

# STUDY ON A LIFTING DEMOLITION METHOD USING DIAGONAL SLAB CUTTING

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## Abstract

In Japan, urban construction projects often require demolition of existing structures, and the number of high-rise building demolition cases has been increasing in recent years. Conventional above-ground demolition methods include the top-down demolition method, in which heavy equipment is placed on the rooftop to dismantle the structure floor by floor, and the block demolition method, in which large sections of the structure are cut into blocks and lowered using tower cranes. However, these techniques present several challenges, such as debris fall risk, dust dispersion, extensive use of temporary supports, and increased construction time and cost.

To address these challenges associated with high-rise demolition work and to enhance productivity, this study proposes a novel technique using a concrete cutter capable of diagonal slab cutting. The specifications of the cutter were experimentally examined, and the method was applied in the field to assess its feasibility and effectiveness. Results indicated that inward blade orientation is optimal for diagonal cutting. On-site application achieved an average cutting speed of 0.78 meters per minute. Compared to the conventional block demolition method, the proposed approach shortened the construction period by approximately two months, resulting in a 20%-time reduction. These findings demonstrate the practical advantages of diagonal slab cutting in enhancing demolition efficiency for high-rise buildings.

**Keywords:** Cutting, Demolition, Diagonal cutting, Skyscraper, Productivity improvement, Safety Introduction

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## 1. Introduction

In urban construction projects, demolition of existing buildings is frequently required, and in recent years, the number of cases involving the demolition of high-rise structures has been increasing. As shown in Figure 1, conventional demolition methods for above-ground structures include the \*top-down demolition method\*, in which demolition machinery is placed on the rooftop and used to dismantle the building floor by floor, and the \*block demolition method\*, in which the structural frame is cut into large block-like units and lowered by tower cranes or similar equipment.

The top-down demolition method poses several challenges, such as the risk of falling or flying debris at the demolition floor, the generation of noise and dust, and the complexity of unloading demolition waste to the ground. On the other hand, the block demolition method involves extensive use of temporary supports to support the pre-cut slabs in advance and must remain in place until they are lowered sequentially from the top floor. Additionally, after each slab is removed, the temporary supports must be repositioned, leading to longer construction periods and increased costs.

To address these issues, a method—illustrated in Fig. 2 has been proposed in which slabs are cut diagonally, and the cut slab is temporarily supported by the adjacent slabs. This approach eliminates the need for temporary supports after cutting and offers the potential to significantly improve the productivity of the block demolition process.

Previous studies have reported applications of the block demolition method; however, in all reported cases, slab cutting was performed vertically. In such cases, temporary supports were required after cutting to prevent slab collapse until lifting operations were completed [1][2][3]. Although there are some studies investigating diagonal cutting using wall saws [4], the cutting speed was relatively slow, leaving room for productivity improvement. There are also reports of diagonal cutting using road cutters [5], but the detailed contents of those studies have not been fully disclosed.

This paper aims to establish a new block demolition method (hereafter referred to as "the proposed method") that utilizes a concrete cutter capable of diagonal slab cutting to improve the productivity of above-ground demolition work for high-rise buildings. Through construction experiments, the specifications of the cutter were examined, including blade orientation, blade mounting position, and wheel positioning. Furthermore, the method was applied to an actual high-rise demolition project to verify the practicality of the lifting demolition technique using diagonal slab cutting and to evaluate its effectiveness in improving productivity compared to the conventional block demolition method.

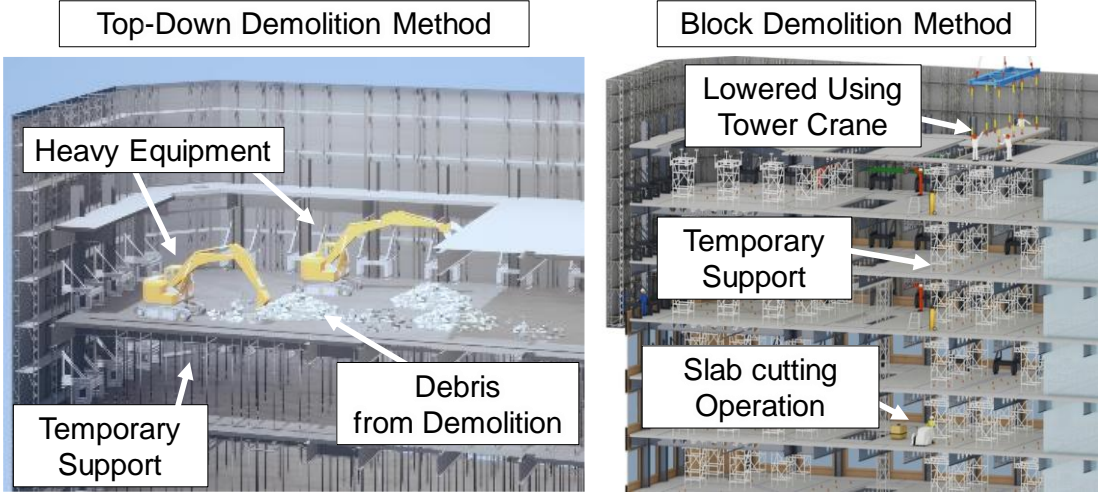


Fig. 1 Conventional ground demolition method

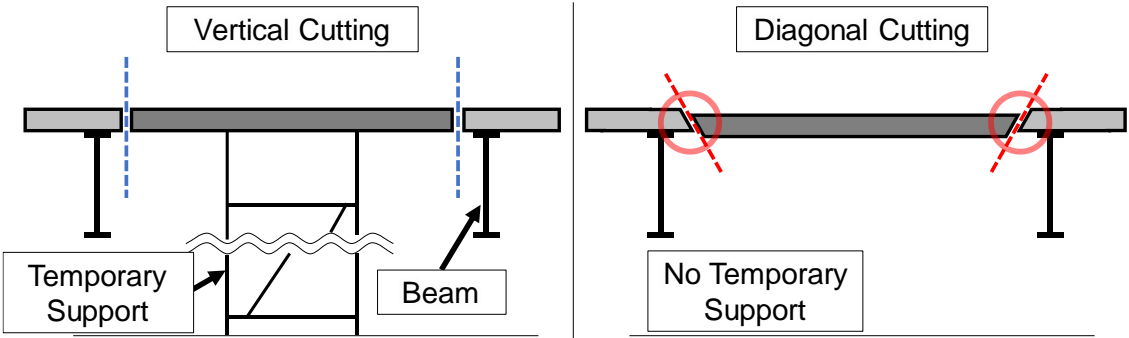


Fig.2. Block demolition method

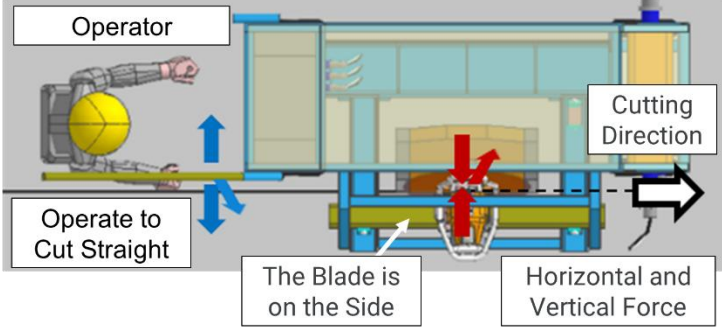
**2. Investigation and Results of Cutting Methods**

**2.1 Blade Orientation**

(1) Method for Evaluating Blade Orientation: To evaluate the optimal blade orientation for diagonal cutting, experiments were conducted using a custom-built trolley to measure both the cutting speed and the force applied by the operator during operation. As shown in Fig. 3, the blade of the slab cutter is mounted on the side of the machine. This configuration causes horizontal forces in the direction normal to the cutting path and vertical forces to act on the machine as it advances. To maintain straight movement, the operator applies force to the push bar. In the case of diagonal cutting, greater reactive forces act on the machine compared to vertical cutting, which is considered one of the main reasons for the reduced cutting speed.

The cutting setup using the experimental trolley is illustrated in Figure 4, and the blade orientations tested are shown in Figure 5. The trolley was configured as a rear-wheel-drive unit, similar to conventional concrete cutters, and was fitted with a wall saw. As shown in Figure 5, three blade orientations were tested: vertical, 30° inward from vertical, and 30° outward from vertical.

The test specimen consisted of unreinforced concrete with a thickness of 250 mm. The cutting depth was set to 200 mm, and each cutting pass was 10 meters in length, with eight repetitions for each blade



orientation. To minimize variation in the measurements, cutting speed and push bar force were recorded over the central 3 meters of each 10-meter cut. The push bar force representing the operator's effort to maintain straight-line motion was measured at 1-second intervals, as shown in Fig. 4.

Fig. 3. Forces on the Machine During Diagonal Cutting

Fig. 4. Experimental Trolley

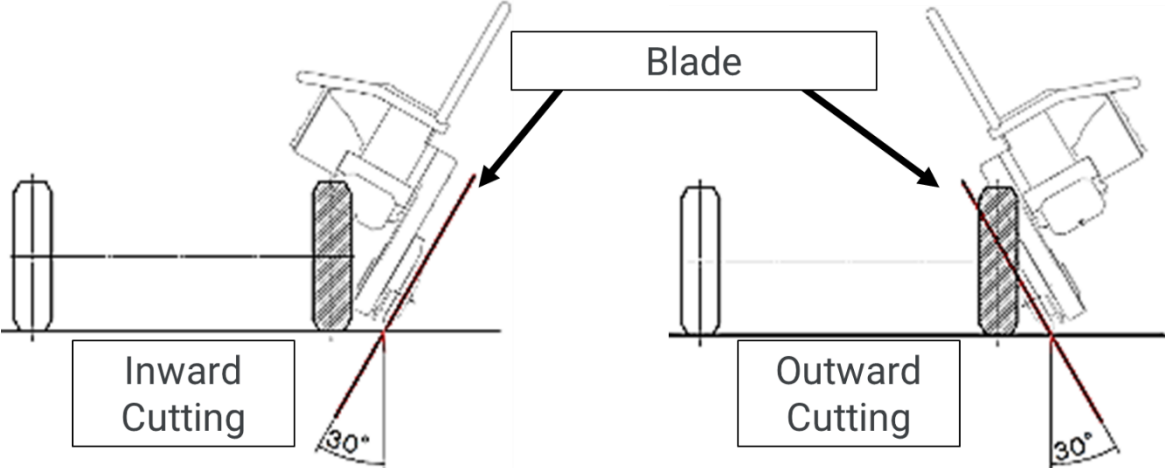
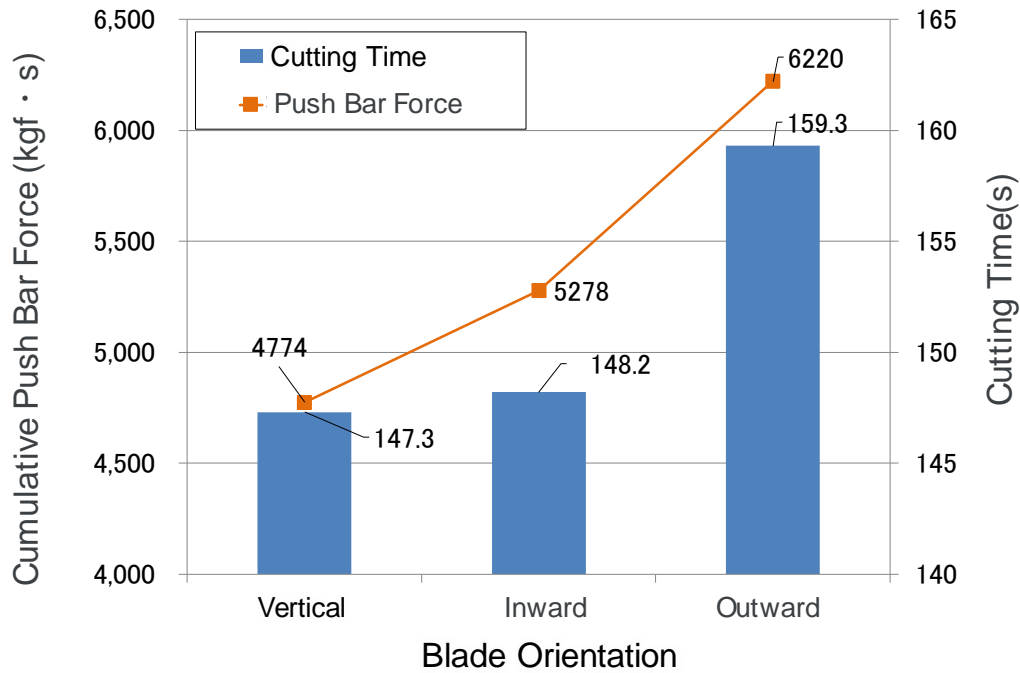


Fig. 5. Blade Mounting Orientation

(2) Evaluation Results: The measurement results for cutting time and cumulative push bar force for each blade orientation are shown in Figure 6. The cumulative push bar force was calculated as the sum of the absolute values of the push bar force recorded over the 3-meter cutting section.



*Fig. 6. Measurement Results of Cutting Time and Push Rod Load*

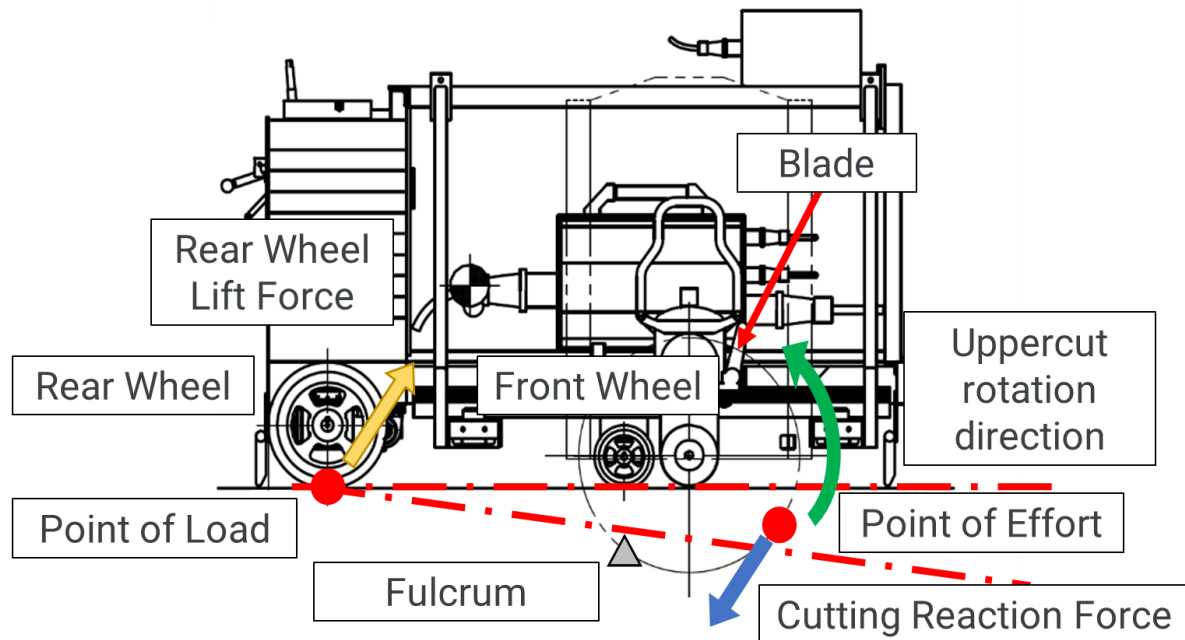
As shown in Figure 6, the cutting time for the inward-tilted and vertical blade orientations was nearly the same, while the outward-tilted orientation resulted in an approximately 8% increase in cutting time compared to the vertical orientation. Furthermore, the cumulative push bar force for the outward orientation increased by approximately 30% relative to the vertical, whereas the inward orientation showed only about a 10% increase. Based on these results, it was concluded that the inward blade orientation is most suitable for diagonal cutting.

## **2.2 Blade Mounting Position and Wheel Position**

(1) Method for Evaluating Blade Mounting Position: To improve the stability of the machine during cutting and to increase cutting speed, the optimal blade mounting position and wheel position were evaluated. Figure 7 illustrates the blade rotation method and the forces acting on the machine.

In a conventional concrete cutter, the machine body is grounded on the top surface of the cutting target, and the blade rotates as the machine moves in the cutting direction. The most commonly used rotation method is the down-cut method, where the blade rotates from the top surface of the target downward, in the direction of the cutting path. In the case of the block demolition method, however, it is necessary to simultaneously cut through the deck plate on the underside of the slab. With the down-cut method, the deck plate could potentially peel off downwards, preventing simultaneous cutting.

Therefore, the upper-cut method, which rotates the blade in the opposite direction (counterclockwise), was adopted. This ensures that the deck plate is pressed down onto the underside of the slab, allowing for simultaneous cutting. However, as shown in Fig. 7, the reaction forces during cutting could cause the rear wheels to lift, which might reduce cutting efficiency. To investigate this potential issue, during the previous cutting experiments, the vertical load on the rear wheels of the experimental trolley was measured using a load cell.



*Fig.7. Blade Rotation Method and Forces Acting on the Machine*

## **(2) Evaluation Results for Blade Mounting Position**

The measurement results for the vertical load on the rear wheels during cutting with the inward blade orientation are shown in Figure 8. As indicated in Figure 8, values below zero were recorded during cutting, indicating that the rear wheels were in an unloaded state and were lifted off the ground, leading to a condition where the wheels were spinning freely.

Since the rear wheels could not generate the necessary reaction force to propel the machine forward, the machine lacked straight-line stability, and the operator experienced significant strain during cutting. As a solution, the blade mounting position and wheel position were adjusted as shown in Figure 9.

From the previous experiments, it was confirmed that when the blade axis is positioned forward of the front wheels, a cutting reaction force would lift the rear wheels off the ground, using the front wheels as a pivot. On the other hand, as shown in Figure 9, when the blade axis is positioned behind the front wheels, even if cutting reaction forces occur, the load can mainly be absorbed by the right front wheel, reducing the effect of rear wheel lift.

Based on this, the optimal positions for the blade and wheels were determined. Furthermore, the center of gravity was placed within the triangle formed by the right front wheel and the two rear wheels, with an emphasis on positioning it as far back as possible to help prevent rear wheel lift. Testing the new mounting positions confirmed that the machine was able to cut without lifting the rear wheels.

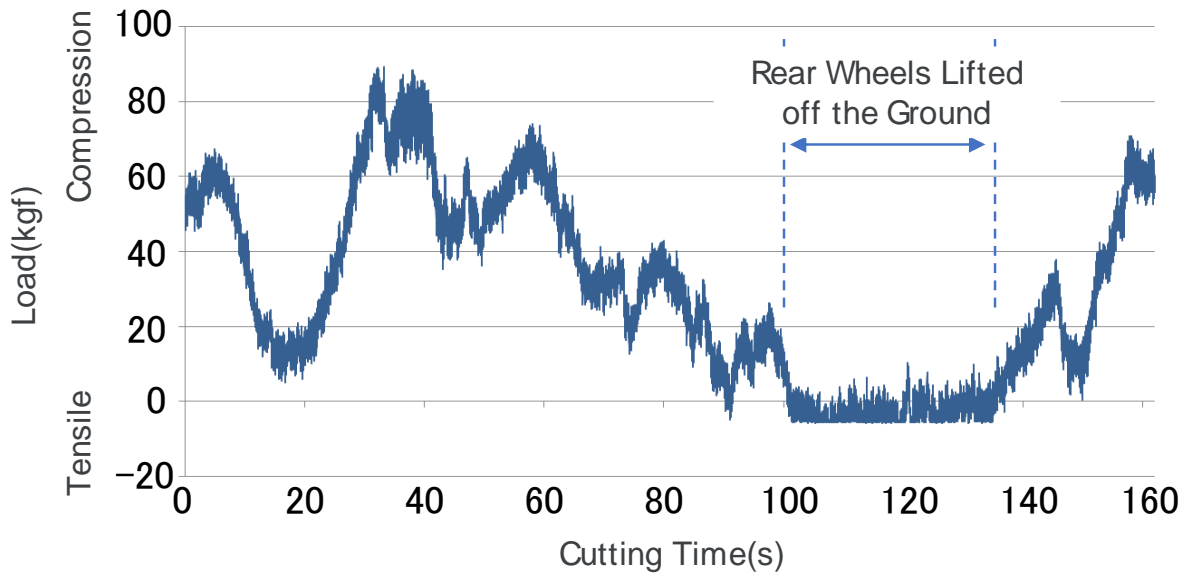


Fig. 8. Measurement Results of Rear Wheel Load During Inward Cutting

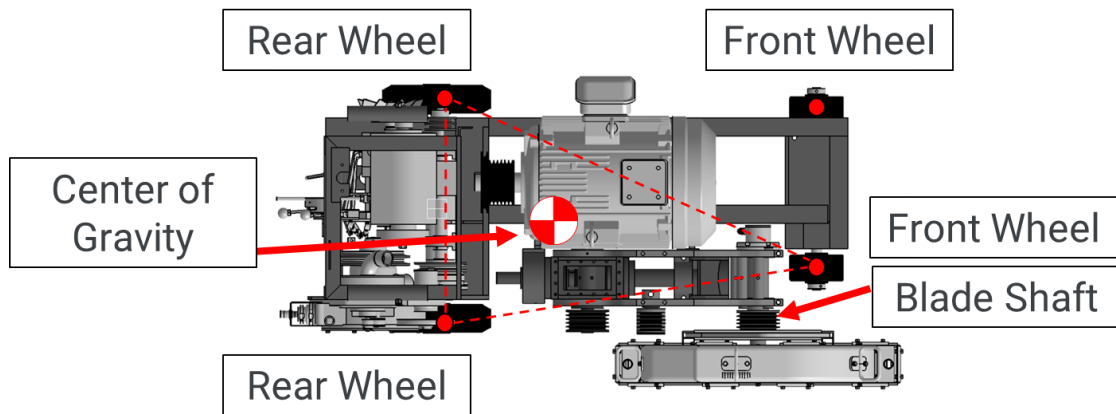


Fig. 9. Center of Gravity and Mounting Positions of Blade and Wheels

### 3. Site implementation

#### 3.1 Objective of site implementation

The overview of the building to be demolished is shown in Table 1. The building to be demolished is a super high-rise structure with a maximum height of approximately 162 meters. The surrounding area of the site is near a railway line, with a high volume of people and traffic. Therefore, it was essential to eliminate the risks of falling or flying debris, ensuring safety and considering the surrounding environment.

Table 1. Overview of the Demolished Building

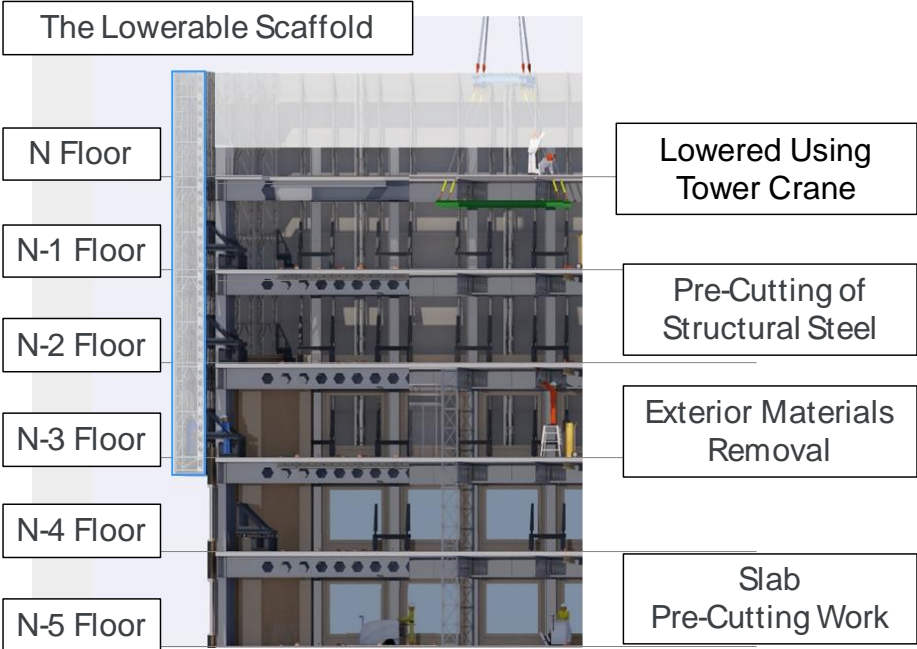
Completion Date	March 1970 (51 years old at the time of demolition commencement)
Use	Office, Retail, Parking
Maximum Height	162.18m
Number of Floors	40 above ground, 3 below ground, 2 in the tower
Structure	Reinforced Concrete (RC) above ground, Steel Reinforced Concrete (SRC) from basement level 1 to 2, Steel (S) from 3rd to 40th floor
Total Floor Area	135,000m <sup>2</sup>
Cut Slab Thickness	82mm to 160mm

In this context, the proposed method utilizing slab diagonal cutting was adopted to confirm its usefulness in the demolition of super high-rise buildings and to evaluate its effectiveness in improving productivity compared to the traditional block demolition method.

*3.2 Overview of Field Application*

A cross-sectional diagram of the demolition site is shown in Figure 10. In applying this method, a structural analysis was carried out by the structural designer to ensure the seismic performance of the building during the demolition process. Various aspects were evaluated, such as how many floors could be pre-cut in advance using the slab diagonal cutter, and the range of pre-cutting work was determined. Scaffolding was set up on the top four floors of the building, and it was planned to be lowered as the demolition progressed. The work on each floor was as follows:

- Nth floor, N-1 floor: Unit lifting and removal work
- N-2 floor: Pre-cutting of structural steel
- N-3 floor: Removal of exterior materials (lowest floor of scaffolding)
- N-5 floor: Slab cutting work



*Fig. 10. Cross Section diagram of the Demolition Site*

The scaffolding was planned to be lowered, and the construction elevator was to use reverse climbing, with the demolition scheduled to be completed in a 5-day cycle per floor. Dust and noise-generating work were completed on floors N-4 and below, prior to the removal of exterior materials, reducing the risk of debris scattering or wind dispersal.

After the units were lifted using the tower crane, they were lowered to the first floor through a large lifting opening installed inside the building, avoiding wind effects. On the first floor, the concrete was broken into smaller pieces, and the rebar and structural steel were separated and transported out.

The layout of the structural units and the main types of units are shown in Figure 11. To reduce the number of lifting operations and shorten the construction period, the units were arranged to be as large as possible. These included slab units cut diagonally between major beams, large beam-slab units integrated with the beams, perimeter units where the slab and outer columns were integrated, and core units in the core section.

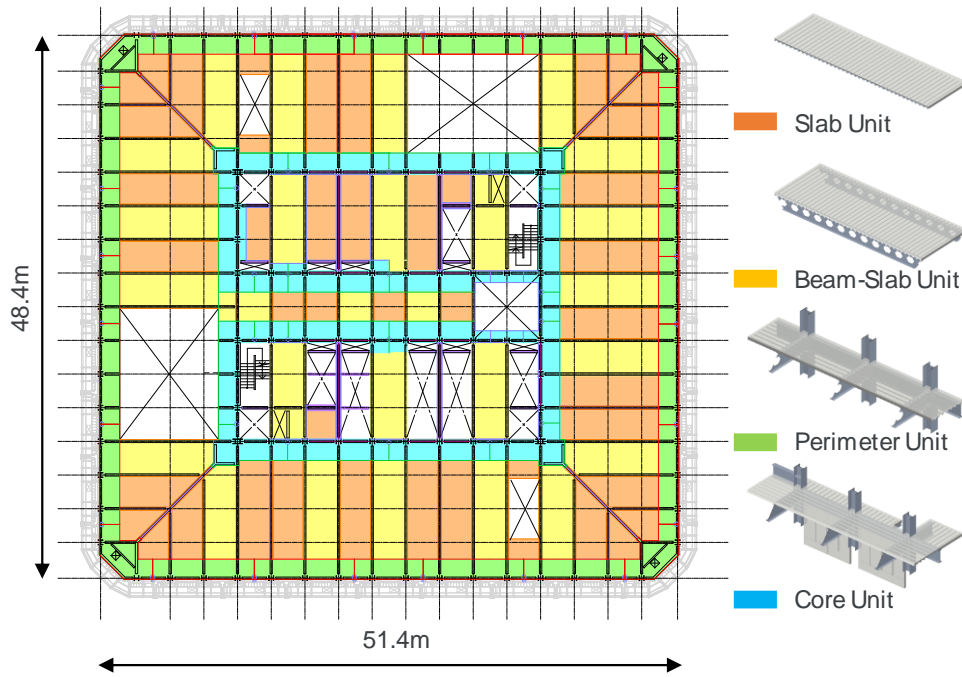


Fig. 11. Unit Layout

### 3.3 Site Implementation Results

#### (1) Implementation of Slab Diagonal Cutting Cutter

The specifications of the slab diagonal cutting cutter were determined based on the previous study results, as shown in Figure 12. Since the slab cutting work was to be carried out indoors, a three-phase 400V electric motor was used to avoid generating exhaust gases. Additionally, to eliminate the need for a power supply during relocation between different floors or switching tasks, a 24V battery was installed, allowing for 30 minutes of autonomous movement over 500 meters. The slab cutting was performed at a 30-degree inward angle relative to the vertical direction.

Figure 13 shows the cutting speed on each floor during the actual construction. The average cutting speed from the 36th to the 4th floor was 0.79 meters per minute. Notably, wire mesh and rebar were also cut simultaneously, and no peeling of the deck plates occurred during cutting. Work on each floor was completed within 5 days, achieving results that fully met the initially anticipated performance.

#### (2) Application of the Slurry Water Dewatering System

The slurry water dewatering system is shown in Figure 14. During cutting with a concrete cutter, slurry water is generated as a mixture of blade cooling water and concrete cutting powder. Normally, slurry water is treated as industrial waste; therefore, reducing its volume contributes to lowering environmental impact and disposal costs.



Motor	Three-phase 400V 4P-22KW
Body Size	L:1,500mm W: 760mm H:1,070mm
Blade Size	22 inches
Cutting Depth	0 degrees: 214 mm 15 degrees: 206 mm 30 degrees: 185 mm
Body Weight	890kg

Fig. 12: Specifications of the Diagonal Slab Cutting Cutter

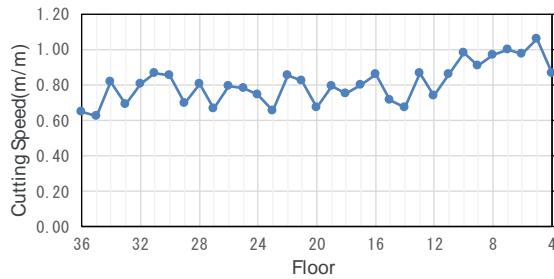


Fig. 13. Cutting Speed of the Diagonal Slab Cutting Cutter



Fig.14. Slurry Water Dewatering Device (Right)

In this method, the slurry water collected by suction from the blade cover of the slab diagonal cutting cutter was filtered and dewatered using the slurry water dewatering system. The system separated the slurry water into dewatered cake and recycled water. The recycled water was reused as cooling water for the blade.

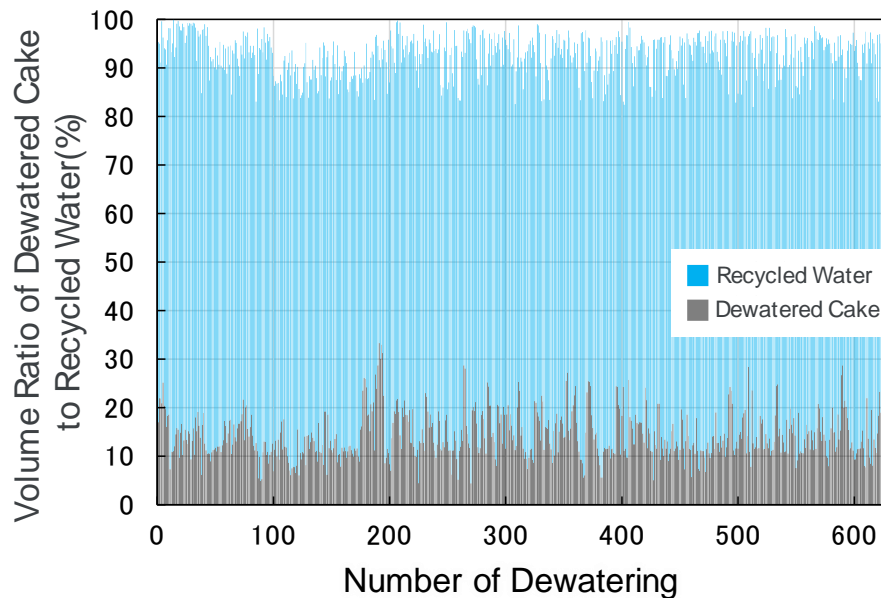


Fig.15. Dewatering Result

The dewatering results of the system are shown in Figure 15. As indicated, the average recovery rate of slurry water into recycled water and dewatered cake was 92.6%, accounting for minor losses due to overflow and residue within the pipes during dewatering. On average, 78.3% of the input slurry water was recovered as recycled water, and 14.3% as dewatered cake. As a result, the volume of slurry water

requiring disposal as industrial waste was reduced to just 14.3% of its original volume, and water usage during cutting operations was also reduced.

**(3) Application of the Slab Cutting and Lifting Fixture**

Figure 16 shows the conditions of the temporary supports and beam members beneath the slab before and after cutting, while Figure 17 illustrates the lifting fixture and slab hoisting operation. After the diagonal slab cutting, temporary support was no longer required. However, during the cutting process, temporary supports were installed below the slab to prevent the cutting blade from becoming jammed between the separated slabs and to suppress the slab's deflection and potential collapse.



Fig.16. Lower slab before and after cutting

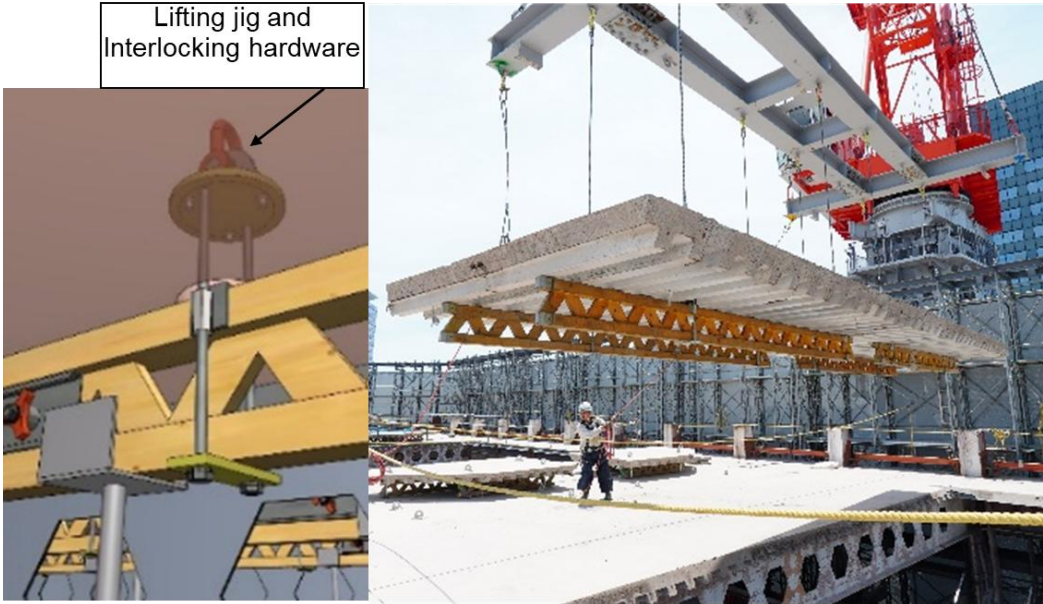


Fig.17: Lifting Jig Combined with Connecting Hardware and Slab Hoisting Condition

At the same time, during the hoisting of slab units on the N floor, it was necessary to prevent cracking or damage to the slabs and ensure a safe lifting process. To achieve this, the beam members above the temporary supports were retained. A lifting fixture, which also served to connect the slab to the beam members, was used to support the slab units from underneath via the beam members during hoisting. This method helped prevent cracking during the lift.

As a result, this approach enabled safer hoisting operations, improved work efficiency, and reduced the number of temporary materials required.



*Fig.18. Four-Point Automatic Lifting Device and Slab Hoisting Condition*

#### **(4) Four-Point Automatic Lifting Device**

Figure 18 shows the four-point automatic lifting device. Because the center of gravity of the cut units was uncertain, it was necessary to lift them safely while keeping them level. Furthermore, automatically flipping and placing the unit after lowering it to the first floor helps shorten the demolition and transport time.

To achieve this, a system was developed that allows the simultaneous operation of four electric chain blocks using a single button. This simplified the adjustment of chain lengths and improved the efficiency of posture control during lifting. Additionally, remote operation reduced the need for work at height or near the suspended load, contributing to safer work conditions.

#### **(5) Productivity Comparison with the Conventional Method**

The construction period of this method was compared to that of the conventional block demolition method based on the application results. By using the diagonal slab cutting cutter, temporary supports could be rearranged immediately after diagonal cutting, which led to a reduction of approximately two months in the construction period. This corresponds to an approximate 20% improvement in overall schedule efficiency.

#### **4. Conclusion**

With the goal of improving productivity in the ground-level demolition of high-rise buildings, this study established a construction method utilizing a concrete cutter capable of diagonal slab cutting. Through experimental work, the optimal blade orientation, blade installation position, and wheel arrangement were determined. In addition, the blade specifications suitable for diagonal cutting were experimentally evaluated, clarifying configurations that enhance cutting efficiency.

The method was then applied in an actual high-rise building demolition project, confirming the usefulness of the lifting-based demolition technique using diagonal slab cutting. The productivity improvement over the conventional block demolition method was also verified.

The key findings of this study are summarized as follows:

- Measurement of cutting time and pushing force for each blade orientation showed that inward-facing blades are optimal for diagonal cutting.
- Vertical load measurements on the rear wheels during inward cutting revealed that positioning the blade shaft between the front and rear wheels is appropriate.

- The slab diagonal cutting cutter, designed based on the study's findings, achieved an average cutting speed of 0.78 m/min during on-site application.
- Comparison with the conventional block demolition method showed that the construction period was reduced by approximately two months, achieving around a 20% schedule reduction.

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