Architectural and Civil Engineering Contributing to Developing Infrastructures*

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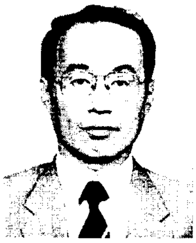

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Synopsis:

This paper deals with 50-year long historical changes of architectural and civil engineerings in Kawasaki Steel. Both engineerings started with the construction of steel mills and plants, and now have grown up to several business fields such as construction materials, marine construction, buildings, bridges, steel fabrication and pipelines. These engineering technologies will be also necessary in the future in order to provide infrastructures of the society. Advanced technologies which respond to ecology, energy saving and performance based design are expected hereafter.

1 Introduction

Activities of architectural and civil engineers at Kawasaki Steel began almost at the same time as the establishment of the company, i.e., the construction of Chiba Works in Tokyo Bay. The roles of architectural and civil engineers in the steel industry in the Showa Era (1926 to 1989) were reported 12 years ago[1]. This paper describes the 50 year history of these engineering fields at Kawasaki Steel, including the activities given in the previous report, but focusing on recent activities.

In the previous report[1], the architectural and civil engineering activities were divided into four major streams of development. Those associated with the construction of the steel works were the "first stream", i.e., the headstream, and it was stated that the first stream spread out to "the second stream" (the construction materials sector), "the third stream" (Engineering Center = EC and Engineering Div. = ED) and "the fourth stream" (subsidiary companies). The report described that the history of the architectural and civil engineering activities such that the development of technologies corresponding with the times was performed and business were changed to suit the times. During that time the number of engineers increased steadily and the two engineering fields contributed to the company's infrastructure and thus to the startup of the steel works. After that, emphasis shifted to selling steel products and obtaining orders for construction projects in which the technical capabilities acquired through the initial activities could be fully utilized.

By the time, the constructions of main facilities at Chiba and Mizushima Works were nearing completion in 1980, "the first stream" changed to the modernization of works and a form in which maintenance and control techniques are used. Furthermore, from "the second stream" to "the fourth stream", there were great changes in the order-receipt environments, technological trends, etc., such as the collapse of the bubble economy, the high yen, the Hanshin-Awaji Earthquake, and obsolescence of structures constructed in the period of high economic growth. The architectural and civil engineering activities in the steel industry have since changed,

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entering an age with a stronger stream of business innovation, such as restructuring and integration.

Today of Kawasaki Steel, many engineers are involved in construction, bridge and structural steel and the pipeline business, in which receiving orders for projects is their main job, and the construction material business whose purpose is the selling of structural steel products. In each business which has been consolidated, activities have features of Kawasaki Steel as a steel company. The greater part of the activities was carried out in business fields in which the development of technologies required by the construction works for the company's steel works has been, or in business fields in which results of the development of technologies related to the manufacturing of materials, etc., required by the steel industry are made use of. In Japan, where the ratio of public works investment to the gross national product is said to be higher than in Europe and North America, it is expected that investments in public works will decrease relatively in the future. Firmly rooted business and technical fields in which the features of a steel company are fully utilized will display the company's strong points.

In this report, summary and background of the business on which the energies of the company's architectural and civil engineers have been concentrated in each field is explained. At the same time, the forms and features of business which have been changed according to trends in public works and private investments are explained and future technological and business strategies of the company for its survival amid fierce competition are also described.

2 Field of Domestic Construction

2.1 Field of Civil Engineering

On the basis of the construction engineering technology developed and further refined through the construction of the steel works, the company's civil engineering business has shown good accomplishments in the construction of port and harbor facilities, general steel and other civil engineering structures, etc., with the aid of core technologies involving the fabrication and construction of structural steel products, construction techniques in the field of geotechnology and foundation engineering, and general management of constructions works.

2.1.1 Construction works of port and harbor facilities

Various works have since been executed using the technologies accumulated during the construction of both Chiba and Mizushima Works, where revetments and quays with a total length of more than 33 km have been constructed.

Quays for sea fishing were constructed by the underwater junction method in Yamagata Pref. (1980) and Aomori Pref. (1983). This method has been further developed into the underwater strutted structure system by the company (Construction Materials Center) in collaboration with Nippon Steel Corp. After that, in a joint venture with a general contractor, sea berths were constructed for two oil storage bases (in Akita 1988 and in Shifushi 1991). Further, a quay for Urayasu Distribution Center was constructed (1990) by the Super Traveling Erect Pile (STEP) method which was developed in the construction work of Berth NA at Chiba Works. Results from this project were used in the subsequent construction of the Ohmiya super platform. In the berth construction work for Chugoku Lumber Corp. (1992), the construction of steel pipe piles with corrosion prevention coatings by the use of KPP piles, rapid construction by the prefabrication of superstructures and the adoption of CM method were especially highly valued by the client because of their economy. Since the corrugated cell revetment work of Kobe Port Island in 1993, the main sales department in this field has shifted from Construction Div. to Bridge & Steel Structure Div., and the division's personnel have expanding the sales of the fabrication and field construction works of steel members such as steel jacket structures.

2.1.2 Construction of general civil structures

In this field, most projects were executed from the latter half of the 1980s to the 1990s, such as Handa Golf Links (1988), Koumi Re-ex (1990), Yasuzuka Cupid Valley (1990), Washuu Golf Club (1991) and Onokoro Island (1998). By making the most of its know-how in planning, design, construction and management acquired during these projects, the company succeeded in redeveloping the former site of a waste treatment and disposal plant as Mizushima Golf Links in a short time and at low cost (1999). This track record can contribute to solving the present-day problems of the shrinkage of municipal public works budgets construction of waste treatment and disposal plants and utilization of the former sites of such plants. This redevelopment work is promising for future sales activities.

Another large stream in this field is the seismic recovery and reinforcement work after the Hanshin-Awaji Earthquake in 1995. Starting with the restoraction of Nishinomiya Bridge, removal and demolition of Fukae-Hamanaka Bridge of the Hanshin Expressway, etc. immediately after the earthquake, the company has continuously obtained orders since 1995, especially for reinforcing by steel plates on pier surfaces in the Hanshin and Tokyo areas. The company's accomplishments have greatly helped to improve the construction technology and reputation of Kawasaki Steel group.

2.1.3 Construction of steel structure

In this field, the company displays its strong points by making the most of its own technologies as a steel-

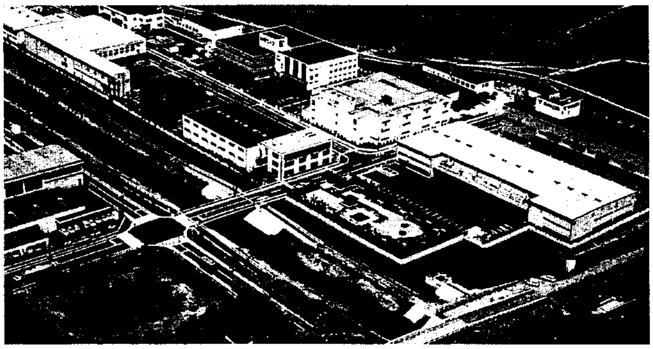

Photo 1 Ohmiya super platform structure

maker, such as the design, fabrication and on-site construction related to steel products. Some examples of the company's achievement include the construction of an alcohol plant for the New Energy and Industrial Technology Development Organization (NEDO) (1994), fabrication of soundproofing wall bases for Central Japan Railway Co. (1996), and the fabrication of steel shells of MMST (Multi Micro Shield Tunnel) of the Japan Highway Public Corp. (1999).

Further, the Ohmiya super platform project (1993, **Photo 1**) in which an artificial ground was constructed by the STEP method above a private flood-regulating pond for a distribution center, is also one of the works in this field. On the Ohmiya super platform structure works, not only the STEP method, but also steel pipe piles with corrosion prevention coatings, a technique of bearing capacity analysis (PDA) based on the wave theory and other technologies owned by the company were widely and fully utilized.

This construction of artificial ground has developed in two directions. One is the technology of self-running workshop wagon platform obtained by putting the construction technology of the STEP method to general use. The Shinjuku South Exit super platform (1996) and the revetment repair of the Kanda River (1996) are good examples.

The other is the expansion of applications of artificial ground structure. Works by the Metal-Road method, which is used to increase the width of mountainous roads, are the Hagiyama-Fukuoka Road (1992), Youka-Yamazaki Road (1994, **Photo 2**), and the Yaendani woodland path (Yamanashi Pref., 1997). In the Iwaya Dam heliport project (1996), artificial ground structures were built for a heliport parking ground. In March 2000, government authorization for new construction for these works was awarded by the Road Management Technology Center, and future expansion of the business is expected by municipalities and consultants.

The construction business in the field of domestic civil engineering has been described above by citing examples of the company's accomplishments in three categories. Additionally, in the fields of soil investigation and geological and geophysical survey, the company has recently introduced and developed technologies for investigating ground structures, faults and coefficient of permeability using geoacoustic tomography, earning a high reputation at both home and abroad. In the future, the company, with the aid of top-ranked engineers in the fields of geotechnology and foundation engineering and steel structure technology, will use its experience to develop the construction business in its strongest fields.

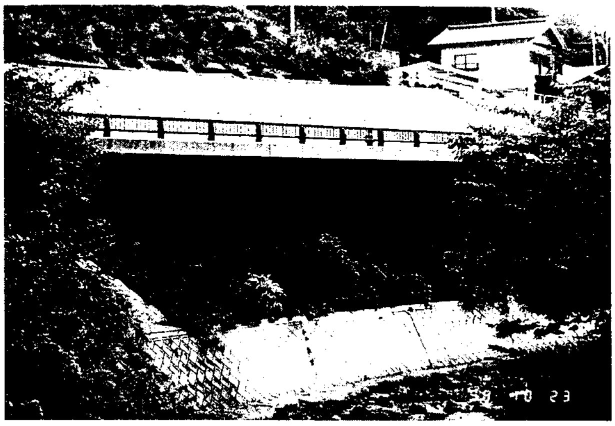

Photo 2 Metal road structure (Youka-Yamazaki Line)

2.2 Field of Building Construction

The company's work in the field of building construction can be divided into two areas: (1) the construction business in which pre-engineered metal building systems are placed as key products and distinctive elementary techniques owned by the Kawasaki Steel group are fully utilized, and (2) project planning and construction management with a proposal for real estate development that is completely adjusted to customer needs. In both areas, the company is formulating concepts of what the construction business should be in the new century, and making a commitment to taking on new challenges.

2.2.1 Pre-engineered building systems and peripheral technology

In the field of building construction, the building engineering department has recently made use of the above stream (1), i.e., pre-engineered building systems and peripheral technology.

With the construction of the Head Office Building of Kawasaki Steel in Kobe and River Kuramae Building as a momentum-builder, the company has been practically using an urban office building system called "New Excel-core"[2] which incorporates all the company's construction technologies, such as concrete-filled steel tubes, passive seismic control system using low-yield-strength steel dampers, and design and construction management utilizing information technology (**Photo**

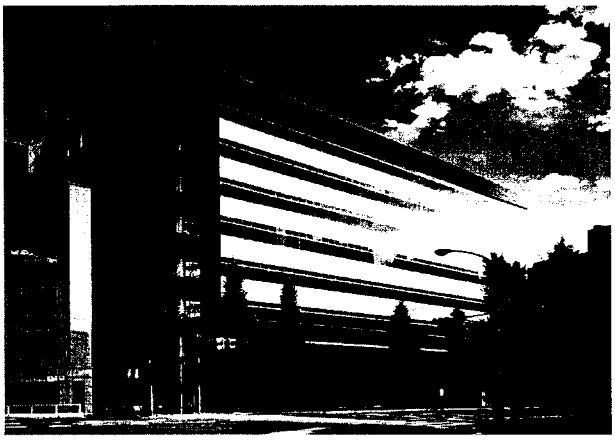

Photo 3 New Excel-core (River Kuramae Building)

3). Since then, the urban office building system has been applied constantly to the construction of JA Agris[3], Kokusai-Kogyo Mita Office Building (tentative name), Eiju Hospital, and other facilities.

Next, "K-FLAT" is being used for medium-height and high-rise residential buildings. It is a new building system which manifests the advantages of concrete through steel, and labor savings and short construction time. This building system features concrete-filled steel tubes combined with precast concrete members[4], a structural system in which skeletons (structural parts) are separated from in-fills (nonstructural parts), and residential space of barrier-free and lifesafety, and various features required of next-generation dwellings as infrastructure, such as economy, seismic resistance, high durability and renovation. "K-FLAT" was first used in Viento Hongo Kikuzaka and then applied to Kobe Kaigan-dori Harbor Flats, which is a large-scale development project.

In the construction of industrial and commercial buildings, "Kawaken Metal Building" a pre-engineered metal building system with 30 years of accomplishments, provided the basis for the building engineering department to carry out total engineering, in which distinctive technologies of Kawasaki Steel group's construction subsidiaries such as Line Type Clean Room System[5], high bay and multi-story parking systems (KP park) are incorporated. Among its many achievements is the construction of the Citizen Hachinohe factory.

All the pre-engineered building systems in the above three fields are ecologically value added products with great use of substitutions of wooden formorks. Further, these next-generation pre-engineered building systems contribute to labor savings and safety on a construction site due to the mechanization/automation of processes for producing building parts and members.

Looking back, it could be said that these pre-engineered building systems were a group of products that were produced by a technological dynamism. They are the result of an organic combination of the building construction technology which has been developed and further refined in engineering business activities and the technology which has been accumulated in the process of expansion of sales of steel materials for construction and steel structures.

The company's pre-engineered building systems of the future should be built by a construction system with a high cost/performance ratio and with understandability and clarity for clients.

The productivity in the construction business still has much room for improvement, and cost reductions covering the entire life cycle including energy consumption, maintenance and renewal are indispensable factors in the construction industry of the 21th century. Furthermore, structural reforms of the construction business and the information revolution by the Internet will advance and the construction sector is also entering an era in which building performance, cost efficiency and construction period are being held to the same accountability as general consumer products.

In the company's pre-engineered building systems, the technology for mechanization and productivity-improving that have been developed and refined in the production of steel products should be used to maximize the cost/benefit ratio through processes from project planning to construction. At the same time, buildings must be supplied to clients at straight forward and rational costs as fast as possible. In the company's pre-engineered building systems, the theory and culture, so to speak, derived from manufacturing industries will be brought into the construction industry.

2.2.2 Planning the management of building (construction) project

The above stream (2) has been consistently supported by the company's rich experience and track record that have arisen from the construction of large steel works and urban development of surrounding cities[6] and were further refined in engineering activities.

Examples are Hotel Ohsado Kasuga, which was constructed by comprehensively promoting construction and consultation with general diagnoses of existing buildings as a momentum, Chiba Port Square[7], in which the development, design and construction of a large complex were carried out, the construction of the Wholesale Housing Complex Cooperative Association of Saitama Pref.[8], which is the first elevated super steel platform on a flood-regulating pond in Japan, and the Eastern Japan Cooperative Feed Factory, in which the company was in charge of the architectural sector of the full-tern-key project.

The greatest feature of these works lies in the company's posture that all problems of construction projects have been consistently tackled in a comprehensive manner always from the standpoint of clients, and the improvement of the level of client satisfaction by the accumulation of solutions of problems with attention given to every detail is a tradition that has taken root in the company's building engineering department.

3 Overseas Construction

Using technologies developed and further refined through the construction of its steel works, the company has participated in overseas projects, the field of civil and building for the construction of port and harbor facilities, general architectural and structural steel works, railroads, and steel plants. Especially in the Philippines, the company has been undertaking civil engineering, building construction, pipeline laying, etc., by taking advantage of its experience obtained through the construction of Philippine Sinter Corp. (PSC) established in 1974. In 1989, the company established RIOFIL Corp., which has become Kawasaki Steel's local construction arm in the Philippines. There, Kawasaki Steel invested in Laguna Technopark and succeeded in management as well as its locator's construction.

Photo 5 Bank of China Tower (Shanghai)

3.1 Civil Engineering for Construction of Port and Harbor Facilities

With the construction of sea berths for PSC as a foothold, in the Philippines, Indonesia, Malaysia and Taiwan the company has undertaken mainly sea-berth projects in which steel pipe piles are used in large quantities. The company has a technologies for controling the bearing force of large-diameter steel pipe piles by the pile dinamic wave analysis (PDA), KPP piles, etc. It also has competitiveness with its pile-driving barges. The company takes part in not only projects financed by yen loans, World Bank and Asian Development Bank, but also many private projects including design, and is valued highly for its proposals to lower costs, by means of logistical and value engineering. **Photo 4** shows the INDOKODECO port facilities on Kalimantan Island of Indonesia. This project entails cement transportation equipment, cargo handing equipment, packing equipment, jetty construction, buildings, reclamation and dredging, and KPP piles used as foundation piles.

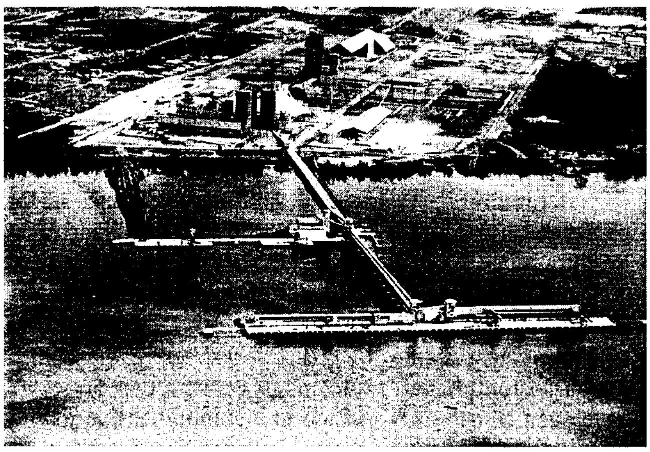

Photo 4 INDOKODECO Cement Jetty (Kalimantan)

3.2 General Architectural and Structural Steel Works

Based on the technology developed through structural steels of large-span building and heavy-weight plants, the company has expanded the scope of work from the conventional supply of structural steels to the supply and erection. At the same time, it has localized fabrication work, as in the structural steel of 53 story Bank of China Tower in Shanghai (1999, **Photo 5**). The company has supplied 400 000 t of structural steel so far and has applied Super High Slend H-shapes in overseas projects. The company has also constructed urban buildings such as hotels and shopping centers and adopted the Super Wing method in the roofs of Salt Lake City Delta Center in the USA.

In recent years, Kawasaki Steel has undertaken building and structural steel works mainly for the industrial plants in the Philippines, China and Indonesia. In China, KPEBs (Kawatetsu pre-engineered buildings) have also been built.

3.3 Railroads

Chiba, Mizushima and Chita Works have a total of 120 km of railway line. Making the most of its construction and maintenance techniques for ensuring safe operation of torpedo cars (weighing about 800 t each) and other freight cars, the company has been pushing ahead with railway projects with yen loans in the Philippines,

Photo 6 Kazafstan railway transport capacity development

Indonesia and Kazakhstan. The company has built not only tracks, bridges, workshops and depots, but has also undertaken supply and installation work for signaling, communication and electrical systems, and maintenance and inspection equipment. The company is presently involved in the railway transportation capacity development project (Silk Road Railroad, **Photo 6**) as the first yen loan project in Kazakhstan. The work is being carried out steadily in accordance with GOST and SNIP, which are the standards of the former USSR. As the first railway project with yen loans in the CIS, this project is drawing attention from various engineering fields and its future development is anticipated.

3.4 Construction of Steel Plants

In overseas plant construction projects, which include Thai Tinplate Manufacturing (TTP) in Thailand (1972), PSC in the Philippines (1974) and Tubarao in Brazil (1974–1983), the company has performed construction work in a tight schedule through its mechanical equipment department that provides design and technical expertise for complex heavy machine foundations and heavy steel structures. In the construction of the cold-rolling mill plant of Ton Yi Industrial Corp. (1995) in Taiwan, the company applied its experience in the design of foundation on a cohesive sandy alternate layers and high-rise plant building in continuous annealing section. As a result, the company contributed greatly to the cost reduction and short construction period required by the client. Furthermore, in the construction of the electric-arc furnace and rolling mill in Batangas, Philippins (BSII project), RIOFIL Corp. played an important role in the equipment foundation building and installation work.

Despite the economic recession that began Southeast Asia in 1997, the company has continued to undertake construction projects, particularly construction of port and harbor facilities, general architectural and structural steel works, and railroads. Based on its experience mainly in the East Asia construction industry, the company aims to promote overseas construction in the Philippines, Indonesia, China and Central Asia.

4 Bridge & Steel Structure Div.[11,12]

4.1 Bridge and Steel Structures for Civil Engineering

The first completed bridge construction project of a Kawasaki Steel group companies was the Asahi fly-over bridge (Tokyo), which was constructed in 1963 by Kawasaki Electric & Machine Co., Ltd. After that, Kawasaki Electric & Machine Co., Ltd. constructed numerous pedestrian bridges and gradually received an increasing number of orders for highway bridges. In 1976, Kawasaki Electric & Machine Co., Ltd. constructed the Akashi Service Area bridge, in which hot-dip galvanization was used for the corrosion protection system. That was revolutionary for its time. On the basis of these achievements, Kawasaki Electric & Machine Co., Ltd. and Oihama Tekko Co., Ltd. merged in 1978 and Kawaden Co., Ltd. (today, Kawatetsu Machinery Co., Ltd.) was established and a platform for the bridge construction business was formed.

At that time, Kawasaki Steel carried out activities for recieving orders for offshore structures, such as oil exploring and drilling rigs, and these structures were fabricated at Harima Works of Kawatetsu Machinery Co., Ltd. As a result, the wharf of the Harima Works were reinforced to provide for the roll-off of large offshore structures. Many jacket-type oil drilling rigs were rolled off from the wharf and even now the functions of the wharf are fully utilized in the construction of various offshore and onshore structures.

In the bridge sector, the company participated in large-scale construction projects such as Bannosu fly-over bridge (1984) in the initial stage of Honshu-Shikoku Bridge project, Oku-Nagashima Bridge (1988) in which large block erection method was applied on the sea, steel bridges piers for Kansai International Airport access bridges (1989), etc. After that, the company constructed large truss access bridges for Kansai International Airport (1991), steel piers of Trans-Tokyo Bay Bridge (1992), an anchor frame of Akashi Kaikyo Bridge (1993), etc. and steadily enhanced its technical expertise for the construction of large bridges.

In the offshore structure sector, demand in the fields related to energy decreased greatly due to a decline in oil prices. However, application of jacket-type structures and steel-concrete hybrid caissons to port and harbor structures, such as revetments, wharfs and breakwaters, increased and these port and harbor structures provided new fields for business.

In 1994, the bridge department of Kawaden Co., Ltd. was integrated into Kawasaki Steel and Bridge & Structure Div. was established. With this consolidation, the

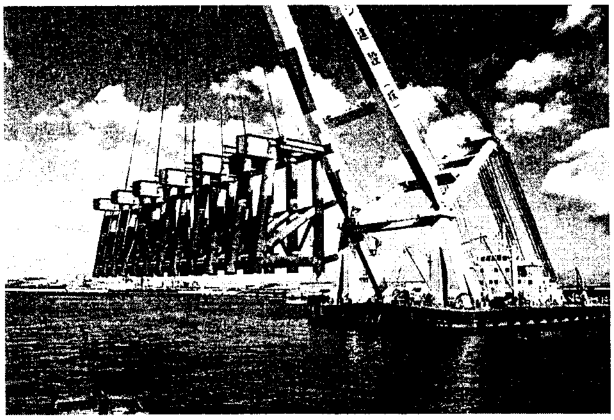

Photo 7 Installation of Kobe Central Jetty with jacket-type wharf

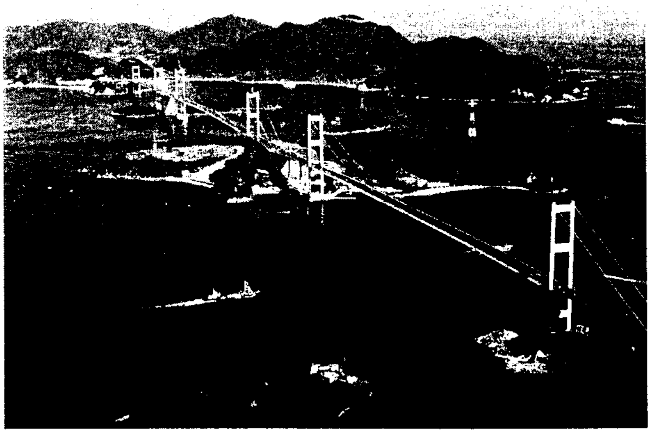

Photo 8 Kurushima Kaikyo Bridge

company's place as a general fabricator of civil engineering steel structures, mainly bridges and offshore structures, became established and its technical and sales expertise came together.

In January 1995, the year after this business consolidation, the Hanshin-Awaji Earthquake occured and many structures were destroyed or seriously damaged. Bridge & Steel Structure Div. reconstructed Hamate Bypass superstructures, Kobe Central Jetty with a jacket-type wharf (**Photo 7**) etc., thereby contributing to the reconstruction of Kobe.

After the business consolidation, Bridge & Steel Structure Div. constructed Imai interchange bridges (Japan Highway Public Corp.). One of these was erected in one night by a special construction method involving collective withdrawal and erection by large transporters. The Asamushi pedestrian bridge construction used trapezoidal box girders with steel deck whose corners rounded up in consideration of view, Nadagawa Bridge, which is a V-shaped rigid steel frame bridge having the greatest structural height on the land portions, etc. (all in 1997), and could achieve success in the construction of bridges with difficulty to erect heights. Furthermore, Bridge & Steel Structure Div. has had success in the design, fabrication and erection of all types of long-span bridges that are called high-difficulty-level bridges, such as Kurushima Kaikyo Bridge, which is the world's first triple-linked suspension bridge (1998) (**Photo 8**) and Hamada Marine Bridge, which is a cable-stayed bridge with un-asymmetrical spans, (1999) (**Photo 9**). Thus, Kawasaki Steel has established its position as a general fabricator.

In terms of development of technologies, Bridge & Steel Structure Div. has put to practical use steel-concrete composite slab bridges (KCSB) in which deformed flange T-shapes are arranged in main girders, steel deck plates for replacement (named Battle-deck) that permit construction with a minimum of trafic control, and semi-prefabricated cables for cable-stayed bridges (PAC-H)

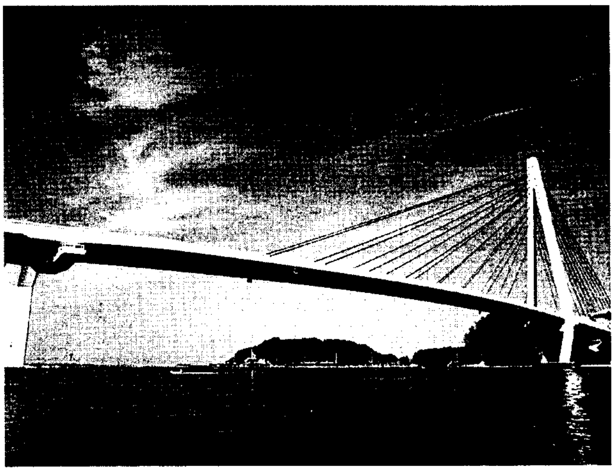

Photo 9 Hamada Marine Bridge

and is carrying out activities for obtaining orders.

Further, with a view to expanding the steel product market and creating a new field of steel structures, Kawasaki Steel has participated in the National Research Project on super large floating structures (named Mega-float) to apply for a marine air port (**Photo 10**) and a floating-type disaster prevention base and has pursued technological development. In parallel with these, Bridge & Steel Structure Div. is carrying out activities for project development. Technology related to large floating structures can also be applied to floating bridges, etc. and is considered promising as a next-generation construction method of strait-crossing bridges.

In addition, to reduce construction costs and minimize life cycle costs that have been strongly required in the construction of recent civil engineering structures, Bridge & Steel Structure Div. is carrying out, activities that will expand demand for steel in the civil engineering field by using new high-performance steels that meet these requirements.

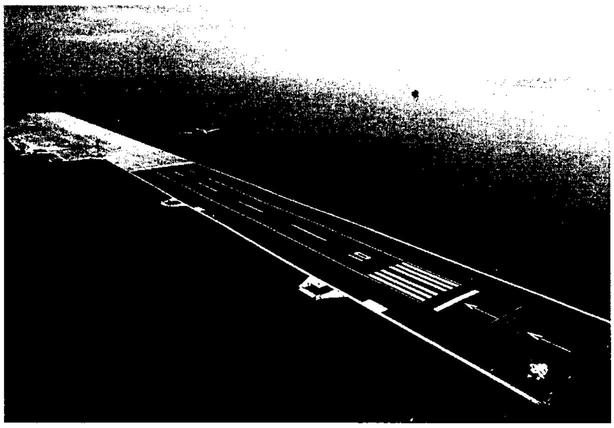

Photo 10 Mega-float air port model

4.2 Field of Steel Structures for Building Construction

Since the establishment of Engineering Div. (ED) in 1981, the company has entered the business of steel structure construction, in which it fully utilizes its excellent steel products and welding technology and the steel product utilization technology developed in the construction of the steel works and the development of steel products for building use, and has tried to expand the steel structure business. Although main items of the business include the supply of steel structures to domestic and overseas users, ED was also developing structural steels for building use until the establishment of Construction Materials Center in 1996, and has played a pioneering role in the field of steel structures for building construction by using its technical expertise through every phase of activities from the production of steel products to fabrication and site work.

Twenty-five years have elapsed since the establishment of ED. During this period, ED has fabricated about 2 500 000 t of structural steels, of which about 2 000 000 t have been supplied to domestic users and about 500 000 t to overseas users. With the high yen, exports have declined since the recording of 150 yen against the dollar in 1986. However, in a single fiscal year in the period of bubble economy, ED supplied as much as 160 000 t of structural steels. Although the supply of structural steels has been decreasing year by year with the collapse of the bubble economy, Bridge & Steel Structure Div. (Bridge & Steel Structure Div. was separated from ED in 1996.) still supplies about 100 000 t of structural steels a year. Further, in recent years, it has successfully entered the field of steel towers for mobile communication and is working enhance its engineering expertise in the field of steel towers for mobile communication in addition to lighting steel towers.

The history of the technology that supports the steel structure business mentioned earlier and its future development are briefly described below. The development of construction materials will be described in detail in Chapter 6.

4.2.1 Development and application of new construction materials

Various new construction materials have been developed to meet market needs. By testing these new construction materials prior to their application to actual projects, their excellence has been demonstrated and techniques for processing these construction materials, particularly welding methods, have been developed.

(1) High-Strength Steels

In 1988, a TMCP (thermo-mechanical control process) steel, which marked a milestone in the start of the era of high-strength steels, was for the first time applied to a box section by four plane plates (River Box), which are the column members of Makuhari Techno Garden, providing good weldability and weld performance even at a low preheat temperature. Further, in 1990, 590 MPa class steels having both high strength and a low yield ratio were applied to column members of an SRC (steel-reinforced concrete) structure of the Kusatsu WEST project. The company has since had many other successes in the use of 570 MPa class steels, which helped the company to acquire the Ministry of Construction's permission for general use as SA440 (1996). Further, Bridge & Steel Structure Div. used high-strength steels in steel pipe columns in the Harumi 1-chome redevelopment project and showed both experimentally and by actual-size members that the performance of column members after cold forming can be sufficiently ensured by various treatments during fabrication, such as stress relief. Similarly, in 1996, Bridge & Steel Structure Div. used 570 MPa class seamless steel pipe as column members in the Edogawa-ku Tower (**Photo 11**) and demonstrated that the steel product and welds have excellent aseismic performance.

(2) Fireproof Steels

The company developed fireproof steels that have excellent high-temperature strength and weldability and a fireproof design method for verifying the structural performance of structural steels made of these fireproof steels during a fire, and started marketing these fireproof steels in 1991. At that time, a "fireproof design method" was quite a new concept and it took much labor and time to bring fireproof steels into widespread use because of people's conceptions of real accomplishments. Fortunately in carrying out its projects, Bridge & Steel Structure Div. achieved various successes, including the acquisition of the Ministry of Construction's permission for project use and obtain the cooperation of a multi-story parking system marker which has a close relation to Bridge & Steel Structure Div. As a result, the company could expand the sales of structural steels for multi-story parking buildings, etc., in which fireproof covers can

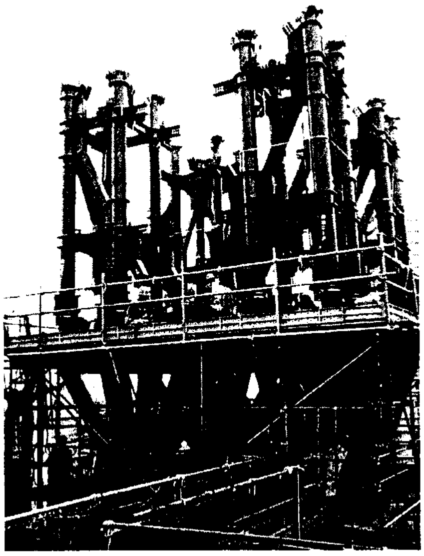

Photo 11 Erection of Edogawa-ku Tower

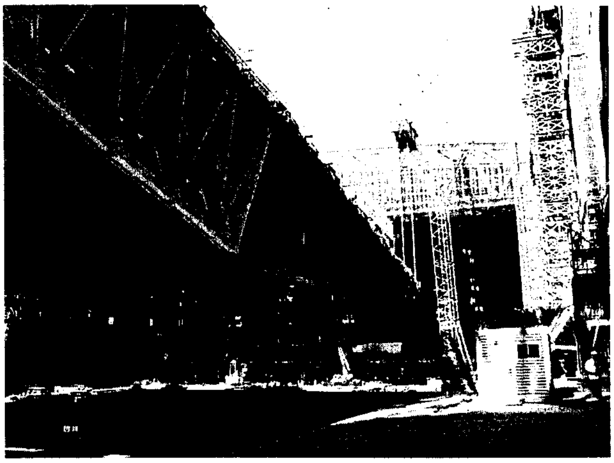

Photo 12 Lift-up of roof trusses for Saitama Arena

be reduced. As a result, the amount of fireproof steels sold in Japan reached 30 000 t a year and about half the amount was used in structural steels supplied by Bridge & Steel Structure Div.

Further, know-how on fireproof design which has been accumulated through business activities will become of great importance for the performance of fireproof structures under the Building Standards Act, and be of great help in the expansion of applications and sales of steel products.

4.2.2 Improvement in efficiency of steel fabrication

An increase in the efficiency of welding work, which accounts for the greater part of labor involved in steel fabrication, is essential for increasing the competitiveness of steel fabrication. Bridge & Steel Structure Div. has also aimed to increase the efficiency of welding work by increasing heat input and to save labor through the use of welding robots.

By applying high-efficiency 3-electrode submerged arc welding (the KX method) to seam welds of a box section by four plane plates (River Box), Bridge & Steel Structure Div. established technology for one-pass welding of plates with plate thicknesses of up to 70 mm. Although there was apprehension that weld quality might be degraded by large heat input, good weld quality was ensured by improvements in steel materials, etc., resulting in greater welding work efficiency. This welding method gained a great reputation during the construction of the Shinjuku Washington Hotel, and Bridge & Steel Structure Div. began to obtain orders for other large-scale projects. Since then, this welding method has been adopted in many projects.

Bridge & Steel Structure Div. has grappled with the development of welding robots since the initial stage, and has improved welding robots and expanded their applications, from the member welding by unsophisticated welding robots in the Arc Hills redevelopment project in 1985 to the "CYCOLON Robot" which welds a column and a diaphragm simultaneously in two places. In 1993, Bridge & Steel Structure Div. developed a large-assembly welding robot that automatically performs flat welding, vertical welding and horizontal welding through the use of a multi-articulated robot. This development has enabled 24 h continuous welding to be performed without human supervision, thereby not only saving welding labor, but also enabling nighttime electric power to be used, greatly reducing costs.

Bridge & Steel Structure Div. also developed construction methods that incorporate approaches from design methods, for example, "SHIBORAN" in which the taper connection of columns having different section is eliminated, and the nonscallop construction method by which aseismic performance is improved by eliminating scallops. Thus, in these new construction methods Bridge & Steel Structure Div. has devoted its energies also to developing joints, which play a pivotal role in steel structures. Since the Hanshin-Awaji Earthquake, the performance of joints particularly welded joints of steel structures, has been reexamined and the importance of joints has been gaining renewed attention.

An outline of the steel structures for building use supplied by Bridge & Steel Structure Div. has been given above. In addition, there are the Super Wing construction method in which high-tensile-stress cables and steel trusses are combined, the Kamikita-chō Gymnasium in which keel trusses and KT trusses (three-dimensional system trusses) were combined (1998), the Saitama Arena in which the jack-up construction method was adopted (**Photo 12**), the Miyamoto Musashi Budo Kan of space steel frame construction for which three-dimensional CAD was put to full use, and other special steelframed buildings. Furthermore, Bridge & Steel Structure Div. has had much experience in the construction of lighting and communication steel towers made of weathering steel plates, from design to field construction. All these special steel structures require comprehensive technical expertise although the technology required differs from a project to another. The Chiba Fabrication Center was closed in 1996. However, in conjunction with its associated companies including Kawatetsu Metal Fabrica, Ltd., Bridge & Steel Structure Div. is striving to further enhance its technical expertise through every phase from the production of steel products to steel fabrication and construction work in the field, or from design to execution of work, on the basis of its own technologies are fully utilized.

5 Pipeline Engineering and Construction Services

The company's pipeline engineering and construction services has been developed from two main streams. In one stream, the completion of the industrial-water pipelines from Lake Imba-numa to the Chiba Works laid since the construction of the works provided important experience and knowledge of pipeline engineering and construction. In the other stream, the application of steel pipe was expanded from the construction materials business (steel pipe piles) to the field of pipeline engineering and construction. Since its formation, the pipeline engineering and construction services, the company has made steady progress at home and abroad in various pipeline construction project. Examples are the Narita International Airport aviation fuel pipeline project (completed in 1982), the Manila city water supply projects PG6 and PG7 (completed, respectively, in 1985 and 1987), the Singapore submarine water supply pipeline project (completed in 1987), and the Futtsu-Sodegaura and Anegasaki-Chiba gas pipeline projects of Tokyo Electric Power Co., Ltd. (completed, respectively, in 1992 and 1995).

The reliability of the company's gas pipeline technologies was proven by the Niigata-Sendai gas pipeline project of Japan Petroleum Exploration Co., Ltd.[13] This is a long-distance gas pipeline having the second largest total length in Japan. The company was engaged in the pipeline construction through every phase of the project, from the feasibility study to planning, design and construction. The company's technology related to high-pressure gas pipeline was developed based on the company's participation in this project. This technology led to the successes in the design and execution of work for major city gas companies such as Tokyo Gas Co., Ltd. and Toho Gas Co., Ltd. Using the experience and knowledge accumulated in the Niigata-Sendai gas pipeline project, the company's affiliated companies, particularly Kawatetsu-Techno-Construction Co., Ltd., have received orders for project from other city gas companies.

In the water works business, the company has built many other facilities since the construction of the above water-supply pipelines from Lake Imba-numa. Works worthy of special mention include the construction of the Kita-Chiba water works for the Tokyo Metropolitan area and the pipeline project for supplying water to Awaji Island via Akashi Kaikyo Bridge. Further, the company has expanded into steel water storage tanks, emergency water storage tanks, etc. to meet today's needs of the water supply business.

5.1 Services for Energy Facilities

In recent years, environmental issues have been in the spotlight and the adoption of clean energy has been required. Among others, natural gas is receiving international attention as a relatively environmentally friendly energy that emits little NO_X and does not emit SO_X. Demand for natural gas has been increasing year by year and its reserves are abundant worldwide. Abundant reserves have been found in East Siberia close to Japan.

At the same time, Japanese energy policy has been reviewed and it is expected that Japan will work to bring gas turbine generation by natural gas and fuel cells of natural gas into widespread use. If this materializes, the gas pipeline systems will have to be expanded in the future. Important technologies required for the construction of gas pipelines are described below.

(1) Niigata-Sendai Gas Pipeline

This project involves the construction of a 251 km long pipeline of Japan Petroleum Exploration Co., Ltd. for transporting natural gas produced in Niigata Pref. and gasified LNG of Indonesian origin unloaded at Niigata East Port to users in the Sendai district. Kawasaki Steel participated in this project from the feasibility study in 1986 to the completion of the pipeline system in March 1996. The pipeline has since been operating smoothly. An important key to the realization of this project was cost reduction. Examples of cost reductions in the construction of this pipeline are described below.

In general, when a pipeline is to be laid across a river, etc., via a bridge, it is most economical to use an existing bridge. However, when this way of construction is unfeasible, it is necessary to construct a pipeline bridge. Such a bridge that is worthy of special note from a technical standpoint is the Kosutegawa Suspension Bridge (**Photo 13**). In this project, a non-stiffened suspension bridge was used as a pipeline bridge in order to lower costs. This was the first example of a non-stiffened suspension bridge application for a gas pipeline.

(2) Development of Pipeline Construction Technologies

When a pipeline is to be installed in an urban district, its effect on neighboring residents and traffic must be minimized. Therefore, the company developed a non-digging method (the Kansen mole method) for shortening the construction period of

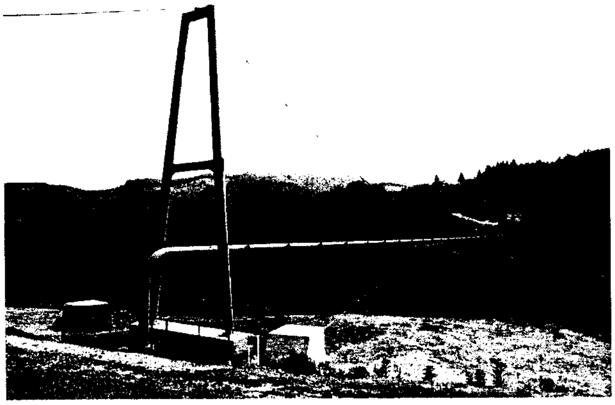

Photo 13 Kosutegawa Suspension Bridge

jacking a pipeline to be laid in an urban district and for laying a long-distance pipeline. This method enables a casing pipe to be simultaneously thrust in (jacked) and drawn into a gas pipe. The casing pipe and the gas pipe constitute a double-pipe construction. The construction is such that sliding occurs between the casing pipe and the gas pipe, enabling the construction work from jacking to the drawing-in of the pipe to be performed in a single process. A cross section of the pipeline during thrusting is shown in **Fig. 1** and the laying of the pipeline is shown in **Photo 14**.

Figure 2 shows a non-digging method (the K-lead method) by which obstacles such as a river can be crossed by drilling earth in arc form through the use of oil drilling technology and a no-thrust pit. This method permits drilling for a long distance even if the pipe has a small diameter. It can be applied not only to gas pipelines, but also to water and oil pipelines.

(3) Gas Regulating Station

As cogeneration has come into widespread use and gas turbine technology has been developed, it has become necessary to meet severe conditions for delivering gas to equipment: high pressure, large capacity, and high-accuracy pressure control. In order to meet these customer requirement, the company participated in the project through every phase from basic planning to design, construction and commissioning. **Photo 15** shows a gas regulating station for supplying gas to the Shin Sendai Thermal Power Plant of Tohoku Electric Co. at the terminal of the Niigata-Sendai gas pipeline.

At this station, gas is received at a pressure of 7.0 MPa and the gas pressure is reduced to 1.5 MPa. In terms of the flow rate of gas to be treated, this station is the largest gas regulating station in Japan. On the other hand, in the gas regulating station for supplying gas to Hokuetsu Paper Mills, the allowable pressure range during delivery was very narrow (2.0 ± 0.02 MPa) due to the operating conditions of gas turbines.

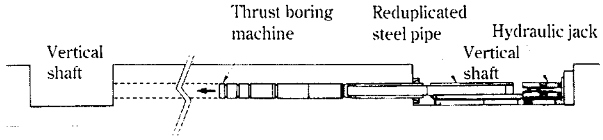

Fig. 1 Kansen mole

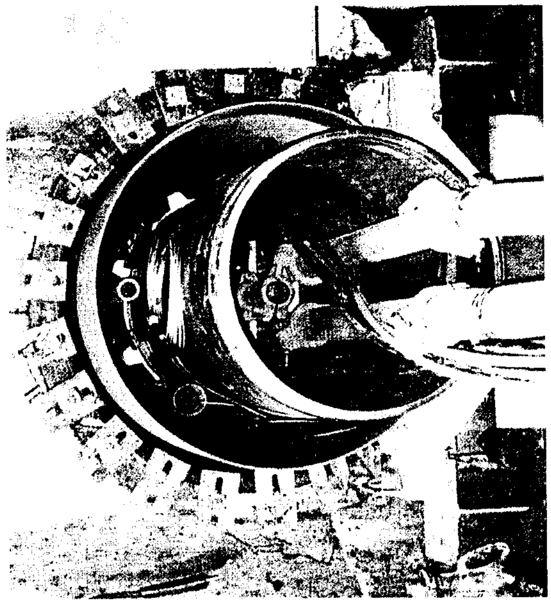

Photo 14 Kansen mole (under construction)

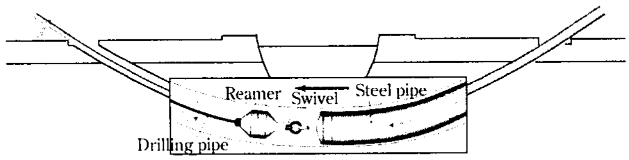

Fig. 2 Profile of K-lead

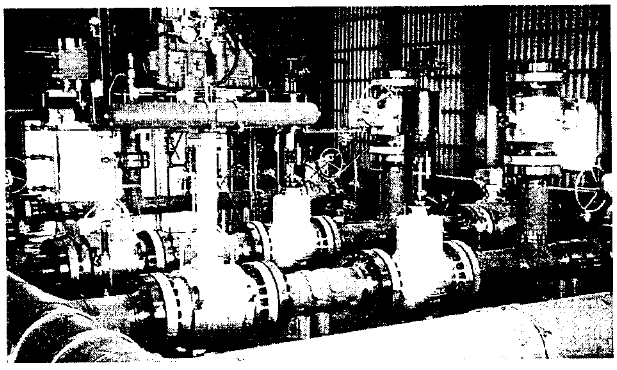

Photo 15 Sendai-Shinko gas regulating station

However, an optimum method of regulating pressure-reducing values was determined by using a process simulator. The simulation results of gas pressure and data during a test run are shown in **Fig. 3**, which

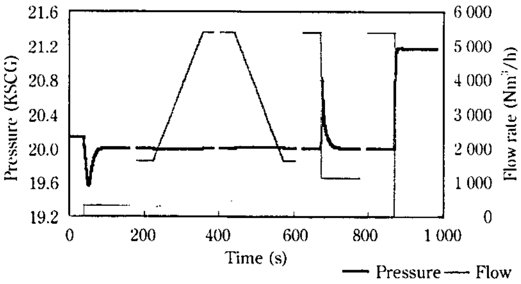

Fig. 3 Simulation of gas pressure

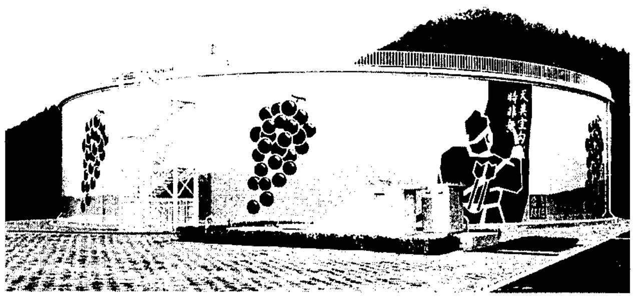

Photo 17 Water storage tank

clearly shows that the analytical results are in good agreement with measured data.

5.2 Service for Water Works

Since the Hanshin-Awaji Earthquake, the importance of life lines has been recognized anew and along with the improvement and construction of water pipelines, the construction of steel water storage tanks, emergency water storage tanks, etc. has been carried out to build up water stockpiles. While the percentage of water supply has risen to 96.3%, replacing pipes, eliminating redundancy (double loops), improving quality, etc, have become issues to be resolved in the future. A typical example of water pipe bridge constructed by the company is shown in **Photo 16**. This water pipe bridge is a water pipeline installed on the Akashi Kaikyo Bridge for supplying water from Akashi to Awaji Island.

(1) Steel Water Storage Tanks and Emergency Water Storage Tanks

There are products that came from water pipeline technology. **Photo 17** shows a steel-made water storage tank of the largest class in Japan (Okayama Pref.), which was designed and constructed by the company.

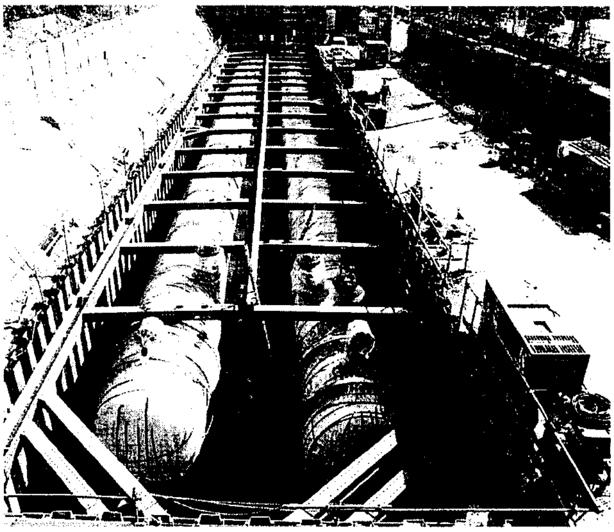

Photo 18 Emergency water tank ($V = 600\,m^3$ type)

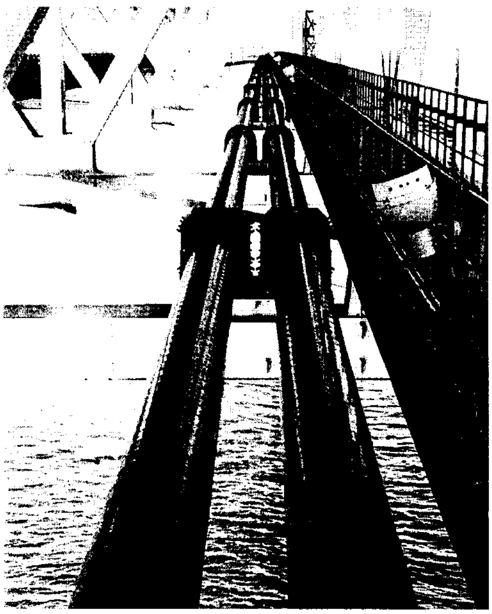

Photo 16 Water pipeline on Akashi Kaikyo Ohashi Bridge

Since the Hanshin-Awaji Earthquake the importance of water storage has become more apparent. Thus, the company has been engaged in the development of such water storage tanks by conducting fluid analyses of circulation in water storage tanks. An emergency water storage tank with a capacity of $600\,m^3$ under construction is shown in **Photo 18**. The results of a simulation of water circulation in the tank are shown in **Fig. 4**. It can be ascertained that the water in the tank is constantly circulated.

(2) Defect Detecting System for Anti-Corrosive Coatings

With the increasing importance of pipeline maintenance, the company developed "PICO FINDER" a defect detection system for anti-corrosion pipeline coatings. This system permits an examination of damaged anti-corrosive coatings of both water and gas pipelines.

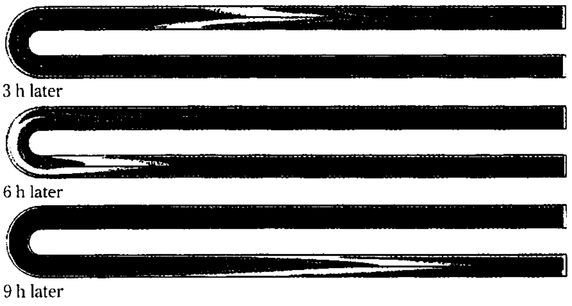

Fig. 4 Simulation results of step-function response for colored tracer in a water circulation tank with a capacity of 600 m^3

5.3 Welding Technology

At present, various pipeline projects are being planned. One of the technical elements of projects is welding technology. The application of automatic welding systems to high-pressure gas pipelines on-site has already been field-proven in more than 1 000 rings. For on-sit automatic girth welding systems, the company is planning to do the following:

(1) Minimize welding time (by 1/3 to 1/5 the present welding time)
(2) Improve welding quality (reduction of weld defects)
(3) Application to high-strength steels
(4) In-process welding

Photo 19 shows a 2-head type automatic girth welding system as one of the measures to increase welding speed.

On the other hand, when laying water pipelines in which large-diameter steel pipes are often used, high-speed welding is required of on-site automatic girth welding systems. The company developed an on-site automatic girth welding system (the K-ING method, **Photo 20**) which uses an FCW (flux-cored wire). Further saving of welding time will be required in the future.

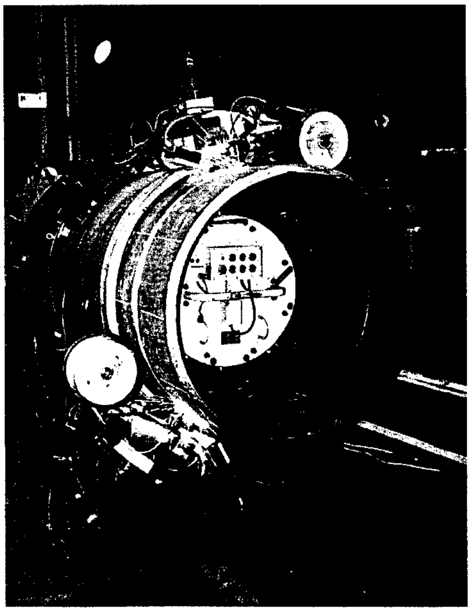

Photo 19 2-head type automatic welding system

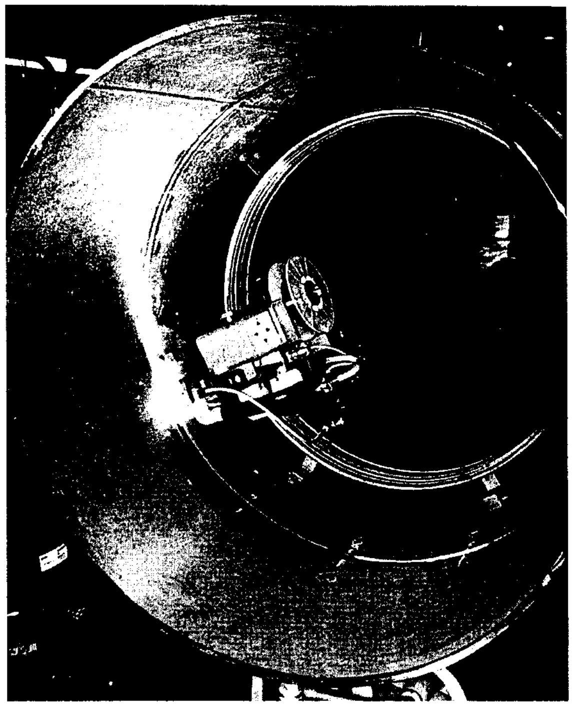

Photo 20 K-ing automatic welding system

5.4 Future Technical Developments

The company has been developing technologies that constantly meet the needs of the times and customers. It will now start to develop new technologies for long-distance gas pipelines.

6 Construction Material Business

It is very important for a steel company to analyze the market and technological trends in construction materials for civil engineering and building construction, which are said to account for 40–50% of the domestic demand for steel products. Since the start of Construction Materials Res. Sec. (1962) and Construction Materials & Engineering Service Dept. (1966), which were organized to provide support in the selling of construction materials for civil engineering and building construction, the building material business at Kawasaki Steel has focused on technical services, product development, etc. in terms of architectural and civil engineering technologies[1]. Past reports[14,15] described activities to provide support for the selling of steel products (R&D, technical services) based on technologies developed and refined on the basis of the technologies employed in the construction of the steel works, and future prospects aimed at further expansion of the business. However, the construction material business faces an uncertain future due to the collapse of the bubble economy, particularly sluggishness in consumer spending and the cooling of demand after the temporary brisk demand, as well as restoration measures after the Hanshin-Awaji Earthquake.

This report describes the past activities in the construction material field and the future prospects in the light of the business environment for which a long-range declining tendency of investments in infrastructure is expected due to severe cost reductions. In the Kawasaki Steel group, supply systems differ according to the characteristics of products (for example, rolled products and working techniques). Due to limited space, descriptions will be confined to the products, construction methods and business fields related to the company.

6.1 Field of Construction Materials for Civil Engineering

The majority of construction materials for civil engineering are used in public works. In the past, the principal role of steel companies was to supply products necessary for upgrading the country's infrastructure. Recently, however, by making use of technologies developed and improved by civil engineering works, applications of civil engineering materials have been expanded to building structures (for example, foundations) mainly in private business projects, and fields in which steel companies are to be active have changed owing to changes in market environment and technological advances. This subsection gives a general description of the activity with civil engineering materials, in six different fields: roads and railroads, ports and harbors, flood control (rivers), erosion control (mountains), underground facilities, and building foundations.

(1) Roads and Railroads

This field has supported the development of steel pipe piles. The steel pipe sheet pile foundation[16] which the company put to practical use in 1965, earlier than any other steel maker, has been field-proven in a large number of road and railroad foundations. At the beginning of the development, steel pipe piles were constructed mainly by pile driving method with a hammer, but various execution methods, such as the inner excavation pile installation method and the steel pipe and soil cement composite pile method, have been developed since the implementation of the Basic Law for Environmental Pollution Control in 1967. Recently, through the activities in the Japanese Association for Steel Pipe Piles, the company has developed new construction and management methods, such as the vibration method and the dynamic loading test method. In addition, research activities related to the performance evaluation of steel pipe pile foundations and steel pipe sheet pile foundations (for example, the plasticity ratio) have been conducted.

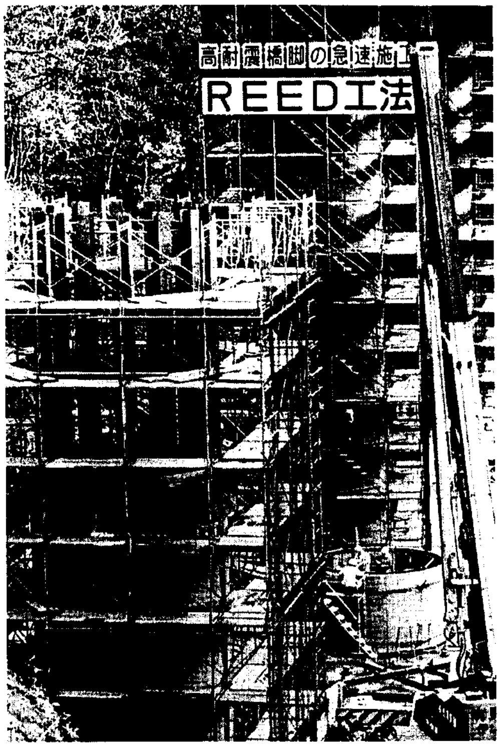

Photo 21 Composite pier (REED method)

Regarding construction materials other than foundations in the field of roads and railroads, the company developed the underpass method (JES shapes) represented by the pipe-roof structure, sound absorption walls for bottom surfaces of elevated railroads, new compact electrical and communications cable conducts for underground service called metal CCBOX[17], etc., and entered new fields such as environment and information. Further, in the field of bridges and tunnels, the company has been developing methods related to the utilization of materials substituting for reinforcing bars in piers (the REED method (**Photo 21**))[18] and the high pier composite method using steel pipes[19]. However, development of technologies and construction methods is demanded which facilitate construction and reduce life cycle costs.

(2) Ports and Harbors

As is apparent from the restoration work in the aftermath of the Hanshin-Awaji Earthquake, various structures in which the properties of steel that are highly resistant to bending have been proposed and adopted. In the field of ports and harbors, the unit consumption of steel products is highest among the public works. In addition to general structural methods (for example, the cantilevered method, the anchored method, the combined piles method), the company has developed products and construction methods by conducting studies that cover every phase of a project, from

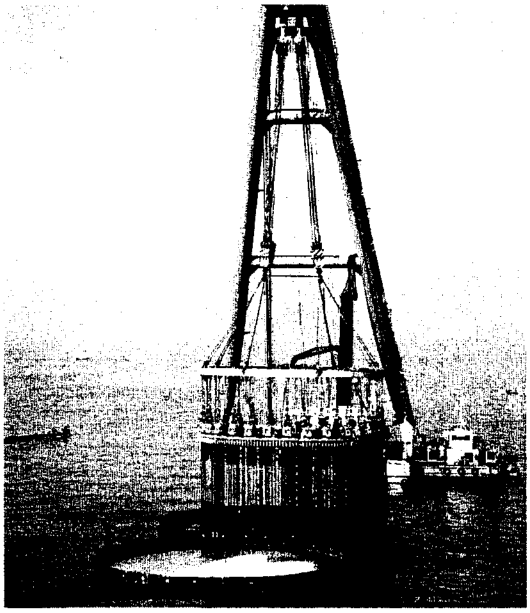

Photo 22 Prefabricated cell by steel sheet piles

design to construction. They are, for example, structural methods which can fully utilize the resistance of ground, i.e., the double-wall structure[20], the prefabricated cell structure by steel sheet piles[21] (**Photo 22**), and the underwater junction method[22] that can be used for reinforcement.

In the future, technical proposals and new construction methods leading to lower costs will be required for great-depth berths, earthquake-proof berths and marine air ports the construction of which is publicly announced in the Ministry of Construction's five-year program for the construction and improvement of ports and harbors. This will require diverse combinations of technologies, such as composite structures as observed in hybrid caissons and steel sheet shell caissons, or methods for making better use of the strength and resistance force of ground. Furthermore, because of the recent lack of land fills, a ground swell of construction of sea-level dumping grounds has been developing[23] and it is essential to evaluate seepage control techniques and make them more reliable.

(3) Flood Control (Rivers)

Because mountains account for more than 90% of its territory, Japan has a very large number of small rivers and river improvements using steel products have been continuously carried out. The steel sheet pile mainly used in this field is a revolutionary product in which the materials on both sides of a neutral axis are fabricated to form a single-piece structure via joints (although with fewer joint). Because this product is a rolled steel and has an unusual shape, it is not so versatile as a steel pipe pile. Recently, however, the company has developed and marketed wide-flange sheet piles with an effective width of 600 mm (**Photo 23**) as a measure to reduce costs.

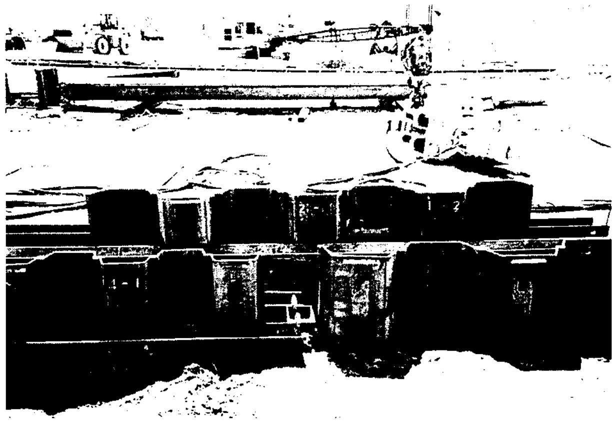

Photo 23 Wide flange sheet pile

As a result of urban flood control measures, rivers that are habitat-poor and which are uniform and uninteresting have increased. Therefore, the company developed revetments which conserve nature[24] and materials that blend in with landscapes[25]. However, the utilization technology must be improved in order to supply products that are adapted to the environment in which they are used.

(4) Erosion Control (Mountains)

A typical example of a steel product used in this field is a steel pipe pile for landslide prevention. This pile often features a heavy-wall steel pipe pile, depending on its application. In order to facilitate the use of site-welded joints, the company developed a fully-automatic welding method called "the KH-P method" and has used it extensively. Further, the company has recently put into commercial production a screw joint not requiring site welding called "Mechaneji"[26,27] (**Photo 24**) and a high-strength material called "K60"[27] for reducing material costs.

In this field, however, as symbolized by the eruption of the volcano Unzen-Fugen Dake, a speedy and safe construction method should be combined with automated construction.

(5) Underground Facilities

In the field of underground facilities, the company has carried out activities by stressing the development and improvement of the construction technology by making use of existing products. For example, the low-space piling methods of sheet pile (for example, K-domeru[28] **Photo 25**) to which the company has devoted its energies have been adopted in many construction sites as a method that can meet the condition that execution is available with the roads and railroads within cities kept in service. In the future, it will be necessary to take steps to meet requirements for great depths while paying attention to trends in underground development.

(6) Building Foundations

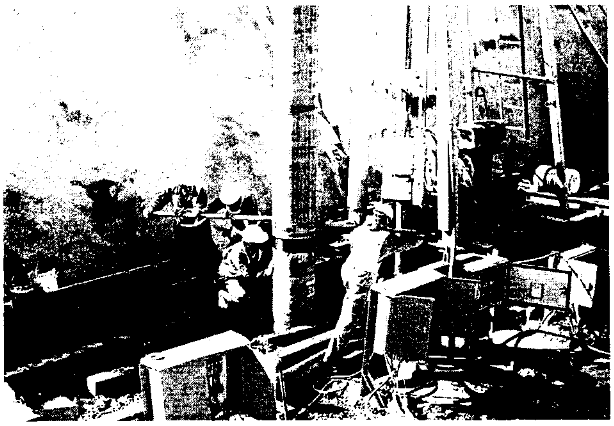

Photo 24 Landslide control steel pipe pile with screw joint (mecha-neji)

Photo 26 Rotary penetration steel pipe pile (drill pile method)

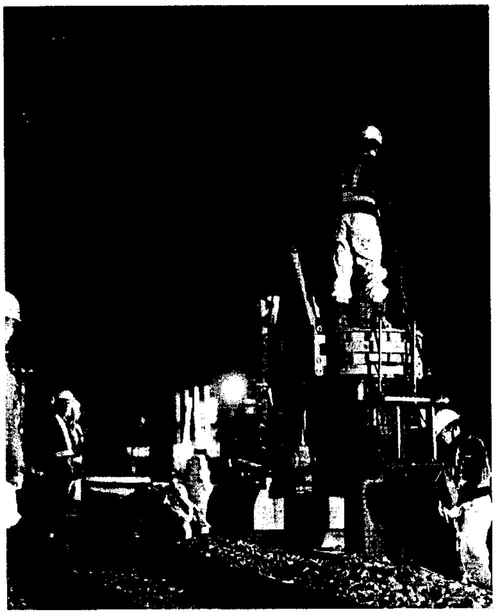

Photo 25 H-shaped steel sheet pile (K-domeru)

When the pile driving method with a hammer was the prevailing construction method for steel pipe piles, building foundations were limited to reclaimed coastal districts, etc., where noise and vibration posed little problem and building foundations were used in special applications that could cope with difficult conditions and land subsidence. With the start of the selling of the Kawasaki Steel type rotary penetration steel pipe pile method (the drill pile method)[29] (**Photo 26**) in 1990, the company began its full-scale entry into the field of private building foundations. Because this method features low-noise and low-vibration and does not generate surplus soil, the company has had many successes with this environmentally friendly method by developing construction technology (for example, the body rotation method), construction management technology and peripheral technology. Further, the company improved the inner excavated piling method for foundations of large building structures and pursued the development of KING method that has the mechanical excavation bit[30,31], permitting applications to steel pipe pile diameters of up to 1 000 mm.

Because cast-in concrete piles generate large amount of waste soil, the company has been involved in the development of cast-in concrete pile reinforced by outer steel shell[32], which enables the volume of excavated soil to be reduced by about 30%. However, with a decrease in dumping grounds of surplus soil and industrial waste and public concerns about the environment, further burdens on surplus-soil dumping are expected and it is necessary to regard waste-soil dumping as a serious problem for society and the entire steel industries.

As mentioned above, steel companies and their civil engineers have been required to give technical services and develop utilization technology for supplying consistent-quality, user-friendly products at low cost. At present, public opinion requires public works investments to be equitable and contribute to the aging society and improvement of the Erath's environment. The same is required of the steel industry and the civil engineers working there. Also for cost reductions, it has become necessary to consider the roles required for creating a recycling-oriented society in the 21st century, that is reduction of life cycle cost and making action for recycling. Design specifications with performance requirements represent a stream in the new trend. We are living in an age when enterprises and engineers can survive only when they become aware of changes in public needs earlier than others and can take innovative measures to reflect such changes in their business.

6.2 Field of Construction Materials for Building Use

Among the ordinary steels for building construction, which account for about 30% of domestic demand for ordinary steels in Japan, demand for building materials for structural use, such as steel plates, H-shapes and steel pipes, is presently about 7 500 000 t/y. Therefore, these building materials are in great demand. However, the supply and demand balance was lost due to the effects of the sluggish business conditions after the collapse of the bubble economy and the building recession, prices of structural steels have remarkably decreased, and user demands for cost reductions of building materials have become very severe. Although the business mood has somewhat improved, there is no guarantee that building demand will recover in the future. Consequently further cost reductions of building materials will be demanded.

On the other hand, as a result of the Hanshin-Awaji Earthquake in 1995, higher quality and performance of building materials have been demanded in order to improve the aseismic performance and safety of structures. Furthermore, with the new performance guidelines of the Building Standards Act, a shift to a design system with a higher degree of freedom is expected and further specialized performance will be required of building materials.

To meet these seemingly contradictory user needs, the manufacturing and architectural engineers of Kawasaki Steel are making a concerted effort to commercialize new building materials. These materials are classified below into (1) general construction materials that are widely used regardless of the scale or application of the building, (2) high-performance construction materials for large-section and high-strength members that are mainly used in special buildings such as skyscrapers, and (3) multifunctional construction materials having special functions. Regarding the above classified materials, products developed in the 1990s, along with future trends, are described below.

(1) General Construction Materials

Brittle fracturing of cold-formed steels and poor structural steels such as lamination steel plates at the beginning of the 1990s created problems for the construction industry. New construction materials that were developed as a result of collaboration among industries, academia and government are the new JIS materials for building use represented by SN materials[33], which were standardized in 1994, and cold-formed rectangular hollow section pipe BCR[34], which were approved in 1995. In these new construction materials, weldability and plastic deformation capacity were improved in consideration of the uses of buildings. At present, the use ratio of SN materials in steel plates is about 50% and the use ratio of BCR is about 30%. Thus, these new construction materials are extensively used, and will likely become even more widely used because importance will be attached to ensuring weld quality after the implementation of the new building standards act.

(2) High-performance Construction Materials

New construction materials of higher strength and larger section have been demanded owing to the adoption of new structural types such as mega structures. Further, heavy-gauge H-shape and concrete-filled tubes have begun to be used as construction materials that replace the four plate section welded box, which has been used a lot as column members of skyscrapers.

To meet these needs, in 1996, the company obtained the Ministry of Construction's permission for general use of a high-performance 590 N/mm^2 structural steel for building "SA440"[35]. Further, the company developed heavy-gauge TMCP H-shapes and in 1999 gained the Ministry of Construction's permission for general use of RT325 and RT355[36]. At the same time, the company put RT440, which is equivalent to SA440, to practical use. Moreover, it developed the 700×500 series, the world's largest, enabling the section performance in the direction of strong axis with the same cross-sectional area to be improved by about 20%, thereby reducing the weight of structural steel. Although the steel pipe "KS-Column" with ring-diaphragm is a latecomer that began to be marketed in 1998, it can meet various structural plans because it features a ring-diaphragms for steel plates.

"Super HISLEND-H" an H-shape with a constant outside dimension[37] mainly used as beam structure enjoys great popularity it is the largest available in Japan. In 1999 products of $H = 1\,000$ mm, the largest size in Japan, were put on the market as an alternative to built-up H-shapes, helping to reduce working costs.

(3) Multifunction Construction Materials

Since the Hanshin-Awaji Earthquake, a rapidly increasing number of hysteretic dampers containing steel products have been adopted as a means for improving the aseismic safety of structures. For example, the company developed "RIVER FLEX", a low-yield-stress steel as a steel for damper[38,39]. Further, the company put wall dampers of low-yield-stress steel[40] and double-tube braces[41] to practical use. It also obtained the Ministry of Construction's permission for general use[42], for the wall dampers of low-yield-stress steel.

In order to adopt dampers in which low-yield-stress steel is used, it is presently necessary to obtain the Ministry of Construction's permission for each building, which hinders the widespread use of these dampers in medium- and low-rise buildings. Furthermore, the nature of the Ministry of Construction's permission is such that these wall dampers cannot be used for maximum effect. Therefore, it is urgent to generalize design methods of buildings in which dampers are used.

As mentioned above, the company has so far developed various steel products for building use capable of meeting user needs, ranging from general construction materials to multifunctional construction materials for special uses. In the future, various structural types and design techniques will be adopted under a new building standards system and needs for new construction materials will arise for them. The architectural engineers of Kawasaki Steel intend to link users and manufacturers and to promote the development of even more attractive products.

7 Concluding Remarks

Architectural and civil engineering techniques provide the essential technology for building a country's infrastructure. For the past 50 years, Japan has been aggressively construction and improving its public infrastructure. As a result, the consumption of steel products for architecture and civil engineerings has steadily increased, accounting for a little less than 50% of the domestic gross production. On the other hand, with the recent changes in industry and society, various changes have also occurred in concepts of infrastructure. Therefore, architects and civil engineers should prepare to tackle many technical challenges that they will be facing.

The greatest feature of Japan's recent policies for constructing and improving its infrastructure is that they are based on environmental conservation and the effective utilization of the Earth's resources. In other words, importance is attached to the minimization of life cycle cost, recycling, endurance performance design, rehabilitation and maintenance. Naturally, there is also the perennial task of cost.

In addition, as represented by a major amendment to the Building Standards Law of Japan, incorporation of performance requirements and deregulation are inevitable and it is certain that the degree of freedom in design methods and construction methods and the construction materials used in carrying out design and construction will increase.

In the midst of dramatic changes in Japanese society, restructuring of the company's business related to architectural and civil engineering is under way to avoid overlaps among specialized fields and to create a more rational and efficient organization. Against this backdrop, activities for the formation of a secure technological footing, and the development of application technology and products, are earnestly demanded.

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