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Expanded Application of Stripe H™ for Labor-Saving of RC Structures

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Abstract:

Stripe H™ has been applied to RC structures as a substitute for steel bars since 1980 in Japan. As an example, it was adopted as a main material of the REED method™ for shortening the construction period for viaduct piers. Recently in Japan, adoption of Stripe H™ as a substitute for steel reinforcing bars has also increased because the improvement in efficiency, labor saving, and productivity are desired at construction sites due to labor shortages. This paper introduces the expansion applications of Stripe H, along with application examples.

1. Introduction

The construction industry in Japan suffering from the aging of workers (**Fig. 1**[1)]). For this reason, there is an increasing need for labor saving in field of construction from the viewpoints of work style reform and productivity improvement. As a result, labor saving has been achieved in field reinforcing bar arrangement work by applying Stripe H™, which was originally developed in 1980 as substitute for reinforcing steel with the aim of shortening the construction period for viaduct bridge piers and is also a main material of the REED construction method™.

2. Overview of Stripe H™

2.1 Specification of Stripe H™

In Stripe H, lateral protrusions (“stripes”) are formed on the outer surface of the flanges of H-shape steel by hot rolling in order to improve adhesion performance with concrete. The protrusion height and space are 1.5 mm and 15 mm for the H-150 and 200 sizes and 2.1 mm and 21 mm for the H-300 size, respectively. The protrusions are formed over the entire length of the flange outer surface (**Fig. 2**, **Fig. 3** and **Photo 1**). **Table 1** shows the cross-sectional of Strip H.

2.2 Basic Performance of Stripe H™ 2)

The following summarizes the main test results, which are conducted for specification setting and verification of the basic performance of Stripe H.

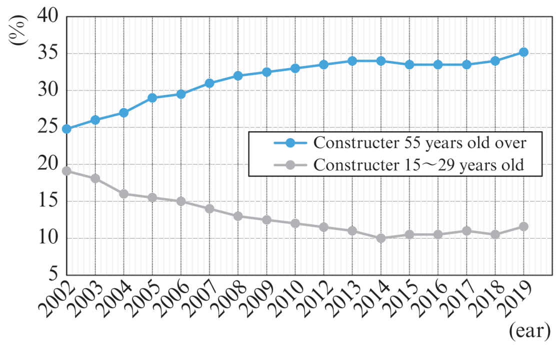

Fig. 1　Transition of construction workers by age group

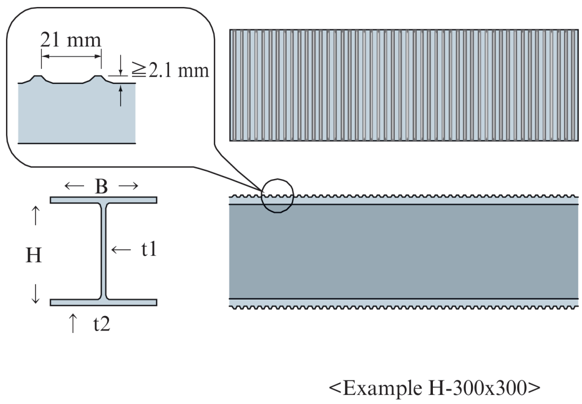

Fig. 2　Stripe H™ specifications

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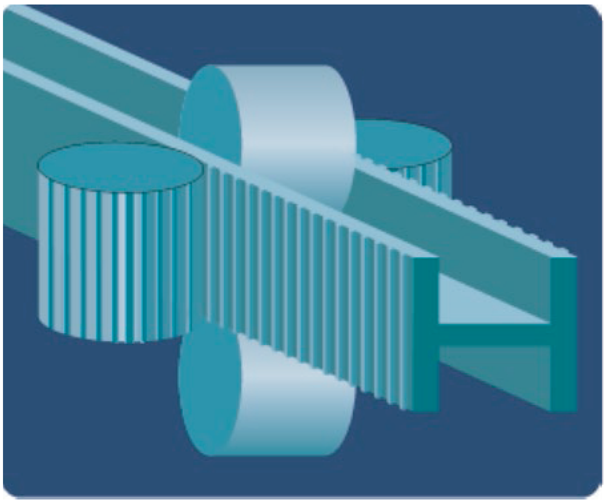


Fig. 3 Method for manufacturing Stripe H™

Photo 1 Stripe H™

Table 1 Performance of Stripe H™

Series lenge	Height H (mm)	Width B (mm)	Thickness t1 (mm)	Thickness t2 (mm)	Area A (cm^2)	Shear stregth W (kg/m)
150×150	150	155	8	10	41.95	34.1
	154	157	10	12	51.23	41.4
	158	158	11	14	59.09	47.6
	160	159	12	15	63.85	51.4
200×200	200	204	8	12	64.49	52.1
	204	205	9	14	74.69	60.1
	208	206	10	16	84.97	68.2
	210	207	11	17	91.19	73.1
	212	208	12	18	97.45	78.0
300×300	300	308	10	15	120.9	97.4
	304	310	12	17	139.3	112
	308	312	14	19	157.8	126
	312	314	16	21	176.5	141
	316	316	18	23	195.4	156
	318	317	19	24	204.9	163
	320	323	25	25	230.5	184
	324	320	22	27	233.7	186
	328	322	24	29	253.0	201
	332	324	26	31	272.5	217
	336	326	28	33	292.2	232
	340	328	30	35	312.1	248
	344	330	32	37	332.1	263
	348	332	34	39	352.2	279
	350	333	35	40	362.4	287

2.2.1 Test Method and Evaluation of adhesion property

A test conducted to evaluate the adhesion performance of Stripe H, steel plates were cut from the flange part of a Stripe H section, and specimens were bonded together to form a test piece with protrusions on both sides. After that the test piece was installed in concrete placed in a steel pipe as a form, and a pullout test was performed.

Since relative slip with concrete occurs in steel with protrusions at 20% to 30% of the maximum adhesion strength, in this paper, the adhesion property of Stripe H was evaluated using the adhesion strength at the initial slip amount of 0.05 mm based on past test results[3]. This evaluation confirmed that the adhesion property of Stripe H is equal to or greater than that of deformed bar (D 51) (**Fig. 4**).

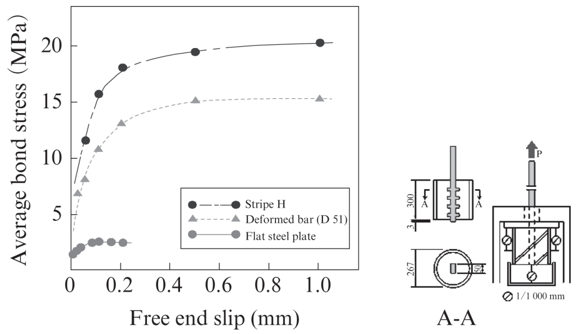


Fig. 4 Adhesion performance verification test of Stripe H™

2.2.2 Evaluation of SC structure[4]

In this paper, a flexural shear test of a beam (**Fig. 5**) with a reinforced concrete section (RC structure), and a beam with a steel frame concrete section (SC structure) using Stripe H having equivalent sectional performance was conducted in order to evaluate the deformability of the SC structure using Stripe H.

Figure 6 shows the relationship between the applied load and the deflection at the center of the span. The load and displacement were non-dimensionalzed by P_{FY} (calculated value) and δ_y (experimental value), respectively. Here, P_{FY} (calculated value) is obtained by multiplying the yield stress of the steel by the total cross-sectional area of the tensile side steel, and δ_y

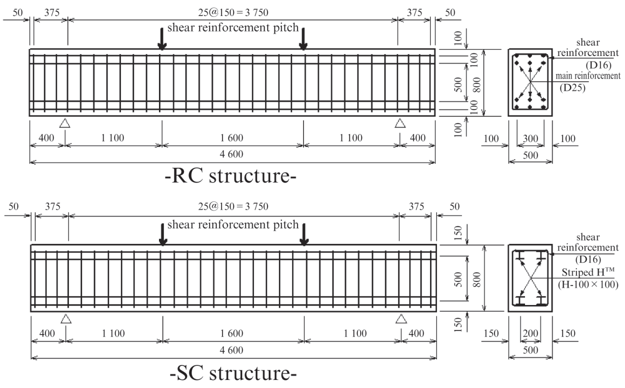


Fig. 5 Beam bending shear specimen shape

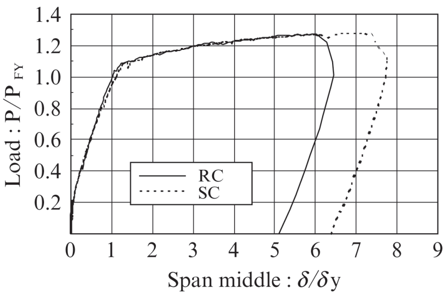


Fig. 6 Load and middle span deflection

(experimental value) is the displacement when the steel test specimen yields.

As shown in Fig. 6, the SC structure demonstrates the same strength and rigidity as the RC structure, indicating that the plane holding in the member is established. These results confirmed that proof stress and deformation property equal to those of the RC structure could be obtained when the reinforcing bar cross-sectional area was replaced with the equivalent Stripe H™.

2.2.3 Joint specification settings[5, 6)]

Because Stripe H is produced by hot rolling, long products can be used. Therefore, the longitudinal joint of Stripe H is formed by friction bonding using high-strength bolts so as to secure full strength.

Since Stripe H has protrusions on the flange outer surface, the slip resistance of the longitudinal joint was evaluated to confirm the performance of a high-strength bolt friction joint of materials with protrusions.

In order to evaluate slip resistance, tensile tests were carried out on steel plates cut from the flanges of Stripe H (Case 1) as shown in **Fig. 7**, and a tensile test (Case 2) was also conducted for Stripe H with a specification in which slip occurred in the flange before the web. The friction bonded surfaces were shot blasted, and the axial force introduced into the bolts was controlled by the value of a strain gauge affixed to the

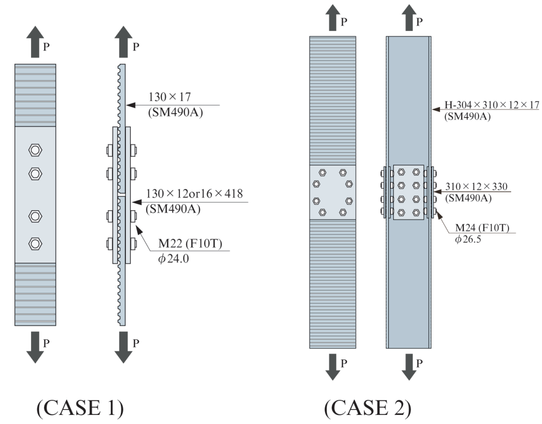


Fig. 7 Tensile test of flanged steel plate

Table 2 Comparison of slip coefficients

Test case	Slide spec
Case 1	0.55
Case 2	0.58
Road bridge specifications	0.40

bolts with the aim of a 10% increase in the axial force of the design bolt, which is specified in Specifications for Highway Bridges Part II Steel Bridges[7)].

The value used to confirm the slip coefficient was obtained by dividing the smaller of the load when a clear slip occurs or the load when the slip between the plates reaches 0.2 mm by the number of bolts and the initial average axial force of the bolts.

As shown in **Table 2**, the slip coefficients μ obtained in Case 1 and Case 2 were μ=0.55 and 0.58, respectively, which were higher than the prescribed values in Specifications for Highway Bridges and Commentary[7)]. This result confirmed that the high-strength bolt friction joint system could be applied to the longitudinal joint of the Stripe H, even under a condition protrusions exist on the flange outer surface.

3. Expanded Use of Stripe H™

Examples of expansion of the applications of Stripe H having characteristics as a substitute for reinforcing bars are described below.

3.1 Outline of REED Method™

This section describes the application of Stripe H to the REED method™.

3.1.1 Outline of construction method

The REED method is a construction method which makes construction of bridge piers with high toughness as a total structure in comparison with conventional RC structures possible by arranging Stripe H as a sub-

Photo 2　Example of SEED form fabrication example

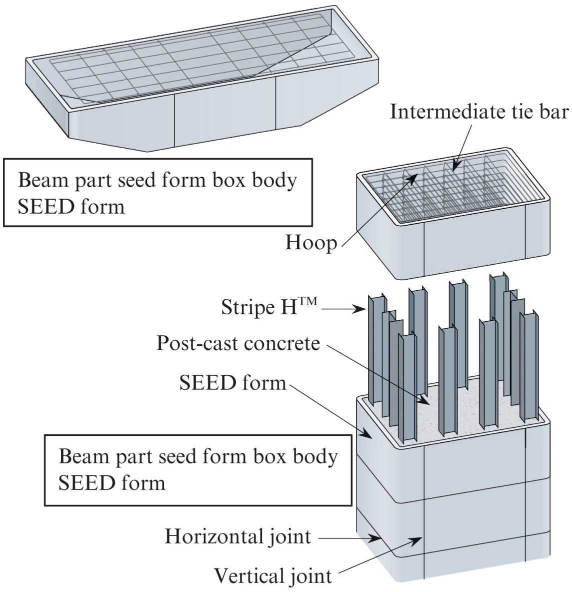


Fig. 8　Conceptual diagram of REED method™

stitute for the main reinforcement in the structure and installing an embedded SEED form (put the same description in introduction) (**Photo 2**) around its circumference. **Figure 8** is a conceptual diagram. This method was developed jointly by Maeda Corporation and JFE Steel.

As a feature of this method, the construction period can be drastically shortened compared with the conventional RC method. **Figure 9** shows a comparative example of the construction periods of the two methods for a pier with a height of 10 m. The REED method is expected to reduce the time required to construct the column of the bridge pier by about 60% compared with the conventional method (detail information is necessary) because easy construction is possible by prefabricating and precasting the members and no special skills are required (for what, for construction). As of October 2020, the REED method had been used in more than 70 projects, and the number of application is also expected to increase in the future from the viewpoint of improving productivity at the

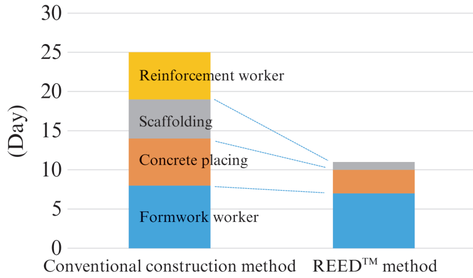


Fig. 9　Comparison of construction period by type between conventional method and REED method™

site.

3.1.2 Recent Examples of Application

The REED method is applied to viaduct piers for roads and railways. As an example of application, this paper describes the Fukui Development Viaduct of the Hokuriku Shinkansen.

1) Project name: Hokuriku Shinkansen, Fukui Kaihotsu Bridge Line
2) Business Entity: Japan Railway Construction, Transport and Technology Agency
3) Main contractor: Obayashi, Meiko, Michibata Hokuriku Shinkansen, Fukui Kaihotsu Elevated Railway Bridge Construction Joint Enterprise

Because this viaduct construction section was used as a temporary track for the Echizen railway viaduct project, construction work started late, and shortening of construction period was required. Rapid construction was possible by adopting the REED method in the construction of the bridge pier, and a shortening of the construction period by about 40% was attempted in the construction from the footing division to the beam division by introduction of various types of parallel work. An application example is shown in **Photo 3**.

3.2 Application as Main Reinforcement of Overflow Pier of Dam Body

Next, this section presents an example of application of Stripe H as the main reinforcement of the bridge piers[8] over a dam body.

1) Subject (project name) Yamba Dam main body construction work
2) Project Entity: Ministry of Land, Infrastructure, Transport and Tourism, Kanto Regional Development Bureau
3) Main construction company: Shimizu, Tekken, IHI Construction Joint Enterprise

In the structural examination of the bridge piers in the overflow section of the dam body (**Photo 4**), Level 1 (L1) ground motion was examined in the basic design stage, but in the detailed design stage, a safety examination for L2 ground motion was required based on

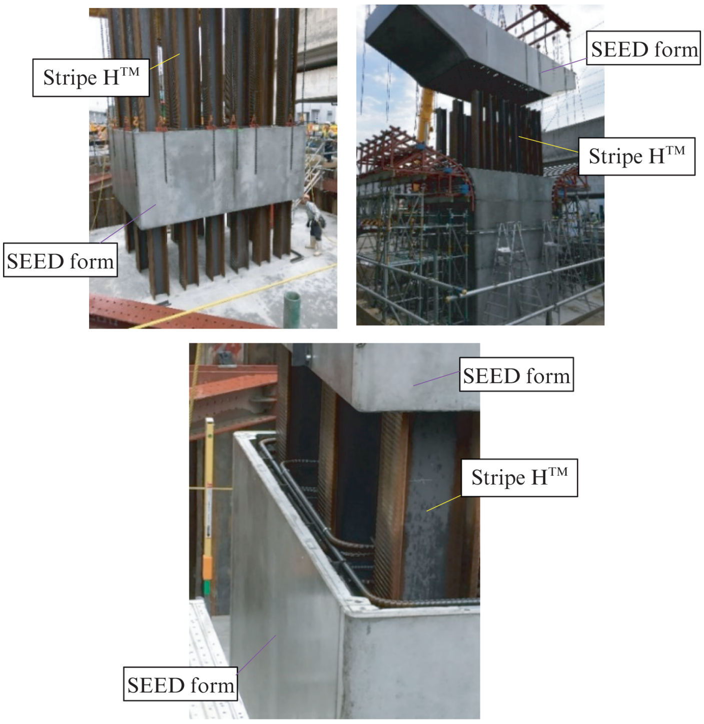


Photo 3 Construction status of REED method™

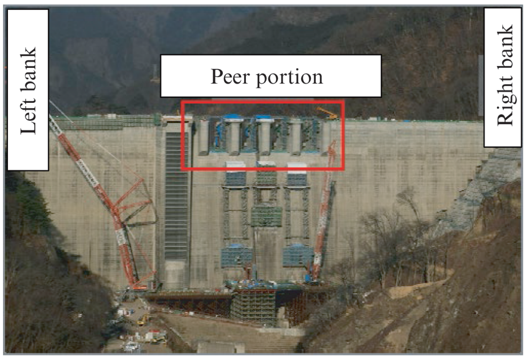


Photo 4 Installation position of sluice gate

Guidelines for Seismic Performance Evaluation of Dams During Large Earthquakes[9], which was published in March 2005. Therefore, the design was examined under the following constraints.

(Design Constraints)

- As the separation dimension of the sluice gate columns, in addition to the specification decided in the basic design stage, this dimension is set to a specification which can also secure the flow rate.
- Considering L2 ground motion, the displacement of the sluice column in the dam axial direction (perpendicular to the water flow) is held to 10 mm or less from the viewpoint of gate damage protection.
- Concrete placing construction quality and workability at the site are secured.

If the conventional method was applied under these design conditions, it was assumed that the arrangement of reinforcing bars would be overcrowded, problems

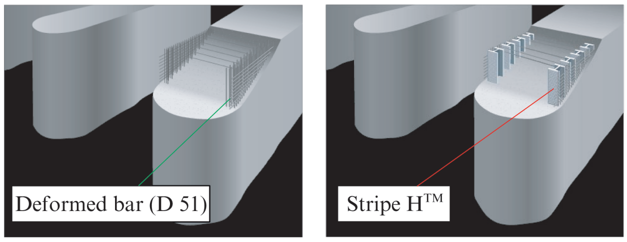


Fig. 10 Arrangement

Photo 5 Construction scene

would arise in the quality of concrete construction, and the construction period would be extended. In order to solve these problems in the actual construction, the construction of the main reinforcement arrangement D51@130-2.5 stage (**Fig. 10**) in the original design was examined from the comprehensive viewpoint of concrete placing workability and construction quality assurance, etc. As a result, Stripe H was adopted as the optimum construction method because it was possible to satisfy the constraint conditions and solve various problems by applying Stripe H. **Photo 5** shows the condition of construction of the frame using Stripe H.

3.3 Application as Main Reinforcement of Large-Diameter Caisson Type Piles

The following describes application of Stripe H to the large-diameter caisson type piles of a highway bridge.

1) Subject: Construction of Kawachigawa Bridge on New Tomei Expressway
2) Project operator: Central Nippon Expressway Company Limited
3) Main contractor: Kashima-Taisei Special Construction Joint Enterprise

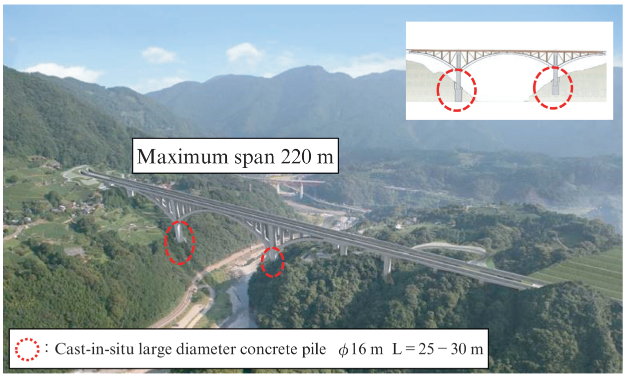


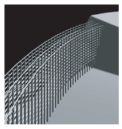
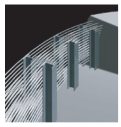
Photo 6 Cast-in-situ large diameter concrete pile

Rationalization was studied in each type of construction, that is, the foundation, bridge pier, and superstructure of the expressway, and the foundation work was rationalized by using Stripe H for internal reinforcement of the caisson type piles. **Photo 6** shows the location of the large-diameter caisson type piles which were the object of the design. The piles had a diameter of ϕ16 m and a length L of 25 to 30 m.

There were problems in replacing the original RC design with Stripe H, as deformed bar has protrusions on the whole circumference, while Stripe H has protrusions only on the flange outer surface, and application of Stripe H with a comparatively large cross section was necessary in this structure. Therefore, when setting the cross section of the Stripe H and planning the arrangement, the possibility of securing the predetermined adhesion resistance against stress caused by bending moment was confirmed, and the arrangement plan was prepared considering workability in the erection and securing the space necessary for high-strength bolt connections.

As a structural comparison of the caisson type piles, **Table 3** shows the results of a comparison of applying deformed bar steel (D51-SD490) and Stripe H (SM490YB) to the main steel. Application of Stripe H made it possible to save the labor required for bar arrangement work and reduce the number of days necessary for the construction by about 60% (from 198 days to 79 days) compared to the conventional construction method, resulting in drastic rationalization[10, 11].

Table 3 Application comparison

		Conventional RC	Stripe H™
Schematic drawings			
Steel spec.		SD490	SM490YB
Material test σy (N/mm^2)		490	355
Material design	Out side (pic)	D51-228	H-320X323X25X25-28
	Inside-1 (pic)	D51-228	H-320X323X25X25-28
	Inside-2 (pic)	D29-114	—
	Total (pic)	570	56
Steel weight (ton)		194	256
Construction days (day)		198	79

4. Conclusion

Although the construction industry is indispensable for improving Japan's social capital, workstyle reform and future labor shortages have become urgent problems. As a method for solving these problems and improving productivity, JFE Steel intends to promote further expansion of the applications of Stripe H and the development of new methods, and to contribute to expansion of infrastructure improvement.

In writing this paper on Stripe H, as introduced here, the authors received invaluable cooperation and advice from everyone concerned in the Ministry of Land, Infrastructure, Transport and Tourism, the Japan Railway Construction, Transport and Technology Agency, and the Central Nippon Expressway, as well as the various construction joint ventures. We wish to take this opportunity to express our gratitude for this generous assistance.

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March 2005.
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