*Technical Report*

# Diversification of Building Sheet Products/Structural Properties and Energy Saving Performance of Light-gauge Steel Framed Houses

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## Abstract

***Building sheet products are products that meet SDGs and carbon neutral requirements. In the construction field, they are widely used for exterior materials such as roofs and walls, secondary structural members such as furring strips and purlins, and main structural members such as columns and beams for low-rise buildings. In this paper, after describing the features of building sheet products, we present examples of development and construction aimed at minimizing the steel framework and reducing on-site man-hours in steel houses targeting low-rise buildings. We also introduce our efforts toward zero energy in terms of heat insulation performance.***

## 1. Introduction

In the architectural field, steel sheets 0.35 mm–6.0 mm thick are widely used for exterior materials such as roofs and walls, secondary structural members such as furring strips and purlins, and main structural members such as columns and beams of low-rise buildings.

Building sheet products have the following three features.

① Free form of SHAPE is realized by cold forming such as roll forming and/or by benders (**Fig. 1**).

② Selection of optimized specifications for correct use from among the variety of materials (strength x surface treatment) is possible. For secondary structural member use, in terms of strength, the 600N class joined the lineup in addition to the conventional 400N and 490N classes, and as high corrosion-resistant-specified surface-treated steel sheets, ZAM™ and SuperDyma™ having 3.8 times the corrosion resistance of corrosion-resistant Zn-coated steel sheets, and ZEXEED™ that has 5.0 times the corrosion resistance of Zn-coated steel sheets have joined the lineup. Furthermore, as roof and wall materials, SGL™, high corrosion-resistant surface-treated steel sheets having three times the corrosion resistance of the corrosion-resistant Galvalume steel sheets are also in the lineup.

③ Utilization is possible as multi-function materials having various performances such as structuring, fire resistance, sound insulation, and warm heat comfort through composite use with other materials such as heat insulation materials, sound insulation materials, and covering materials.

The Nippon Steel Corporation group is promoting, by exploiting and/or combining these advantages, the development of products that meet SDGs and carbon neutral requirements such as “resource saving (weight reduction)”, “realization of longevity (high durability)”, and “high performance (high strength, efficient energy saving,

**Fig. 1 Free form of thin sheet building materials**

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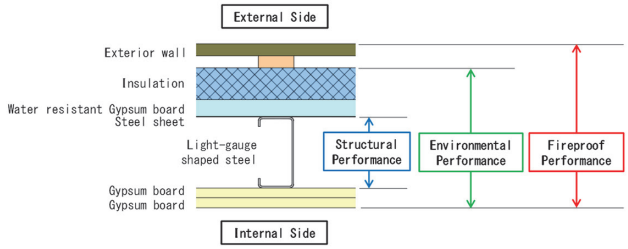



Fig. 2 Example of multi-function panel

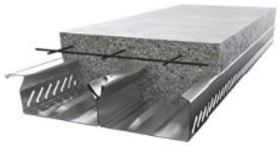


Fig. 3 High-performance steel deck

Fig. 4 Fitting-type folding plate

and high sound insulation capability)". This report introduces the NS Super-Frame construction method™ as an example of multi-functional component merchandise (**Fig. 2**).

In two other reports in this technical report, the "high-performance steel deck" (**Fig. 3**) and "fitting-type folding plate" (**Fig. 4**) are introduced as examples of solving the problems of the existing merchandise by improving the SHAPE.

## 2. Steel House Overview

The steel house (**Photo 1**) has gained solid recognition, obtaining high appreciations from the market and customers through the development aiming at securing and enhancing the warm heat comfort performance and energy saving performance in addition to the structural performance and the fire protection and fireproof performance by employing the external heat insulation ventilation construction method.

Firstly, features of the steel house construction method developed mainly by steel companies are presented. Secondly, the structural characteristics and the construction examples of the NS Super-Frame construction method™ are discussed. The method was developed exclusively by Nippon Steel aiming at expansion in the low-rise building market. In addition, among the growing needs of decarbonization, the energy-saving performance utilizing the external heat insulation construction method is introduced.

As shown in **Fig. 5**, in the steel house construction method, the frame material of the framework wall construction method (two by four) is replaced by a pre-zinc-coated sheet light-gauge shaped steel about 1.0 mm thick, and the structural face material such as plywood and gypsum boards are fixed to the frame with drill screws to form a wall panel and a floor panel, which are assembled like a box.[1)]

The structural panels are manufactured in a factory as shown in **Photo 2**, and connected to each other with drill screws at the construction site (**Photo 3**). This construction method does not require skilled workers, allowing easy construction with fewer man-hours on site, and realizes short period construction.

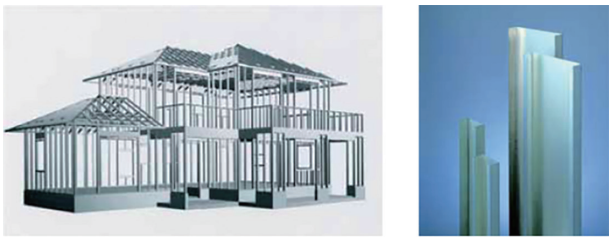


Photo 1 Steel framed house and light-gauge shaped steel

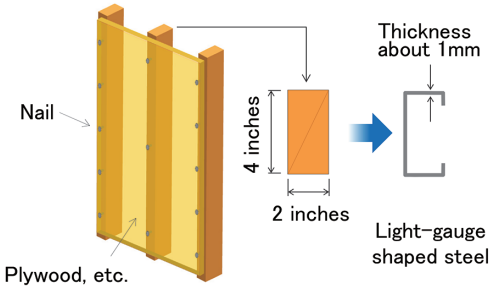



Fig. 5 2×4 wooden frame and light-gauge shaped steel

Photo 2 Scene of structural panel production in factory

Photo 3 Jointing method for structural panel with self-drilling screw

## 3. Development of NS Super-Frame Construction Method™ and Construction Examples

Domestically, the Kozai Club (an incorporated association, presently the Japan Iron and Steel Federation) acting as the secretariat, the Kozai Club type (hereafter referred to as the KC type) two-sto-

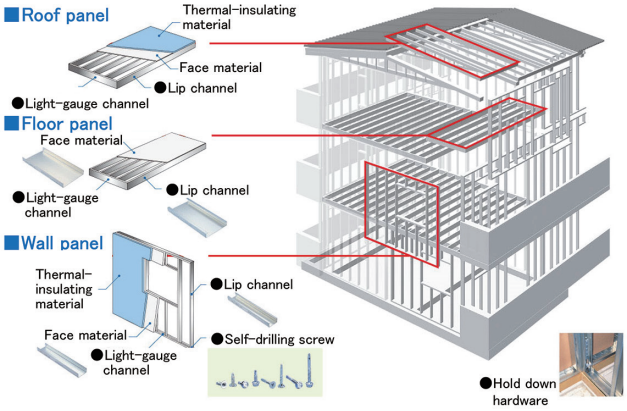
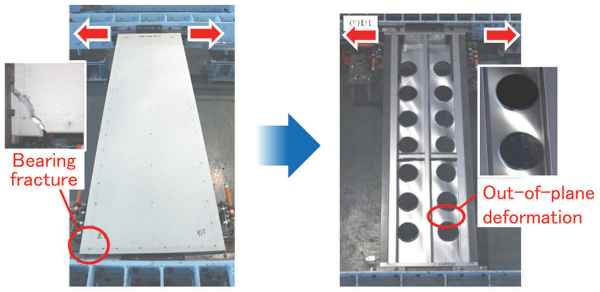



**Fig. 6 Structural system of "NS-Super-Frame"**




(a) Ceramic face material bearing wall for 3-story building (b) Steel sheet face material bearing wall for 4-story building

**Photo 4 Destructiveness of bearing wall**

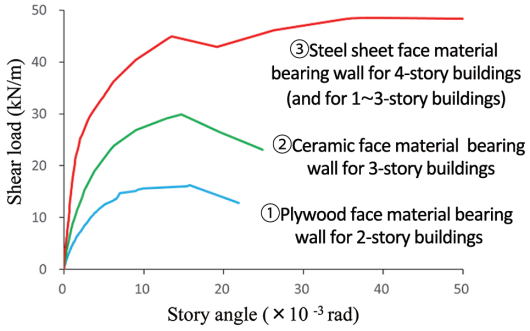



**Fig. 7 Shear load-story angle relation of bearing walls**

ried detached residence steel house merchandize was developed by the six iron and steel companies back then (Kawasaki Steel Corporation, Kobe Steel Ltd., Nippon Steel Corporation, Sumitomo Metal Industries Ltd., Nisshin Steel Co. Ltd., and NKK Corporation), and was put on the market in 2000 on a full scale basis. In order to expand this construction method in the low-rise building market, Nippon Steel back then developed independently its own steel house construction method, the NS Super-Frame construction method™ as shown in **Fig. 6** (hereafter referred to as the NSSF™ construction method).[2)]

### 3.1 Three to four-story apartment house employing high strength bearing wall

In order for the NSSF™ construction method to be applicable to three to four-story apartment houses with which the KC type could not comply, high strength bearing walls using ceramic face material and/or steel sheet face material are being developed. The ceramic face material (**Photo 4** (a)) has high hardness, and as compared with the plywood face material bearing wall used for two-story detached residences, is able to exert twice the rigidity and strength (**Fig. 7** ②).

In steel sheet face material bearing walls (Photo 4 (b)), large out-of-plane deformation is suppressed by providing plurality of holes with the barring function (hereafter referred to as the barring hole), and by producing plurality of small diagonal wrinkles between the holes, deformation performance is enhanced while maintaining resistant force,[3–5)] and three times the strength of the plywood face material bearing wall is exerted (Fig. 7 ③).

Although the larger the number of stories and/or the area becomes, the larger the shearing force (earthquake force and/or wind velocity pressure) that acts on the bearing walls grows, by employing the steel sheet face material bearing wall excellent in earthquake energy absorption performance, increase in the quantity of the structural skeleton (bearing wall) is suppressed, and effective use of the indoor area is possible.

**Photo 5** shows examples of three-story and four-story company condominiums built on a common site. Even for a four-story building, by employing the steel sheet face material bearing wall, increase of the quantity of the bearing wall installed in a room is suppressed, and the same floor plan as that of the three-story building (ceramic face material bearing wall employed) can be configured (**Fig. 8**).

**Photo 6** shows an example of a three-story dormitory. For a room with a frontage of 3185 mm, by employing the steel sheet face material bearing wall for the exterior wall of the south to north face (in the cross beam direction), a wide open space without emergence of a wall in the room is secured (**Fig. 9**).

In the case of the four-story company condominium, the amount of steel material consumption is about resource-saving 60% of the reinforced concrete construction method (hereafter referred to as RC construction method) (**Table 1**). Since the weight of the building above ground is smaller, being about one third of that of the RC construction method, labor-saving is possible at the foundation building work stage (including soil stabilization work). At the construction site, the only work is to connect the premanufactured panels with drill screws, therefore the construction schedule is shortened by about two months as compared with that of the RC construction method (**Fig. 10**).

### 3.2 One-story office building and shop building employing unit roof truss

In one-story buildings, in order to accommodate offices and shops having large spaces, instead of the roof panel composed of joists of single body sheet light-gauge shaped steel (roof panel in Fig. 6), a roof truss having high bending rigidity is employed.

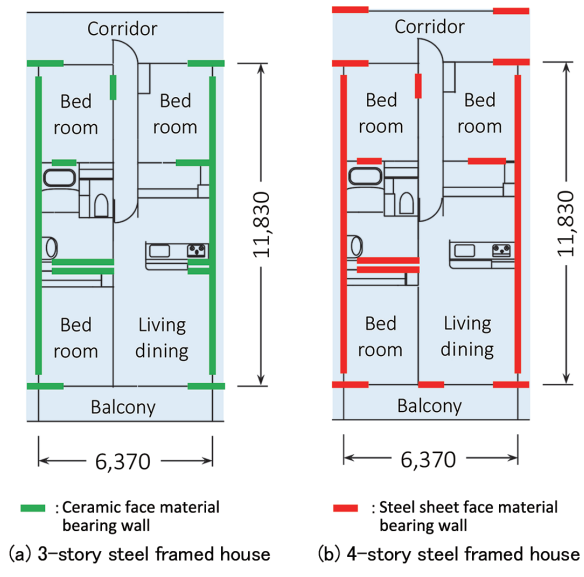
As shown in **Fig. 11**, a unit roof truss consisting of beam truss, cross truss, and horizontal brace (registered design number 1643895) is prefabricated in a shop, only to be joined mutually at the construction site, thereby reducing the work load at elevation, and reducing on-site man-hours significantly. Since this construction method reduces the amount of steel used per unit floor area to about 60% of that of the general steel-framed structuring method, this method is successively employed by the offices of SDGs and/or large carbon-neutrality minded enterprises (**Photo 7**).

In order to further reduce the amount of steel required to im-

(a) 3-story steel framed house

(b) 4-story steel framed house

**Photo 5 Company condominium**




(a) 3-story steel framed house (b) 4-story steel framed house

**Fig. 8 Floor plan of company condominium (3-story and 4-story)**

prove this construction method, application of high tensile strength steel (tensile strength = 560 N/mm²) to roof truss members is planned. According to the trial calculation based on the model with a long span of 9.1 m, due to the rise of buckling strength intensity of high strength steel, steel material weight can be reduced by 14%, and additionally, since the bearing pressure yield stress of the section steel at the screw drill connecting site also rises, reduction of the number of drill screws (construction man-hours reduction) is

**Photo 6 3-story steel framed dormitory (Source: Nippon Steel Texeng. Co., Ltd.)**

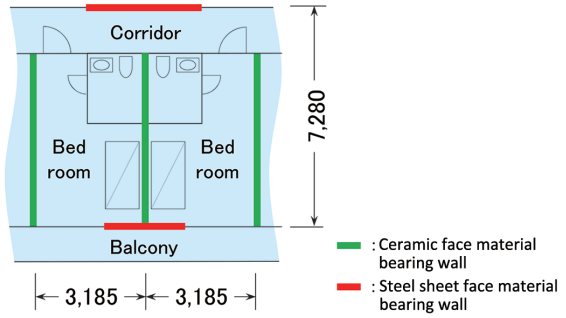



**Fig. 9 Floor plan of 3-story dormitory**

**Table 1 Steel weight and building weight per unit floor**

| Type of weight | NS-Super-Frame™ | Reinforced concrete building |
|---|---|---|
| Weight of steel (N/m²) | 450 | 800 |
| Weight of building (N/m²) | 4 000 | 12 000 |

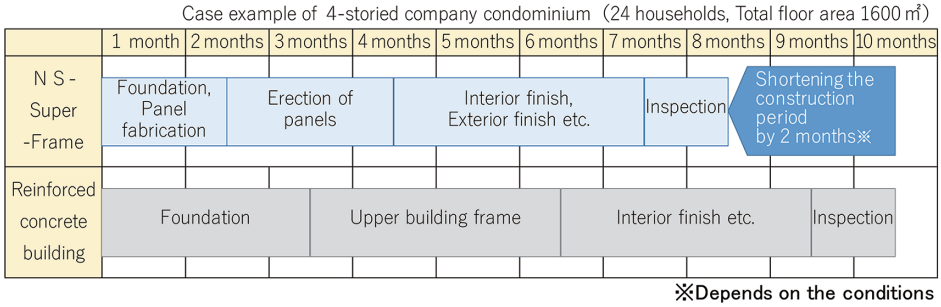



**Fig. 10 Construction schedule of "NS-Super-Frame" and reinforced concrete building**

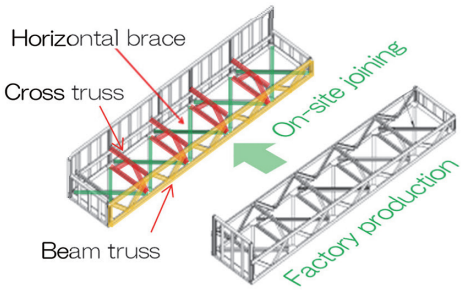



**Fig. 11 Composition of unit truss**
**(Source: NS Hi-Parts Corporation)**


**Photo 7 Scene of 1-story steel framed office construction**

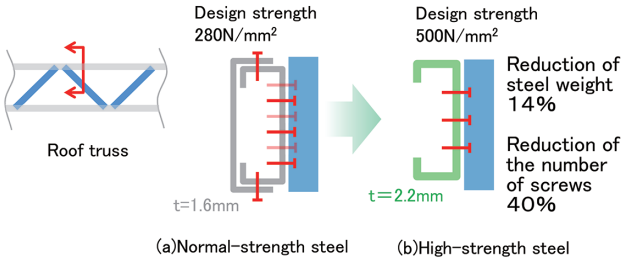



**Fig. 12 Effect of high-strength steel**

also possible (**Fig. 12**). Its effect shall be confirmed through the construction of a one-story building planned in future.

## 4. Warm Heat Comfort Performance of NS Super-Frame Construction Method™

Amidst the global current of decarbonization, in Japan, a government plan to achieve ZERO ENERGY of new houses and buildings has been launched, wherein the aim is to reduce $CO_2$ by 40% not later than 2030 in the housing and building sectors. With this, it is prospected that the standards for Net Zero Energy House (ZEH) and Net Zero Energy Building (ZEB) in newly constructed houses and buildings will become mandatory, and the move of transition in future to heat insulating performance higher than those of ZEH and ZEB is emerging. In the NSSF™ construction method as well, ZEH and ZEB specifications are incorporated, publicized to customers, and application to actual projects is promoted, and additionally, the development of specifications toward higher heat insulation performance is in progress. Hereunder, the current warm heat comfort performance of the NSSF™ construction method is quantitatively shown, and an example of the ZEH specification and its application to the latest project are introduced.

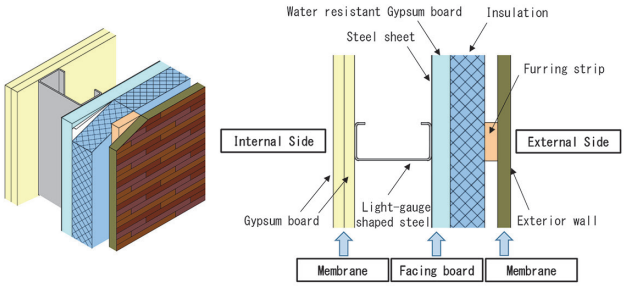



**Fig. 13 Exterior wall structure of steel framed houses**

### 4.1 Current warm heat comfort performance and improvement measures to realize ZEH

**Figure 13** shows a representative exterior wall and the wall inner structure of the NSSF™ construction method. The structural skeleton consists of panels each composed of sheet light-gauge shaped steel and structural face material which are integrated into one body via drill screws. The employment of the "external heat insulation ventilation method" consisting of a heat insulation material and a ventilation layer is specified as standard for the entire exterior of the whole dwelling space. On the external side, an external material of the ceramic family is used as a membrane, and on the internal side, a gypsum board is used as a membrane. Thus with the employment of the external heat insulation ventilation method in which the external side of the steel-made skeleton is covered with a heat insulation material without gaps, high heat insulation performance that greatly exceeds the present energy saving standard is exerted.

This was proven by the result of the quantitative evaluation of the performance of the external shell conducted with respect to an actual building. Selected for the evaluation was the six dwelling units of one end side (corner) dwelling unit and one middle (inside) dwelling on all floors of a three-story company condominium built in Kimitsu City of Chiba Prefecture by the NSSF™ construction method, and the amount of heat loss in element places in each dwelling unit was calculated. The heat insulation specification of each element place is shown in **Table 2**, and the result of the calculation is shown in **Fig. 14**. The value of $U_A$, the average coefficient of overall heat transmission of the external shell of all dwelling units significantly clears the current energy-saving standard ($U_A$ in area division 6: 0.87), and the values other than those of the end side dwelling units of the bottom floor and the top floor satisfy the ZEH standard ($U_A$ in area division 6: 0.6). The heat loss amount in each dwelling unit is high on the external wall and window. The heat loss in the top dwelling unit becomes higher with the addition of heat loss through the roof. By changing the windows of the top and bottom floor end side dwelling units to Low-E multi-layered glass, all dwelling units satisfy the ZEH standard. Furthermore, not only by changing the window glass, but also by applying intensively heat insulation measures to element places having high heat loss such as the external wall, further enhancement of heat insulation performance is expected. Presently, high heat insulation specifications exceeding the ZEH standard are being studied.

### 4.2 Example of latest application to project

Of late, needs for the applications of ZEH and ZEB to the NSSF™ construction method are rapidly increasing, indicating strong interest in the realization of ZERO-ENERGY. Hereunder, an example of the application of ZEB is introduced.

**Table 2 Insulation specifications of company condominium**

| | Current specifications | ZEH specifications |
|---|---|---|
| Roof | Extruded poly-styrene ($\lambda$: 0.028) 40 mm | |
| Exterior wall | Extruded poly-styrene ($\lambda$: 0.028) 25 mm | |
| Window | Ordinary double grass | Low-E double glass*1<br>Ordinary double glass*2 |
| Foundation (Under slab of indoor side) | Extruded poly-styrene ($\lambda$: 0.028) 25 mm | |

*1 Top & bottom floor corner dwelling unit, *2 Others

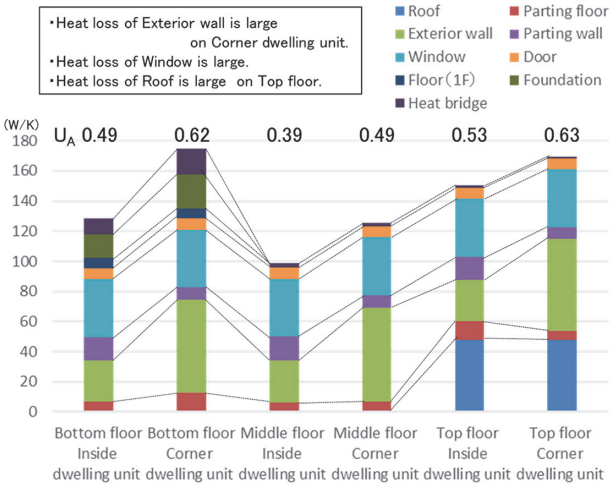



**Fig. 14 Heat loss of company condominium**

"ZEB in Nagoya Training Center of Nippon Steel Texeng. Co., LTD."

Nippon Steel Texeng, a company of the Nippon Steel Group which operates a construction business, built its own Nagoya Training Center based on its own design and construction, and was ZEB-certified for the first time (**Photo 8**: in Obu City, Aichi Pref., NSSF™ construction method, two-storied above ground, total floor area: 935.36 m$^2$, completed: April, 2022). While employing the conventional heat insulation specification, this project yielded 3% surplus energy by combining "energy saving" realized by means of introducing LED illumination, lighting control (automatic light-up), a dispersed air conditioning system and high-efficient total heat exchange system, and the "energy creation" realized by means of joint use of solar panels and "energy storage" by means of lithium batteries (energy saving ratio of 53%, energy creation ratio of 50%). Hereafter, by taking advantage of the strength in ZEB, our company aims to expand the sales of this construction method not only to Nippon Steel Group projects, but also to our customers' office buildings.

**Photo 8 Nagoya Training Center**
**(Source: Nippon Steel Texeng. Co., Ltd.)**

## 5. Conclusion

Development aimed at minimizing the structural skeleton and reduction of on-site man-hours in steel house construction to be applied to low rise buildings, and examples of the construction and the approach to establishing ZERO ENERGY in terms of heat insulation performance have been introduced.

Amidst the current global trend toward SDGs, supporting technologies for effective utilization of resources and carbon neutrality are demanded. Furthermore, domestically, needs for labor-saving are also growing with the background of aging of on-site construction workers.

The steel house construction method is able to comply with these needs, and hereafter, a wide range of applications to fields such as housing, offices, and nursing health care facilities for aged people are expected.

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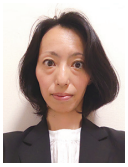

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