Prospects for Steel Materials Used in Civil Engineering

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1. Introduction

In the past twenty years, demand for steel materials in the civil engineering field has changed to account for 14 to 18% (9 to 12 million tonnes) of the total domestic consumption of common steel[1] (see **Figs. 1** and **2**). The greater part of civil engineering steel materials is used for public works investments centering on the development of social infrastructure, which amounts to 80% or more of civil engineering demand.

Looking back over public works investments in the first half of the 1980s, the brakes were put on the long-practiced high economic growth policies, and a period of zero ceiling public works investments continued for several years. Civil engineering demand was kept at around 9 million t/y. In consumption fields, however, its share declined from 18% to 14% because of the growth of the automobile industry. In May of 1987, as a measure to deal with the recession caused by higher yen value, an emergency economic program of 6 trillion yen was put into practice, and large nationwide construction projects started full scale. In addition to the start of the three big projects, the Honshu-Shikoku Bridge, Kansai International Airport and Tokyo Trans Bay Highway, the construction of a super highway network (expressway) pushed mainly by Japan Highway Public Corporation reached its zenith, and consumption was quickly changed to a recovery phase.

In 1990, total domestic consumption exceeded 80 million tonnes, which was the largest steel material shipment in history. Demand for civil engineering steel materials reached 12 million tonnes. From this time, however, Japan and US trade friction came to the fore and, in June of 1990, an agreement was reached on a first public works investment plan (1991 to 2000) of 430 trillion yen as a domestic demand expansion measure. But while the size of public works investments increased year by year, the objects of the investments greatly changed (see **Fig. 3**). In other words, a propensity of investments related to a living environment became pronounced, which resulted in the great decline in steel material consumption per public works investment value. It was 45 t/100 million yen in 1990, but four years later, in 1994, it dropped to 25 t/100 million yen (see **Fig. 4**). The bubble economy collapsed in 1992, and it is still fresh in our memory that the Great Hanshin Earthquake Disaster in January of 1995 caused many casualties and much damage. The recovery from the Disaster created a temporary demand increase of 600 to 700 thousand tonnes from 1995 to 1996. But there has been no change in the tendency of gradual consumption decline after 1996 till now. Japan is still in the tunnel of the public works cost reduction, the collapse of the bubble economy, the collapse of the monetary system, the construction recession and the deflation related recession.

In fiscal 1998, the Government decided to take large (16 trillion yen) emergency economic measures at long last. The core of the business-stimulating measures is public works investments in the fields related to the development of social

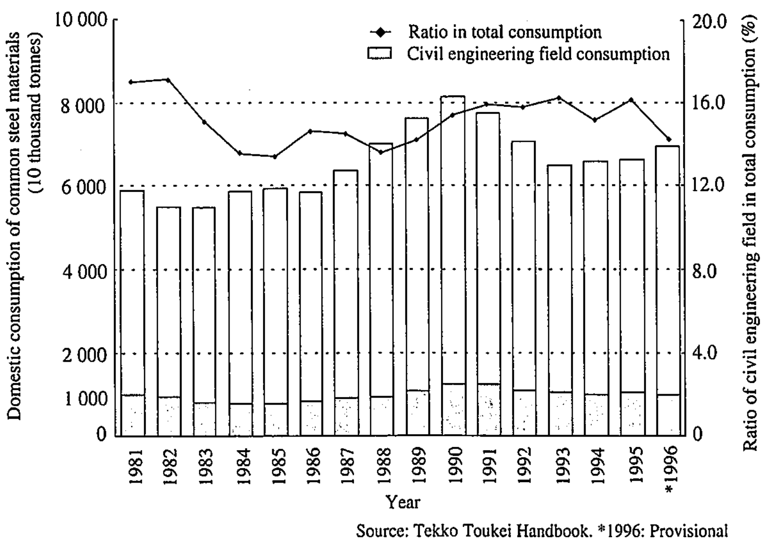

Fig. 1 Changes of total domestic consumption and civil engineering field

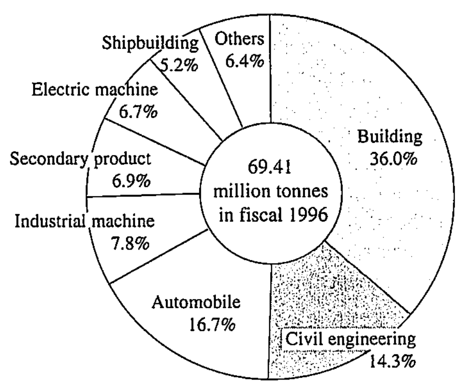

Fig. 2 Breakdown of consumption by demand fields for common steel materials

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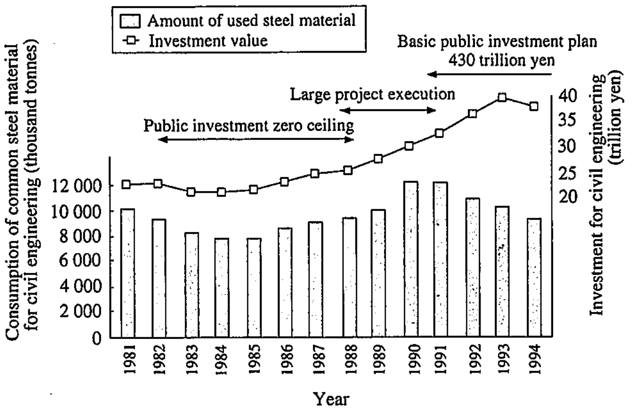
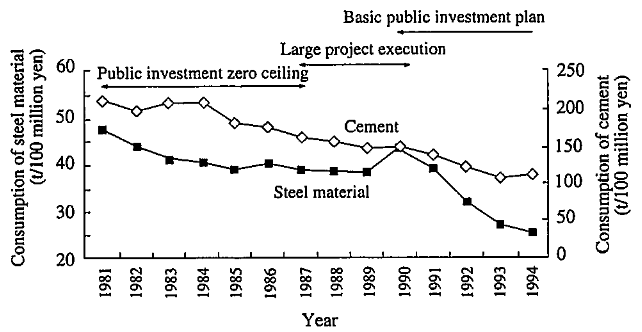


Source: Economic Planning Agency for public investment, Japanese Steel Association (issued in 1995) for steel material consumption

Fig. 3 Relationship between investment value and steel material consumption for civil engineering



Source: Steel material consumption was made from data of Fig. 3, Cement consumption was made from civil engineering shipment in cement almanac

Fig. 4 Changes in unit consumption of common steel materials and cement for civil engineering

infrastructure and, as in the past case, civil engineering steel materials play an important role.

There are many technical problems to be solved for steel material development and product development. The current economic recession must be considered as a golden opportunity for the development of technologies. Keywords for the coming 21st century include life cycle cost (LCC), high performance steel utilization technology, seismic design technology, transition to demand performance design, mixed structure, ISO global standard, fabricate minimum, environment harmonious type steel material (eco-material), recycling, minimum maintenance, and so on. A development concept needs to be reevaluated based on these keywords, and steel material development must be pursued based on the idea of "finding origins" rather than "returning to origins". The task of Nippon Steel is to make contributions toward construction technology for continued development through steel material development.

2. Current Situation Surrounding Civil Engineer ing Projects

2.1 National land construction for the 21st century in Japan

The National Comprehensive Development Plan made in March of 1998 is based not on the conventional idea of "Public Works Projects come first" but on the idea of putting importance on the natural features and culture of Japan. The plan was also based on a point of view of changing the idea of traffic axes and divisions. Based on this idea, the concepts of "Northeast traffic axes", "Japan sea traffic axes", "Pacific traffic axes" and "West Japan traffic axes" as new traffic axes were established. Trans Tokyo Bay Bridge was opened in December of 1997, Akashi Kaikyo Bridge was opened in April of 1998 and, one year later, the Honshu-Shikoku Bridge is scheduled to be opened. It is expected that in the 21st century, there will be active discussion on the development of expressways for the four traffic axes, the ratios of cost minimum construction technology will grow for long and large bridges such as Tokyo Bay Mouth, Ise Bay Mouth or Kitan Strait, mountain bridges and tunnels and, accordingly, great advances in conventional technology will be required.

In the USA, the renewal of social overhead capital was planned (CONMAT PLAN) at a cost of 2 billion dollars over twenty years. Japan is now also seeing conspicuous need for maintenance and renewal of the current stock of road structures.

2.2 Harbor and airport construction for global competition

The economies of Japan and other Asian countries are now in the doldrums while the economies of the USA and European countries are steadily growing. The expected trend in the future is a great increase in world trade volume. For example, in the year 2010, the volume of container cargoes between Japan and other Asian countries will be 3.9 times as large as today's. Following the increase in the trade volume, vessels will be larger, and the vessels of Over Panamax class capable of loading 6,000 containers will be the mainstay of marine transportation. The ports for vessels of Over Panamax class needs a water depth of 14 m to 15 m[3]. At present, Japan has only one berth as a container terminal in Kobe Harbor which can accommodate such vessels. But in 42 berths nationwide, high standard harbor development plans centering on the construction of 14 m deep berths are being put into action. For the construction of such ports, the development of high technology for securing both a 10% reduction in construction costs and high seismic resistance are based on the lessons learned from the Great Hanshin Earthquake Disaster of three years ago.

After the opening of Kansai International Airport in September of 1995, the 7th airport development 5-year plan was decided by the Cabinet in December of 1997. To deal with the expected increase in air transportation demand of the 21st century, the plan is designed to realize an international hub airport comparable to those in other countries[4]. For this purpose, in addition to the realization of a general plan for Kansai International Airport designed to start the common use of a new runway in 2007 and the development of New Chubu International Airport for Aichi International Exposition scheduled to be held in 2005, the third stage of the Haneda Airport Extension, the second stage of Narita Airport and the construction of New Metropolitan International Airport will be carried out.

2.3 Internationally competitive urban development giving consideration to safety and environment

Concerning seismic design completed after the Great Hanshin Earthquake Disaster of three years ago, following the revision of "Specification for the Road Bridge Construction" in December of 1996, "Technical Standards for Port and Harbor Facilities in Japan" is scheduled to be revised in March of 1999. Accordingly, all standards, including main civil engineering standards and currently studied seismic standards for railway structures, will be completed. Of these, new demand performance has been requested for steel materials used in civil engineering. Thus, the steel makers will be required to provide higher performance steel materials in the future.

In January of 1996, the "agreement on government procurement" of the World Trade Organization (WTO) went into effect, and it was stipulated that equal treatment should be provided to domestic and foreign corporations for construction work and public works. Thus, construction related companies must obtain ISO9000S and ISO14000S, and JIS standards related to civil engineering steel materials will have to be gradually made compatible with ISO standards[5].

Furthermore, according to the protocol of the Third Conference of the Parties to the Framework Convention on Climate Change (COP3) adopted in Kyoto in December of 1997, Japan needs to reduce CO_2 emissions by 6% from 1990 levels. The steel industry decided to aim at 10% reduction in the steel manufacturing process by evaluating the possibility of energy conservation in the respective stages of steel manufacture, steel material transportation and steel material utilization based on the concept of life cycle assessment (LCA) and also 7% energy conservation by diffusing highly functional products including wide steel sheet piles, high strength steel, new weathering steel, steel sleepers, and so on[6].

3. Demand for Steel Materials Used in Civil Engineering and Approach of Steel Makers

3.1 Development of "deck-girder-pier-foundation system" in bridge field

For promoting the construction of superhighways at low cost, an integrated approach to a bridge system as a whole is necessary. A bridge girder rolling fabrication system shown in **Photo 1** is one such example.

For bridge girders (upper work), the development of steel bridges themselves including high performance steel and technology development for providing structures mixed/synthesized with concrete must be made.

Concerning approaches to raw materials, "Research Group on Steel Bridges" was organized in the Kozai Club. The purpose of this Group is to give an impetus to the utilization and development of steel varieties having higher performance in tensile strength, ductility, welding and bending formability and anti-corrosion characteristics compared with steel varieties generally used for steel bridges. The Group is trying to standardize high performance steel not included in JIS on behalf of the Kozai Club and to create a mechanism which enables steel material users to adopt rational steel bridge construction based on the high performance of steel materials (see **Table 1**)[7].

In October of 1997, the Japan Society of Civil Engineers published "Draft of Design and Construction Code for Mixed Structures". As Nippon Steel's approaches to mixed/synthesized structures for joining between steel girders and pre-stressed concrete girders (PC girders), the application range of a steel and concrete fixing method by perforated steel plates will be expanded in the future, the fixing method having been put to practical use by a high-speed execution method for high piers.

Concerning foundation structures, it is expected that in addition to the improvement and revision of the conventional steel pipe pile work method, steel-soil cement composite piles made by synthesizing cement milk established in the soil and steel pipes having projections will greatly contribute to the development of urban civil engineering work, which has suffered from the problem of earth removal caused by in-situ concrete piles (see **Photo 2**).

3.2 Timely proposals in harbor field

In the harbor field, before the upcoming second "age of great navigation", there is a pressing need to develop low-cost berths

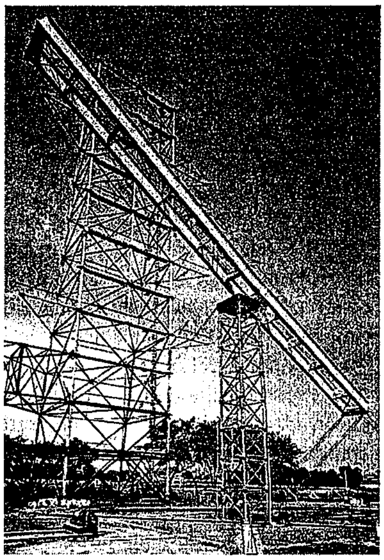


Photo 1 Jack-up erection work method

Table 1 Outline of high performance steel for bridge

Item	Name
Tensile strength	High strength steel, Constant yield point steel (thickness of over 40 mm), Narrower-range yield point steel, Low-yield-point steel, Very soft steel, Very thick steel plate
Ductility, Weldability	High ductility steel, Low-weld-cracking-susceptibility steel, Large-heat-input-weldability steel, Anti lamella tear steel
Anti-corrosion capability, Others	Weathering steel, Galvanized steel, Stainless steel, Clad steel, LP steel (taper plate), Vibration Damping steel , High strength wire for bridge

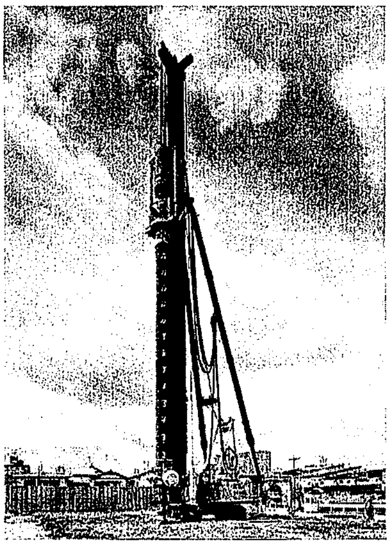


Photo 2 Steel-soil cement composite pile

for deep sea areas. Conventionally, the rahmen structure with supported piles (underwater strut beam method) composed of steel pipe sheet piles and steel pipe piles was developed to realize a work method of arranging a longitudinal direction in a usual berth with steel pipe piles and transverse strut members. This work method is very effective for deep water work, where there are very soft clay and a deep support layer (see **Photo 3**).

For the construction of a large international hub airport, research on Mega-float (super floating marine structure) has been active, and a verification experiment is planned for taking off and landing on fixed wing of aircraft at a floating airport of 1,000 m class in fiscal 1998. For utilizing Mega-float as a comprehensive technology for very long durability, the level of the anti-corrosion technology conventionally developed for the construction of port steel structures must be improved. At present, there is hope for the practical application of titanium to the splash zone (see **Photo 4**)[8].

3.3 Surface/linear development of urban underground space

Tunnel markets in urban areas have been increasing in size year by year in the field of developing underground roads and underground railway lines. For the development of urban underground space, shield tunnel construction has mainly been carried out in recent years because of the relationship with upper space and the depth of work. Thus, efforts have been made to develop steel materials used for resisting structures with large sections for supporting surface space such as for underground station resisting walls or shield machines to set up vertical shafts and the tunnel linings for tunnel main bodies.

Concerning surface approaches, efforts on the part of makers to develop designs for two-dimensional slabs and reduce manufacturing costs achieved good results for NS-BOX which has been sold for the past ten years. Orders easily exceeded 10 thousand tonnes in fiscal 1997, and future prospects for this product are very bright.

Concerning linear approaches, because of the development of segments which can omit the second tunnel lining, a reduction of about 8% has been made in construction costs. Nippon Steel has provided a segment menu for using NM segments (fitting type synthetic segments) for large sections such as underground rivers and CP segments for common ditches or sewage work, and has promoted various steel material menus such as joints with high rigidity for CP segments. Both of these segments have synthesized structures made of steel and concrete, and for NM segments, special NM shape steel has been developed for rationalizing on-the-spot fabrication work and segment manufacturing. Its basic structure is a steel frame fitting without bolts which is made by filling a steel core made of H shape steel and a thick plate with concrete. CP segment is obtained by changing the conventional steel segment to four main girders for minimizing fabrication, and concrete is placed in the steel core (see **Photo 5**).

Furthermore, for the cable box corresponding to the foundation development of an information communication network, CC-BOX (cable steel pipe) has just been put to practical use by joint development in the Kozai Club (see **Photo 6**).

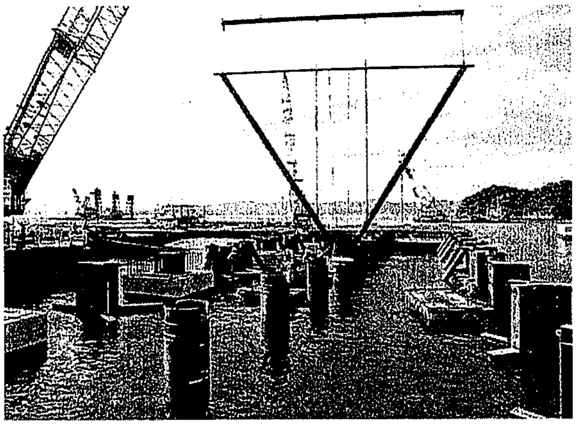


Photo 3 Underwater strut beam method

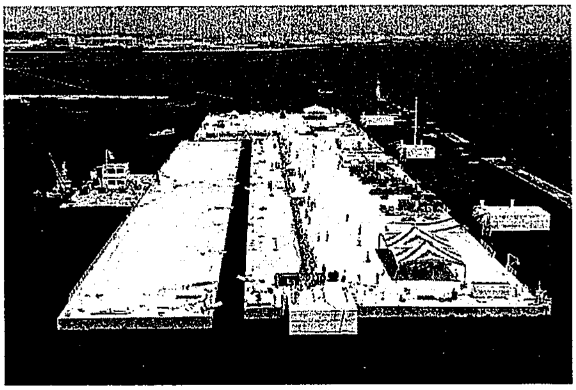


Photo 4 Ultra-large floating structure work method verification experiment[8]

Photo 5 CP(Concrete-plate) segment

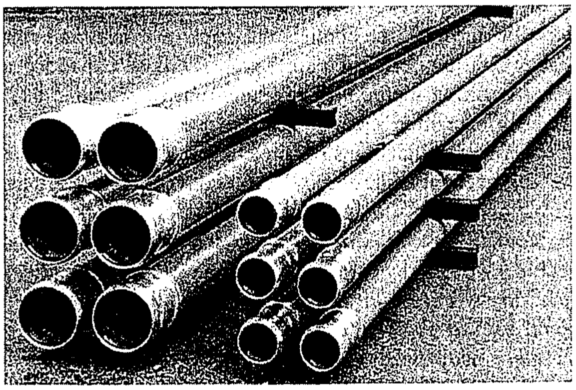


Photo 6 CC-BOC cable protection steel pipes

Table 2 Request for steel material in civil engineering field in the Great Hanshin Earthquake Disaster

Field	Idea	Request for steel material
Road: "Specification for the road bridge construction"	• Investigation by maintained horizontal resisting force method at time of earthquake regarding steel bridge and foundation	• Utilization of high performance steel material having high ductility, weldability and machining capability • Improvement of plastic performance of steel material
Railway: "Basic idea for new seismic standard"	• Consideration of earthquakes at level 2 • Importance of structure is decided based on the degree of damage effect to human life or the difficulty of recovery	• Establishment of seismic reinforcement work method menu by rahmen high pier steel pile (bolt joining type, fitting joint type, sheet pile joint type)
Harbor: "Reevaluation of seismic standard for harborand port facilities"	• Addition of the investigation of function maintenance by checking on deformation or the like in seismic reinforced berth	• Improvement of plastic performance of steel material (steel pipe pile, steel sheet pile)

3.4 Approach to cost reduction and safety

Concerning civil engineering public works, there is a pressing need to develop raw materials and a work method which contribute to cost reduction, and efforts have been made to develop civil engineering steel materials in various fields.

In the river/harbor field, three types II_w, III_w and IV_w of wide steel sheet piles having a greater effective width of 600 mm compared with the conventional type (400 mm) and receiving big demand have been put on the market centering on the river/marine/harbor field since 1997. Now, its annual volume has exceeded 40 thousand tonnes.

Concerning approaches to safety, various ideas (see **Table 2**) of the related organizations for seismic design have been arranged in sequence, and demand for steel materials providing higher performance has increased. Nippon Steel is currently engaged in building a joint research system with the Public Works Research Institute of the Ministry of Construction, and the Port and Harbor Technical Research Institute of the Ministry of Transport through the Kozai Club, the Japanese Steel Pipe Pile Association and the Japanese Steel Structure Association.

4. Conclusion

This paper described in outline the approaches to Public Works Projects and the development of civil engineering steel materials for the development of social infrastructure. In the future, environmental problems, internationalization and performance design will need deeper discussion.

Concerning environmental problems, in the Ministry of Construction, discussion is now under way for the reduction of CO_2 emissions in the manufacturing stage, energy conservation in the constructing state, the long life of structures after construction and recycling capabilities in an effort to develop materials for ecosystem development (eco-material). This is why there has been an increase in demand for the development of steel materials having high strength and good durability. In the future, Nippon Steel intends to rebuild a systematic organization mainly through the Kozai Club, the Japanese Steel Structure Association and the Japanese Steel Pipe Pile Association on the basis of research projects for civil steel structures of universities and colleges currently promoted by five blast furnace corporations.

The market for the steel materials of civil engineering was originally based on domestic demand, but recently the wave of internationalization has been closing in at a fast speed. Thus, in the future, higher quality and higher performance products will have to be manifested as much as possible.

Concerning performance design, not only the descriptive expression of standards and manuals has changed but also a mechanism for carrying out standards and manuals including design process, responsibility sharing among engineers, and so on, have changed. Thus, the steel makers will have to deal with performance design by advancing the above internationalization.

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