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Surface Treated Steel Sheets (Structurals)

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Abstract

Coated steel sheets have been used widely for a long time for construction applications. Nippon Steel & Sumitomo Metal Corporation has endeavored to improve the properties of these products through R&D activities. Coated sheet products originate from hot-dip galvanized sheets with pure Zn coating layers, and to enhance the corrosion resistance, Al was added to the Zn coating. Then, in 2000, to improve corrosion resistance yet further, the company added Mg to the coating alloy, and launched to the market a new product, SuperDymaTM, coated with a Zn-Al-Mg-Si alloy. The developed product has accumulated rich track records in more than 10 years ever since.

1. Introduction

Corrosion-resistant coated steel sheets have been long and widely used for structural applications. This is because structures are often exposed to corrosive environments and corrosion resistance is an essential requirement for structural materials. In this field of use, Nippon Steel & Sumitomo Metal Corporation has concentrated their efforts on enhancing the corrosion resistance of these products and launched a variety of value-added coated sheet products into the market.

The company once sold hot-dip-galvanized sheets with pure zinc coating as the basic product for the market sector and then improved the corrosion resistance by adding Al to the zinc coating. To enhance the corrosion resistance yet further, Mg and Si were added to the coating alloy, and based on this, steel sheets coated with a Zn-Al-Mg-Si alloy were launched into the market under a trade name of SuperDyma[™]. Since then, the new product has been widely used as a highly corrosion-resistant structural material for more than 10 years.

Focusing mainly on SuperDyma[™], this paper presents Nippon Steel & Sumitomo Metal's coated sheet products for structural use, and technically reviews the Mg addition, which enabled the development of the product.

2. Overview

2.1 Types of coated steel sheets for structural applications and their development

Coating, or plating, is applied to the surfaces of metal products to prevent them from rusting. A popular kind of coated steel product is galvanized sheets, which are manufactured by having steel sheets go through a bath of molten zinc.

Conventionally, the coating layers consisted of pure zinc, but to

obtain better corrosion resistance, Al was added to the zinc coating, and this practice was called zinc alloy coating: such alloy-coated products include Zn-5%Al coated sheets and GALVALUME STEEL SHEETTM with Zn-55%Al alloy coating.

Then, by roughly adding 11% Al, 3% Mg, and a small amount of Si to zinc, Nippon Steel & Sumitomo Metal developed a new coating alloy that drastically improved corrosion resistance, and in 2000, began marketing a new steel sheet product coated with the developed alloy under the trade name of SuperDymaTM. It has earned high market appreciation through a great number of track records since the start of its sale more than 10 years ago, and its use is expected to expand yet further. Taking advantage of high corrosion resistance due to the addition of Mg, the company has developed another galvanized sheet product called SGLTM, coated with a zinc alloy containing 55% Al and some Mg. The developed product is being marketed through Nippon Steel & Sumikin Coated Sheet Corporation, and its application is expanding.

2.2 Characteristics of SuperDymaTM

SuperDymaTM is a new type of galvanized sheet coated with a zinc alloy containing Al, Mg, and Si. Thanks to the combined effects of these alloy components, it exhibits excellent corrosion resistance at cut edges as well as at flat surfaces. Its corrosion protection performance is conspicuous especially under highly corrosive conditions, and it is suitable for use in environments containing high airborne salt, humidity, alkali, etc. The principal characteristics of SuperDymaTM are presented below.

2.2.1 Corrosion resistance at flat parts

The coating alloy reacts chemically with humidity and oxygen in the atmosphere to form corrosion products on the surface. While the

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corrosion products of conventional galvanized sheets are coarse and loose, those of SuperDymaTM are dense and closely packed due to the effects of Mg, and they serve as a protective coating to suppress the progress of corrosion.

The protective effects of the coating alloy of SuperDyma[™] are roughly four times than those of conventional hot-dip galvanized sheets with pure zinc coating. **Figures 1** and **2** compare SuperDyma[™] with conventional hot-dip galvanized sheets in terms of the surface appearance and corrosion weight loss during exposure tests in Okinawa, the southernmost island region of Japan.

2.2.2 Corrosion resistance at cut edges

The base metal is exposed to the atmosphere at cut edges, and red rust forms there at an early stage of exposure. In the case of Super-DymaTM, however, the alloy elements dissolves from the coating layers near a cut end, and closely packed corrosion products forms to cover the edge; this way the progress of edge corrosion is effectively suppressed. **Figure 3** shows the results of salt spray test on the corrosion resistance at cut ends. Here, we see that GALVALUME STEEL SHEETTM is inferior in terms of the corrosion resistance at cut edges, although it is excellent in the same at flat portions.

2.2.3 Corrosion resistance in alkaline environments

Corrosion resistance of various types of galvanized sheets under different pH conditions is given in **Fig. 4**. While GALVALUME STEEL SHEETTM corroded easily especially in strongly alkaline environments, SuperDymaTM was the most resistant of the tested specimens.

2.2.4 Lineup of environment-responsive products

Like in the field of materials for electrical appliances, the demand for environment-responsive products is increasing in the field of construction materials over the last few years. As stated earlier, ecological measures are taken in the manufacture of highly corrosionresistant SuperDymaTM: chromate-free solutions are used for the chemical treatment applied to the coating surfaces. As seen in **Fig. 5**, the chromate-free treatment of SuperDymaTM exhibits performance superior to that of conventional chromate treatment. (The symbols in the graph indicate the type of chemical treatment: QN is chromate-free treatment for environment-conscious products; QFK chromate-free treatment for environment-conscious products is specially designed for good frictional performance to improve formability; and Y chromate treatment for conventional products.)



Hot-dip sheet Fig. 1 Appearances of un-painted SuperDyma[™] and conventional hot-dip galvanized sheet after 3-year exposure in Okinawa



Fig. 2 Corrosion loss of un-painted specimens in 3-year exposure in Okinawa







Fig. 4 Acid and alkaline resistance of various coated sheets



Fig. 5 Performance evaluation of chemical treatment films through salt spray test

2.3 Applications of SuperDymaTM

While SuperDyma[™] is widely used for varied fields of application such as the manufacture of electrical appliances and automobiles, yet the most significant field of use is construction; it is used for practically all types of civil and building structures.

Of various structures for houses, public and commercial buildings, civil work, roads, railroad, power generation and distribution, communication, agriculture, livestock farming, etc., typical application examples of SuperDymaTM and the advantages it brings about are explained below.

2.3.1 Housings

Modularized prefab housings highly resistant to earthquakes account for a significant part of the housing market in Japan. Galvanized steel sheets have long been used for lumber girders, bridging joists, trusses and its other structural members. Of different types of such sheets, those with Zn-5%Al coating, excellent in corrosion resistance were used most widely for these applications. With the latest increasing demand for three-generation houses, 100-year houses, etc., the required service life of housings has increased, and materials more corrosion resistant than Zn-5%Al coating had to be developed. In this situation, in 2000, Nippon Steel & Sumitomo Metal launched Super-Dyma[™], which the company had developed and brought to a technically matured state to the market. Ever since, the product has earned high customer appreciation as a substitute for Zn-5%Al coated sheets, and it is now used as the standard material in this field of use.

Housing accessories were made mostly of conventional hot-dip galvanized or stainless steel sheets, but as the use of SuperDymaTM for structural members expanded, its application to accessories has increased for the same reason.

Thin sheets of GALVALUME STEEL SHEETTM, coated with a Zn-55%Al alloy, have been used for the roofs and walls of housings, and where appearance is important, pre-painted GALVALUME STEEL SHEETTM were used; these products have rich track records of such applications. Since GALVALUME STEEL SHEETTM is as good as SuperDymaTM with respect to corrosion resistance at flat parts, it is used without problems in normal conditions. Under highly corrosive conditions, however, GALVALUME STEEL SHEETTM is known to corrode, and as higher corrosion resistance was required for these housing parts, modifications to GALVALUME STEEL SHEETTM (such as SGLTM mentioned earlier) is attracting attention.

2.3.2 Buildings and civil construction

In the field of building construction, better corrosion resistance than that of conventional hot-dip galvanized sheets is considered, and in appreciation of the cost advantage to post-galvanized materials, SuperDyma[™] is used in the forms of square tubes and roll-formed sections for the substrates of external walls, furring strips for reinforcements, purlin members of public and commercial buildings, warehouses, and plant buildings.

While roll-formed sections for ceiling support are mainly made of conventional hot-dip galvanized sheets, stainless steel sheets are occasionally used for those of indoor swimming pools and the like where corrosion is likely. Due to the fact that red rust forms on stainless steel in environments containing chlorine, the use of SuperDyma[™] as a substitute is increasing.

Besides these, SuperDyma[™] is used for applications such as cable racks, deck plates, ducts, sound insulating walls, windbreak fences, building exterior panels, corrugated perforated sheets, punching metals, etc., significantly serving to extend the service life. 2.3.3 Road and railroad structures

SuperDymaTM has been used for sound insulating walls for roads, structures inside tunnels, and railroad station buildings. Since the structures for roadways and tunnels are used in highly corrosive conditions, conventional post-galvanized pieces are considered insufficient in terms of corrosion resistance, and thus, SuperDymaTM is preferred. 2.3.4 Power systems and communication

SuperDyma[™] has been used in quantities for structures, distribution boards, etc., of thermal power plants, relay station facilities for communication systems, and likewise. In addition, thanks to the rapid expansion of photovoltaic power generation over the last few years, its application to structures related to solar power generation devices is rapidly increasing.

2.3.5 Agriculture, animal farming, and others

From the viewpoint of steel corrosion, agricultural housings are mostly in tough conditions, at high temperature and high humidity, and their structures have been primarily made of Zn-5%Al hot-dip galvanized sheets. Now, SuperDyma[™] is beginning to replace them as a promising substitute.

Animal housings are in strongly alkaline conditions, and for this reason, GALVALUME STEEL SHEETTM, which easily withstands normally corrosive conditions, is unsuitable and is likely to corrode rapidly. SuperDymaTM is expanding its application to such buildings as poultry houses, cowsheds, pigpens, and compost sheds as a better suited material.

2.4 Expansion of SuperDyma[™] application to growing fields

Of widely varied fields of application of SuperDyma[™], the following fields look especially promising.

2.4.1 Photovoltaic power generation

Photovoltaic panels are employed for solar power generation either industrially or for household use. SuperDyma[™] has been used for the support structures for residential panels for more than 10 years; it has replaced post-galvanized and aluminum supports for cost advantages.

Large-scale photovoltaic power plants, known as "mega solar plants" in Japan, have been proposed and built in numbers recently. In appreciation of the application references in widely varied fields, SuperDymaTM has been selected as the preferred material for the panel support structures of such large-scale plants, especially in coastal locations where severe salt attack is feared. Compared with conventional post-galvanized materials, SuperDymaTM has better corrosion resistance and the material costs are lower because of less material weight, and as a result, it is now used as the principal mate-



Fig. 6 Solar panel support structure

rial for the application. A typical example of panel support structure is shown in **Fig. 6**.

The above advantages are common to the panels either for industrial or residential use, and the use of the product for the application is expected to increase further to help with wider use of photovoltaic panels.

2.4.2 Agriculture and animal farming

Agriculture and animal farming are attracting increasing attention lately as new fields of growth; an increasing number of agricultural and pastoral exhibitions are being actively held, and many people see new business opportunities in these fields. This is largely due to the growing awareness of and request for safety, reliability, stable supply, guaranteed quality, and product differentiation of food stock, and as a result, the agricultural and pastoral industries of Japan are changing after a long period of decline.

High-tech vegetation factories are attracting attention as a typical example of such a new trend in agriculture. **Figure 7** shows an agricultural plant; SuperDyma[™] has been used for the structures of such plants, and many similar facilities are expected to be built especially in the regions heavily hit by the big earthquake in March 2011. 2.4.3 Infrastructures

The business atmosphere is recovering in Japan after a long calm period, but at the same time, the need for improvement and maintenance of infrastructure facilities is being strongly felt. In this situation, the demand for construction materials is expected to increase. Super-Dyma[™] has been effectively used for anti-seismic reinforcements of various buildings, and its use is expected to increase yet further, spurred by the construction projects for the 2020 Tokyo Olympic Games.

2.5 Evaluation of SuperDymaTM and property improvement

As SuperDymaTM has accumulated supply references, its recognition in the market has increased, and the feeling of reliability has risen, leading to the following.

2.5.1 Award of Invention Prize

In June 2012, Nippon Steel & Sumitomo Metal was awarded the



Fig. 7 Agriculture plant

Invention Prize from the Japan Institute of Invention and Innovation for the year. The prize was awarded to encourage and promote invention and innovation in Japan, to promote the technical development, and help the industrial advance of the country, and thus is highly esteemed as an authoritative prize.

2.5.2 Registration in JIS

On November 20, 2012, the Ministry of Economy, Trade and Industry of Japan instituted hot-dip Zn-Al-Mg-alloy-coated steel sheets and strips in Japanese Industrial Standard (JIS) as G 3323.

SuperDyma[™] has been certified to conform to JIS G 3323, which is expected to be instrumental in expanding its use for public construction projects.

2.5.3 Award of Prize from Minister of Education, Culture, Sports, Science and Technology

In recognition of the development and manufacture of SuperDymaTM, the related people of Nippon Steel & Sumitomo Metal received the Science and Technology Award (Development) by the Minister of Education, Culture, Sports, Science and Technology for the fiscal year 2013; this series of award is to acknowledge distinguished accomplishments for the development in and promoting general understanding of science and technology.

2.5.4 Eco Products Award

At the 10th Eco Products Awards in November 2013, SuperDyma[™] received the Chairperson's Award, Eco-Products Awards Steering Committee. For the purpose of promoting the development and popularization of ecology-conscious products and services in Japan, these awards are given every year to ecologically excellent products and services to bring them to consumers' acknowledgement and encourage their suppliers.

2.6 Modification to GALVALUME STEEL SHEETTM

GALVALUME STEEL SHEET[™] are used principally for building roofs and walls. While they are highly resistant to corrosion in normal use conditions, they are prone to rusting in severely corrosive environments of high humidity, airborne salt, alkali, etc., and also at such

building parts not directly exposed to rain water as under-eave walls; improvement in its corrosion resistance was awaited in view of such applications. In response, by applying Mg addition to GALVALUME STEEL SHEETTM, the Nippon Steel & Sumitomo Metal group has developed a new sheet product, SGLTM, hot-dip coated with a Zn-55%Al-Mg-alloy. The new product is being marketed by Nippon Steel & Sumikin Coated Sheet Corporation.

3. Closing

Steel sheets for construction applications are used exposed to corrosive environments, and for this reason, they are mostly coated sheets highly resistant to corrosion. Nippon Steel & Sumitomo Metal has focused efforts on R&D to enhance the corrosion resistance of these products. SuperDymaTM, which was launched to the market in 2000, is a fruit of such efforts; it is a highly corrosion-resistant galvanized sheet coated with the zinc-base alloy containing roughly 11% Al, 3%

Mg, and a small amount of Si.

The product has accumulated successful track records in more than 10 years in fields such as housings, public and commercial buildings, civil engineering, road and railroad facilities, power generation and distribution, communication, agriculture, pastoral farming, etc. Over the last few years, its use has also spread to the support structures for photovoltaic panels, and it is expected to expand to other new fields of application. In appreciation of the rich application references and wide recognition of its reliability, the product has been approved for JIS registration and honored with several awards of high reputation. The effectiveness of the Mg addition technology, which is one of the keys in the development of SuperDyma[™], has been effectively applied also to the performance improvement of GALVALUME STEEL SHEET[™]. Nippon Steel & Sumitomo Metal will continue contributing to the society exercising its leading edge technologies.



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