Technical Report

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Expanding the Overseas Market through Valued Design Proposals by Emphasizing Advantages of the Profile of Structural H-shapes

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Abstract

This report is to show the expansion of the overseas market of H-shapes, initially developed in Western countries and then improved in Japan through the development of innovative manufacturing technology. The section profile, known in Japanese as "KATACHI", of NSHYPER BEAM™, HC400 and HC500 has multiple advantages compared to H-shapes conventionally used in Western countries. Looking at the advantages of "KATACHI" from a structural design point of view, we have made it clear that NSHYPER BEAM, HC400 and HC500 are competitive options.

1. Introduction

The construction of energy facilities is conducted positively all over the world, and in the Afro-Asian countries, the construction of infrastructure is pushed forward. In this way, many projects are conducted in the overseas market, and new demand for steel structure is expected. Furthermore, for a project to exert its investment effect as early as possible and cope with soaring construction cost due to rush on projects, efforts are being made to enhance the productivity at construction site and the following construction methods are becoming more widely employed. They are the module construction method in the field of energy wherein a unit equipment is constructed off-site and installed on-site after being transported to the site in order to minimize the on-site construction work volume to the extent possible, and the top-down construction method in the field of high-rise building construction in which the constructions of the underground part and the above-ground part are conducted simultaneously, aiming at reducing the construction period. In the field of material, large H-shapes are used for beams to secure long spanning effectively in module structures and the jumbo sections are used as the column material (king post) for the underground part to support the heavy load in the top-down construction method. They are contributing to the enhancement of the productivity in various construction works and are becoming more widely applied.

On the other hand, dimensions and the size composition of the H-shapes used in various constructions are different between those of Japanese material and foreign material. The Japanese section profile, known in Japanese as "KATACHI," has been developed in Japan with the development of steel structures and exhibits a strong advantage over the H-shapes of foreign countries. By taking advantage of the features properly, construction of high economy with high productivity is feasible even in foreign countries.

Then, in this article, features of Japanese H-shapes and those of foreign countries are organized and the superiority of Japanese H-shapes is clarified, and the effects of the dimensions and the size composition on designing of steel structures are verified and reported.

2. History of Production of Rolled H-shapes and Awareness of Problem

The production of the rolled H-shapes began in early 20th century by the invention of the universal rolling method [1)] in Western Europe. In the universal rolling method, a universal rolling mill with vertical and horizontal rolls (**Fig. 1**) is used. Rolls corresponding to sizes are prepared, and as the rolling is conducted by changing the rolls according to the size to be produced, the producible sizes are limited. **Figure 2** shows the size composition of the European rolled

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H-shapes of British universal beams (UB) and the European wide flange beams (HE), both representing the rolled H-shapes in Europe. The sizes above the height of 700 mm and the width of 300 mm are limited. As a result, the present size composition cannot comply with the buildings that are growing bigger in size in recent years and with the optimization of designing sufficiently.

In Nippon Steel & Sumitomo Metal Corporation, production and marketing of the rolled H-shapes were started in 1959 behind Europe and USA by about 60 years [2]; however, their dimensions and size composition are different from those of Europe and USA. For example, the jumbo sections of HC400 and HC500 mainly used for columns are produced by the universal rolling method in the same way as the one employed in Europe and USA. However, in order to comply with the needs of selecting optimized large-section column material to meet the condition of frequent earth quake specific to Japan, the sizes of the jumbo sections exceeding greatly those of Europe and USA in number have been lined-up owing to meticulous efforts made to comply with the needs. Furthermore, in 1989, in order to compete for the welded built-up H-shapes (BH) used for many steel-framed reinforced concrete structure high-rise buildings built at the time in Japan, a rolling technology capable of adjusting the inside web height dimension freely by using the skewed roll [2] (**Fig. 3**) was developed and the rolled H-shapes "NSHYPER BEAM™" that provides the depth and flange width interval of 50 mm, same with those of BH, was commercialized. Freedom in choice of the rolled H-shapes sizes, which had been considerably limited up to then, was greatly enhanced, and the H-shapes have come to be generally used for domestic large-scale steel structure constructions.

The H-shapes that started its production with the technology of Europe and USA have made independent progress in Japan later on, and the section profile has grown to characteristic "KATACHI" different from that of the foreign H-shapes. By differentiating designing and application technologies with the deep knowledge of the superiority of the "KATACHI," the demand in the expanding foreign market, the Asian market in particular, is being approached and captured.

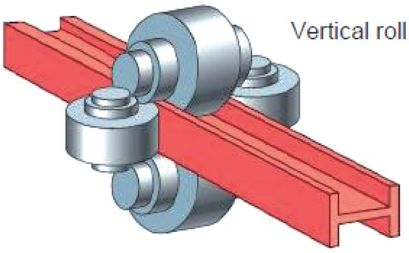


Fig. 1 Picture of the universal rolling mill

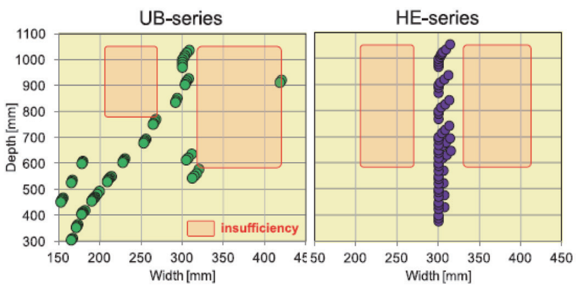


Fig. 2 Comparison of depth and width of UB (Universal beams) and HE (European beams)

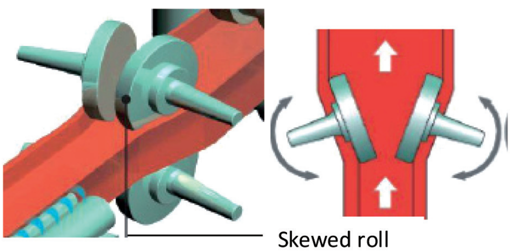


Fig. 3 Picture of the skewed roll rolling

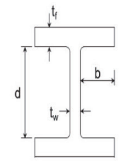
3. H-shapes for "Column" Use

3.1 Concept of "KATACHI" (features of HC400, HC500)

Ultra-thick H-shapes of HC400 and HC500 are called H400 × 400 series and H500 × 500 series domestically and are the H-shapes that were started to be put into full-scale application in 1960s as column material for high-rise buildings [3]. Since the H-shapes correspond to the European H-shapes of the UC356 × 406 series, in foreign countries, the H-shapes are used for the members in which extremely large axial forces are exerted like the king post in the top-down construction method, the large truss chord members, and so on.

The depth of HC400 ranges from 398 to 508 mm, the flange width, from 402 to 462 mm, and the flange thickness, from 20 to 75 mm and the depth of HC500 ranges from 492 to 582 mm, the flange width, from 465 to 500 mm, and the flange thickness, from 20 to 65 mm and the steel grade conforms to EN10025-2 S235, S275, and S355 in addition to JIS. As shown in **Table 1**, as opposed to about 7 of UC356 × 406 series, numbers of the sizes are 69 in HC400 and 35 in HC500 with total of 104. Owing to these abundant sizes, HC400 and HC500 have won the appreciation; for instance, as a material reducing the amount of welding when compared with BH in the de-

Table 1 Comparison of giant H-shapes: UC356×406, HC400 and HC500



(mm)

Series	d	b
UC356X406	320.6	188.2
HC400	358	193.5
HC500	452	225

UC356X406-7sizes

tw : Web Thickness (mm); tf : Flange Thickness (mm)

	18.4	22.6	26.6	30.6	35.8	42.1	47.6
77.0							O
67.5						O	
58.0					O		
49.2				O			
42.9			O				
36.5		O					
30.2	O						

HC400-69sizes

t_w : Web Thickness (mm); tf : Flange Thickness (mm)

	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
80															
75								O	O	O	O	O	O	O	
70							O	O	O	O	O	O	O		
65						O	O	O	O	O	O	O			
60					O	O	O	O	O	O	O				
55					O	O	O	O	O	O					
50				O	O	O	O	O	O	O					
45				O	O	O	O	O	O						
40			O	O	O	O	O	O							
35			O	O	O	O	O	O							
30		O	O	O	O	O	O								
25					O	O									
20				O	O										
15															

HC500-35sizes

t_w : Web Thickness (mm); tf : Flange Thickness (mm)

	10	15	20	25	30	35	40	45	50	55
80										
75										
70										
65									O	
60								O	O	
55					O	O	O	O	O	
50					O	O	O	O	O	
45				O	O	O	O	O		
40			O	O	O	O	O			
35			O	O	O	O				
30		O	O	O	O					
25		O	O	O						
20		O								
15										

signing of king post, and as a material contributing to the reduction of the steel material weight when compared with foreign H-shape sizes.

3.2 Superiority in designing and application technologies

Another feature of the "KATACHI" of HC400 and HC500 is that the depth and the flange width are slightly larger than those of the sizes of European UC356×406 series. As a result, the second moment of area per unit weight around the strong axis and the weak axis of HC500 becomes larger than that of UC356×406 series (**Fig. 4**) and the designing of members with higher economy becomes possible.

In **Fig. 5**, the relationships between the buckling length and the buckling resistance strength of HC572×495×45×60 (631 kg) and UC356×406×634 (H474.6×424.0×47.6×77.0, 634 kg/m) are shown. It is the result of a calculation based on EN1993-1-1. Although they are H-shapes having almost an equal unit weight, when a buckling length is 8 m, the buckling resistance strength of HC572×495×45×60 becomes 17367 kN, higher by 1.1 time than 15598 kN of UC356×406×634 as a result. Furthermore, HC400 and HC500 can secure with smaller thickness the buckling resistance strength equivalent to that of UC356×406 series, realizing manpower saving in welding in joining column materials, contributing to the reduction in the construction cost and shortening of the construction period in this regard.

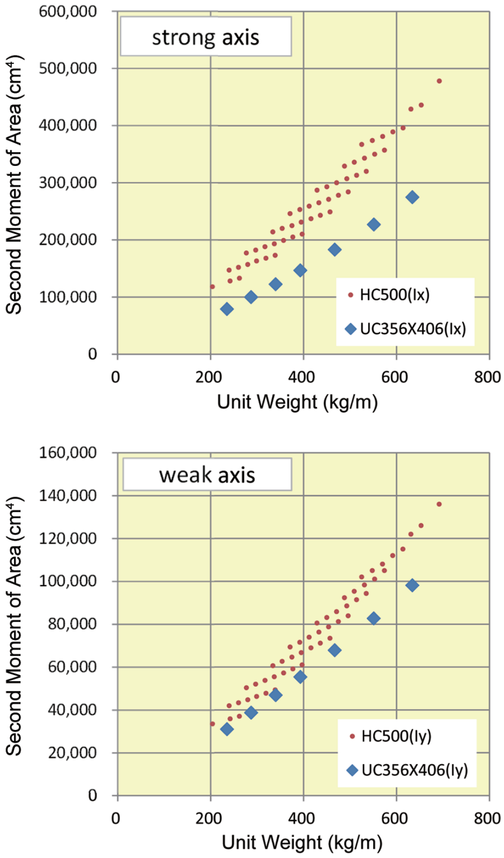


Fig. 4 Comparison of giant H-shapes using second moment of area and unit weight

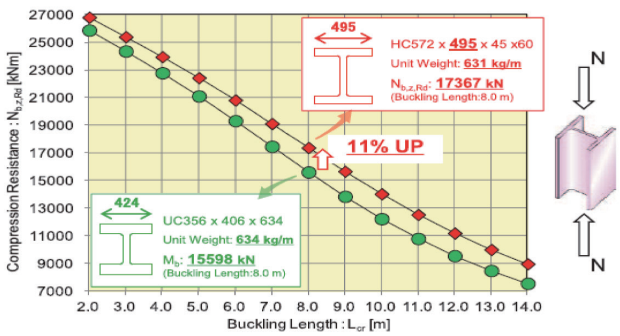


Fig. 5 Comparison of UC356×406×634 to HC572×495×45×60 using compression resistance and buckling length

4. H-shapes for "Beam" Use

4.1 Concept of "KATACHI" (features of NSHYPER BEAM)

The features of the "KATACHI" of NSHYPER BEAM are the magnitude of sizes and the abundance in sizes up to the depth of 1000 mm and the flange width of 400 mm. In **Fig. 6**, the section profile of NSHYPER BEAM is shown. They are the H-shapes ranging from 400 to 1000 mm in depth and from 200 to 400 mm in flange width, and the depth and the flange width interval in the series is 50 mm, same with that of the general BH-shapes. As for the flange width of the H-shapes that is definite in the H-shapes of European sizes, five flange widths of 200, 250, 300, 350, and 400 mm are provided to satisfy the optimization of structure designing depending on the subject members such as large beams or small beams (**Fig. 7**). Thickness is abundant in variety and the number of the sizes has reached as high as 609 at present. The steel grade conforms to the foreign standards such as ASTM, EN, and so on in addition to JIS (**Table 2**).

NSHYPER BEAM with large section and with the depth and flange width interval of 50 mm is most suited to substituting the BH and the application is increasing in plant projects that imply the risk of delay in delivery. In such projects, in addition to the shortened construction period and the enhanced quality realized by the elimi-

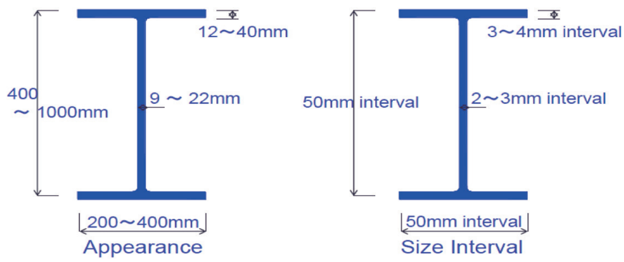


Fig. 6 Specifics of the section profile of NSHYPER BEAM

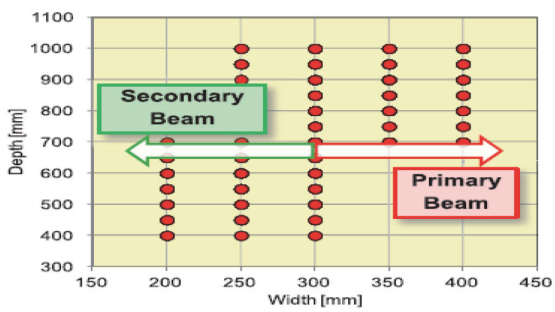


Fig. 7 Size structure of NSHYPER BEAM

nation of welding, since change in designing load that takes place specifically in plant projects can be dealt with by simply changing the flange thickness without changing the depth and thereby without exerting influence to other equipment designing, NSHYPER BEAM has obtained the appreciation as a material that can contribute to the improvement of entire engineering efficiency. Furthermore, as for the "KATACHI" of NSHYPER BEAM, 303 sizes were listed on the "Standard Sectional Dimensions of H-shapes" of JIS G 3192 "Dimensions, mass, and permissible variations of hot-rolled steel sections" in February 2014.

4.2 Superiority in designing and application technologies

4.2.1 Case of lateral buckling of "beam" taken into consideration

For the designing of beams of steel structures without flooring like those of manufacturing plants, designing must be executed by taking into consideration the drop in the resistance strength due to lateral buckling.

Figure 8 shows the lateral buckling resistance moment vs. buckling length when NSHYPER BEAM of HY700×400×12×25, HY700×400×12×22, and HE700B (H700×300×17×32) of an European size are used for the beams of a virtual frame structure with relatively large beam spacing distance of 8–10 m. This result is based on EN1993-1-1.

In case of the buckling length of 8 m, the respective lateral buckling resistance moment of the H-shapes are 1 663 kNm of HE700B, 2 121 kNm of HY700×400×12×25 and 1 887 kNm of HY700×400×12×22. Furthermore, when the buckling resistance moment per unit weight taking into consideration the respective steel weight is compared, the lateral resistance moment of HY700×400×12×25 is 1.40 times and that of HY700×400×12×22 is 1.35 times higher than that of HE700B.

The reason of the difference is the difference in the Imperfection Factor specified in Eurocode in addition to the difference in modulus of section due to difference in width and thickness of the member materials. The Imperfection Factor is a coefficient determined by taking into consideration the influence of residual stress and or the initial asymmetry of the member materials on the structures. The factor varies depending on the strength of H-shapes and the height/width ratio, providing more advantageous values to the wider-flange H-shapes based on the view that the wider-flange H-shapes are less influenced by the initial asymmetry or the like when calculating buckling resistance moment.

To be specific, in **Table 3**, the Imperfection Factors listed in the UK National Annex to Eurocode 3 are shown. A buckling curve is arranged for each of (h/b) ratio of H-shapes depth (h) vs. flange width (b) and the Imperfection Factor corresponding to the buckling curve is given. For example, h/b of HE700B is 2.33 and h/b of HY700×400×12×25 and HY700×400×12×22 is 1.75, and the Imperfection Factor becomes 0.49 for HE700B and 0.34 for HY700×400×12×25 and HY700×400×12×22, which is more advantageous in the calculation of the resistance moment. This difference constitutes one reason of the aforementioned difference in the resistance moment.

Furthermore, the influence of residual stress, and so on, of BH is assessed to be larger than that of rolled H-shapes and the value of the Imperfection Factor of BH is more disadvantageous than that of the rolled H-shapes from the viewpoint of resistance moment. Accordingly, as a result, NSHYPER BEAM is equipped with the lateral buckling resistance moment larger than that of the BH of same size. For example, the lateral buckling resistance moment per unit weight of HY700×400×12×25 of length of 8 m is larger by 1.07 times than that of BH700×400×12×25 (**Fig. 9**).

4.2.2 Case of bending buckling of "beam" not taken into consideration

In case of H-shapes used as a composite beam integrated with floor slab, since there is no decrease in resistance moment due to lateral buckling because of the confinement of the buckling by the floor slab, the performance of the H-shapes is assessed by the stiff-

Table 2 Steel grade ability of NSHYPER BEAM

					NSHYPER BEAM™
Steel grade	ASTM		A36		e
			A572 Gr50		e
			A992		e
	EN10025-2		S235	JR/J0/J2	e
			S275	JR/J0/J2	e
			S355	JR/J0/J2	e
	EN10225		S355	G11+M	e
	JIS	JIS G 3101	SS400		e
		JIS G 3106	SM400	A/B	e
			SM490	A/B	e
				YA/YB	e
		JIS G 3136	SN400	A/B	e
			SN490	B	e
Tolerance	ASTM	ASTM A6			e
	EN	EN10034			e
	JIS	JIS G 3192			e

e: "experience" in past projects

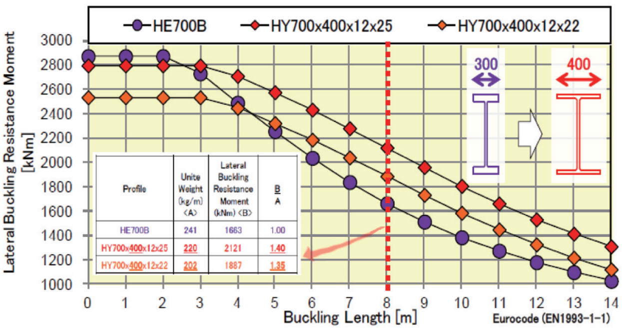


Fig. 8 Comparison of HY700×400×12×22, HY700×400×12×25 and HE700B using lateral buckling resistance moment and buckling length

Table 3 Selection of bucking curb for a cross-section (UK National Annex to Eurocode3)

Section	Limits	Buckling Curve
Rolled Section	h/b ≦ 2	b
	2 < h/b ≦ 3.1	c
	3.1 < h/b	d
Welded Section	h/b ≦ 2	c
	h/b > 2	d

Buckling Curve	b	c	d
Imperfection Factor α_{LT}	0.34	0.49	0.76

superior ⇔ inferior

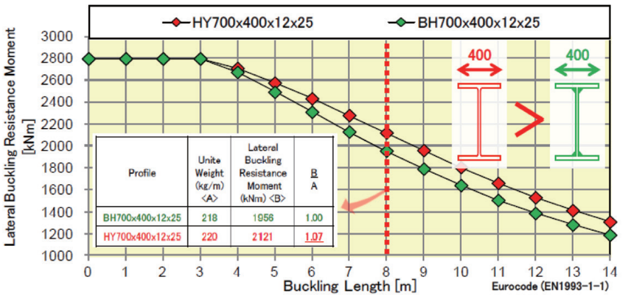


Fig. 9 Comparison of BH700×400×12×25 to HY700×400×12×25 using lateral buckling resistance moment and buckling length

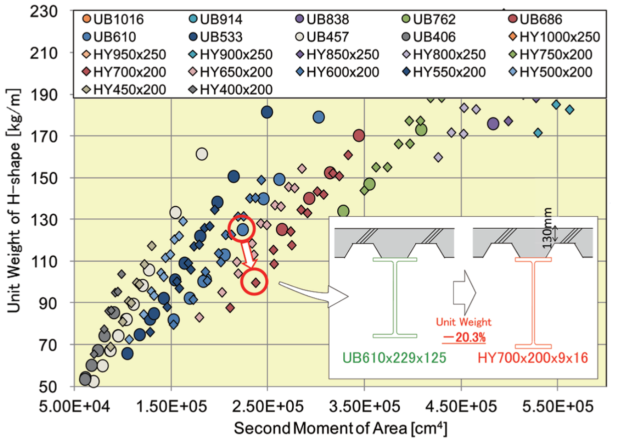


Fig. 10 Comparison of UB-sections to NSHYPER BEAM using second moment of area for composite floor beam and unit weight

ness of the composite floor beam.

Figure 10 shows the relationship between the second moment of area of composite floor beam and the unit weight of the H-shapes of UB series and NSHYPER BEAM when they are used for beams. It is the result based on EN1994-1-1.

As opposed to sparsely available values of UB sizes (marked with ○), there are a variety of sizes of NSHYPER BEAM even in the range below the flange width of 250 mm (marked with ◇) and, it is known that for a composite floor beam of UB series H-shapes, designing of a lighter composite floor beam with equivalent second moment of area is possible by using a lighter NSHYPER BEAM.

To be specific, when designing composite floor beam that requires second moment of area of about 230000 cm^4 for an office building or the like, when an H-shape is to be selected from UB series, only one size of UB610×229×125 (H612×229×12×20, 125 kg/m) is available and, when it is to be selected from among NSHYPER BEAM with abundant sizes, choice of plurality of sizes such as HY600×200×12×25, HY650×200×12×19 or the like is feasible even if limited to below the flange width of 200 mm and, when a larger effective space above the ceiling is available, HY700×200×9×16 (99.6 kg/m) can also be selected and with the higher depth, flange and web thicknesses can be made thinner, resulting in saving of steel weight by about 20%.

5. Conclusion

Concerning the features and superiority in designing and application technologies of Japanese H-shapes that has "KATACHI" that foreign H-shapes do not have, following three points have been reported based on the examples of HC400, HC500, and NSHYPER BEAM.

(1) As to the H-shapes for "column" of HC400 and HC500, buckling resistance strength becomes higher owing to its profile larger than that of the H-shapes of European and American sizes.

(2) As to the H-shapes for "beam," when lateral buckling is taken into consideration, the wide width NSHYPER BEAM is advantageous and it is possible to select a member material having the larger per-unit-weight buckling resistance moment as compared with that of the H-shapes of European and American sizes.

(3) As to the H-shapes for "beam," when lateral buckling is not taken into consideration, narrow width NSHYPER BEAM abundant in size is advantageous and it is possible to select a member material that can save steel weight.

In this report, expanding sales of the H-shapes from the viewpoint of designing and application technologies has been described. On the other hand, to expand sales, the solution of problems related to delivery term and the amount of order receivable are also important. When fabricators in Asian countries procure European or American H-shapes, there are cases in which the delivery term become longer and or procuring a small quantity is not easy. These are the problems related to the location of a mill and or how to deal with the sizes that are not produced routinely. Nippon Steel & Sumitomo Metal now takes advantage of its geographical superiority that the company is located in the same Asian region and complies with short-term delivery and small-lot orders by adjusting the rolling schedule and the size change to the routinely produced NSHYPER BEAM to satisfy order-acceptance status.

Hence, the authors are determined to continue to promote further designing proposal of HC400, HC500, and NSHYPER BEAM by taking advantage of the features of their "KATACHI" and to comply with users' needs including delivery term issues, and so on, as a manufacturer located in Asia.

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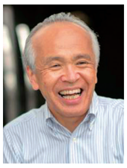
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