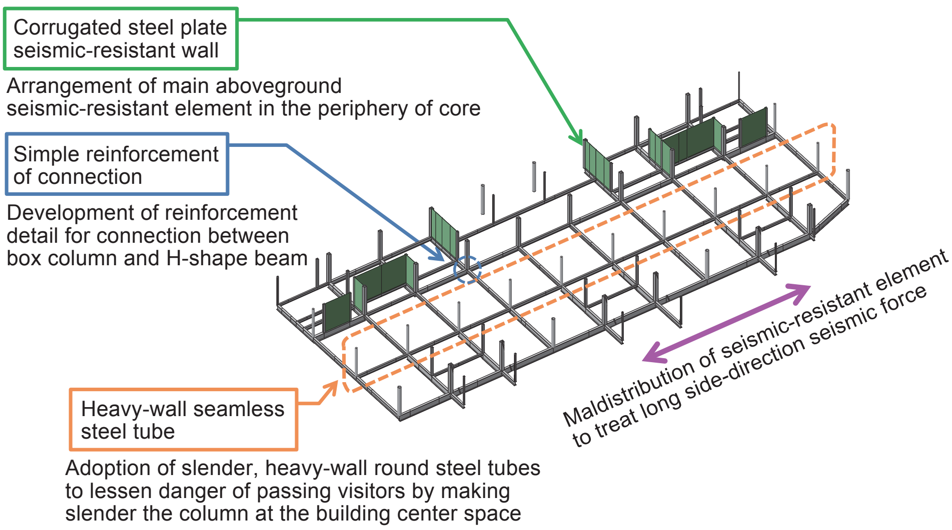
PHOTO: TAKENAKA CORPORATION

Photo 5 Heavy-wall seamless steel tube used as column

PHOTO: TAKENAKA CORPORATION

Photo 6 Building structure employing heavy-wall seamless steel tube

Fig. 3 Arrangement of Steel Structural Members at Fourth Floor



Support of Workshop on Steel Structures in Jakarta

The Workshop on Steel Structures in Jakarta was held on July 19, 2018. This workshop was hosted by the Ministry of Public Works and Housing (PUPR) of Indonesia, into which the Japan Iron and Steel Federation (JISF) and Japanese Society of Steel Construction (JSSC) participated as supporters.

Total participants amounted to more than 60—those working in related government agencies and industries, and university professors. Subsequent to an opening address each by the Minister Economic Affairs of the Embassy of Japan in Indonesia and Director General Syarif of Construction Development of PUPR, several lectures pertaining to steel construction were delivered by lecturers from both Japan and Indonesia. On this occasion, PUPR expressed its intention to establish the Indonesian Society of Steel Construction (ISSC) by assembling those involved in iron and steel in both the public and private sectors in Indonesia. In this regard, JSSC is expected to play a role in driving the dissemination of steel construction in Indonesia.

Japan's Ministry of Economy, Trade and Industry promoted the "Project on Human Resources Nurturing Support for the Introduction and Dissemination of Japan's Disaster-prevention Steel Technologies in Indonesia" for three years from 2014. Following this, JISF and JSSC have jointly promoted diverse projects to disseminate steel construction in Indonesia. As a link with this project, JISF and JSSC have extended advice and cooperation to PUPR and other related organizations concerning the establishment of the ISSC.

Lecture Delivery at the SEAISI Annual Conference

The Conference and Exhibition of SEAISI (South East Asia Iron and Steel Institute) were held on June 25~28, 2018 at the Ritz-Carlton Jakarta in Indonesia, to which the Japan Iron and Steel Federation (JISF) dispatched Chairman Kenichiro Fujimoto of JISF's International Environment Strategic Committee (Environment Div., Nippon Steel & Sumitomo Metal Corporation) to deliver a lecture.

In the Session 10B Environmental Management on the third day of Conference sessions, he delivered a presentation titled "Steel's Competitiveness from the Environmental Perspective." Specifically, he introduced the Japanese steel industry's initiatives to preserve the global environment—highly-efficient CO_2 emissions reduction technology and COURSE50 (CO_2 Ultimate Reduction System for Cool Earth 50) and at the same time explained that steel is a very high-performance material from the perspective of lifecycle assessment. His presentation at the SEAISI Conference was taken up in major Japanese steel press and created a lot of attention.

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