NIPPON STEEL TECHNICAL REPORT No. 101 NOVEMBER 2012

Technical Review

UDC 699 . 162 . 21 : 628 . 511 : 628 . 1

Development of Civil Engineering, Building and Water Treatment Technology

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1. Introduction

In this technical review, we describe the development history of civil engineering, building and water treatment technology at Nippon Steel Corporation since 1980.

Construction of several of the company's new steelworks had been completed by the end of the 1970s. The 1980s marked a period of transition from quantity to quality, with the focus on prolonging the life, reducing the cost, and improving the quality of equipment. Many of the fundamental technologies that we rely on today were born in that period. They include, for example, fatigue resistance design for crane runway girders, seismic design for blast furnace/converter buildings, factory ventilation design based on airflow analysis, removal of heavy metals from plating waste liquor, and treatment of wastewater from desulfurization equipment. In addition, the company began activities to prevent equipment deterioration over prolonged periods, such as developing technology to prevent the corrosion of port facilities and solving the problem of deterioration of concrete.

In the 1990s, under the bubble economy and the subsequent economic recession, cutting the cost for construction became a watchword. Nippon Steel developed new underground structures, including the one-pillar/one-pile foundation and the concrete-filled steel underground continuous wall, which allows for labor savings in construction work, and new earthquake-resisting structures, including the rod-type seismic response control device. In the field of water treatment, following the entry of the former Engineering Division into the field of sewage and river purification, the company started to develop technology for cleaning the environment as well as advanced sewage treatment technology (nitrogen, phosphorus, etc.). In addition, in response to the growing need to shorten the time taken to reline a blast furnace and expand the inner volume of blast furnaces, the company employed new technology and a new method in the field of civil engineering and building each time it relined or expanded a blast furnace.

In the 21st century, with the aim of further reducing the environmental impact of steelmaking, Nippon Steel has developed new technology to treat wastewater from the steelmaking processes using sulfur- and iron-oxidizing bacteria, etc. and has offered solutions based on airflow analysis to the problems of dust blowing about in steelmaking buildings and dust scattering over outdoor raw material yards. Preventing disasters caused by earthquakes has also become an important issue. In this respect, the company has developed plans and methods to improve the earthquake resistance of quays and original methods for reinforcing factory buildings.

Of the above technologies, we discuss below the three technologies that support the foundation of integrated iron and steelworks—blast furnace relining technology, airflow analysis technology, and water treatment technology.

2. Introduction of Representative Technologies

2.1 Blast furnace relining technology

Relining a blast furnace affords a good opportunity to increase the capacity (inner volume) of the blast furnace, although it entails a decrease in output of hot metal during the relining work. From the standpoint of engineering, therefore, planning to expand the furnace inner volume at that time and reduce the duration of furnace relining is strongly preferred. Described below is our civil engineering and building technology that helps meet this challenge.

2.1.1 Technology to shorten the relining period

In recent years, blast furnaces are relined by using the large furnace body block method,[1] which was co-developed by Nippon Steel and its affiliated company, Nippon Steel Engineering. In the fourth relining of the No. 3 blast furnace (blowing-in in April 2000) at the Nippon Steel Nagoya Works in which the above method was applied for the first time, the planned relining period of 128 days was drastically reduced to 93 days.

Recently, on the other hand, during relining of a blast furnace, extensive reconstruction of its casthouse is also carried out. Therefore, it is necessary to shorten the duration of the casthouse reconstruction as well. The company has been active in the development of technologies and engineering methods to reduce the processes for furnace body renovation and casthouse reconstruction.

As a method of speedily restoring the casthouse, which interferes with the work of carrying in and out the furnace body, the company developed the large casthouse block method. In this method, a new casthouse is prefabricated almost completely in a separate location, then transported by a heavy-duty unit dolly to the prescribed place for installation when the restoration is performed. Since the concrete floor, hot metal runner refractory bricks, etc. of the casthouse are already in place, the method calls for a work plan and design with due attention to damage/cracking caused by deformation or vi-

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bration during transportation.

In the face of the above problem, we calculated the allowable strain for each of the casthouse structures and made a detailed study of the optimum casthouse support structure, device layout, dolly disposition, etc. using a three-dimensional analysis to take into account the calculated permissible strains. The problem has been resolved by reflecting the study results in the casthouse structural and transportation planning. In the third relining of the No. 2 blast furnace at the Nippon Steel Oita Works that was blown-in in April 2004, huge blocks for the casthouse that were about 1,000 m^2 in area and about 3,000 tons in weight were used (**Photo 1**).

For the other parts of the casthouse too, in order to drastically reduce the conventional relining process, the casthouse structure that was formerly made of concrete and filled with ballast has been changed to a hollow steel structure. In particular, the runner wall is exposed to the molten iron radiation heat of almost 1,500℃ and has a complicated shape. Therefore, it was necessary to develop a runner wall with a rational structure.

Eventually, we worked out two types of structure, either of which is used according to the thermal load and plane shape of the runner wall. One is the plate-type runner wall consisting of a reinforced steel plate fixed to the casthouse frame, and the other is the column-type runner wall consisting of square steel tubes welded together in the form of a wall. In developing those new runner walls, we began by measuring the temperature/thermal elongation of the existing runner walls, and then studied efficient methods of air-cooling the steel frame members and their design taking into account the temperature dependence of the steel material's yield strength, and methods of absorbing the thermal elongation of the runner wall. These have been improved at every opportunity during casthouse reconstruction.

2.1.2 Activities to expand blast furnace inner volume

In the relining of blast furnaces in recent years, a plan to maximize the blast furnace inner volume without any major modification to the existing equipment is adopted. It is not uncommon that the inner volume of a blast furnace is limited by the yield strength of the foundation piles supporting the furnace body. Therefore, developing an economical foundation reinforcement method that does not affect the blast furnace operation is strongly called for.

The foundation for a blast furnace consists of some 200 large-diameter steel pipe piles on which a concrete foundation is built. This supports the furnace body, upper structure, casthouse, etc. with a total weight of about 30,000 tons (**Fig. 1**). The newly developed foundation reinforcement method applies ground improvement technology that consolidates the comparatively loose portion of the ground right under the blast furnace foundation with cement, etc.. The vertical load that acts upon the blast furnace foundation is transmitted to the solid bedrock via the reinforcement layer, making it possible to reduce the load on the piles (**Fig. 2**).

In addition, whenever there is a fear that a horizontal seismic load input from the superstructure should exceed the yield strength of the foundation, we implement an equipment plan based on the concept of seismic response control/base isolation to reduce such a seismic load.

2.2 Airflow analysis technology

At integrated iron and steelworks, there is a possibility that the working environment in plant buildings deteriorates due to the incredible heat and much dust generated from steel production processes. Therefore, many plant buildings are equipped with ventilators which smoothly exhaust hot air to the outside and dust collecting

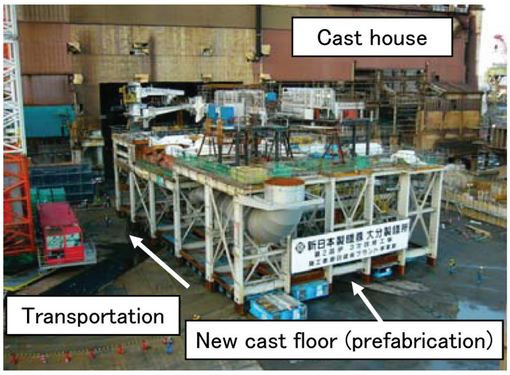

Photo 1 Prefabrication method of cast floor (relining of Oita No.2 blast furnace)

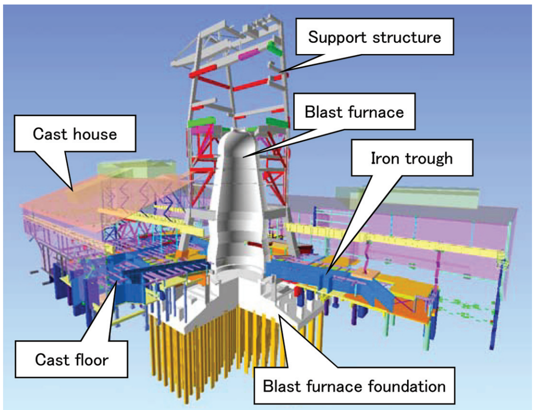

Fig. 1 Outline of blast furnace equipment

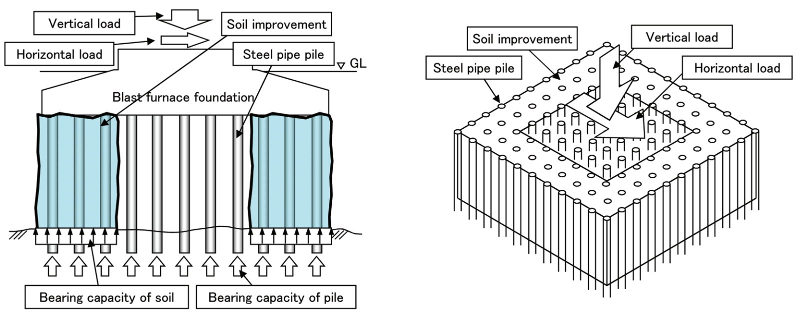

Fig. 2 Outline of reinforced blast furnace foundation

hoods which draw in suspended dust without allowing it to scatter about inside the building.

In order to maximize the effect of installing those devices, Nippon Steel has implemented new equipment designs and studied improvements to existing devices using numerical airflow analysis.[2] **Fig. 3** shows the basic concept of a dust analysis model. Dust gets mixed with gases from the furnace. Since dust is normally heavier than the gases and air, it begins gravitational settling once it slows down enough while dispersing. By using the basic equation of hydrodynamics, it becomes possible to obtain a solution to the above phenomenon. In an actual plant, however, the airflow is strongly influenced by machinery, overhead cranes, openings, etc. which have complicated shapes. In order to reproduce the actual phenomenon accurately, therefore, a certain degree of know-how regarding meshing and parameter setting is indispensable. The company's strength in this respect is that it has accumulated extensive know-how in many different fields through verification by comparison between measurements obtained in its many plants with numerical analysis results.

Fig. 4 shows an example of our study on the reinforcement of dust-collecting equipment for a steelmaking plant. First, we created a non-steady analytical model reproducing the time-serial change in the amount of gas generated from the furnace. Then, using the model, we estimated the concentration of dust in the building when the airflow for dust collection was increased at three points where dust-collecting hoods were installed in front of the furnace, near the flue and at the ceiling. As a result, it was found that because of the strong outflow of gas generated, increasing the airflow near the dust sources (the furnace and flue) was not very effective, whereas increasing the airflow for the ceiling hood away from the source of the dust was effective. Eventually, we optimized the amount of additional airflow

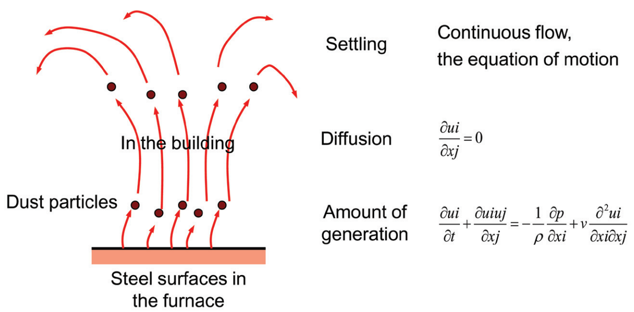

Fig. 3 Basic concepts of simulation of airflow and dust diffusion

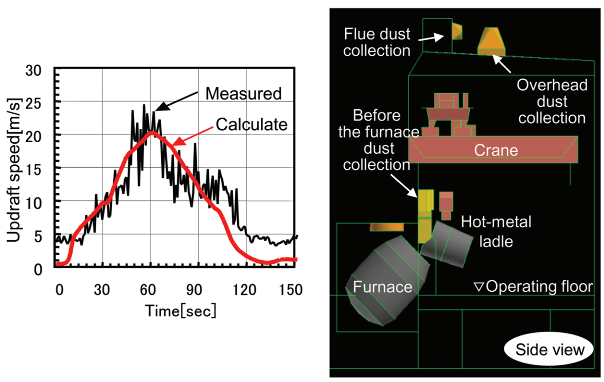

Fig. 4 Case studies in the steel plant dust collection measures

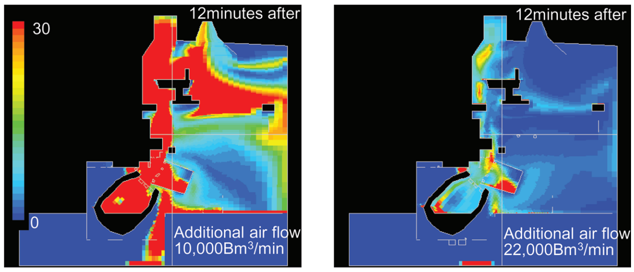

Fig. 5 Steel plant dust on the simulation results

and the shape of hoods (**Fig. 5**) and formulated an equipment reinforcement plan to reduce the amount of suspended dust in the plant to one fifth. Execution of the plan has improved the working environment of the plant dramatically.

In the steel production process, the boundary conditions change from moment to moment. Therefore, they often require a non-steady analysis. Besides, since the space to be analyzed is wide, the computing load is comparatively large. Today, however, numerical airflow analysis has become an indispensable tool in our studies to improve the working environment in plant buildings. In fact, it is widely applied not only in dust collection plans and ventilation equipment plans for plant buildings, but also in studies on measures to prevent hyperthermia in workers, leakage of harmful gases, and dew condensation in the downstream processes, etc.

2.3 Advanced water treatment technology

The steel industry is a water-consuming industry which utilizes various types of water treatment technologies, such as solid-liquid separation, chemical oxidation/reduction treatment and biological treatment. For example, the Nippon Steel Kimitsu Works uses around 3,400,000 m^3 of water daily, about 93% of which is recycled and reused.

Biological treatment technology utilizing microorganisms is an environment-friendly, economical and efficient water treatment technology that does not consume much energy. In the field of sewage and industrial wastewater treatment, the activated sludge process and biological nitrogen/phosphorus removal process are used to reduce biochemical oxygen demand (BOD) and chemical oxygen demand (COD) or remove nitrogen/phosphorus. At Nippon Steel, wastewater treatment technology utilizing microorganisms is widely applied to reduce the environmental load of wastewater. For example, sulfur-oxidizing bacteria are used to treat alkali wastewater containing reduced sulfur compounds and iron-oxidizing bacteria are used to separate and recover metallic elements contained in waste plating liquor (**Photo 2**).

Alkali wastewater containing sulfides or thiosulfates must not be

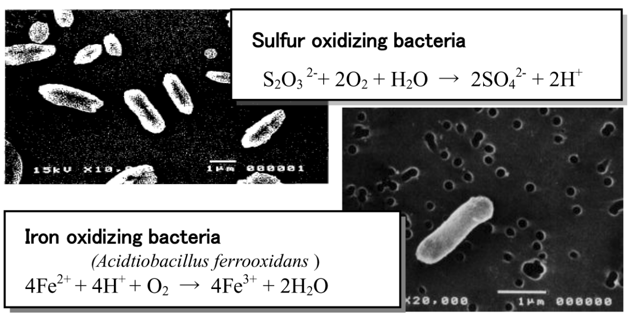

Photo 2 Sulfur oxidizing bacteria and iron oxidizing bacteria

discharged directly into public water area because of its high COD ascribable to the presence of reduced sulfur compounds. Generally, therefore, it is first oxidized by injecting a large volume of sodium hypochlorite into it and then pH-neutralized using a neutralizer. In order to reduce the doses of those chemicals, Nippon Steel developed technology that acclimates sulfur-oxidizing bacteria which are active in the pH neutral region to oxidize the reduced sulfur compounds contained in the wastewater by biological reactions and that lowers the pH value of the wastewater by the sulfuric acid produced in the above process. This technology has been used to treat alkali wastewater.[3)]

On the other hand, acid wastewater generated from the plating process contains metallic ions of iron, nickel, and zinc, etc. which cannot be separated out chemically. Generally, therefore, it is first neutralized and then the mixed metal hydroxide is separated from the wastewater. In order to selectively separate metals from the wastewater, Nippon Steel developed a process that utilizes iron-oxidizing bacteria to treat acid wastewater. Namely, the company has built a wastewater treatment system that first oxidizes Fe^{2+} to Fe^{3+} by using iron-oxidizing bacteria under acidic conditions of around pH 4 to precipitate the iron in the form of $Fe(OH)_3$, and then separate out and recover the nickel and zinc, respectively.[4)]

The above sulfur-oxidizing and iron-oxidizing bacteria are autotrophic bacteria which allow for carbon dioxide assimilation using the energy generated in the oxidizing process. Thus, they have made it possible to cut the running costs of the wastewater treatment system significantly.

3. Conclusion

The sphere of civil engineering, building and water treatment technology is steadily expanding to embrace various fields relating to steelmaking, such as protection of the local environment, response to the arrival of a low-carbon society, effective utilization of slag, prevention of natural disasters, business continuity plans (BCP), and equipment maintenance.

In the future, there will be an ever-increasing demand for technology for the proper maintenance and renovation of obsolete structures, technology for the rational realization of civil engineering, building and water treatment systems for steelworks that can withstand even exceptionally strong earthquakes/tsunamis, and technology to respond to increasingly stringent regulations on water- and air-pollution control.

In order to meet the above needs of the times in the field of civil engineering, building and water treatment, Nippon Steel continues to develop component technologies that are unique to the steel industry while adopting, as required, the most advanced technologies in various other fields.

References

1) The Iron and Steel Institute of Japan, Production Engineering Department: Ferrum. 15 (5), 22 (2010)
2) Ishii, K.: Shinnittetsu Giho. (364), 51 (1997)
3) Yoshimori, H.: Shinnittetsu Giho. (360), 5 (1996)
4) Kato, T.: Collection of Wastewater/Polluted Water Treatment Technologies. 1st Edition. Tokyo, NTS, 2007, p.139

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