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All-round Engineering by Kawasaki Steel Corporation - The Island and Town Construction as Starting Points

Seitaro Saito, Takayuki Hineno, Chiyomaru Takahashi

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The body can be viewed from the next page.

All-round Engineering by Kawasaki Steel Corporation —The Island and Town Construction as Starting Points*



Seitaro Saito
Managing Director, Kawatetsu Engineering, Ltd. (Former General Manager, Iron- & Steelmaking Technology Dept., Engineering & Construction Div.)

Takayuki Hineno
General Manager, Building Engineering Dept., Engineering & Construction Div.

Chiyomaru Takahashi
General Manager, Construction Materials & Engineering Services Dept., Engineering & Construction Div.

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1 Introduction

Technically, Kawasaki Steel Corporation's Engineering & Construction Division had its starting point in the construction of the company's steel works. Taking advantage of the availability of steel materials as a steel maker the Division subsequently accumulated and developed technologies in diverse fields such as plant construction, civil engineering, pipeline construction, architectural construction, and construction materials. Moreover, in responding to the needs of the times in fields related to energy and the environment, which have drawn concentrated attention in recent years, Kawasaki Steel, in concert with other Kawasaki Steel group companies, has promoted the growth of all-round engineering as a function of the Kawasaki Steel group. This paper presents an overview of the technical trends and outlook in each of the above-mentioned fields.

2 Plant Engineering

In Kawasaki Steel's long history of steel plant construction, which includes plant operation, automation, and systemization, we have naturally developed and accumulated a steel plant engineering capability. However, we also developed other technologies indispensable to steelworks, including water treatment technology and technology for treating the sludge generated by water treatment equipment. In response to social needs, we are also developing plant engineering capabilities for waste treatment, expanding the technology for use of thermal energy in the works. Moreover, we have applied the techniques of production, physical distribution, maintenance and energy control characteristic to steelworks to general plant design, and adopted the newest factory automation (FA) techniques in the construction of plants.

2.1 Engineering for Iron- and Steelmaking

Several examples of full turn-key orders for plants outside Japan will illustrate Kawasaki Steel's capabilities in the field of engineering for iron- and steelmaking, which was the origin of the company's plant engineering activities. These orders include Philippine Sinter Corp. (PSC, startup in 1977), Tubarão Steel Works in Brazil (CST, startup in 1983)[1], and electrolytic tinning

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lines in Colombia, Thailand, Malaysia, and Taiwan (these lines and their technical features are discussed elsewhere in this special issue)[2]. Kawasaki Steel was responsible for the construction and startup of these and other facilities, and on the basis of this experience, has steadily developed expertise in functions ranging from concept engineering to construction management.

Individual steelmaking processes developed and marketed by Kawasaki Steel also deserve mention. These include blast furnace revamping and operation technology, which contributes to extended BF life and stable operation; the top and bottom blowing converter (LD-KGC)[3], which is characterized by excellent stirring of the molten steel and dephosphorization; oxygen top blowing for the vacuum degasser (KTB)[4], as part of the ultra-low carbon steelmaking process; the plan view pattern control system for plate rolling (MAS rolling)[5], which has contributed to improved plate shape accuracy and yield; work roll shifting in the hot rolling process (K-WRS)[6] for higher quality in strip profile and flatness; the continuous annealing method (KM-CAL)[7] for heat treatment for multiple grades of cold rolled sheet, which contributes to energy saving; and the grooveless rolling method[8] for productivity improvement in billet and bar mills. With recent moves by Japanese automakers into Europe and the United States, we have received requests from local steelmakers for technical assistance in the manufacture of coated steel sheets for automotive applications. In particular, we have supplied technology for galvannealed steel sheet[9] to BREGAL in Germany, STELCO in Canada, and others, where our company has earned an excellent reputation.

In the areas of total environmental improvement and energy saving in steelworks, we have also provided technical assistance to the Kremikovtzi Joint Company in Bulgaria. From the viewpoint of protection of the global environment, requests for total engineering assistance of this type are expected to increase in the future. The developing nations, which aim to become self-sufficient in steel production, have also requested technical assistance from Kawasaki Steel, for example, in the Taiwan Cold Rolling Mill Construction Project and in the construction of mini-mills with electric arc furnaces, as well as in connection with stainless steel sheet, electrical steel sheet, and other high-grade steels. Thus, our Engineering Division is steadily preparing itself to meet a variety of client needs, particularly in wider-scope full turn-key projects.

2.2 Water Treatment Engineering

Kawasaki Steel's water treatment engineering is based on the planning, design, construction, operation, and maintenance control of water and waste water treatment facilities at steelworks. Steelworks water and waste water cover a wide range, including clear water; industrial water, circulating water, sea water, waste water containing oil and heavy metals, and domestic waste water. On the basis of technology developed in its steelwork, we began marketing water treatment technology and equipment commercially in 1984, setting as our initial goal entry into the sewerage industry. Our company's range of activities has gradually expanded from partial fabrication and installation of water treatment facilities, including items such as automatic screens in the initial period, to the system-level water treatment projects.

2.2.1 Sewerage

At present, only 47% of Japan is served by sewer systems, but public works plans call for an increase to 70% by the year 2000. The trend toward greater public investment in sewerage makes this a promising field. We have accumulated a wide range of actual results in this field, including grit chambers, sludge thickening facilities, and rural sewage treatment plants, and in particular expect to see wider use of the circular grit chambers with rotary cylinders,[10] which are superior to conventional equipment in grit removal efficiency.

2.2.2 Industrial water and waste water

Although we have recently constructed water treatment facilities as auxiliary facilities for steelworks at An Feng Steel Co., Ltd. and Tung Ho Steel Enterprise Corp. in Taiwan, wider diffusion of steel plant equipment is also likely in China, Thailand, Malaysia, Indonesia, and other nations in the coming years. In fields other than steel, we were responsible for water and waste water treatment engineering at Nihon Semiconductor Inc. where we established ultra-pure water treatment and waste water treatment techniques for a semiconductor plant. This technology should make an important contribution to the expected future construction of semiconductor plants in southeast Asia.

2.2.3 Purification of water areas

Amenities are an indispensable part of regional development and resort development projects. In particular, recreational facilities typically include calm areas of confined water. However, the water quality in such confined water areas must be maintained by using water treatment equipment. We have devoted considerable effort to pilot scale purification tests and purification simulations to ensure that the designs of such equipment are effective.[11] With expanded regional and resort development in response to increasing demand for amenities, the technologies developed by Kawasaki Steel should make a significant contribution to water area purification.

2.2.4 Sludge treatment

Treatment of the sludge produced by the various water treatment facilities discussed above is important from the viewpoint of environmental protection. Sludge treatment methods include composting, incineration, melting, and others. In the future, this field must find increasing application in response to social needs, not only in waste treatment, but also in resource recovery and recycling.

2.3 Garbage Treatment (Measures for the Urban Environment)

Municipal waste is generally incinerated in trash incinerators, and the resulting ash is discarded. However, from the viewpoint of recycling resources, we have completed the development of a system for recovering such wastes as solid fuel. As a solution to the landfill problem, we have also developed another system for reducing incinerator ash and recovering resources using a plasma type melting treatment system (PLASMA).

In the refuse derived fuel system (RDF), solid fuel with a calorific value of approximately 4 000 kcal/kg can be produced from raw waste. When electric power is generated from raw waste, the power generation efficiency is about 12%, but when power is produced from this solid fuel, this figure rises to around 30%. Moreover, the fuel is suitable for long term storage and can be used in producing hot water and in heating, as well as in power generation. In Japan, the solid fuel has already been approved by Osaka Prefecture for use as fuel, and the system can be used to produce an energy source from raw waste in virtually any locality, and is therefore considered a promising means of resource recovery for the future. We have entered the field of waste management by establishing the Recycle Management Japan, Inc., together with Itochu Corp. and two other companies, to handle municipal waste and other waste materials. We have already started up solid fuel recycling plants in Haibaracho in Nara Prefecture and Nogicho in Tochigi Prefecture, and are marketing the system commercially.

With the PLASMA, the use of plasma as a heat source makes it possible to use a compact furnace design and obtain high-temperature fusion slag easily. The fundamental experiements for this technology have been completed[12] and a four-party group made up of Kawasaki Steel, The Tokyo Electric Power Co., Inc., Kawasaki Heavy Industries, Ltd., and Chiba City has constructed a demonstration-experiment furnace at the Kita-Yatsu Waste Incineration Plant in Chiba City. The originally expected results were obtained in this demonstration experiment, and a commercial unit is now in the design stage. This furnace can also be applied to the melting treatment of shredder dust incineration residue, and future application to incinerator ash including unburnt material from newly constructed and existing domestic waste incinerators is also expected to increase demand.

2.4 General Plant Facilities

We also have wide experience in the construction of infrastructure and general facilities for steelworks and similar plants. Examples include the harbor facilities and raw material yards at Philippine Sinter Corp. and Tubarão Steel Works; port facilities and material and product yards for a fertilizer plant in the Philippines; a conveyor system for soil in Kobe, Japan; and all-weather cargo handling equipment. The liberalization of markets for meat products has given us the opportunity to newly construct and improve livestock feed plants. In a step beyond our traditional work in fabricating silos and other storage structures, we constructed the Kushiro Livestock Feed Plant for the National Federation of Dairy Cooperation Association,[13] carried out the revamping of the Hokuren Kushiro Plant, and made other moves into the livestock feed plant industry. Here, too, we have taken advantage of our own technology for the automation and systemization of material blending and transportation tasks in the steelworks. In plant engineering, an increasing need for automation, efficiency, systemization, and CIM (computer integrated manufacturing) in the future should provide ample opportunity in all types of plant construction for us to demonstrate our technical capabilities in all-round engineering.

3 Civil Engineering

3.1 Core Technology of Civil Engineering and Expansion

As mentioned earlier, Kawasaki Steel's civil engineering technology has developed through the construction of steelworks. Accordingly, it is interesting that the core technology and the way of its expansion have been varied in response to the requirements of the times. The core technology started with the construction of revetments, reclamation, quay walls, and caisson foundations in and after 1955. After 1965, we made advances in technology using larger diameter steel pipe piles, interlocked steel pipe piles, and soil improvement techniques, and further, large steel structures in fields such as offshore civil engineering and bridges. More recently, its core technologies have come to include those associated with urban and resort development. With a large number of civil engineers currently involved in our engineering business, we possess world-class technologies, in the area of soil characteristics and foundations and also steel structures, both of which were cultivated in the course of the history described above.

On the other hand, some expanded technologies have been developed as peripheral technologies of the above mentioned core technology, such as the drill pile method which is the most advanced low-noise, low vibration piling methods, a pile driving analyzer (PDA)[14,15] capable of accurately estimating the penetration resistance of piles and other variables, and an acoustic tomography method able to survey ground conditions over a wide range and with high accuracy.[16]

In steel structures, and particularly marine structures, we have accumulated outstanding know-how in processing technologies for TMCP (thermo mechanical control process) steel, thick fillet and high-tensile strength steel, weatherproof steel, and other high-function steels. We also possess a full range of independently developed software technologies, such as design systems like MARINEJAST, drawing systems, material control systems, member fabrication systems, and transport systems.

One more important factor in the expansion of this technology is our engineering network. It is extremely difficult to expand engineering business activities in the recent situation that the projects have become complicated. Due to the increase of the project scale, a variety of highly specialized technologies has become required, and in addition, sophisticated new features are also necessary in respective areas of technology. All-round engineering requires all of the above mentioned technology be combined together, and only those who have mastered this all-round technology are qualified to manage such projects. Practically, it is not possible to acomplish the current huge scope of works with a limited number of the engineers. Moreover, it is also not desirable from the viewpoint of the business profitability to keep a large number of their own engineers as a think tank. Among these many types and fields of technology, some special technology should be developed and maintained by the company itself, but most of the others, however, would be imported from outside for the execution of projects as required. We are aiming at the position of "project organizer" and/or "technical coordinator" in the technical respect. Fortunately, there are a variety of types of engineers in the Engineering & Construction Div. Each of them has created good relationships with outside engineers, which results in a wide ranging network of engineers. Therefore, it is not necessary for us to maintain an in-house think tank. We believes the best method is to create a network of "think-points" covering the latest state of the art technology from outside companies and select and/or utilize them to meet the specific requirements of each project.

3.2 Technical Response to Social Needs

3.2.1 Town planning and construction

"The island as starting point," the subtitle of this paper, means that the construction of Kawasaki Steel's steelworks started with the creation of artificial islands along the coastline. The population related to the operation of major steelworks exceeds 100 000 people including families, and the creation of a substantial urban infrastructure for their living is required. Through this experience, we started urban development work as a business, and it is now one of the main businesses of the Engineering & Construction Div. Now urban development work is a new starting point of engineering business for the 21st century. We have recently constructed a super platform structure over an existing flood control reservoir and constructed a wholesale zone on this elevated steel platform.[17] This project is a typical example of "the urban development as the new starting point." Conceptually, the creation of this new town (wholesale zone) was virtually unprecedented, and was the first full-scale project of its type in Japan. For this reason, an extremely large number of system, technical, and social problems were involved, but all the related problems were solved in an up-to-date, flexible manner within three years by the combined efforts of universities, government, and industry. A cooperative arrangement among the five largest steelmakers in Japan, who have a shared culture, provided this opportunity, and the wisdom of a large number of people lead the project to success.

3.2.2 Environmental preservation techniques in resort development

Our concept of resort development is to select the most environment-friendly methods possible, and to ensure that the areas affected eventually return to nature after the completion of the facilities. Satisfying these requirements in a well-balanced manner requires a unified, comprehensive interdisciplinary approach covering manifold fields such as civil engineering, landscaping, ecology, cultural science, and others.[18] The basic image of real-estate development in Japan was frequently unfavorable, equating development with the destruction of nature and the more obscure aspects of the real estate industry. In recent years, as development projects have become larger in scale, major corporations have become involved, and simultaneously, questions have begun to be raised about the social responsibility of the major corporations. The technical progress resulting from social requirement has given greater improvement to the content of development projects. As mentioned previously, we base our work in development projects on an all-round technology encompassing soil characteristics and foundations, which has long been one of the company's core areas of expertise, and undertake the work by assembling various specialized technologies from a dispersed think-point network outside the company. In this situation, we have started to develop a computer grapahics (CG) system, hoping to accumulate our own technologies related to CG,[19] which is expected to see increasing need in the future. Computer graphics is an indispensable technology for achieving harmony between the natural environment and man-made structures. The greatest difficulty with this technology is not in system construction or hardware, but in how to adjust artistic characteristics and how to satisfy human emotion when using CG. Our technology has not yet reached the point where it can fully solve these problems, but we will increase the level and resolve the difficulties as we continues to gain experience in development projects.

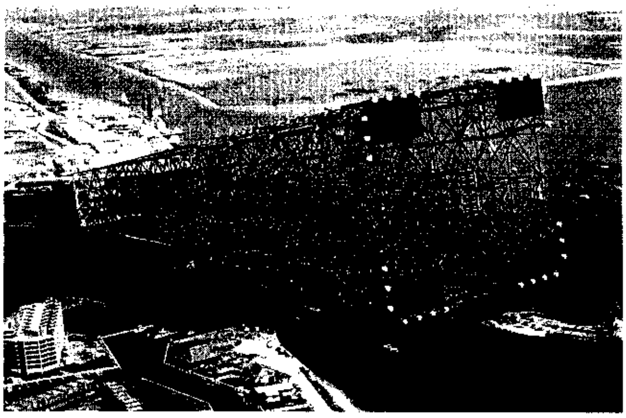

Photo 1 Jacket structure for large-scale deep water platform in Bullwinkle Project

3.2.3 Marine development

Since the first Oil Crisis, oil producers have actively explored and exploited the petroleum resources in offshore areas over the world, and many companies have undertaken the development of huge jacket structures for deep water platforms. Kawasaki Steel acquired the related technologies, which resulted in the project award[20] for materials and fabrication of one unit totaling approximately 40 000 t for the Bullwinkle Project in 1985 (**Photo 1**). However, such projects have continued to be affected by a recession in the oil industry, and the world market for projects of the type has substantially disappeared. On the other hand, the outstanding techniques for marine structures cultivated in this effort were revived and applied to the deep-water revetment structures of the man-made islands in the Trans-Tokyo Bay Highway. This technology was developed by three companies, including NKK Corp. and Kawasaki Steel, with Nippon Steel Corp. as leader. The conventional revetment methods were inappropriate to the 30 m water depth within Tokyo Bay. The jacket method was therefore selected as the most appropriate construction method for these revetments. A more detailed discussion is presented in the article "Construction of Jacket Type Steel Revetment for the Kisarazu Man-made Island of Trans-Tokyo Bay Highway."[21]

3.3 Future Development

Thus far, we have described the history and current level of civil engineering technology at Kawasaki Steel. Future technical trends and development will depend greatly on changes in the environment surrounding the engineering industry. Although the engineering industry to date has not had a strong presence in Japan and has not established such firm position as it enjoys in foreign countries, the entry of foreign competition, particularly American and European firms, in the Japanese market will provide the impetus for restructuring, and for engineering achieving a higher status as an industry. Twenty years have now passed since Kawasaki Steel entered this field. During this period, we have developed respective engineering businesses domestically and overseas, accumulating experience which should play an important part in future growth. Specifically, the further development of Kawasaki Steel's engineering business in the future is linked to our success in its targeted role of project organizer, as mentioned earlier, and the development of a worldwide response to the task of technical coordinator.

4 Pipeline Engineering

In the steelworks, water is the indispensable lifeblood of production activities. Steelworks engineers make ceaseless efforts to ensure that the pipelines used to transport water function stably at all times. At Kawasaki Steel's Chiba and Mizushima Works, we ourself are responsible for the construction, operation, and maintenance control work associated with pipeline facilities having a total length of approximately 450 km, and the wealth of experience gained over the last 35 years has also become the basis for business activities outside the company. In the waterworks business, we began undertaking small and medium diameter steel pipeline projects for water service in the 1960s. In the 1970s, we directed additional efforts toward achieving project results and the related technical development in large diameter and long distance steel pipeline projects for water service, and solidified our company's position in the industry. In the 1980s, we not only improved its pipelaying techniques, but also created a total technology covering the range of pipeline-construction activities from the manufacture of steel pipe through design, pipelaying, inspection, and maintenance, making possible a full-scale entry into the gas pipeline business. In the future, because the problem of global environmental protection will demand resource saving and the efficient use of energy, effort must be put into the planning of National Pipeline Projects for an Energy Trunkline and the development of techniques for efficient energy use in the field of district heating and cooling systems.

4.1 Water Pipelines and Related Facilities

Japan's modern waterworks began with the opening of water lines in Yokohama in 1887, and have now entered their second century. With the higher standard of living enjoyed by the Japanese people after the Second World War, equipment for the expansion of waterworks facilities made rapid progress, and the rate of diffusion had reached 95% by the end of fiscal 1991. On the other hand, sewerage work is being promoted in order to improve the living environment and preserve water quality in public water areas. The diffusion rate reached 45% by the end of FY 1991. In addition, the consumption of both industrial water and agricultural water has increased as a result respectively of postwar industrial growth and increased land improvement. Kawasaki Steel's water pipe business to date was born and grew out of this background.

The Japan Steel Water Pipe Association (1967) and the Japan Water Pipe Systems Research Center (1988) were established to support steel pipe for water service and related facilities, and promote technical development in connection with common subjects of member companies and the standardization of design and pipelaying methods. Common subjects have included the analysis and evaluation of the behavior of buried large-diameter, thin-wall steel pipes with stiffeners, conducted for the Kita-Chiba Water Conveyance Pipeline Project, etc.; full scale mechanical properties tests of steel pipes for earthquake-proof design; standardization of quick backfilling methods and steel pipes for pushing methods; and the development of advanced protective coatings. In recent years, a non-tar type epoxy resin coating was developed to ensure water quality safety as it relates to inside pipe coatings, and guidelines were established for macro-cell corrosion and corrosion control in response to the need to standardize corrosion designs and pipelaying methods.

We has also carried out our own technical development projects in parallel with those described above. The electroslag welding method and the development of an automatic internal girth welding method for large diameter pipes[22,23] using the MAG technique respond to the demand for expanded diameter and distance in water conveyance and transmission pipelines, and are contributing to improved efficiency and more stable quality in field welding. Kawasaki Steel's internal coating machine for water pipes makes it possible to coat the inner surface of the joints for pipes of 700 A and under, solving a long-standing problem related to conventional water quality control and corrosion. The Furesshu Suido (Fresh Water System) Scheme proposed by the Ministry of Health and Welfare requires a higher rate of diffusion, better service, and, in the construction of waterworks, durability, palatability, and flexibility. Technologies which we have developed against this background include potable water storage tanks for emergency use,[24] which have shown their effectiveness in emergency water supply during earthquakes, facility management for pipelines, and automated mapping and facility management system for water pipeline facilities,[25] which are applied in pipeline leakage restoration.

We have carried out a number of distinctive projects on the basis of the technical developments described above. Domestically, these include large-diameter pipeline systems such as the Kita-Chiba Water Conveyance Pipeline Project, fabrication and installation of aqueduct bridges such as the 1 200 A dia., 258-m-long Ichinokawa Aqueduct Bridge, and the application of a steel plate relining method for the internal surface of horseshoe shaped tunnels to the repair of water conveyance tunnels. Overseas, our company's accumulated record of projects includes the water main pipeline project for the Metropolitan Water Works and Sewerage System in Manila, the Philippines and the installation of large-diameter steel pipelines with concrete weight coatings across the Johor Straits between Singapore and Malaysia and a river crossing of steel pipelines at the Chao Phraya River in Thailand.[26] Our policy for the future is to put effort into the technical development of steel pipe for water pipelines and related facilities, reflected the requirements of the times, while continuing to build on our record of projects of the type described here.

4.2 Gas and Oil Pipelines

Kawasaki Steel's involvement in the gas and oil pipeline business began as a steel pipe manufacturer with the sale of steel pipe, but has come to include orders for both the supply of pipe and pipelaying work. In the interim, we have improved our technology by carrying out submarine pipeline projects around its Mizushima Works, undertaking various projects in which we used special techniques such as pushing,[27] and by performing pipeline laying work from time to time for the Toho Gas Co., Ltd. and Japan Petroleum Exploration Co., Ltd.

Early technical development tasks emphasized the automation of welding equipment to realize high-speed, high-quality welding work. However, after repeated field use and improvement, an automatic MAG welding system equipped with a high-level learning function has been developed as discussed elsewhere in this special issue.[28] Together with the development of this automatic welder, we have simultaneously pursued the development of a full complement of auxiliary equipment, such as efficient internal clamps and beveling machines which can be used in the field, with the aim of improving pipelaying efficiency. In pushing methods, we have also pursued the development of the iron mole technique for pushing small- and medium-diameter, long-distance pipelines,[29] and subsequently, the development of a pushing technique for large-diameter, long-distance pipelines.

Research and development related to safety measures began in the 1970s with investigation and research on methods of detecting oil leaks, continued with intermittent research and development projects such as experiments on the destruction of actual large pipes, conducted at the request of the New Tokyo International Airport Authority, and recently has included research on countermeasures against liquefaction in earthquakes. In connection with the seismic safety features of buried pipeline system, we have carried out a series of research and development projects as part of its pipeline engineering work, beginning with the development of non-linear behavior analysis techniques for buried pipelines,[30] and have also developed a gas flow design system. In addition, we are continuing to demonstrate in actual projects the applicability of its pipelaying control systems for investigation data control, which are intended to improve quality control during pipelaying and upkeep control in the future.

On the other hand, against the backdrop of global environmental preservation in the 21st century, natural gas is drawing attention as a type of clean energy, offering a countermeasure for CO_2, which is a cause of global warming, and SO_x, which gives rise to acid rain. Because natural gas is regarded as a main energy source capable of expanded use in Japan, several ambitious pipeline projects have been proposed, including the Japanese Trunk Gas Pipeline Project and others. Kawasaki Steel has long been a supplier of high-quality steel pipe, and is using the engineering capabilities cultivated in the survey, planning, and design of the Sendai-Niigata Pipeline Project, now under construction, and the technology and experience accumulated in high pressure gas pipeline projects for electric power plants to play a role in the realization of wide-area pipeline projects for infrastructure. At the same time, we are positively pursuing technical development aimed at the next generation of technology.

4.3 District Heating and Cooling Systems

Fossil fuels have long been an indispensable heat source for heating and cooling. However, environmental problems and the need for energy saving have recently spotlighted district heating and cooling using untapped energy sources such as the waste heat of factories, buildings, and garbage incinerators, and the heat of waste water treatment and rivers. With governmental leadership, these techniques are being adopted at a rapid rate.

We entered this field approximately six years ago, with the installation of pipelines for the district heating and cooling system in Makuhari (a newly developed urban subcenter in Chiba Prefecture near Tokyo), and subsequently participated in the construction of a center plant. Thereafter, we were involved in the design of pipelines for the district heating and cooling system in the Akashicho area, expanded its engineering for hydraulic design and heat balance calculation, and is now installing lifeline piping in utility box culverts.

In addition to the use of medium and low temperature energy by heat pumps, future tasks include the construction of optimum high-heat efficiency systems which take advantage of steel works heat technology, and the promotion of technical development able to contribute to society.

5 Building Engineering

Like our civil engineering technology, our building engineering technology began with the construction of steelworks. Factory buildings with long-span structures, high-rise and heavy steel strcutures for plant buildings, and similar types of construction demand a high level of steel structure technology, while new concepts for ventilation and lighting have been incorporated in environmental-engineering designs for buildings. Moreover, we have refined our all-round building engineering in the creation of towns neighboring our steelworks, and have made efforts to complete our engineering capabilities in building materials and steel structures through technical services associated with the sale of steel products for building and construction. For safe, reliable construction work, we have also tested construction management techniques on every occasion, thus establishing this as a new technology which meets the needs of the times. Truly, "the starting point is the town construction," but we will continue to push ahead with the development of a new building engineering technology along the axes of steel structural engineering and building material engineering.

5.1 Building Engineering and Construction

Recent features of building engineering and construction at Kawasaki Steel include an increase not only in simple construction jobs but also in the percentage of orders received for total engineering projects involving planning and design work. Projects which we have handled during this period include not only industrial facilities such as factories and warehouses, but also medium- and high-rise residential buildings, hotels, sports facilities, shopping centers, schools, and other urban buildings. The following sections present an outline of the main technologies and products which have supported development in these areas. In the future, we will continue to take full advantage of our steel structural techniques, and will develop building engineering and construction technology in urban facilities which require high-rise and long-span construction.

5.1.1 Project management

We have accumulated an extensive record of projects in which we were totally involved from the planning stage before design through the completion of the work, using project management techniques which ensure the highest possible degree of satisfaction to our clients in terms of cost, term of work, and quality. Examples include the construction of Hotel Niigata and the Sakata South High School Building. Moreover, project management techniques have also become the basis for regional development projects in and outside of Japan. Domestically, the results of representative building-complex projects include the Chiba Port Square Project[31] and Kusatsu West Project in Shiga Prefecture. Overseas, we have increased our experience in Australia and Hawaii, and demonstrated the full range of its project management techniques in a hotel project (**Photo 2**) completed at the end of 1991 in San Diego, California (USA). Subsequently, these techniques were further developed domestically and overseas in high-rise office

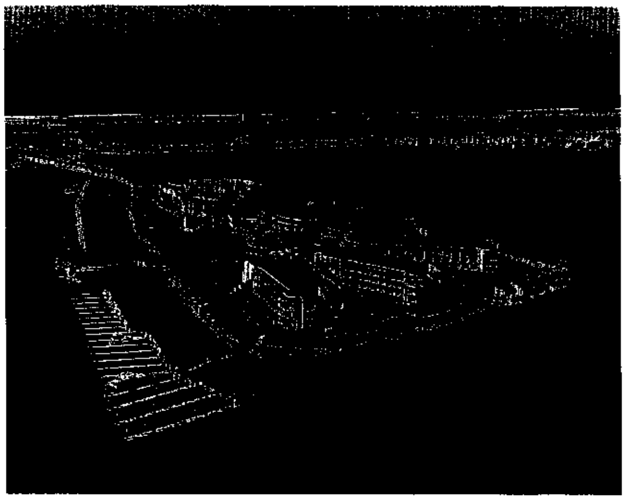

Photo 2 General view of Loews Coronade Bay Resort (San Diego, California)

buildings, hotels, high-rise condominium projects, and others.

5.1.2 Super platform structure

The Saitama Wholesale Zone completed in the spring of 1993 was an epoch-making project, the first of its kind in Japan constructed on a super platform structure over a flood control reservoir. As mentioned previously, a number of points in both the planning and building structure presented difficulties under the existing legal system, but the project was realized through an elaborated engineering capability and cooperation and coordination by central and local government offices and persons of learning and experience. Structurally, the platform is adequate to withstand public use and offers excellent resistance to earthquakes, taking advantage of the strengths of steel construction. It has thus attracted considerable attention as a next-generation method for coping with the overcrowding of urban areas.

5.1.3 Clean rooms

To date, we have constructed more than 100 clean rooms. Kawasaki Steel's line-type clean room system[32] is easy to install and eliminates the need for machine rooms and ceiling duct systems. This low-cost, energy-saving type of clean room realizes a 100-Class cleanliness level with a low ventilation volume, and has been widely adopted in the precision machinery, electronics, chemical, pharmaceutical, food, and other industries.

5.1.4 Systemized warehouses

As part of the recent trend toward rationalization of the distribution function, more than 50 of Kawasaki Steel's systemized warehouses have been installed. Taking advantage of its outstanding strength in accommodating heavy items, which is a distinctive feature of the system, the Kawasaki Steel warehouse has been adopted in a wide range of applications including steel products, frozen foods, electrical components, and printing components. We have expanded our record of sales of the system as a product which includes not only such hardware as rack structures, stacker cranes, carriers, and conveyors, but also incorporates the computer, which is the brain of the system, and has also added improvements. In the near future, we expect to offer engineering technology for the construction of distribution centers based on new developments in soft- and hardware technology.

5.1.5 Construction management for overseas projects

As described elsewhere in this special issue, in the article entitled "Railway Project Management in South-East Asia,"[33] our overseas construction management technology expanded dramatically with the Indonesia PERUMKA (National Railway Company) Depot and Workshop Improvement Project and the subsequent Philippine National Railway Depot and Workshop Improvement Project. This record was linked to further railway projects in which the company assembled materials and engineers from all over the world and demonstrated a high level of management technology in executing projects.

5.2 Steel Structural Engineering

Demand for steel structures increased due to the expansion of domestic demand in Japan in 1987 and thereafter. Among structural types, steel frame construction surpassed wood frame construction in total constructed floor area per year for the first time, marking the start of an unprecedented boom in steel frame building. The collapse of the economic bubble caused Japan to fall into recession in 1992, but demand for steel frame structures has nevertheless remained at a comparatively high level of approximately 9 million t/year. However, the increased amount of construction has not been the only characteristic feature of the steel structure industry in the last five years. In addition, there has also been demand for steel frame construction methods which are capable of creating more pleasant and therefore more productive space, and for labor-saving steel frame methods, responding to a labor shortage in the construction industry. Examples of the former include more spacious large-span structures, and Super Structure, which aims at creating a greater space of affluence in super-high rise buildings. Developments to meet the latter need include mechanization and automation techniques for fabrication, and particularly welding robots. In the midst of these trends, we have greatly expanded our company's steel structure business, both quantitatively and qualitatively, by applying the policies discussed below.

5.2.1 Development of large-span structure systems

Based on the unique concept of combining steel frame trusses and PC cables, we developed the Super Wing roof structure system, which makes possible large open spaces with spans of 200 m.[34] Super Wing has been applied extensively both in Japan and overseas in structures as diverse as sports arenas, distribution centers, and production plants.

5.2.2 New construction of fabrication line for River Box

In response to increased demand for built-up box columns for super-high rise structures, a new fabrication line for River Box was constructed at Chiba Works. The line went on-stream smoothly in March 1992[35] with a monthly capacity of 450 t. This figure, combined with the 1 300 t monthly capacity of the West Steel Structure Fabrication Center, gives the company a capacity of 1 750 t, with bases in both eastern and western Japan.

5.2.3 Development of welding robot

We developed the SYBO-II, Japan's first robot capable of automatically welding the diaphragm used in the H-beam to RHS column connections simultaneously at two points. Following this, SYCORON Co. Ltd. was established in March 1989 as a specialty producer of H-beam to RHS column connections, which it then began marketing. In addition, we succeeded in commercializing an automatic welding robot for steel structural fabrication,[36] which automates the welding of beam to column connections, and began marketing in October 1992.

5.2.4 Establishment of technology for super-high rise buildings

Responding to market needs, we have studied the weldability and workability of TMCP steels (thermo mechanical control process), low yield ratio 590 N/mm^2 class steels, and other new steel structural products,[37] and have examined welding methods for ultra-heavy steel plates.

5.2.5 Establishment of use techniques for fire-resistant steel for building structures (KSFR)

We also established a use technology for KSFR by mastering the new fire-resistant design method, in parallel with the study of the weldability and workability of steel materials which accompanied the development of KSFR,[38] and has received an increasing number of orders for steel structures which employ this product. Examples include multistory parking systems and structures erected over railway stations.

5.2.6 Expansion of fabricators' cooperation network

We have not only upgraded the equipment of our own steel structure fabrication centers, but have also expanded the membership of the Organization of Fabricators in Cooperation with Kawasaki Steel, which is an organization of partner business in the steel structure industry, thus establishing a nationwide network. This network has become a powerful support for Kawasaki Steel's expansion in the steel structure industry, both in coping with expanded demand for steel structures and in improving steel structure quality through technical exchange.

5.3 Future Development

The preceding has been a retrospective view of the building engineering field. In the future, together with providing the world with distinctive products and technologies, it is imperative that Kawasaki Steel, as a steel maker, promote the development of steel structural engineering and building engineering technology for large-span and super-high rise structures and for the super structures of the future, and establish positions in and outside of Japan, while further improving its all-round engineering technology.

6 Construction Materials

In construction materials, Kawasaki Steel has taken advantage of its strengths as a steelmaker to conduct technical development centering on steel materials, in step with changing societal needs. This history of development has advanced in parallel with the construction of our own steelworks. Specifically, a major feature of the company's practical method of technical development is that it has developed construction materials with stable quality and excellent economy, usability, and mechanical features, and expanded its steel sales, by adopting new technical concepts experimentally in steelworks structures. The latter point is important, because it means Kawasaki Steel has consistently been able to put itself in the user's place. Beginning with the interlocked steel pipe pile method, which was developed for use in the foundations of large-scale blast furnaces, the company has created and developed a number of world-renowned technologies in the course of constructing its steelworks. Examples include the prefabricated corrugated cell bulkhead method for land reclamation revetments, the coupled pile-anchored sheet piling bulkhead method, prefabricated H-frames, which are the result of the development of use technologies for H-shapes, and Super HISLEND H-shapes for SRC strctures.

With the striking increase in population density and concentration of functions in urban areas in recent years, horizontal development of living space has its limits in small countries such as Japan. This has prompted expansion of the living environment into high-rise, subterranean, and waterfront areas, with the aim of creating new space.

On the other hand, the environment surrounding construction is undergoing numerous changes. In addition to a severe labor shortage attributable the reduced number of skilled workers, the increasing age of the working population, and a declining rate of entry by young people due to the dangerous, dirty, and difficult work conditions in the construction industry, shorter working hours and greater workplace safety are being demanded. Thus, higher productivity and improvement of the working environment have become critical tasks. Moreover, environmental regulations related to construction are becoming increasingly strict, particularly with regard to the problems of noise and vibration in urban areas, the discharge of soil during construction, and the disposal of waste material. From this viewpoint, the development of technologies which will not burden the environment is desired.

Where construction materials are concerned, emphasis has shifted from simple function to a more public perspective. There is an increasingly strong trend toward landscape design, which considers structures to be an integral part of the surrounding landscape, while needs related to maintenance control, including repair techniques, improved durability, and maintenance free techniques, are rapidly rising.

6.1 Construction Materials for Civil Engineering

In the development of products and methods for civil engineering construction, Kawasaki Steel has responded to the societal requirements and environmental changes described above in the following manner.

For building foundations, we have developed the low-noise, low-vibration drill pile method,[39] which does not produce waste earth in the construction process. This method contributes greatly to improvement of the working environment by giving consideration to the surrounding environment and maintaining a safe, clean site. A Drill-Pile Execution Association was established for implementation, and the method was popularized through close cooperation with affiliated companies. Higher strength and a reduced volume of earth in excavation were achieved by combining cast-in-place concrete pile, which is a low-noise, low-vibration construction method for the foundations of higher-rise structures, with spiral-ribbed steel pipe.[40] For retaining walls which answer the need for effective use of land and space in urban areas, we commercialized the H-shaped steel piling "K-Domeru,"[41] which offers high rigidity and can be applied in restricted spaces and locations with little headroom using a low-noise, low-vibration compact pile jacking machine. A quarter-century has passed since the first practical use of the interlocked steel pipe pile method, but thanks to its outstanding economy, labor-saving advantages, and speed of construction, this method continues to enjoy an unshakeable position in the construction of large-scale bridges, which are being constructed in increasingly deep waters. We have also supported the expansion of this method by promoting the development of peripheral technologies, such as an underwater plasma arc cutting machine for efficient cutting of heavy gauge steel pipe piles in deep water,[42] and research on rational design methods for larger-scale foundations.

We have also grappled with the development of design-quality civil engineering materials capable of responding to the diverse needs associated with the landscaping of urban facilities. Examples are designed lighting poles, embodying an ingenious selection of shape, color, and material for harmony between the roadway space and neighboring environment; lighting poles with resistance to wind vortex induced oscillations, with both excellent aesthetic features and improved material life; colored steel sheet pile for use in roadway breast walls; and colored steel sheet pile and revetments covered with concrete panels, aimed at improving the riverside landscape. Various other products and methods developed in response to special needs include heavy-duty coated steel pipe piles and sheet piles, which are designed to improve the durability of structures and realize maintenance-free service; epoxy-coated reinforcing bars as a measure for preventing the deterioration of ferroconcrete; and grouted joints for threaded deformed bars,[43] which are easily installed by workers without special skills and offer high reliability.

6.2 Building Materials

Building materials are generally categorized as structural, non-structural, and system materials depending on their application. However, all such materials should respond to the increasing diversity and sophistication of needs described previously. We have therefore put great effort into the development and popularization of a wide variety of new products. Examples are presented below.

6.2.1 Structural materials

New high-strength, high-function steel materials developed against the background of higher-rise, larger-scale construction and the development of aseismatic design methods include structural use TMCP steel plate products (MAC325, MAC355), which have already been approved by the Ministry of Construction, and the first 590 MPa low-yield ratio steel applied to SRC construction in Japan. High-functional steels for labor saving in processing and execution include fixed depth H-shapes (Super HISLEND H)[44] and fire-resistant structural steel (KSFR). Super HISLEND H is hot rolled to the final dimensions, and thus is an extremely important labor-saving substitute for built-up (i.e. welded) H-shapes. Kawasaki Steel was the first in the industry to introduce this type of product, which is now established in an unshakeable position as one of the company's main products with a market scale of 600 000 t/year. Where KSFR is concerned, the strength of the product increases at high temperatures, eliminating the need to apply a fire-resistant covering. In commercializing these products, we carried out research and development work on fire-resistant design and other design methods, and performed a variety of research, including application research and experimental demonstrations, in connection with the use of these new steels as structural materials. In supporting the popularization of these new products, we also did basic research on problems which affect structural performance, including the cold forming of roll-formed RHS columns (K Column R) and weld access holes at the H-shape beam end.

6.2.2 Nonstructural products for buildings

Nonstructural products for buildings are categorized by part as temporary material, materials for roofs, walls, ceilings, finishes, floors, frame elements for openings, doors and windows, and functional material. The types of material include steel, nonferrous metal materials, wood, ceramics (including concrete), and chemical products. Suppliers of steel materials differ greatly in the product lines they handle, depending on whether they are integrated steelmarkers, specialty makers or small/medium sized firms. **Figure 1** shows the market scale of nonstructural products by part and by material. Categories marked with the symbol "※" are product lines in which integrated steel makers (and their affiliates) are particularly active. It is an unfortunate characteristic of nonstructural products that considerable time is required to win recognition in the marketplace, but the life cycle of the product itself is short. For this reason, considerable difficulty is involved in both product development and product lines in this industry. At Kawasaki Steel, development is promoted through cooperation among the Construction Materials Business Development Department, Structure Research Laboratories, and Kawasaki Steel's affiliates in the construction material business.

In temporary material, the future is expected to see a further changeover from wood to steel in order to reduce weight, improve upkeep control, and support forest preservation. New products are therefore being developed with consideration given to mobility and safety. In roofing, ceramic material (tile) has long enjoyed a strong position in residential roofing in Japan, but materials such as stainless steel and fluoro-polymer coated steel sheet, which offer a new sensibility, are beginning to find use. The product group which includes PLEGEL[45] was developed to satisfy both functional and design needs. For factory and warehouse roofs, long-life steel sheets such as fluoro-polymer coated steel sheet and galvalume-coated steel sheet have been developed partly as a response to the asbestos problem, but also with the aim of establishing an integrated system from the basic material to the actual construction work. In recent years, higher functionality has been required in factory and warehouse walls, in terms of insulation and soundproofing. The share of new wall materials such as thermal insulation panels seems likely to grow, as these materials gradually sup-

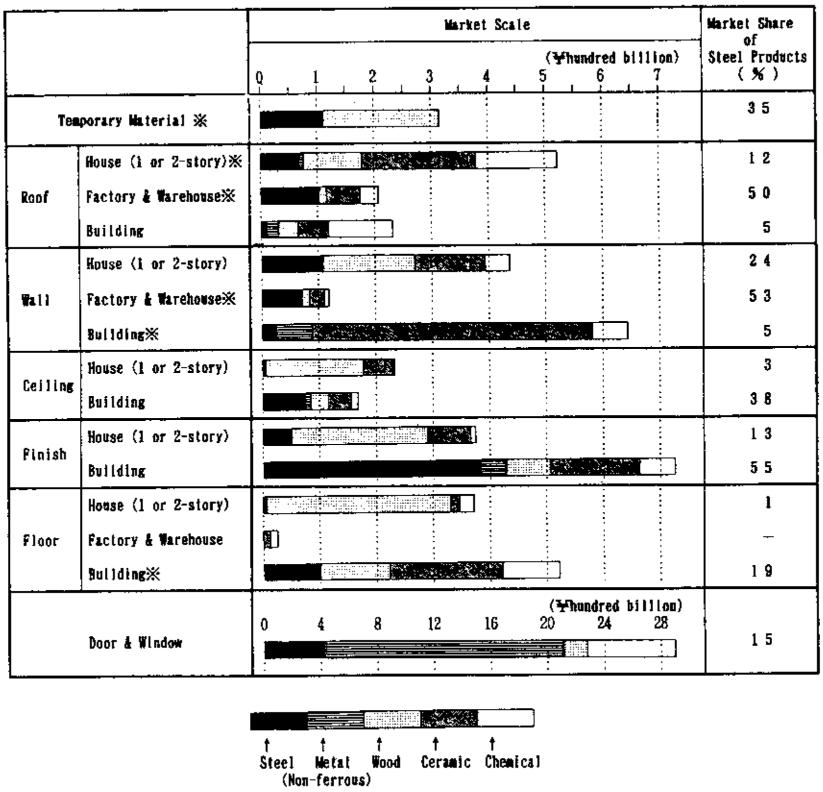

Fig. 1 Market scale of non-structural products for buildings

plant walls composed of profiled metal roof panels with cemented excelsior backing material. In building walls, the share held by ceramics and aluminum is high, but the use of products requiring at-site working and wet working is decreasing. With wider use of curtain walls in middle-rise buildings, the need is increasing for high-grade building materials such as stainless steel and fluoro-polymer coated steel sheet, and we are using our advantage as a material maker to rapidly expand its line of new products. Among supporting elements for floor finishes, the trend is toward reduced use of wood materials for concrete frameworks. In addition, flat decks of steel material and high-functional composite slab are considered promising growth materials due to the progressive adoption of office automation and construction of intelligent buildings. As functional material, rock wool is widely used as a material which combines all the basic functions of fire-resistance, thermal insulation, and soundproofing, but the current need for rationalization of execution in construction work demands functional materials which in themselves offer strength and design features, and product development in this direction is being earnestly promoted.

6.2.3 Systemized building elements

Systemized building elements typically have small-and-medium urban-type buildings as their object. These elements are applied in "systems buildings" which combine individual building elements into a total corporate-group product in a unified system that covers all the steps from design through execution and maintenance. In April 1993, we began marketing a product of this type as a Kawatetsu Systems Building called EXCEL-CORE.[46)]

6.3 Future Development

The foregoing has presented an outline of recent technical trends and accomplishments in materials for civil engineering and construction at Kawasaki Steel. Japan's national policies give importance to investments directly linked to qualitative improvement in the everyday lives of the nation's citizens, in areas related to their personal lives. Kawasaki Steel's own philosophy is to grasp accurately the needs accompanying this revolutionary change in social direction, and to promote research and development related to high value-added construction products, including work methods. Moreover, every possible effort must be made to ensure the growth and development of construction material technology, because of its crucial role as a basic technology supporting Kawasaki Steel's engineering activities in civil engineering and architectural construction.

7 Conclusion

In presenting a total picture of Kawasaki Steel Corporation's all-round engineering capabilities, this paper has briefly reviewed the trends and features of technology in respective fields of engineering, as well as the prospects as the company looks ahead to the 21st century. In the future, we will continue to be sensitive to changing societal needs, and will offer our clients an all-round engineering technology which is characterized by the marked advantages the company enjoys as a major steelmaker. In spite of the difficult environment, we remains committed to positive, creative growth in the field of engineering.

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