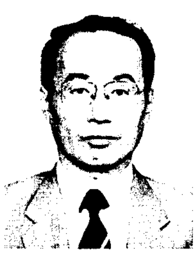
Steel Section Products for Current and 21st Century Social Infrastructure Applications*





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Synopsis:

Kawasaki Steel has developed many new products in the field of steel sections in these last ten years as the 21st century approaches. For architectural use, the company has made fixed outer dimension H-beams commercially available for the first time in the world and has developed various large section products of the company's own, including those of the 1 000 mm web depth series. As for heavy gauge H-shapes, the company developed TMCP heavy section products and has been leading the industry. For civil construction use, the company has developed "K-Domeru", 600 mm width sheet piles and the REED construction method and has been contributing toward reduction of public expenditure. Described in these reports are the details of those new products and methods and the prospects for technological trends in the future.

1 Introduction

With the 21st century at hand, the economic and social conditions have been drastically changing and it has been strongly required to reduce construction costs and to improve steel qualities including the seismic resistance performance. Since starting production of H-beams by means of the universal rolling method for the first time in Japan in 1961, Kawasaki Steel has been developing various section products meeting the customers' needs. This report describes the results of a number of recently developed products for architectural and civil construction use and the future trends in these fields are predicted.

2 Newly Developed Products for Architectural Use

2.1 Trends in the Building Construction Market

The building construction market in Japan has dramatically shrunk since the bubble economy collapsed. **Figure 1** shows the trends in the total construction floor area of each type of structure.[1] It is apparent that the present level has dropped nearly to the lowest in these ten years. In addition, the construction cost has also dropped to a large extent due to the owners' request for cost reduction, therefore, it has been strongly required to develop new products which bring about not only reduction of steel cost but also reduction of construction cost.

On the other hand, improvement of the quality of steel products themselves has also become an important issue as represented by the trend of requiring adequate steel quality against various problems such as laminated steel plates and deteriorated steel structures reflecting the

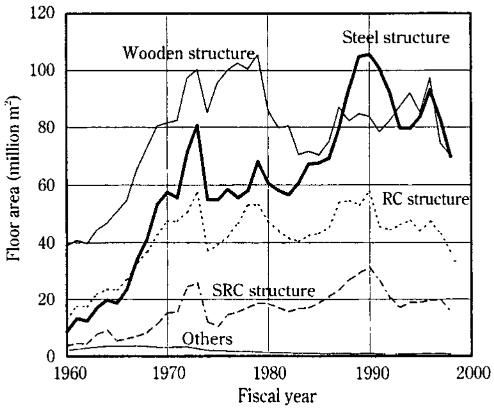

Fig. 1 Trend of total construction floor area of each structure

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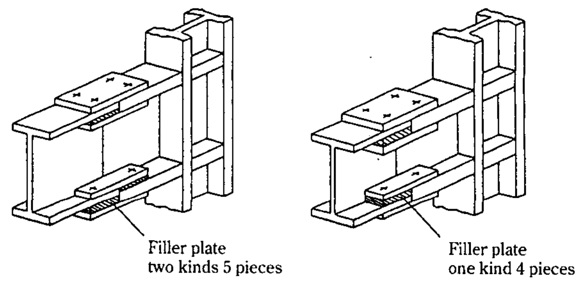


(a) Fixed inner dimension H-shapes (b) Fixed outer dimension H-shapes

Fig. 2 Comparison of fixed outer dimension H-shapes with conventional H-shapes

damage caused by certain earthquakes including the Northridge Earthquake of January 17, 1994 and the Hanshin-Awaji Earthquake of January 17, 1995.[2)] In order to respond to these needs, Kawasaki Steel has been tackling the development of new products in the area of steel sections for architectural use and has achieved development of many new products in recent ten years, in particular. As for beams for architectural use, the fixed outer dimension H-beams "Super HISLEND-H" were put on the market in 1989 to replace built-up H-beams. As for columns, matching the trend of increasing use of heavy gauge H-shape steel sections, those of the "Rever Tough" series produced by adopting the TMCP method were commercialized in 1996. Furthermore, heavy gauge H-shape steel sections of 700 × 500 series were also put on the market in 1998. This series is of the maximum web height among various heavy gauge H-shape steel section products. These major products are outlined in the following sections.

2.2 Fixed Outer Dimension H-Beams "Super HISLEND H"

Conventional rolled H-beams were made with a fixed inner dimension as shown in **Fig. 2** due to the conventional rolling technique and therefore the on-site workability of these H-beams could not be regarded as excellent, therefore, it has been a long-standing objective to produce rolled fixed outer dimension H-beams. By developing a web inner width reduction method using an adjustable width roll shown in **Fig. 3**,[3)] it has now become possible to produce fixed outer dimension H-beams with a constant web height even if the flange thickness is different. The "Super HISLEND H" was put on the market in 1989 and longer H-beams with a flange width of 350 mm and 400 mm were additionally made available in 1993. From 1999, the 1 000 mm series with the largest web height in Japan was commercialized and has gained a good reputation with the customers.

2.3 TMCP Type Heavy Gauge H-Beams "Rever Tough"

The section property of a steel section product is mostly determined by the shape and dimension. However, with the experience of steel fractures in structures caused by the Hanshin-Awaji Earthquake acting as turning point, the seismic resistance performance has become important also for steel sections. Heavy gauge H-beams with flanges as thick as 80 mm are increasingly used for columns of ultra high rise building for the various advantages gained by the decrease of welded parts including improvement of the safety of buildings, reduction of production costs and reduction of lead time.

In addition to conventional controlled rolling techniques which are to respond to these needs, more advanced studies were made. As a result, RT 325 (MAC 325 equivalent) and RT 355 (MAC 355 equivalent) were developed by means of the third generation TMCP method which makes maximum use of the enhancement of ferrite nucleation by fine inclusions such as vanadium nitride (VN), i.e. fine inclusion metallurgy (FIM), to the maximum extent[4,5)] and RT 440 (SA 440 equivalent) using extremely low carbon banitic steel with precipitation strengthening were made commercially available.[6)] The typical chemical compositions of these heavy gauge H-shapes are shown in **Table 1**, and the mechanical properties are shown in **Table 2**.

As shown in Table 1 and 2, the steel sections of all grades up to the SA 440 class can be produced without heat treatment and have sufficient strength and high toughness at every section meeting the target values. Furthermore, an excellent welded joint performance was achieved with the possibility of welding without preheating. As for the seismic resistance performance when used for actual structure, the safety performance has also been confirmed through loading tests using full-size beam to column joint structure.[7)]

Based on these results, RT 325 and 355 were recognized by the Ministry of Construction with respect to the specified steel strength.[8)] As a result, reduction of F-values has become unnecessary even with flanges thicker than 40 mm and application of these section products to columns of ultra high rise buildings has expanded. Furthermore, responding to the needs for larger sections together with the needs for higher strength, the sections of 700 × 500 series having the highest web height among many heavy gauge H-shape steel sections were developed and the products to meet the customers' needs have been made available in a full series.

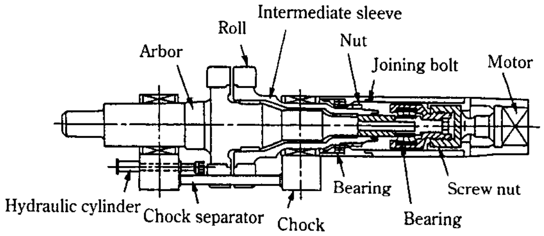


Fig. 3 Adjustable width roll for finishing universal mill

Table 2 Mechanical properties at specific portions of TMCP type heavy gauge H-shapes

Steel	Spec. and size	Position	Direction	YP (0.2%YS) (MPa)	TS (MPa)	YR (%)	vEo (J)
RT325	MAC325B/C	F1/4–1/4 t	C	325–455	490–610	≦80	≧27
	500 × 500 × 50 × 80 mm	F1/4–1/4 t	L	403	530	76	203
		F1/2–1/2 t	L	352	537	66	168
		W1/4–1/4 t	L	398	532	75	—
RT355	MAC355B/C	F1/4–1/4 t	C	≧355	520–640	(≦80)	≧27
	500 × 500 × 50 × 80 mm	F1/4–1/4 t	L	417	560	75	258
		F1/2–1/2 t	L	406	556	73	230
		W1/4–1/4 t	L	422	564	75	242
RT440	SA440	F1/4–1/4 t	C	440–540	590–740	≦80	≧47
	500 × 500 × 60 × 65 mm	F1/4–1/4 t	L	487	636	77	212
		F1/2–1/2 t	L	463	634	73	90
		W1/4–1/4 t	L	458	632	72	153

Table 1 Typical chemical composition and microstructure of TMCP type heavy gauge H-shapes

(mass%)

Steel	C	Ceq	Microstructure
RT325	0.12%C-V-N	0.36	Ferrite + Pearlite
RT355	0.12%C-V-N	0.40	Ferrite + Pearlite
RT440	0.02%C-Cu-Nb	0.28	Bainite

2.4 Steel Section Products for Architectural Use in the Future

An official announcement was made for a revision of the building standard law on the June 12, 1998.[9] One of the main points of this revision was to improve the standard system including to specify the performance definition of building standards and it is expected that the revision of the standard will bring about various effects such as enhancement of the degree of freedom in design, smooth introduction of new technology linking to rational cost reduction and activation of the market. Furthermore, taking the opportunity of having studied the disaster of Hanshin-Awaji Earthquake, the provisions on steel materials, welded parts, etc. were also reviewed. With respect to H-shape steel sections, in particular, very tough products having a satisfactory impact property all over including welding heat affected zones are required in order to prevent brittle fracture at the beam ends. Improvement of materials at all sections including the fillet parts becomes important and upgrading of weldability and size accuracy for reduction of processing cost as well as further shortening of lead time will be the important subjects from here on.

3 Newly Developed Products for Civil Construction Use

3.1 Trends in the Civil Construction Market

The civil construction market in Japan will continue to contract for the long term as seen from the trend of public investment shown in **Fig. 4** and cost reduction has been an important subject. On the other hand, with the Hanshin-Awaji Earthquake as turning point, seismic resistant design methods were reviewed in various areas including road and harbor construction and a better seismic resistance performance is requested for civil construction structures. In addition to the above, new requirements such as harmony and symbiosis with nature and labor-saving technology following the shortage of skilled labor are needed.

Kawasaki Steel has been working to develop new products responding to such requirements of clients in the area of steel sections for civil construction use. In the last ten years, the company started, in 1992, to sell steel landslide protection walls called "K-Domeru" developed for meeting the demand of rapidly increasing urban underground construction and put colored steel sheet piles on the market. These piles take into consideration harmony with scenery and material environment. Furthermore, in 1997, the company developed wide width steel sheet piles which made an extensive cost reduction possible both for materials and construction

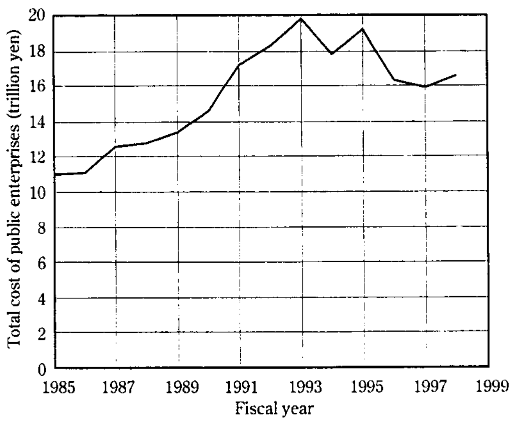


Fig. 4 Trend of official investment for civil construction

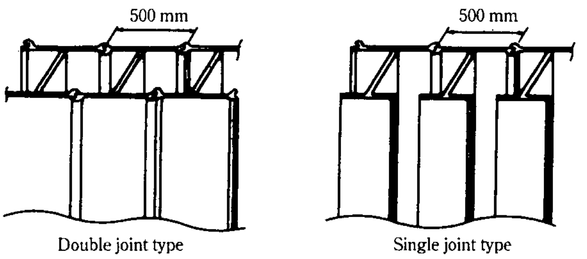


Fig. 5 Type of K-Domeru

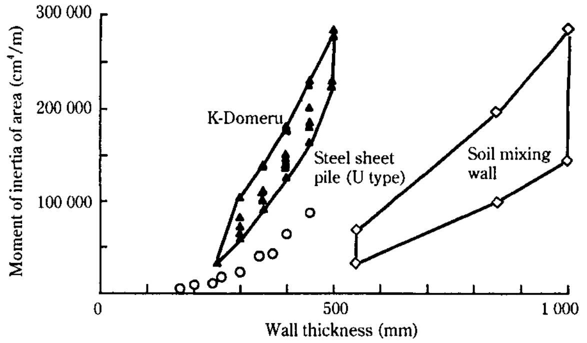
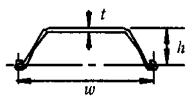


Fig. 6 Relation of wall thickness to rigidity



(mm)

Size	w	h	t
KSP-2W	600	130	10.3
KSP-3W	600	180	13.4
KSP-4W	600	210	18.0

Fig. 7 New type sheet piling with 600 mm in width

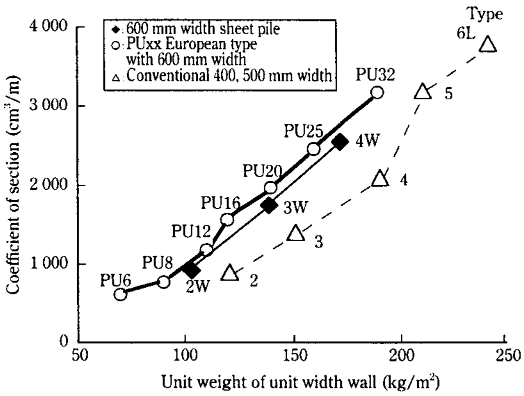


Fig. 8 Comparison of wall efficiencies

work. These piles replace conventional steel sheet piles and have highly been valued by the clients as well as by the Ministry of Construction. Therefore, the company has been working with users to contribute to labor-saving in working on bridge piers by developing the REED construction method combining these piles with H-shape steel sections fitted with projections, and thus has been quickly responding to the customers' needs. These new products are outlined hereunder in this chapter.

3.2 "K-Domeru"

Overpopulation in large cities has progressed and the requirements for technologies to use underground space and to construct underground facilities have become very strong. For this reason, landslide protection methods with low noise and vibration are also required. In addition, the walls have to be thin but with high rigidity, and construction work to be completed quickly.

In order to respond to these requirements, the company developed welded assembled H-shape steel landslide protection walls, (Trade name: "K-Domeru") and commercialized this product in 1989. "K-Domeru" is a type of steel landslide protection wall and is made by combining a straight steel sheet pile used for the cell bulk head method with a thick plate or a shaped steel (CT, H) by welding. There are two types, the double joint type and single joint type, shown in **Fig. 5** in "K-Domeru". The relationships between the moment of inertia of area and wall thickness are shown in **Fig. 6** for U-type steel sheet pile, soil mixing wall and "K-Domeru". It can be seen from the figures that by making use of these special features of H-shape sections, "K-Domeru" provides a higher rigidity with a thinner wall than other walls built by conventional methods.

As for the working method for "K-Domeru", in addition to the method of driving the walls directly into the ground, it is possible to use "K-Domeru" as a stress burden material for the soil cement continuous wall installation method. Installation by means of the small scale self-propelled pile installation method, in particular, has proven powerful in restricted narrow environments such as public civil construction work in city areas.

3.3 Wide Steel Sheet Piles

The wide steel sheet piles shown in **Fig. 7** are new sheet piles with an effective width expanded to 600 mm from the conventional width of 400 mm and 500 mm. An extensive reduction in public investment has been realized with these new sheet piles through reduction in material costs due to decreased number of pile installations per unit working length and the increase of rigidity of the wall. This product is made thick in order to improve the installation performance compared with European products and as shown in **Fig. 8**, the coefficient of section per unit weight (as a wall) is increased compared with conventional domestic products.

Since starting production of 3W type sheet piles in April 1997, the company has well organized its production and sales systems for the 2W and 4W types. As a result, the percentage of wide type of U-type steel sheet piles being sold has reached more than 70% and wide sheet piles are expected to be used more and more to reduce public expenditures by the government and public offices.

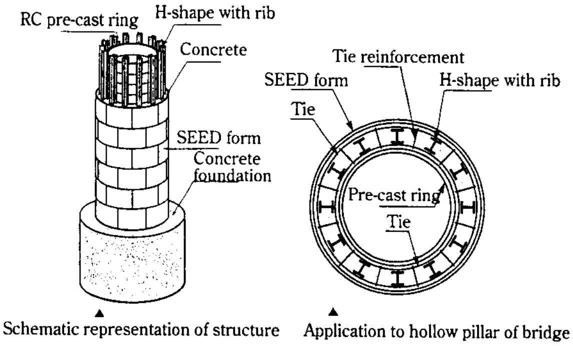


Fig. 9 Outline of "REED" construction method

3.4 REED Construction Method

As shown in **Fig. 9**, the REED construction method is a bridge pier construction method of steel reinforced concrete of a complex structure type. This method is designed to combine projection fitted H-shape steel sections "Stripe H" having a superior sticking performance in place of SEED form axial direction steel reinforcement which is a highly durable buried form usable as a part of main structure. By using steel frames, the seismic resistance performance is improved and the preparation reinforcement is reduced to a large extent, thereby simplifying the construction work. With this method, the principle is that the SEED forms are separately manufactured part by part and assembled in a box form at an on-site assembly yard or a secondary product workshop and the hoops and middle hoops are fitted to the box at the same time. As explained above, this construction method saves labor in on-site operation through introduction of prefabrication and has realized reduction of working hours and by simplifying work.

This method was developed jointly with Maeda Construction Co., Ltd., and received a technical judge certificate for advanced construction technology in December 1998 from the Advanced Construction Technology Center. The method was adopted for the piers of large land bridges on the express way running through Hokkaido built in 1995 and has been increasingly used for construction of piers, road and railroad bridges.

3.5 Steel Section Products for Civil Construction Use

As a result of the experience that the local communities suffered hugely by the roads and harbors being destroyed in the recent Hanshin-Awaji Earthquake, it has become required to build complete infrastructures which are strong against disasters and are highly reliable. In response to these requirements, the specification for highway bridges[10] were revised in December 1996 and the technical standard for harbors (with an explanation)[11] were revised in April 1999 respectively and the specifications and standards relating to seismic resistance design were reviewed extensively. In the field of civil construction as well, the limit state design based on a performance guarantee is pointed to. As for steel materials, not only high strength and high toughness but also various kinds of performance such as sticking performance with compound structures with concrete in mind are more and more required and development of low cost construction methods corresponding to cost reduction is designed.

4 Closing Remarks

Steel products for architectural use comprise about 50% of the steel demand in Japan and steel sections are used for more than 30% of these materials. When thinking of construction purposes, steel materials are superior to other metallic materials in any point of modulus of elasticity, cost per strength, amount of deposits and recycling performance and will undoubtedly be used continuously also in the 21st century. As steel materials of the next generation, development of supermetals, etc. is in progress at present, however, in order to support the social infrastructure of the 21st century, the company is of the opinion that we must continue our development efforts also in the field of steel section production for further improvement of materials and for improvement of workability, additional function, etc. and to respond to the needs of the industries concerned.

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