Japan Society of Civil Engineers 1992 Study Tour –Travel Report-

Svante Roupé
Scandiacounsult International
(Recommended by the Swedish Society of Civil and Structural Engineers)

1. Introduction

In 1992 the Japan Society of Civil Engineers decided to offer study tour grants to six different countries, to promote exchange and dialogue between civil engineers. One of these grants was offered to the Swedish Society of Civil and Structural Engineers, and I was given the honour of being chosen as the very first recipient.

Such a dialogue is a very important way to enhance mutual understanding between colleagues in different cultures and different parts of the world, and to learn from each others experiences and the ways problems are solved. It is also much more interesting to get a view of culture projects and techniques by means of study visits to the sites and discussions with the engineers involved, than by merely reading about them in international branch magazines.

This travel report aims at giving the reader a brief insight in a few of the large civil engineering projects currently going on in Japan, but also to inspire him to make connections and tie bonds between notions and cultures.

2. Study Tour

A study tour like this needs thorough planning a long time in advance. In this process I got invaluable help from the JSCE in arranging a suitable schedule. On an early stage I was asked to suggest projects and institutions of interest for study visits.

Mr.Roupé (left), Dr.Fujii (Presindet of JSCE, 1992-93)

Being specialized in airport and port design myself, with an emphasis on coastal engineering, of course I was interested to study this kind of projects. However I asked for other disciplines as well, and the study tour schedule that JSCE finally arranged for me was a wide and interesting spectre of Japanese skill within the field of civil engineering.

The study tour was performed during November 7 to November 18, 1992.

3. Civil Engineering Projects

3.1 Airport Projects

3.1.1 Kansai Airport

A full day was dedicated to Kansai new airport. I was received at Kansai International Airport Co's head office in central Osaka by Mr. Shinohara and Mr. Furukawa, who gave detailed and very interesting background information about the project.

The Osaka Bay area today has a population of some 23 million people. Osaka is a busy commercial centre, and the existing Osaka airport has 370 aircraft movements per day, a number that is increasing all the time. But its location in densely built-up area results in that it has to be closed form 9 PM to 7 AM due to disturbing noise. Congestion is already a big problem. There is no land available for further expansion. The bay shores are surrounded by steep mountains, and all flat land is already developed.

The demands on a site for an entirely new airport are; enough flat land for the airport itself and its surrounding activities, approach directions free of obstacles, location isolated enough to allow 24-hour operation, but yet easily accessible. The answer was-in the bay!

Necessary land for the new airport is crated by constructing a 511 hectares man-made island in Osaka Bay. This gigantic land reclamation, made at a water depth of 18m, requires a total volume of 180 million cubic metres fill material. All this material is transported from pits shore to the island location 5km offshore.

The sea bed consists of a 20m stratum of sort alluvial clay, under that a sand layer and then Pleistocene clay. To accelerate the consolidation of the upper clay layer the vertical drain method is used. To drain the 20m alluvial stratum, sand piles with a diameter of 0.4m have been placed in a grid 2.5 by1.6m. The total number of such piles amounts some1 million. The settlement of the alluvial and the underlying, Pleistocene clay was estimated to be 8m after 50 years. However, surveys conducted in1990 showed that the settlement rate was greater than expected, and the total settlement was reestimated to 11m. This suddenly created a demand for further 17million cubic meters of reclamation fill to keep the island airport at the planned height above sea level.

The airport will have one 3500m runway, but plans have already been presented to expand the island for 2 more runways.

The huge terminal building in steel and glass, to some extent inspired by Paris Charles de Gaulle airport, is designed by world famous Italian architect Renzo Piano.

The island will be accessed by a3.75km bridge in two storeys with a dual 3-lane expressway on the top floor and a dual railway below. There will also be a high speed ferry service to Kobe city centre.

After the thorough briefing, Mr. Shinohara escorted us on a visit to the island by boat. To understand the huge dimensions of this large scale project, it was almost necessary to see it all on site. The coordination of son many contractors and different activities at one time was in itself fascinating to watch.

3.1.2 Haneda Airport Extension

Haneda Airport, Tokyo’s domestic airport, is currently undergoing major extension works, which all has to be performed amid busy air traffic.

An extensive land reclamation is made, where 3 new runways will be constructed along with taxi-ways, aprons, terminal complexes and new road and monorail facilities. The complex works are performed by a number of contractors, one of which is Kajima. I was taken on an interesting full day tour around the vast site. All works have to be made during full operation of the busy existing airport. The first of the new runways is already completed and in use, alongside with the two old ones.

The seabed where the land reclamation is made is a former waste disposal area, and soil conditions are extremely poor. The sludge-like material which is referred to as the dredged in Tokyo Bay shows the same characteristics. This is all consolidated in 6-12 months by means of vertical drains and an enormous preload, consisting of several meters of extra fill material that will be excavated again when this period of accelerated consolidation is over. Nevertheless, all apron slabs and building foundations have recesses for jacks, in order to compensate for the settlement still expected to occur after completion of the construction works.

The project also includes a new road tunnel under a part of Tokyo Bay, to provide easier access to the airport.

3.2 Port and Townscape Projects

3.2.1 Kobe Port Island

I was received at the city hall of Kobe by Mr. Toyoda from the Port & Harbour Bureau. Mr. Toyoda gave me interesting information about the Port of Kobe, the large expansion projects recently performed, works in progress and future plans.

The Port of Kobe incorporates many different activities, including large shipyards, but the most important cargo handled is containers. Kobe is one of the biggest container ports in world, with an annual throughput of 2.5 million TEU. To provide the necessary stacking areas as well as easily accessible berths, a man-made island with an area of 436 hectares was created, known as Kobe Port Island. The reclamation works were completed in 1981. About half of the island belongs to the Port of Kobe, while the remaining, central part belongs to the City of Kobe, and is used for residential areas, large hotels and other activities.

The island is accessed via a bridge that, except for the car lanes, also leads the Portliner railway to the island. This is an automatic, computer controlled railway running on overhead tracks, with a capacity of 10000 passengers per hour.

A second island of reclaimed land, Rokko Island, has recently been completed. This island measuring 580 hectares, is also shared between urban functions in the central parts and port activities in the peripheral areas. Works are in progress with Kobe Port Island stage 2, an extension that will add 390 hectares at the southern end of the existing island by the year 1996. As this will generate increased volumes of road traffic, a new road tunnel will be constructed to the mainland, and another one to Rokko Island.

Plans have already been presented for development of a new airport on yet another man-made island outside Kobe Port Island.

In order to build the artificial island, earth and sand has been excavated from the mountains behind the city. To move the earth from the mountainside to the sea, an integrated system was created to increase efficiency of the engineering works and to minimize the environmental impact on the city. A large conveyor belt transports the material through a mountain tunnel, thereafter the belt continues elevated and covered through built-up area to an automatic loading pier for hopper barges. The excavated area, in turn, are used for new residential and industrial estates.

After a presentation Mr. Toyoda took us on an interesting tour around Port Island, and showed the ongoing reclamation and soil improvement works for the second stage.

3.2.2 Minato Mirai 21

The seafront of Yokohama is currently undergoing major changes, giving the city a new face towards the Tokyo Bay. I was received at Yokohama's Municipal Office by Mr. Okazawa and Mr. Seki, who presented the Minato Mirai 21 Project. This is an enormous urban development project, changing the function of a vast area in the central part of the existing city.

Yokohama is Japan's second largest city, with a population of approximately 3.25 million people and is since long one of the world's biggest ports. There are 91 berths operated by City of Yokohama, and in addition to that a great number of privately owned and operated berths.

Minato Mirai 21, that is the main part of "Yokohama 21st Century Plan", has two objectives:

(1) to concentrate into one area Yokohama's city centre which is presently divides between the area around Yokohama Station and the Kannai district, and (2) to create new functions like a seafront park and recreation area, large convention facilities, hotels, cultural activities etc, as well as new arterial roads.

186 hectares of land has been allocated for this purpose, of which 110 hectares are existing land from the inner harbour area. This was formerly a port zone, also with heavy industrial

activities like shipyards etc. All of these factories were rather old and deteriorated and have now moved to new and more functional areas in outer parts of the port. The land obtained by clearing these areas was enlarged by reclamation of further 7 hectares of land. On this area the town planners and architects have had the challenging task to create a functional environment for conventions, business, commercial and cultural functions as well as recreation. It is a project carefully prepared in all scales, from the smallest details to monumental buildings like the new, high-rise Landmark Tower with 70 storeys. The seafront pedestrian area, situated in the heart of a busy port, has an existing view.

Minato Mirai 21 aims at being renowned over the world as the ideal spot for international conventions and exhibitions, easily accessible and with facilities to meet all needs.

After the presentation, we were taken on a boat tour around the port, looked at all berths and stacking areas and passed under the impressive Bay Bridge, a 860m long cable stayed bridge. Finally we disembarked at Pukarisanbashi Pier and walked along the shoreline promenade, through the Rinkoh Park to the Exhibition Hall at the Pacific Convention Plaza. An interesting glimpse of the 21st Century.

3.3 Bridge and Road Tunnel Projects

3.3.1 Akashi Kaikyo Bridge

The Akashi Kaikyo Bridge will be one of three connections between Honshu and Shikoku islands two of the four main islands in Japan. The bridge is going to be the longest suspension bridge in the world, with a total length of 3910 m and a centre span of 1990 m.

I was greeted at the site office by Mr. Kawaguchi, who told me about the planning of the project and the engineering problems encountered during the design phase. After that, I was taken out by boat to the Akashi Straits, a busy fairway utilized by about 1400 ships per day, to have a closer look at the works in progress on the caissons and towers.

The clearance at the centre of the bridge will be 65m. The two towers will be 297m high, founded on steel caissons. These were prefabricated ashore, towed in place and sunk in a water depth of approx 40-45m. One problem was to avoid undermining of the foundations by scouring, as very strong tidal currents occur in the straits. The caissons are set on filter beds of graded stone material, designed for a current velocity of 4.5m/s. The bridge structure is designed for an average wind velocity of 46m/s during 10 minutes, with a peak of 80m/s. and for an earthquake of 8.5 on the Richter scale. These conditions have a statistical return period of 150 years.

The bridge will have 2x3 lanes, and be a part of a new highway system, stretching from Honshu, the largest of the Japanese islands, via the relatively small Awaji Island to Shikoku.

3.3.2 Trans Tokyo Bay Highway

The Trans-Tokyo Bay Highway Project will result in a 15km toll highway that runs across the central portion of Tokyo Bay from east to west in connecting Kawasaki district on the Tokyo side and Kisarazu on the opposite side of the bay. Two 10km long tunnels will lead under the Kawasaki waters where surface traffic is heavy, and 1 5km long bridge over Chiba waters where surface traffic is sparse.

There will be two man-made islands along the stretch, one at the middle of the tunnel, and one where the traffic is led from the tunnel up to the bridge. The tunnels will be made using shield tunnelling technique, with an outer diameter of 13.9m for each tunnel.

At the centre of the tunnel is Kawasaki Man-Made Island. This circular, 193m diameter island is being constructed for the purpose of providing a base for the shield tunnelling works during construction, and to serve as a ventilation shaft for the traffic after completion. The water depth is 28m, and to a depth of more than 30 m under the seabed the soil is very soft.

The Kisarazu Man-Made Island is constructed to create a slope on which the tunnels will rise from the bay bottom to the bridge embankment. The 5km bridge will consist of steel piers on steel piles, supporting a superstructure of steel box girders with orthotropic decks. It will be 40.85m high at the centre spans of the deep water area, where the fairway will cross under the bridge.

I was taken out tour the site by boat. First we saw the works at the Kawasaki side then we visited the Kawasaki Man-Made Island, to see the ongoing construction works. After this stop we went past the Kisarazu Man-Made Island and the works on the bridge piers.

3.4 Tunnelling and Rock Cavern Projects

3.4.1 Loop 7 Underground River

Due to urbanization and paving of most areas in Tokyo, flooding of the existing rivers during heavy rainfall has become a frequently occurring problem. To widen the existing rivers is difficult because of the problems to obtain the adjacent land. Therefore Tokyo Metropolitan Government has decided to develop an “underground river system”. Underground rivers are constructed under arterial roads, combined with regulation ponds, to help accommodate the water during a peak flow situation.

The total length of Loop 7 Underground River will be 30km. It will draw water from ten different rivers on its way down to Tokyo Bay, where the water will be discharged by pumps. The first portion of the project, Loop 7 Underground Regulation Pond, is an excavated tunnel, about 2km long and constructed by a joint Venture with Kajima as one of the partners. The pond is made by using shield tunnelling technique. For this purpose a shield tunnelling machine with an outer diameter of 13.94m, the biggest such machine in the world, has been developed.

When I visited the site, the excavation works of the tunnel itself had only just begun. From the 28 m Diameter launching shaft, some 50m had been driven through the gravel and silt layers at a depth of 50m below ground level. The average tunnelling capacity will be 5m/day during full operation, which will generate 700 cubic metres of excavated material per day. Although not very long yet, it gave the full impression of the huge machine and the automatically set and anchored, pre-fabricated concrete shields.

3.4.2 Sabigawa Dam Project

The Sabigawa Dam Project is situated close to the town of Nasu-Shiobara, about 130km north of Tokyo. This is an area famous for its scenic landscape.

I was met by Kajima's site manager, who first took me to the site office, where I was shown a video and was given some further information about the project. Thereafter we went to see the site, beautifully situated within the Nikko National Park. Because of the location, special care has been taken during all phase of construction to preserve the environment.

The project consists of the construction of a pumped storage power station. The principle is to lead water from an upper reservoir through turbines to a lower dam in the daytime, i.e. more or less an ordinary hydropower plant. During night however, when electric power is less expensive, the water is pumped back the reverse direction, to the upper dam. The next day the same water is used again to generate power when the demand is high.

The upper dam is a rockfill dam with an asphalt concrete facing. It is 90.5m high, making it the highest dam of its type in the world. The lower dam is a concrete gravity dam with a height of 104m. From the upper dam with a gross storage capacity of 11900000 cubic meters, tunnels with a total length of 2.3km are drilled through the mountain, to form headrace, penstock and tailrace, leading down to the lower dam. Effective water head is 338m. The largest tunnel is the headrace, with a diameter of 8m.

The powerhouse is also situated in a rock cavern, about 300m below the mountain surface. This cavern is 29m wide, 51m high and 165m long, housing three generator units, each 300MW. The total excavated volume of rock from tunnels and powerhouse is 238570 cubic meters.

3.5 Research Institutes

3.5.1 Kajima Technical Research Institute

Kajima Corporation have their own large research facilities in Tokyo, the Kajima Technical Research Institute. This Institute has amazing resources to perform research in a wide field of disciplines. I was shown several different laboratories, e.g. the hydraulic laboratory that among many facilities has a large wave basin with a computer-controlled, serpent type wave generator able to create all kinds of irregular waves by superposition. I also visited the laboratory for soil mechanics, where a huge geotechnical centrifuge was demonstrated.

Another impressing visit at the institute was the earthquake research department, with its computer-controlled shaking table. 5x5 m, it is capable of producing a 2 G acceleration in both horizontal and vertical direction, loaded with a 30ton test specimen. This way it is possible to simulate earthquake forces on very large models as well as full scale tests on individual building members. One result of this research is a proposed high-rise building, where the stiffness of the steel-frame structure is continuously variable by a computer. When this building is rocked by seismic forces, the swaying of the structure can be damped out. I also saw acoustic laboratory with its Anechoic chamber and many other facilities.

In elegant exhibition halls many results of the research were shown, such as light-weight carbon fiber reinforcement for concrete, proposed floating residential complexes, floating waste incineration plants, etc, etc. Indeed a creative environment!

3.5.2 The Port and Harbour Research Institute of Yokosuka

The Port and Harbour Research Institute of Yokosuka is situated some 50 km from central Tokyo, close to the mouth of Tokyo Bay. I was received by Dr. Katoh, who is head of the littoral drift division and laboratory at the institute.

This institute performs research within all fields of engineering related to marine structures. After having been welcomed by Mr. Watanabe, Director General of the institute, I was guided around the different divisions, where I was given brief introductions to the current research projects.

First I was shown AQUAROBOT, a robot for various underwater tasks, developed at the institute. This is a remote controlled, six-leg concept allows it to operate on very rough surfaces like e.g. a collapsed rubble mound breakwater, where wheel or caterpillar type robots have difficulties to move.

Then I was shown a large laboratory hall for large scale loading experiments, with two 15 m long reaction walls at right angles, and a reaction floor. The walls and floor are designed for 1MN of shear stress and 2MN bending moment per unit width. The laboratory has actuators with a maximum force of up to 1.5MN, to carry out statistical as well as dynamic tests on large specimens. This is used e.g. for fatigue tests on caisson walls. Next stop was hydraulic laboratory with its large, computer controlled, submergible shaking table. With this equipment it is possible to perform large scale tests of the impact of earthquake forces on marine structures. This laboratory also possesses a large basin for current trials.

At the time of our visit model tests were carried out on rubble mound structure exposed to forces from a Tsunami induced current, that may reach 8m/s. In the same hall is a wave basin with a serpent type, computer controlled wave generator, able to simulate all kinds of irregular wave patterns. We also visited the soil mechanics laboratory, where I among other things saw a large geotechnical centrifuge.

Dr, Katoh told me about the Hazaki Oceanographically Research Facility (HORF), operated by the littoral drift division. This is a research pier, a 427m long concrete structure on steel piles and columns, stretching perpendicularly from a sandy beach.

By using this facility it is possible to follow and record a sea wave breaking, propagating through the surf zone and rushing up on the beach. Changes in bottom topography, caused by different wave climate conditions are also continuously registered. Sampling this kind of data, alongside with meteorological recordings and analyzes of sediment size distribution, is of great value in the research to understand the mechanisms of littoral drift and predict the evolution of a sandy coast.

Unfortunately these premises are located to far away to visit in the same day, but I was shown interesting photographs and results of measurements carried out there.

4. Conclusions

Comparing civil engineering in Sweden and Japan shows many differences but also many similarities. One difference is the scale of the projects. Japan today is in a way what the United States used to be; many projects are in one respect or the other “biggest in the world”. This is to a large extent conditioned by the population density. Virgin soil is a limited resource, and land prices are sometimes enormous. This can make technical solutions that would never be financially justifiable in Sweden the best solution in Japan.

What may be absolutely necessary for Tokyo with some 12 million inhabitants, is maybe not even interesting in Sweden and Denmark, to promote business and communication within Europe.

Earthquake forces is something we do not have to consider at all in Sweden, with the stable geological conditions prevailing in the Scandinavian mountain ridge. Rock mechanics is a field where Swedish engineers since long have a reputation of being on the frontline, and there are at present several joint venture projects between Swedish and Japanese companies related to e.g. rock tanks for oil and storage of nuclear waste in rock caverns.

In the field of environmental engineering both Japan and Sweden have come very far. However, since it is still a young science, exchange of experiences can bring it much further.
Regarding industrial welfare and security on construction sites, both countries have a conscious attitude.

When it comes to standard of housing and conditions in offices. Sweden still is the leading country. One thing that is striking about Japan is the large investments in research and the impressive facilities available, in governmental institutes as well as in research departments within the leading construction companies. Finally I would like to thank the Japan Society of Civil Engineers for giving me this fantastic chance to visit Japan. It was an unique and most valuable opportunity, not only to get a closer view of Japanese know-how in the field of civil engineering and have fruitful discussions with skilled colleagues, but also to see the beautiful country and learn more about the rich culture and traditions of Japan.