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Hot-dip Galvanized Steel Sheet for High Temperature, High Strength

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Abstract

Fire-resistant roofs made of steel-frame constructions require a fire-resistant shield coating because the heat from fire reduces the strength of steel materials. However, problems regarding the cost of production, the time required for construction and the working environment for spraying and pasting shields have greatly intensified the need to omit fire-resistant shields. Developments in hot-dip galvanized steel sheets for high-temperature and high strength that maintain the properties of high temperature steel and that are superior to the conventional steel sheets used in roofs have enabled us to produce fire-resistant roofs and to omit fire-resistant shield processing.

1. Introduction

The market for flat roofs is estimated to be 10 to 20 million m^2/year in Japan (See **Fig. 1**) and of that amount, a great majority of the structures have fire-resistance specifications. Until recently, low-cost and lightweight concrete was predominantly used in this field. On the other hand, in the past, it has been required that steel sheet roofing be treated with a fire-resistant shield. This, and the fact that the underside (the side of a roof that is facing the inside of a room) of roofing often is more complex in shape increased the difficulties in the manufacturing and construction costs for fire-resistant shields. This eventually caused steel to be less competitive in terms of cost compared to lightweight concrete. Furthermore, there arose many other problems with regard to the working environment when shield sprays are used. Again, this resulted in an extremely high need to omit fire-resistance shielding. Thus, Nippon Steel Corporation and Toho Sheet & Frame Co. Ltd. collaborated to study and pursue developments that would allow us to omit the fire-resistance shield using steel sheets that have superior high-temperature properties (fire-resistance). This paper reports that Nippon Steel Corporation has developed a hot-dip galvanized steel sheet for high temperatures and high strength. Toho Sheet & Frame Co. Ltd. has succeeded in manufacturing a fire-resistant roof while omitting the fire-resistance shield.

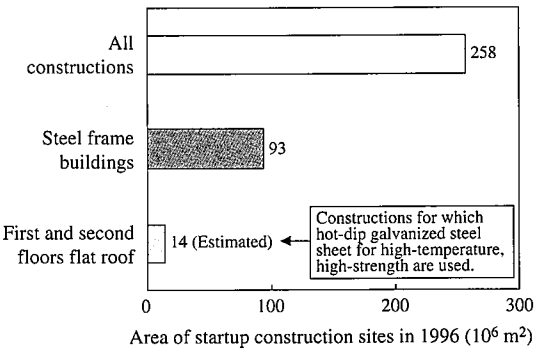

Fig. 1 Flat roof market

2. The Performance of Hot-dip Galvanized Steel Sheet for High Temperatures and High Strength

Until now, fire-resistant roofs were manufactured by applying an approximately 3 mm thick rock-wool type fire-resistance shield coating over hot-dip galvanized steel sheets, as seen in **Fig. 2**. According to the 30 minutes of fire resistance testing defined by Notification No. 2999 of the Ministry of Construction, the maximum temperature of the underside of the fire-resistant shield reach 840°C when a

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standard heating curve is adopted. The temperature of the steel sheet rose to approximately 780°C, if the steel sheet that was used in the test had been coated with a fire-resistance shield. However, the temperature of the steel sheet is estimated to rise to approximately 800 to 850°C if such a fire-resistance shield were omitted because the steel sheet would be directly exposed to the flame environment (**Fig. 3**). Therefore, in order to omit the fire-resistance shield, hot-dip galvanized steel sheets must have higher yield strength at 800 to 850°C than that of current hot-dip galvanized steel sheets (called SGCC below) at 780°C.

Hot-dip galvanized steel sheets for high temperatures and high strength satisfy the standards for hot-dip galvanized steel sheets as set forth by JIS (JIS G 3302). This steel sheet also satisfies the standards of manufacturers who further guarantee strength at high temperatures. **Table 1** shows the standards for hot-dip galvanized steel sheets for high temperatures and high strength. To improve the yield strength at 800 to 850°C, the combined addition of P and Mn was adopted but it was feared that the yield strength at room temperature would be increased by those additions. Tensile properties of hot-dip galvanized steel sheets at room temperature are not provided in JIS (they are provided only to serve as reference values). However, it is necessary that hot-dip galvanized steel sheets for use in roll forming like fire-resistant roofs maintain yield strength equivalent to current steel sheets at room temperature. Increase of the yield strength was suppressed by decreasing the carbon content to a very low level.

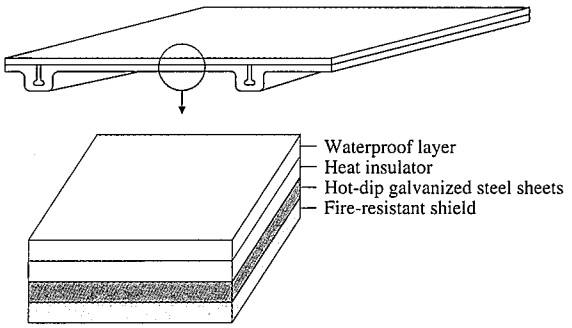

Fig. 2 Structure of current fire-resistant flat roofs

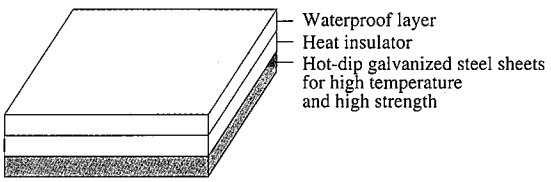

Fig. 3 Structure of fire-resistant flat roofs from which the fire-resistant shield has been omitted

Table 1 Standards for hot-dip galvanized steel sheets for high temperature and high strength

Name	Standard symbol	Room temperature tensile test (MPa)		Composition (%)	
		Yield point	Tensile strength	C	Other
Hot-dip galvanized steel sheets for high temperatures and high strength	NSGCC-HS	≥ 205	≥ 270	≤ 0.005	Mn and P addition

Fig. 4 shows a comparison of temperature dependence of 0.2% proof strength at high temperatures for the hot-dip galvanized steel sheets for high temperature and high strength and that of the SGCC. As is shown in Fig. 4, the 0.2% proof strength of the former at 800 to 850°C was higher than that of the latter at 780°C. The above stated necessary conditions are satisfied.

Furthermore, if steel sheets are used for roofing, then we must conceive of situations where they must endure heavy loads such as snowfall for long periods of time. Thus, we evaluated the creep property of hot-dip galvanized steel sheets at room temperature. **Fig. 5** shows the creep properties of the hot-dip galvanized steel sheets for high temperatures and high strength and the SGCC. Neither steel sheet displayed creep strain at room temperature, which positively confirms its performance for roofs.

3. Conclusion

Fire-resistant construction roofs for which fire-resistant shields were omitted using hot-dip galvanized steel sheets for high temperatures and high strength have passed fire-resistance testing at the Japan Testing Center for Construction Materials. The omission of the fire resistant shields solves the problems such as manufacturing cost and working environment that weaken the competitive power of the steel frames. It might also be added that the omission of fire-resistant shields solves many environmental issues including the disposal of industrial waste of such materials. Nippon Steel considers the effects of this development to be extremely far reaching.

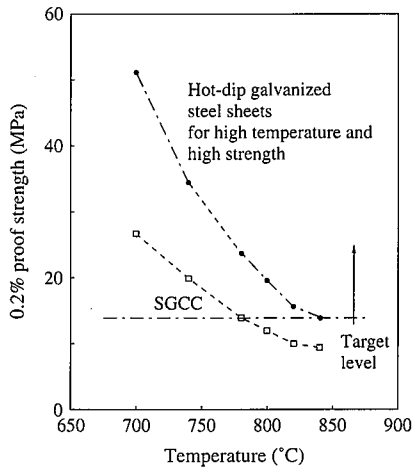

Fig. 4 Temperature dependence of 0.2% proof strength

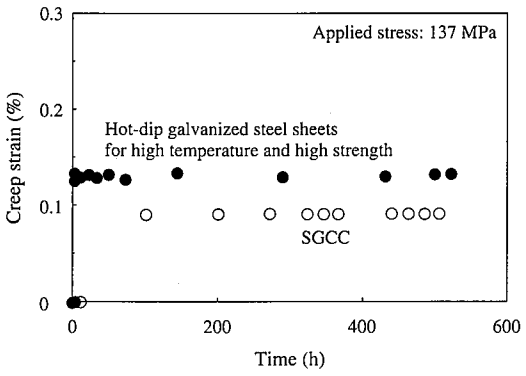

Fig. 5 Creep curve at room temperature