Technical Report

SMart BEAM™ for Timber-steel Hybrid Structures

Yuichi SHISHIDO* Keiichi SATO
Nariaki NAKAYASU

Abstract

SMart BEAM™ is a welded light-gauge H-section, which has been used primarily as a beam member of steel prefabricated residential houses. Recently, aiming for a carbon-free society, an increasing number of timber structures have been constructed not only as residential houses, but also as non-residential buildings. With this in mind, by applying the technology which has been developed for steel prefabricated houses to timber residential houses, Nippon Steel Corporation has already developed the SMart BEAM for short-spanned timber-steel hybrid structures. Furthermore, to expand the application to non-residential buildings, Nippon Steel is now developing the SMart BEAM for long-spanned timber-steel hybrid structures. In this report, together with the timber structure construction trend, a product concept of SMart BEAM for timber-steel hybrid structures is introduced.

1. Introduction

The use of wooden materials is important for the effective utilization of domestic forest resources and the realization of a decarbonized society through forest recycling.

According to the "Statistics on Building Starts" for FY2020, the floor area of new buildings was 99 307 000 m^2, and the ratio of residential and nonresidential buildings was approximately 65% and 35%, respectively. The percentage of timber construction in the residential sector is about 80% (mostly one to three stories), while the percentage of timber construction in the non-residential sector is only about 8%. In response to this situation, the Japanese government, as part of its efforts to promote the construction of timber buildings in the non-residential sector, has enacted the "Act for Promotion of Use of Wood in Public Buildings", and promotes the use of wooden materials for interior and exterior use in public buildings (buildings constructed by the national and local governments, and buildings such as educational facilities, medical facilities, welfare facilities, etc. constructed by private companies). Approximately 30% of low-rise public buildings (one to three stories) are now constructed of timber (FY2020, national average). Furthermore, the partially revised "Act for Promotion of Use of Wood in Public Buildings" was established (enforced in October 2021) as the "Act for Promotion of Use of Wood in Buildings to Contribute to the Realization of a Decarbonized Society", which promotes the expansion of timber buildings not only in the public building field, but also in the general building field in the non-residential sector.

When a timber building is constructed in the non-residential sector, since the construction of a space larger than that in the residential sector is required, component member materials also become larger. In **Table 1**, as examples of large-size section timber beams, the section heights of a timber beam and an H-section having near stiffness are compared for various stiffness levels. As indicated by the Table, the bending Young's modulus of a timber beam is about 1/15 to 1/20 that of steel material, and the higher the required bending stiffness becomes, the larger the difference between the heights of a timber beam and an H-section as only the section height is variable in the case of a timber beam while thickness is also variable in the case of an H-section. For example, for a timber beam approximately 600 mm in height, the height becomes about 1.5 times larger than that of the H-section. Therefore, the timber beam used in the non-residential sector is prone to cause problems such as exerting an oppressive atmosphere in the dwelling space and increasing material and procurement costs (**Fig. 1**).

Under the conditions of the thus changing circumstances of timber structure and subjects pertaining to timber beam becoming clearer, Nippon Steel Corporation developed the floor beam construction method (**Fig. 2**, SMart BEAM™ construction method[1]) jointly with "TATSUMI Corporation", a manufacturer of metal hardware for timber structure, which SMart BEAM (welded light gauge H-section) is used to tie beams and/or the floor beams of timber frameworks with a span of about five meters and of one to three stories high in the residential sector, and introduced it to the market

* Senior Manager, Construction Products Development Div., Plate & Construction Products Unit
2-6-1 Marunouchi, Chiyoda-ku, Tokyo 100-8071

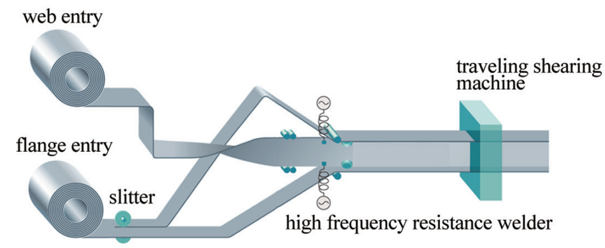
Table 1 Design examples of section depth of timber beam and SMart BEAM

Timber beam			SMart BEAM (SMB)					Section height ratio timber beam/SMB	Recital
H	B	Bending stiffness	H	B	t1	t2	Bending stiffness		
mm	mm	kN/m²	mm	mm	mm	mm	kN/m²		
240	120	1659	200	100	3.2	4.5	2144	1.20	For SMart BEAM construction method
300	120	3240	250	100	3.2	4.5	3545	1.20	
330	120	4312	300	100	3.2	4.5	5375	1.10	
360	120	5599	320	100	3.2	4.5	6236	1.13	
420	120	8891	350	150	3.2	4.5	10427	1.20	For timber-steel hybrid structure
570	120	22223	400	200	4.5	6	23586	1.43	
690	120	34500	450	200	4.5	9	42085	1.53	

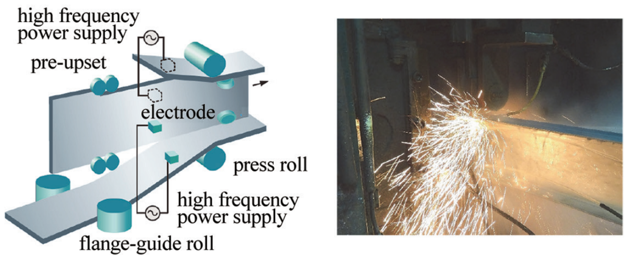
• Young modulus of "Timber beam" is set at 12×10^3 N/mm², and that of "SMart BEAM" is 205×10^3 N/mm².
• Creep deformation of timber beam is not considered in calculating bending stiffness.

Fig. 1 Example of laminated timber beam with large section depth

Fig. 2 Application example of "SMart BEAM" construction method



(a) The entire process



(b) The high frequency resistance welding

Fig. 3 Manufacturing process of a SMart BEAM

in 2011.

This report introduces the history of the development and the outline of the SMart BEAM applicable to the timber framework with a maximum span of 12 m in timber-steel hybrid structure in the non-residential sector where vigorous marketability is expected hereafter.

2. SMart BEAM

SMart BEAM is the welded light gauge steel H sections produced by Nippon Steel (hereafter referred to as light gauge steel H section), which is the H section formed by continuously welding a hot-strip steel sheet, using the high frequency resistance welding process. **Figure 3** shows the manufacturing process where two hot-rolled steel strips each slit to a prescribed width are used, one of them being slit to half of the width and each guided to the flange position, and the other being twisted into a vertical posture, and then guided to the web position. After that, a high frequency electric current is applied across the web-flange, generating arc to develop fusion to pressure-weld the materials.

As compared with the hot-rolled H-section (hereafter referred to as rolled H), since the SMart BEAM, owing to its manufacturing process, is advantageous in that "manufacturing of H sections having a shape and thickness most optimized to meet the required performance is possible", and "has high dimensional accuracy", it is mainly supplied to steel-framed house makers equipped with an automatic processing line.

The product standard of the 400 N/mm² class light gauge steel H section is provided in JIS G 3353 (welded light gauge steel H sections for general structure) as SWH400, and admitted for use for major structures of buildings, being appointed as designated architectural materials provided in Article 37 paragraph (1) of the Building Standards Act. Furthermore, additionally, the 490 N/mm² class light gauge steel H section also acquired the minister's recognition provided in Article 37 paragraph (2) of the Building Standards Act, and is usable for the major structures of buildings.

3. SMart BEAM for Timber-steel Hybrid Structures

The timber-steel hybrid beam using SMart BEAM (**Fig. 4**) is intended for application to beams such as tie beams and floor beams

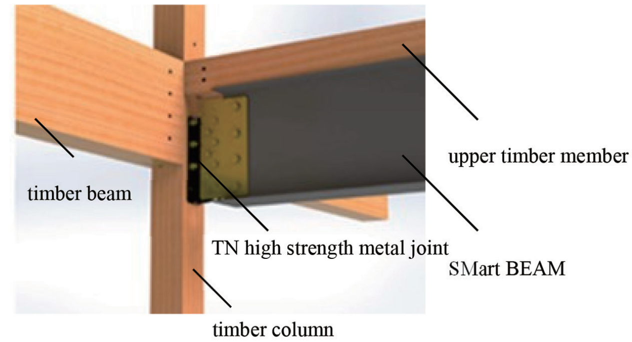


Fig. 4 Product image of timber-steel hybrid beam using SMart BEAM (for illustrative purposes)

of timber frameworks with spans of about 6 m to 10 m in the non-residential sector, and has been developed jointly with “TATSUMI Corporation”, a manufacturer of metal hardware for timber structures.

Under this development, taking into consideration the differences in the processing method, construction method, and design method that exist between timber structure and steel frame structure, both “optimization of construction cost” and “securing space to be realized by a small section beam” are targeted by replacing large section and costly timber beams with the SMart BEAM having a section appropriately selected. The development concept is shown below.

1) SMart BEAM is joined to timber members such as timber beams and/or timber columns by using the ready-made metal hardware for timber use (TN high strength metal joint), and thus, use of the conventional processing machine is possible for processing the timber member, reducing processing cost by avoiding the problem of having to select a new processing plant.
2) In the general steel frame construction work, bolts are inserted while a beam member is being hoisted, and after temporary installation, full-scale installation is then executed. In this construction method, similarly to the widely used metal hardware construction method, bolts are installed in advance on either end of the SMart BEAM, and dropped onto the ready-made metal hardware for timber use (TN high strength metal joint) installed on the timber main beam and/or timber column. Then the SMart BEAM is temporarily installed, and full-scale installation proceeds. The mechanism is designed to facilitate operation of timber structure for construction workers.
3) Timber component members are arranged on the SMart BEAM, enabling easy joining with other timber component members such as vertical roof struts and/or floor plywood.
4) Angle brace materials and/or structural plywood are installed on the timber part of the SMart BEAM so that they are made to bear the horizontal loads of an earthquake and/or wind force, while the SMart BEAM is made to bear the vertical load. By separating the functions of the upper side timber component members and the SMart BEAM, structural design is simplified.
5) Generally, large section timber beams like that of laminated timber are produced on an order-acceptance basis, and unlike generally distributed goods on an inventory sales basis, their delivery schedule is difficult to forecast. On the other hand, for “SMart BEAM for Timber-steel Hybrid Structures”, it is possible to shorten the lead time from acceptance to delivery, because SMart BEAM is regularly of production size and general distribution timber materials are used for the upper timber members for instance.
6) We developed a form for exclusive use for designing to assist structural designers. Furthermore, an order form is also made available in which the automatic estimation of the metal hardware to be used and detailed drawings of the respective processing locations of SMart BEAM are automatically incorporated. With these, further shortening of the lead time from order-acceptance to delivery is enabled.

4. Summary

This report introduced the development of SMart BEAM for timber-steel hybrid structures, which is compatible with the timber buildings in the non-residential sector, which is making great progress in the realization of a low-carbon society.

In addition, SMart BEAM has become applicable to floor joists and/or ceiling joists of the frame wall construction method in accordance with the “Frame Wall Construction Method (2×4 Construction Method) Notification (Ministry of Land, Infrastructure, Transport and Tourism Notification Nos. 1540 and 1541)” (revised in 2015). Hereafter, we continue our efforts to expand the application of SMart BEAM to timber buildings with a view to applying the SMart BEAM for timber-steel hybrid structure to the frame wall construction method.

Reference

1) Shinnittetsu Sumikin Giho. (403), (2015)


Yuichi SHISHIDO
Senior Manager
Construction Products Development Div.
Plate & Construction Products Unit
2-6-1 Marunouchi, Chiyoda-ku, Tokyo 100-8071


Nariaki NAKAYASU
Chief Manager, Head of Section, Doctor of Engineering
Steel Structures Research Lab.
Steel Research Laboratories


Keiichi SATO
Senior Manager
Construction Products Development Div.
Plate & Construction Products Unit