Large-scale Shoring Work in Existing Building

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NKK successfully constructed surface treatment lines, including an electrolytic tinning & tin free (chromium plating) line, at the Erdemir Iron & Steel Works on the coast of the Black Sea in Turkey. One of the most difficult components of this project was the large-scale shoring work in an existing building, which was performed under various restrictions including the choice of construction method, limited construction materials and restricted construction space on site. Shoring was necessary to excavate a half of the building area (1950 m^2) and construct two concrete pits (10 m deep). As a result, the shoring work was safely completed, and the efficiency of the work plan was demonstrated. Problems during construction, along with the associated countermeasures and their effects on this large-scale shoring plan are introduced.

1. Introduction

Erdemir Iron & Steel Works is the largest integrated iron & steel works in Turkey. The facility is located at the town of Eregli on the coast of the Black Sea at a distance of about 200 km East of Istanbul, as shown in **Fig. 1**. NKK has carried out construction at this facility continuously since the 1970's, including the installation of blast furnaces, engineering for the second-stage extension, and delivery of CAL equipment. Recently, following new construction of a series of cold mills, a facility extension was planned to increase the capacity of the existing cold mill. In June, 1997, NKK received orders for an electrolytic tinning line, a sheeting line, and an electrolytic cleaning line. This was a turn-key contract ranging from the design and procurement of equipment to earthwork & building work to the installation of equipment.

A major feature of the earthwork & building work in this project was the large-scale shoring required for looper pits, which are located in the entry and exit sections of the electrolytic tinning & chromium plating line within an existing building. This work was on the critical path for the whole project, so that any delay in this work would result in a delay in the delivery of the whole facility.

Fig. 1 Site location

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This report presents an outline of the work plan that was performed in a foreign country, where the freedom in selecting construction methods and materials is low, and that accommodated restrictions from working in an existing building. The description includes problems that occurred during the planning, design, and construction stages, countermeasures against these problems, and the resulting effects, primarily concerning the looper pit work.

2. Outline of equipment foundations

Fig. 2 shows an outline of the earthwork & building work for the electrolytic tinning & chromium plating line that required the large-scale shoring work. Pay-off reels for uncoiling cold rolled coil and tension reels for coiling sheet were required in the entry and exit sections of the line, respectively. The process section, which lies between these reels, has a length of 71 m and is where the coil surface undergoes electrolytic tinning or chromium plating.

Loopers are installed at the front and rear of the process section to perform continuous coiling and uncoiling. The looper section is subject to a height restriction due to an overhead crane, as shown in **Fig. 2**. Therefore, the looper section requires a pit where the top of the bottom slab is as deep as FL –10 m. The top of the bottom slab of the process section must be FL –5 m for the same reason.

3. Plan of shoring work

When the on-site work for this project was started, Erdemir had already completed the extension of the existing building containing the newly-built line. In this building, Erdemir had already driven steel pipe piles with a diameter of 324 mm and a length of 55 m for the foundations of the newly built line. These were installed in a lattice form with an interval of 2150 mm. The floor levels of the looper and process sections are FL –11.5 m and FL –6.1 m, respectively. The method for large-scale shoring work, which accounted for about half of the 4550 m^2 building area as shown in **Fig. 3**, had an influence upon the success or failure of this project.

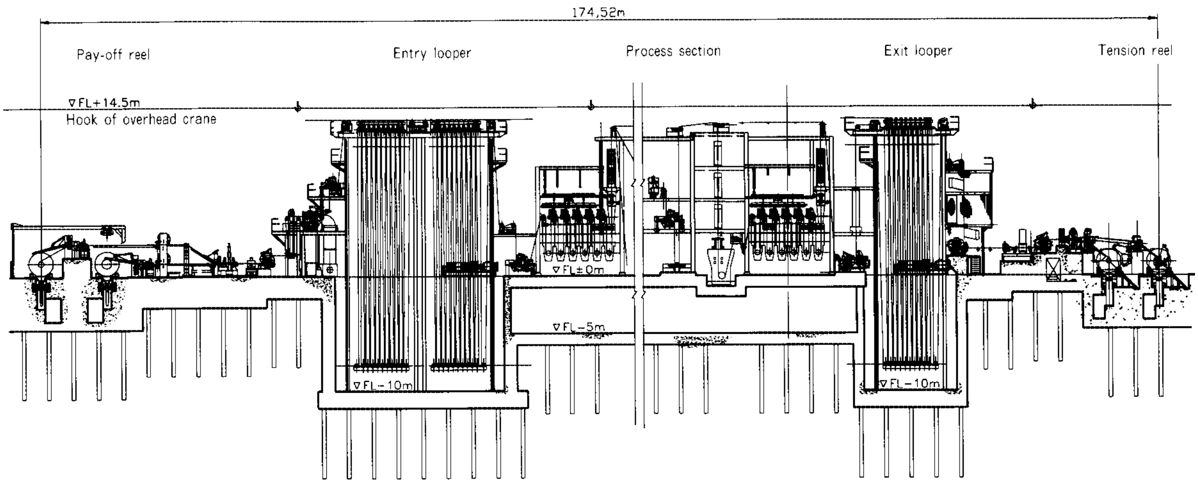

Fig. 2 General arrangement

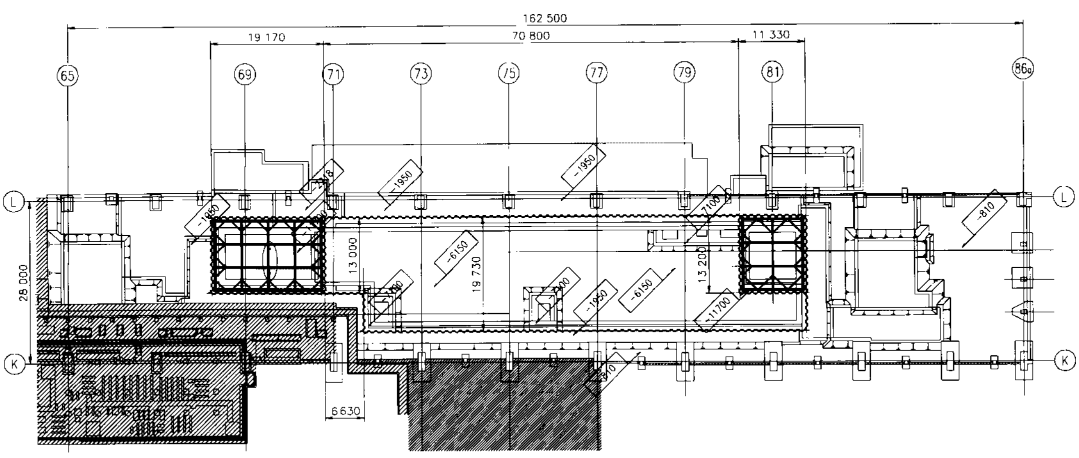

Fig. 3 Shoring plan

3.1 Selection of shoring method and material

The shoring work had to be performed in a limited space within the existing building while avoiding interference with the previously driven lattice piles. Therefore, the shoring method was selected considering the following points.

(1) Method can be used in the existing building
(2) Method has no adverse influence on the existing building foundations
(3) Method has no adverse influence on the operation of the nearby existing production facilities
(4) Local construction companies are familiar with the method
(5) Materials can be acquired on site

3.1.1 Looper pit section

In Turkey, sheet pile installation methods that do not provide a specific joint efficiency are commonly used for shallow excavations, while the continuous bored pile wall method is generally applied to deep excavations.

As shown in **Fig. 4**, the foundations of the existing building are present on the back face of the earth retaining wall. The continuous bored pile wall method is suitable to prevent shifting of the building foundations during the excavation because the earth retaining wall has a higher stiffness than is provided by the sheet pile method. However, it was determined that the continuous bored pile wall method would be difficult to use because the lattice piles that were previously driven in the building may be inclined or deviated, and the construction equipment is subject to a height restriction within the existing building. As a result, the steel sheet piling & bracing method was evaluated instead of the continuous bored pile wall method.

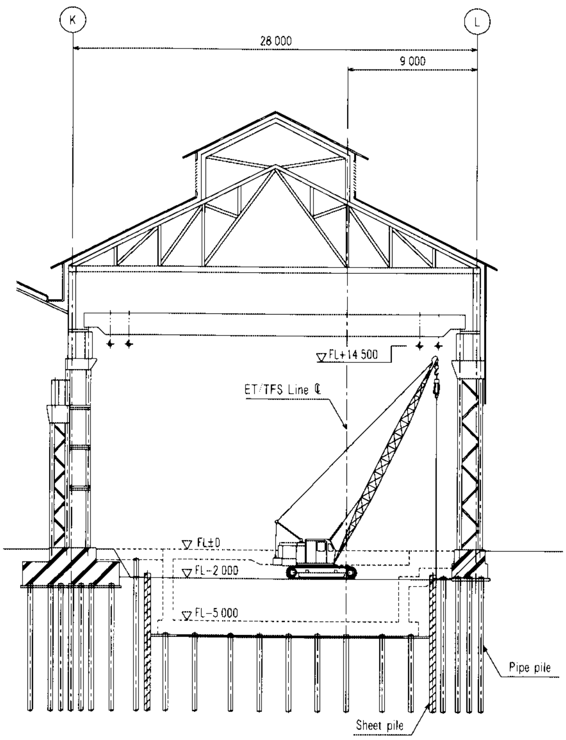

Fig. 4 Sectional plan of shoring work

To restrain shifting of the existing building foundations, it was necessary to use steel sheet piles that can provide a high joint efficiency. However, only secondhand steel sheet piles for the sheet pile installation method were available on the market in Turkey, so that a high joint efficiency could not be expected. Since steel sheet piles were not produced in Turkey, the procurement cost and delivery were investigated. As a result, we decided to import steel sheet piles from a nearby country.

To reduce the cost of wales & struts, a detailed study was made to utilize materials available in Turkey to the extent possible. The study revealed that, although the H steels usually used for wales & struts were all imported, the design could be completed by using imported H steels in combination with I steels produced in Turkey.

3.1.2 Process section

The floor level of the process section is as shallow as FL –6.1 m, compared to the looper pit section where the steel sheet piling & bracing method was used. Because cost reduction and high workability were considered extremely important, a method of installing steel sheet piling without bracing was used on the condition that shifting of the foundations of the existing building was measured during excavation and that the following countermeasures may be taken as necessary.

(1) Leveling concrete 20 cm thick for supporting steel sheet piles from the side could be placed.
(2) Local supporting beams could be placed in front of the foundations of the existing building.
(3) Diagonal bracing could be installed using the existing pile as a brace.
(4) Work could be scheduled to minimize simultaneous excavation in the same area.

3.1.3 Change of work foundation level

The foundation level of the area in which shoring work was to be done was first lowered to a depth of about 2 m to secure a space for hoisting sheet piles in the existing building and to shorten the base length of sheet piles by relieving the earth pressure.

3.2 Design of shoring

3.2.1 Design criteria

Erdemir Iron & Steel Works's in-house design criteria were used. This criteria extensively reflected NKK's design concept because NKK performed engineering for the second-stage extension. The design criteria for shoring is based on manuals published by the Japan Road Association.

3.2.2 Soil property conditions

As shown in **Fig. 5**, the soil on the construction site consists of homogeneous clay with a cohesion strength of C=40–70 kN/m^2. Bedrock for the piles lies underground at –55 m, and the groundwater level is –2 m below ground.

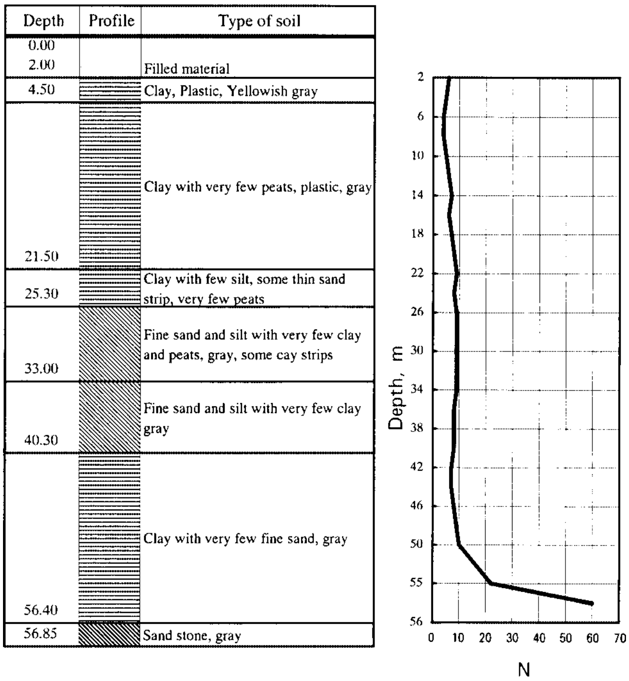

Fig. 5 Soil profile

3.2.3 Design result

(1) Looper pit section

Steel sheet piling & bracing method

Steel sheet pile : 600 mm wide 20 m long

Wales and struts : 3 stages of bracing. Combined bracing was used because a single I–380 has insufficient section modulus.

King pile : Existing piles were left during excavation as well, and bracing was used as a king pile for intermediate support of the bracing.

(2) Process section

Method of steel sheet piling installation without bracing

Steel sheet pile : 600 mm wide 12 m long

4. Shoring work

The steel sheet piles were driven with a 60 kW vibro-hammer since this would not adversely affect any nearby equipment. **Photo 1** shows the progress of sheet pile driving.

Photo 1 Steel pile driving

A backhoe was used for the first-stage excavation of the looper pit section using wales and struts and for the excavation of the process section using steel sheet piling without bracing. Excavation for the second and subsequent stages of the looper section was accomplished using a mini-backhoe.

4.1 Work in entry and exit looper pit sections

4.1.1 Driving of steel sheet piles

Because of the height restriction in the existing building, 20 m long steel sheet piles were cut into two parts, and combined sheet piles consisting of an 8 m long pile and 12 m pile were driven. In this case, the operating time loss of heavy machines such as the vibro-hammer occurs if driving of the steel sheet pile is not started until after welding of the adjacent combined sheet pile is completed, resulting in a decrease in work efficiency. For this reason, and considering the fact that welding can be performed continuously because the interior of the existing building protected from winds, the welding and driving operations were separated. The lower steel sheet piles were driven first, and then every other upper steel sheet piles was welded, as shown in **Photo 2**. After driving the comb-like upper combined sheet piles, the remaining upper steel sheet piles were similarly welded into a comb shape and then driven.

As a result, as shown in **Fig. 6**, the steel sheet piles could be driven efficiently without losing operating time on the heavy machines.

Photo 2 Steel pile jointing

T-shaped corner sheet piles were manufactured to fit the on-site conditions, and the steel sheet pile wall was closed completely, enclosing the entire area.

Soon after the start of shoring primary excavations in the entry looper section, abnormal deformations occurred at part of the steel sheet pile wall. This was presumed to be the result of removing the restraint to earth pressure by the excavation in front of the sheet pile and to the release of strains in the sheet pile accumulated during welding and driving of combined sheet piles. The result was that a kind of buckling phenomenon occurred on the steel sheet pile wall. Fortunately, it was judged that unless further deformation occurred on the steel sheet pile wall, the concrete structure could still be built as designed. As shown in **Fig. 7**, the wales and struts were modified based on the deformation of steel sheet pile wall, and excavation was continued while careful measurements were made. The result was that further abnormal deformation did not occur on the steel sheet pile wall, and the concrete structure was built with the designed location and dimensions.

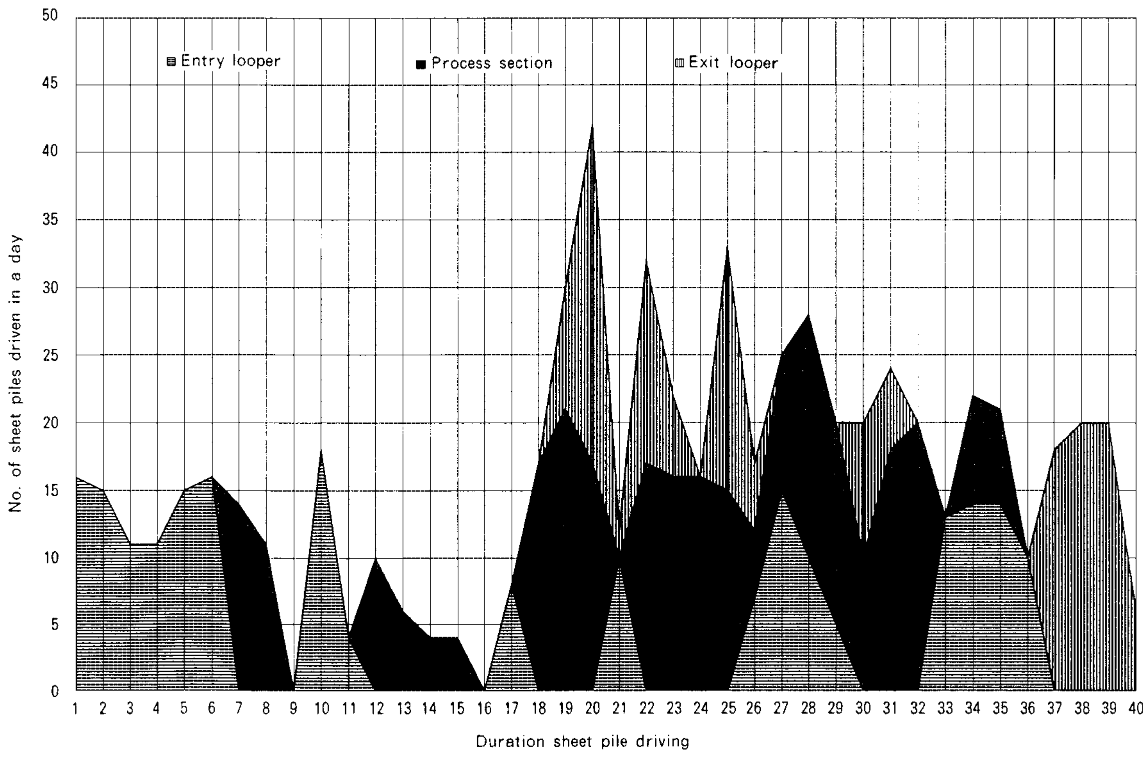

Fig. 6 Progress of sheet pile driving

4.1.2 Abnormal deformation of steel sheet pile and countermeasures

Considering that, at –2 m from the surface, the groundwater level is relatively high, great attention was paid to the cutoff of water in the steel sheet pile joint for the entry looper pit section, for which shoring work was done first. Especially in the four corner sections,

Little inflow of ground water was observed while shoring the entry looper section. Thus, in shoring of the exit looper section, two of the four corners were released to prevent strains from accumulating. As a result, shoring work could be carried on in the exit looper section without the occurrence of abnormal deformation.

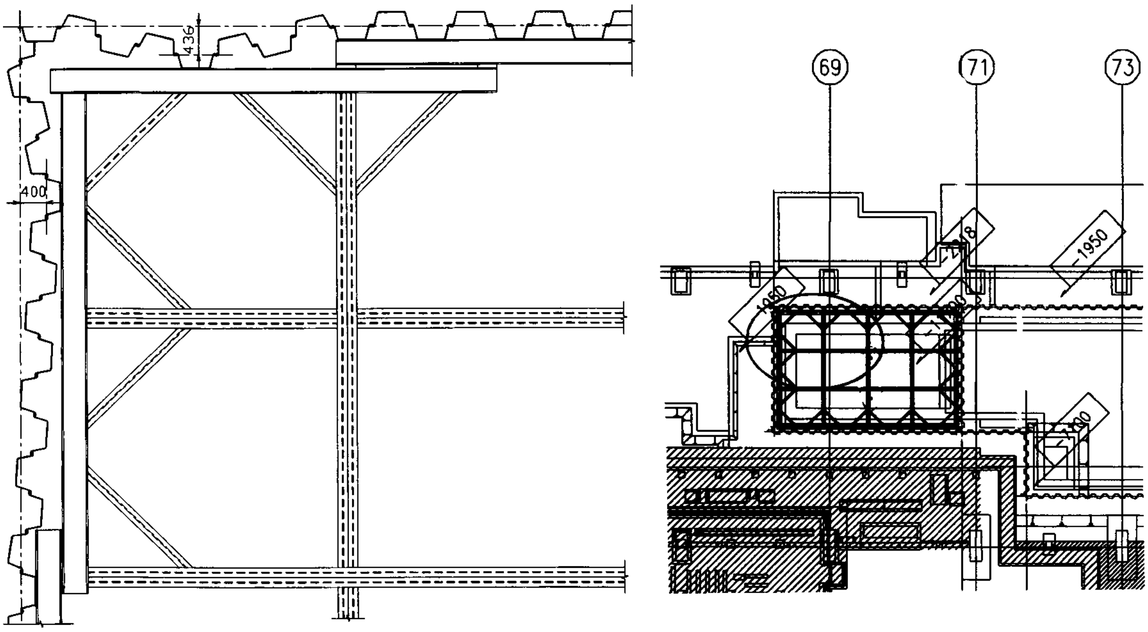

Fig. 7 Deformation of sheet piles

4.2 Work in process section

Excavation of the process section was accomplished by dividing the section into eight blocks, as shown in **Fig. 8**. In the first block, where excavation was started, a tendency for the nearby building foundations to shift was observed as the excavation proceeded within the unbraced, steel sheet pile area. In the first block, the countermeasures that had been evaluated in advance, as described in **3.1.2** (1)–(4), were taken successively. **Fig. 9** shows measurements of the shifting of the foundations of the existing building that occurred during the excavation of the first block.

The measurements taken for the first block suggested that the existing building foundations could shift in other blocks as well. A local support beam was installed as shown in **Photo 3** before the start of evacuation, and work was carried out by using the local support beam for the previous block in the next block. As shown in **Fig. 9**, the second block was also affected by the first block, and a shift in the foundations of the existing building was found. However, the effect of the installation of local support beams became evident in the third and subsequent blocks.

Photo 3 Temporary beam

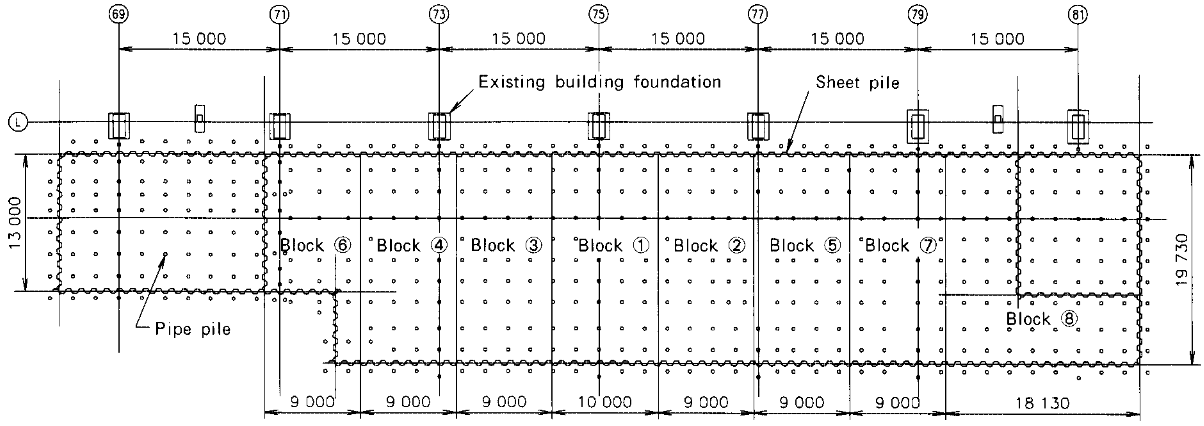

Fig. 8 Allocation of excavation block

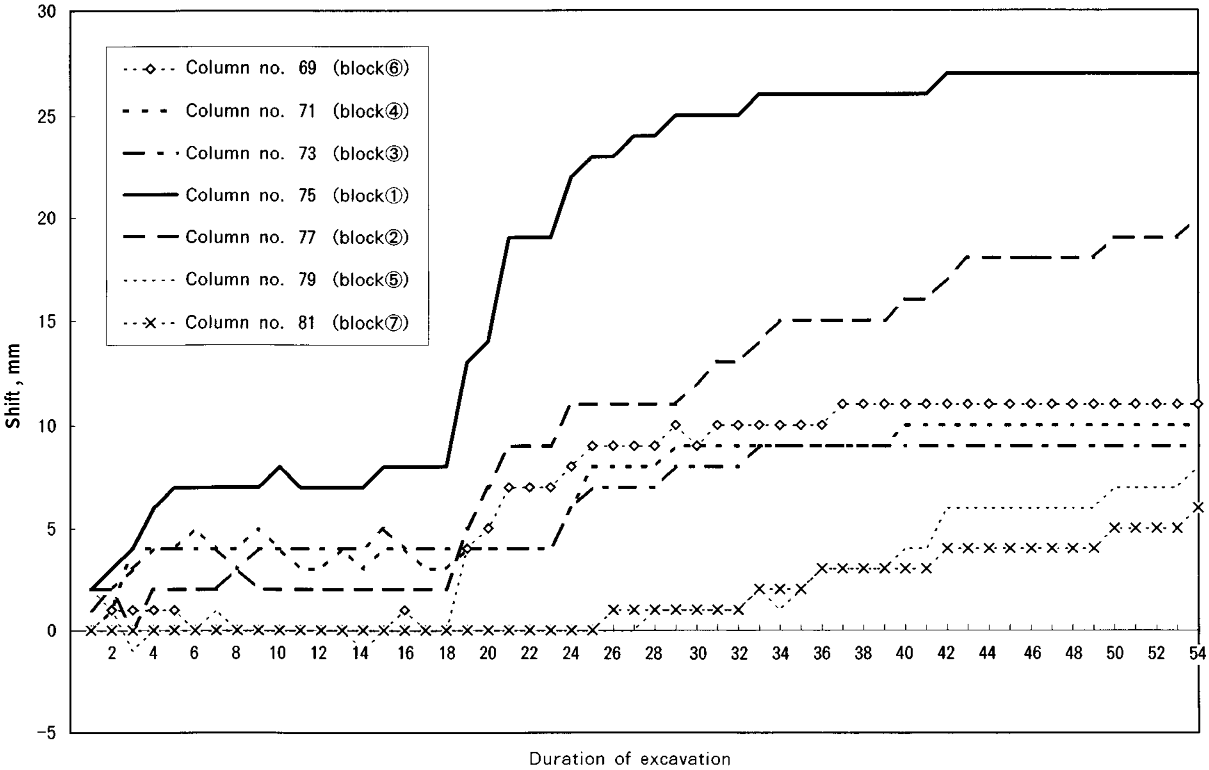

Fig. 9 Shift of existing building foundations

As a result, shifting of the foundations of the existing building was restrained even though the cost reduction and high workability permitted by installing steel sheet piling without bracing were maintained, and deformation of superstructure was kept within the allowable value.

5. Conclusion

Although problems that were not predictable in advance occurred during the on-site work, delivery of the foundation to the erection work group was made at the scheduled delivery time. We believe that the main reason for the smooth execution of work was that we investigated materials that were available on the construction site and gathered on-site information about methods familiar to local construction companies and other information at the initial stage of the project, and that this data was then incorporated into the work planning and design. By using local construction companies and by incorporating materials available at the construction site into the design, we could contribute relevant technology.

The facility started commercial operation in October, 1999. Although Erdemir Iron & Steel Works is less than 100 km from the seismic centers of two great Turkish earthquakes occurring in August and November of 1999, the facilities related to this project were not damaged and still operate smoothly.

References

1) Edited by Japan Road Association. Manual for Road Bridge. Japan Road Association(1996).

2) Edited by Architectural Institute of Japan. Design Manual for Building Foundations. Architectural Institute of Japan(1988).