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Development of Roof Push up Construction Method

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Abstract

The roof push up construction method is a construction method whereby the roof floor is erected first, then the building is constructed by pushing up the roof floor successively by one floor with hydraulic oil jacks.

Because the roof floor is built first by this construction method, the working environment is not affected by the weather. Moreover, this method can concentrate production equipment to construct the building on the roof floor to promote automatic and robotic construction work.

This construction method was first applied in 1990, then the working methods and equipment were improved prior to the second application in 1994.

This paper first introduces the concept of this construction work and the working procedure, then describes the working method of building frame and push up equipment, which is the major constructing technology, with application examples of the two construction works.

1. Preface

Recently, the slow rate of increase of productivity has been pointed in the construction industry in comparison with the manufacturing industry. Moreover, problems with a shortage of skilled workers and aging of workers will be solved from a long-range out look. As a measure to solve these problems, technical development to automate and robotize construction work is being promoted. The range of development is not restricted to individual jobs, but is being expanded to the development of new construction methods aiming to maximize the effects of automation and robotizing. The roof push up construction method is an example of such developments.

This construction method was first applied in 1990, and obtained good results in mitigating the effects of weather and improving safety. In applying this method to practical work, it was necessary to develop a mechanism to successively push up the roof floor and new lifting equipment to transport materials. Moreover, it has become indispensable to secure safety while performing the new working method, which is different from the conventional working method, therefore, a construction accuracy management system, which can grasp the current working status instantly, was developed and applied.

The method was applied to actual construction work, and the construction method is believed to have a bright future, therefore, further improvements to the technology were promoted for the working method and development of equipment for the second construction in 1994.

This paper first introduces the concept of this construction method, then describes the working method for the building frame, and push up equipment, which is the major technology, with an example of actual application.

2. Outline of Construction Method

With this method, the roof floor is erected first and then other floors are subsequently constructed by pushing up the roof floor with oil jacks, as shown in Fig. 2.1. By constructing the roof floor, which serves as the roof, work can be performed even when it is raining to keep the planned schedule. Moreover, by collecting construction work and necessary production equipment on the roof floor, it is easy to improve the working environment and safety. Furthermore, automatic and robotic work can be promoted easily compared to the conventional construction method.

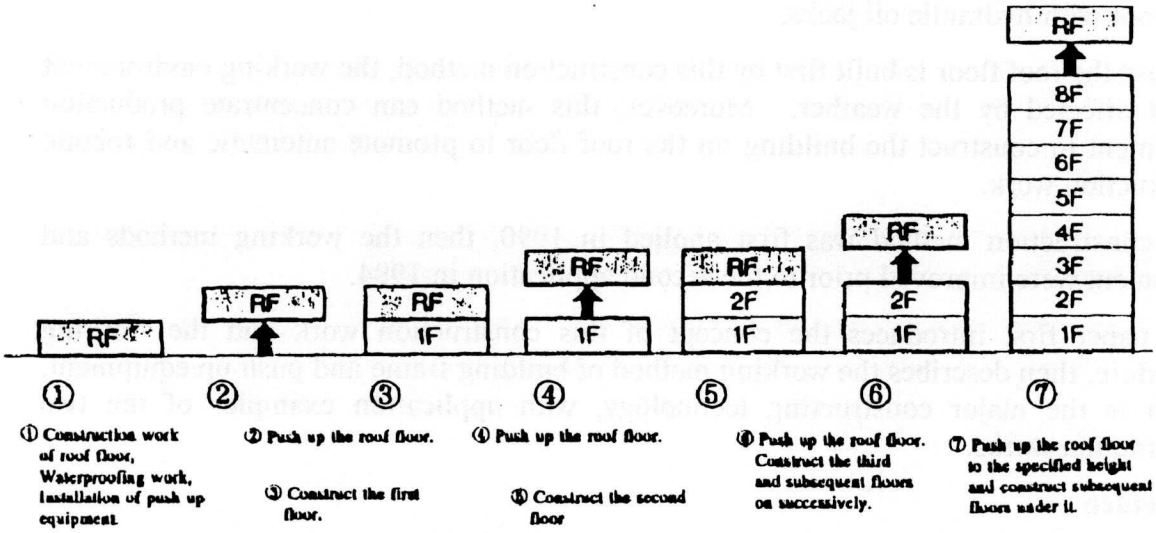

Fig 2.1 Basic Concept of Construction Method

3. First Application

3.1 Outline of Construction Work

Outline of construction work is shown in Table 3.1.

Because this was the first application in construction, and there was a short time for preparations, this construction method was applied to the upper stories comprising the 10th to 12th floors, and a total of three push up works were performed.

Table 3.1 Outline of Construction Work

Purpose	Office
Land area	934.830 m2
Building area	682.880 m2
Total floor area	7940.822 m2
Structure	RC, SRC, S
Number of stories	2 levels underground, 12 stories above ground, 1 story tower
Maximum height	44.95 m
Construction term	Nov. 1989~ Mar. 1991

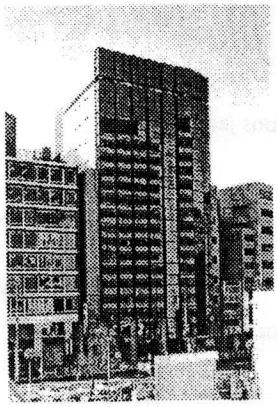

Photo 3.1 General View of Building

3.2 Constitution of the Equipment and Construction Procedure

Constitution of the equipment on the roof floor is shown in Fig 3.1. The elevating mechanism consists of floor jacks to push up the roof floor, columns of the roof floor, and jacks to raise the columns of the roof floor.

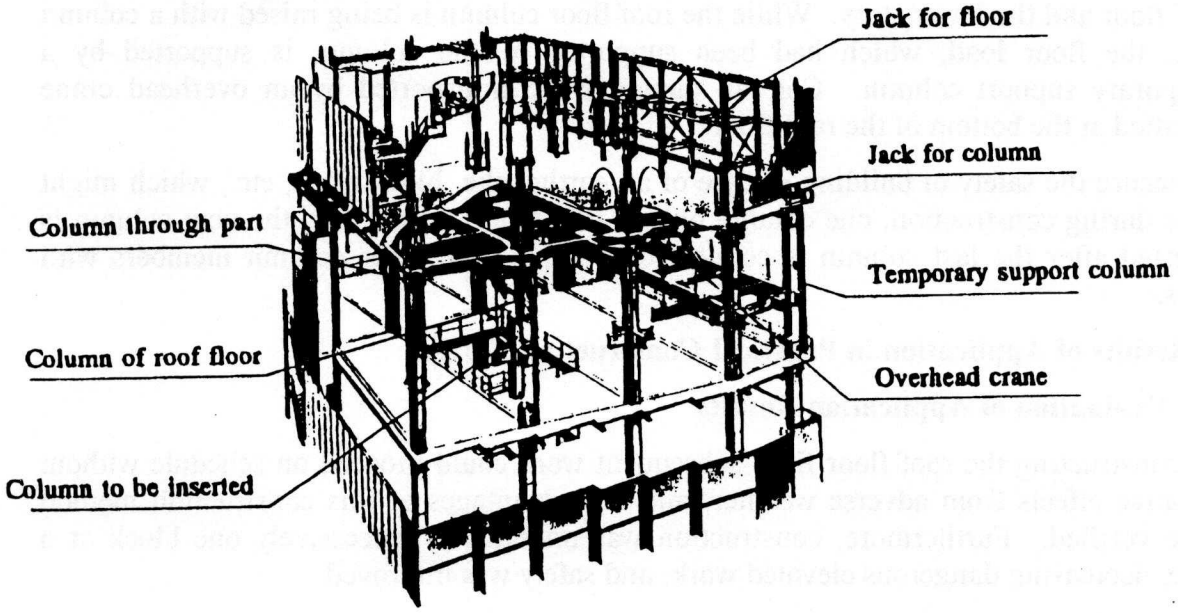

Fig 3.1 Constitution of Roof Floor Facility

Fig 3.2 shows the push up mechanism. The reaction to elevate is taken at the column head of the roof floor, and the roof floor is elevated using two floor jacks for one column. Extension length of floor jacks is controlled with a microcomputer, to secure accuracy of level while pushing up.

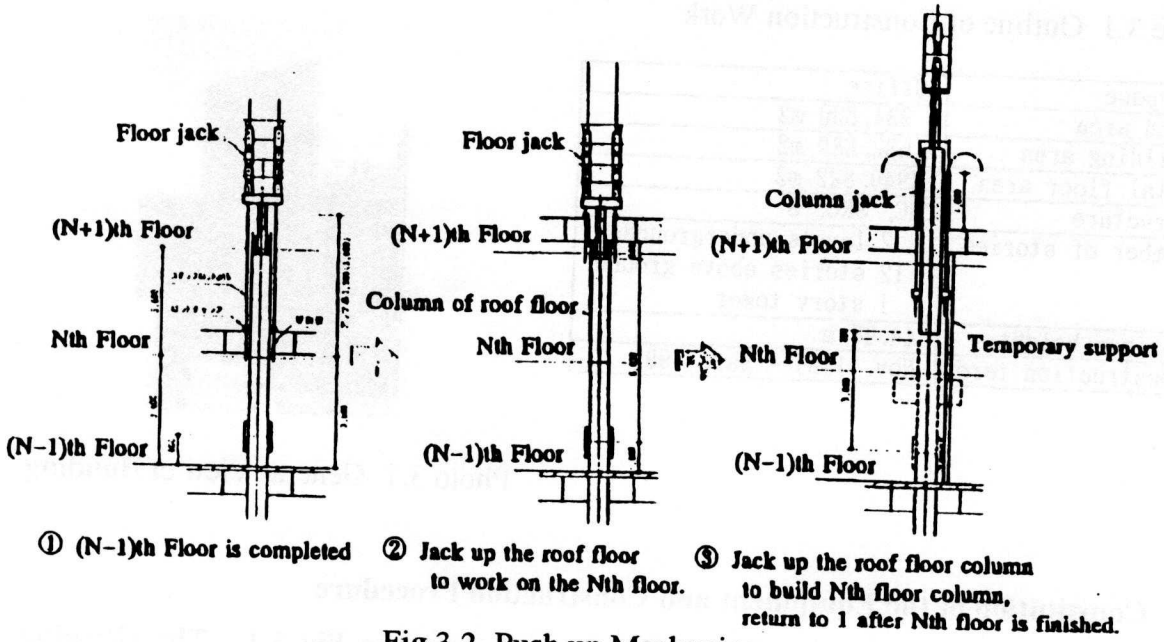

Fig 3.2 Push up Mechanism

After the roof floor was elevated, the columns of the roof floor were raised by the height of one story and column member were inserted horizontally into the space between the roof floor and the lower story. While the roof floor column is being raised with a column jack, the floor load, which had been supported by the column, is supported by a temporary support column. Column members are transported by an overhead crane installed at the bottom of the roof floor.

To secure the safety of building in case of an earthquake, high winds, etc., which might arise during construction, one column only is inserted at a time, and the next column is inserted after the last column is connected to upper and lower column members with bolts.

4. Results of Application in Practical Construction Work

4.1 Evaluation of Application Results

By constructing the roof floor first, subsequent work could proceed on schedule without negative effects from adverse weather, and the advantages of this construction method were verified. Furthermore, construction was undertaken successively one block at a time, decreasing dangerous elevated work, and safety was improved.

Moreover, the following improvements required were grasped:

1) Because the length of a column member was determined to be one floor height, the number of column junctions increased from that with normal steel column, resulting in high production costs.

To secure the safety of the frame during construction, the height of the roof floor from the floor with a completed steel frame assembly, was limited. As a result, the length of the column to be inserted in the horizontal direction was restricted to one floor height.

2) Extra work is required, because, the column for the roof floor, which was fixed with column of the lower floor, is released by removing the fixing bolts, when the roof floor is to be raised next time.

3) It is necessary to have a construction method that is not adversely affected by weather, in addition to the effects of stabling the process.

5. Planning and Executing Improvement Measures

To advance the technical level of construction method by solving the tasks above, development work concentrated on the following two points.

1) To demonstrate the merits of this construction method to the maximum, the added value of roof floor push up construction work was increased.

2) To develop exclusive push up equipment to make raising mechanism simpler.

5.1 Measures to Increase Added Value of Push up Construction

1) Assemble Steel Frame on the Floor

To further reduce work at elevated places the, steel frame was assembled on the completed lower floor, floor and ceiling installing equipment were attached, then they are raised simultaneously by pushing up the roof floor.

Working status is illustrated schematically in Fig 5.1. Compared to conventional work system, the new system eliminates almost all elevated place work when erecting steel frame, significantly improving safety. Moreover, workers only moved horizontally, and their work was simplified, and large improvement of efficiency for steel frame construction work can be expected.

Furthermore, it is possible to apply a refractory covering to the steel frame, to attach equipment above the ceiling directly to the floor, so working efficiency will be improved, and a temporary scaffold will not be required.

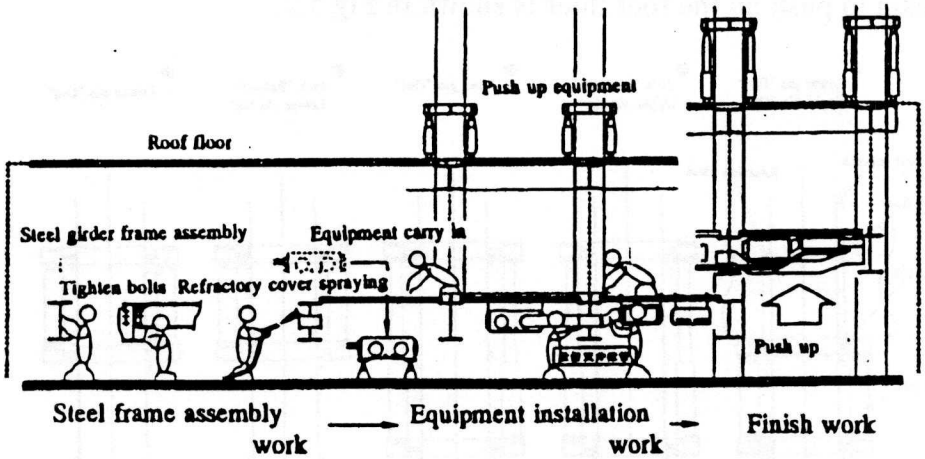

Fig 5.1 Steel Girder Frame Assembly on the Floor

2) Achieving Merit of Working Environment not Affected by Weather

To further reduce the adverse effects of weather on work, the boundary of the working space under the roof floor is covered with a mesh sheet to shut out the effects of rain and

wind. Furthermore, due to the application of PCa material for external facing and development of fixing jig that is easy to assemble and disassemble, water is cut off simultaneously with the installation of the external facing, enabling interior finish work to be started earlier.

As a working environment not affected by weather conditions etc., is achieved, work can proceed as planned, and is possible to reduce disturbances to schedules. As a result, construction administration time, presently spent recovering from a disturbed schedule, is sharply cut. In addition, this improved working environment is used to integrate equipment work into the building framework schedule, so it is possible to reduce the term of construction by starting finishing work earlier.

5.2 Development of Push up Equipment

5.2.1 Aim of Development

The aim was to develop simpler push up equipment and reduce mechanical equipment needed for construction work, and make it possible to use much of the conventional steel frame configuration.

To make it possible to apply a column member two to three stories high, cranes were installed at the upper part of the roof floor to insert column members from above.

Due to the method of joining columns successively from above it is not required to jack up the column, so the system has become simpler by eliminating jacks for column.

5.2.2 Materialization of Equipment Concept

An important task in the development of push up equipment was to secure a safe and stable reaction when pushing up the roof floor.

Various ideas were planned and a system of preparing a protrusion at the column member was adopted as the result of investigations of cost and safety. For the protrusion, plates were welded to the column's surface at regular intervals vertically. The mechanism to push up the roof floor is shown in Fig 5.2.

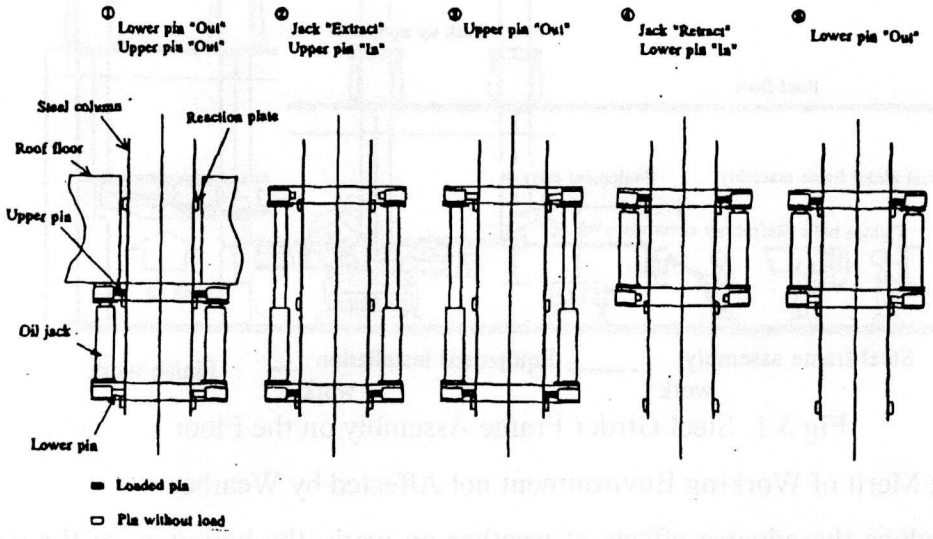

Fig 5.2 Basic Push up Mechanism

5.2.3 Experiments on Element to Check Performance

Plate was welded to actual size steel column as shown in Photo 5.1, and action check experiments were performed on push up equipment.

As the results of experiment, it was confirmed that accuracy of construction work can sufficiently be secured, by employing the roof floor as the scalefor securing accuracy.

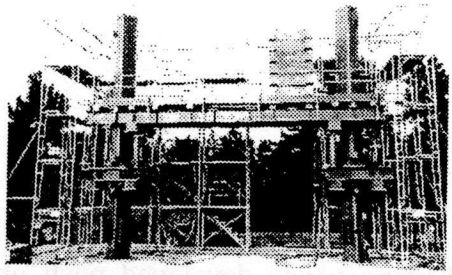

Photo 5.1 Status of Experiment

5.2.4 Development of Practical Machine

Practical equipment was designed and manufactured basing on a series of experimental results. Fig. 5.3 shows the equipment, and Table 5.1 shows the specification. Moreover, to secure horizontal level accuracy during pushing up, leveling control was automated so that pushed-up quantity of all the equipment automatically comes within the set value.

Performance verification test was made after manufacturing, to verify that the expected performance is obtained, and assembly/disassembly procedure was established in preparation for actual construction work.

The merit of this equipment is summarized in the following:

1) Possible to join column members from upper side.

2) Possible to employ long steel column.

3) Surely secure the pushing up reaction, and is highly safe.

4) Use the main construction members effectively, and few of temporary material is used.

Table 5.1 Specification of Practical Equipment

Weight load	120 tons/Column
Stroke	1300 mm
Rising reaction securing system	Reaction plate system
Rising speed Net 4 mm/sec	
Rising system	Continuous up-rising remote operation system
Horizontal leveling	Automatic control

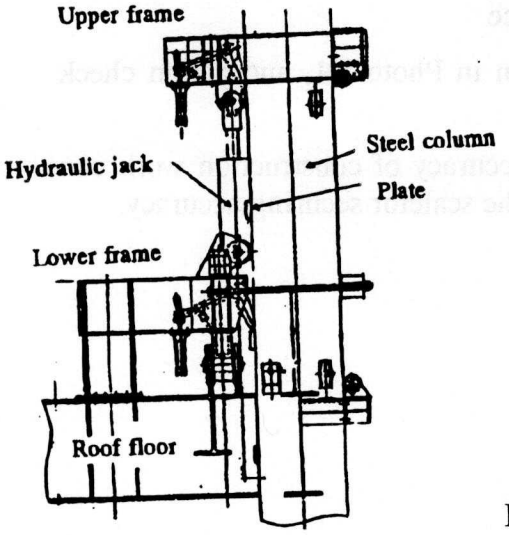

Fig 5.3 Push up Equipment

6. Application to Actual Construction Work

Fig. 6.1 shows construction procedure in the case of using newly developed push up equipment and assembling the steel frame on the floor.

At present, this construction method is being applied to a second construction work to verify the performance of the push up equipment, and simultaneously other technology is being developed. Photos 6.1 to 6.3 show construction status.

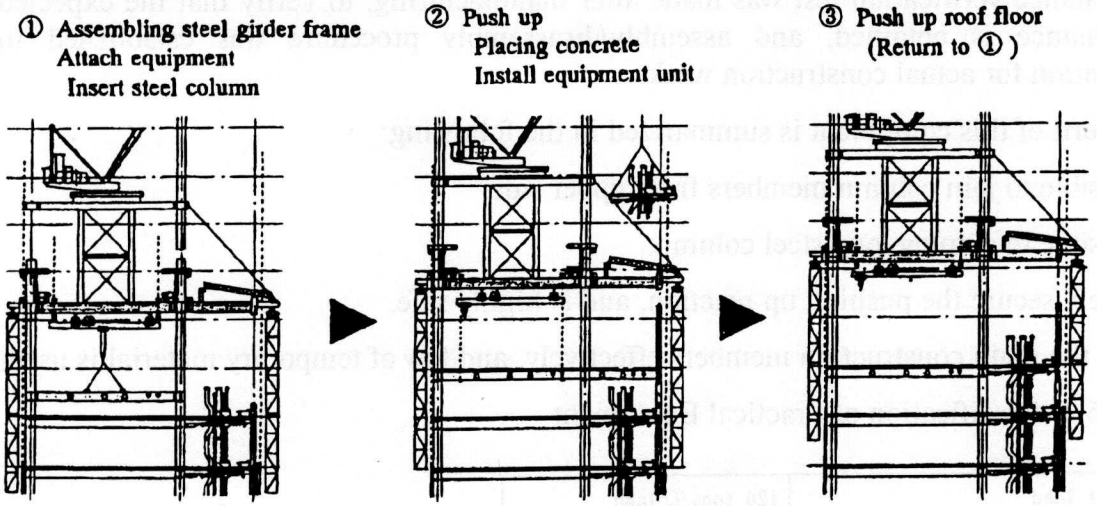

Fig 6.1 Construction Work Procedure

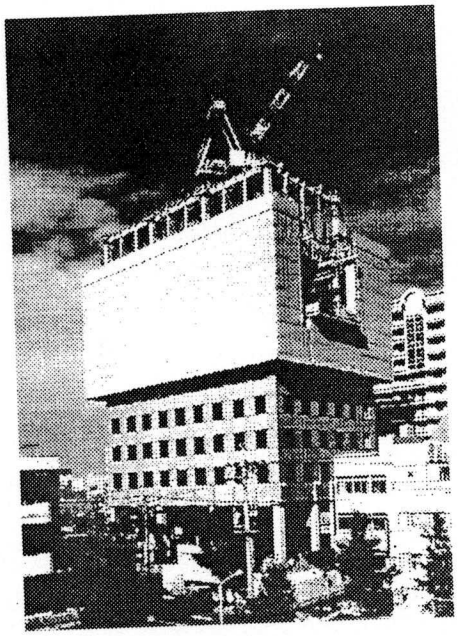

Photo 6.1 General View of Construction Site

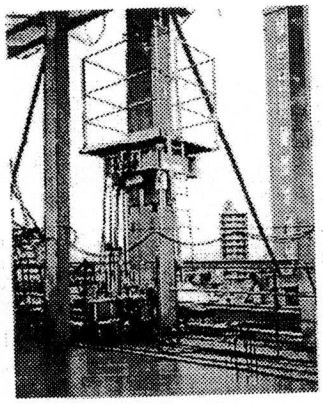

Photo 6.2 Push up Equipment

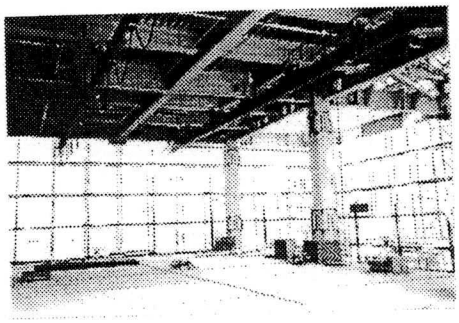

Photo 6.3 Interior View of Working Site

7. Conclusion

Application of this method in construction work was introduced for two actual applications with details of development during the period. Experience obtained from the first application could be applied to improve the technical level of the construction method and push up equipment, and was applied to the second construction work.

Practical data are being collected and evaluations are being obtained from people engaged in the work. It is considered that the development targets have been full attained. Merits of this construction method are summarized in the following:

1) Construction work can be performed on completed lower floor, so dangerous elevated work is largely reduced and safety is secured.

2) Work proceeds in working environment, which is not subjected to rain and wind, allowing introduction of equipment work into the building framework, as well finishing work to be started at an early stage, enabling the working period to be reduced.

3) Each worker can perform more than one job at nearby places, and construction can proceed with a small average number of workers.

4) The major part of the work can be performed on the floor, improving working efficiency with less workload an the workers.

This construction method aims to achieve an easy working environment for workers, however, in the future more mechanization and automation of construction will be sought by studying application to various projects.