Title:	**A New Demolition Method for Tall Buildings. Kajima Cut & Take Down Method**
Authors:	Ryo Mizutani, Group Leader Technology Group 4, Kajima Corporation Shigeru Yoshikai, Senior Group Leader, Kajima Corporation
Subjects:	Construction Structural Engineering
Keywords:	Cost Demolition Structure
Publication Date:	2011
Original Publication:	CTBUH Journal, 2011 Issue IV
Paper Type:	1. Book chapter/Part chapter 2. **Journal paper** 3. Conference proceeding 4. Unpublished conference paper 5. Magazine article 6. Unpublished

A New Demolition Method for Tall Buildings
Kajima Cut & Take Down Method

Ryo Mizutani

Shigeru Yoshikai

Authors

Ryo Mizutani, Group Leader Technology Group 4

Machinery and Electrical Engineering Division
Kajima Corporation
5-11, Akasaka 6 Chome,
Minato-Ku, Tokyo
107-8348 Japan

t: +81 3 5544 0952, f: +81 3 5544 1754
e: ryom@kajima.com
www.kajima.com

Shigeru Yoshikai, Senior Group Leader

Structure Enjineering Department
Architectural and Engineering Design Group
Kajima Corporation
6-5-30, Akasaka
Minato-ku, Tokyo
07-8502 Japan

t: +81 3 6229 7676, f: +81 3 5561 2329
e: yoshikai@kajima.com
www.kajima.com

Ryo Mizutani
Ryo Mizutani graduated from Tokyo Metropolitan University in 1987 with a BS degree in Mechanical Engineering. Mr. Mizutani is responsible for developing and managing new measurement systems for Kajima Corporation. Some of the work in which he was involved include the "AMURAD" automated building construction method, Automatic Elevated type Building Core Forming System, and other new construction technologies for Kajima. He was one of the key personnel developing and implementing Kajima's Cut & Take Down Method for demolition of Kajima's former Headquarters buildings.

Shigeru Yoshikai
Shigeru Yoshikai graduated from the Department of Architecture of the School of Engineering at Kyushu University in Fukuoka City, Japan, and has worked on structural engineering projects for the past 26 years. He is currently the Senior Group Leader of Kajima's Structural Engineering Department. Mr. Isokai's main fields of expertise are the structural design of buildings, structural analysis, and development of new technologies. Some of the major projects that Mr. Yoshikai has been involved with are Tennosu-Seafort square, the Global HQ building of Nippon Express, Phase 2 of the East-Shinagawa redevelopment project, Kajima's Akasaka Annex Building and Kajima's new R&D Center building. He was also responsible for desiging a tubular structure with concrete-filled steel.

"Using conventional demolition methods, ten different materials could have been recycled on the job site, returning a recycling rate of 55%. The C&TD method allowed recycling of 20 kinds of material with a 93% recycling rate."

In recent years, several tall buildings in Japan that were built in the 1960s have been dismantled. These are amongst the oldest tall buildings in Japan as, until 1963, regulation prohibited buildings taller than 31 meters (102 feet) because of earthquakes. In response, the Japanese construction company Kajima Corporation developed a building demolition technique that involves using hydraulic jacks to demolish a building from the bottom up, one floor at a time. As tall buildings are often located in dense urban areas, blowing up a structure with explosives, or using a wrecking ball are often not an option.

Introduction

The Kajima Cut & Take Down (C&TD) method is also known as the Daruma Otoshi Method. Daruma Otoshi refers to a traditional Japanese game toy, which has the object of knocking off the bottom piece of a tower of wooden blocks without causing the tower to fall over. Just like a Daruma Otoshi, the C&TD-method demolishes a building from the bottom up with much of the demolition work being done at ground level.

The KC&DT method was used to demolish two of three towers of Kajima's former head quarter complex in Akasaka-mitsuke, a town in the Minato-ku ward in Tokyo (see Figure 1). There have been a good number of chimneys or other structures which have utilized hydraulic jacks to demolish a structure from the bottom up, but never before buildings. The towers of Kajima HQ are thus presumed the first examples of applying this method to tall buildings. This paper discusses this method and its techniques by sharing the experience gained during its maiden implementation.

Conventional Demolition Methods

The following elaborates on a number of drawbacks to using the conventional demolition method compared to the C&TD method (see Figure 2).

Installing a crane

The conventional method uses a heavy crane which is hoisted on top of the building. The tower is lowered by dismantling materials from the top floor down.

Reinforcing floors

A conventional building floor does not have the capacity to hold a heavy crane and dismantled waste materials. As a result, each floor must be reinforced before demolition work starts.

Demolition provisions

When demolishing a building, often scaffolding with canvas or outer panels need to be installed to prevent dust, noise and vibration from spreading into the surrounding area. 50 meters (164 feet) is considered to be the maximum height for the structural strength of scaffolding. For a building taller than 50 meters (164 feet), a construction elevator needs to be installed on the outer façade of the building.

Environmental issues

Dropped waste materials pose a great risk for laborers when demolishing a tall building. Also, to prevent dust from spreading while using conventional demolishing methods, water is sprayed onto the demolished material. However, running water naturally

Figure 1. Kajima Cut & Take Down (C&TD) method used on Kajima's former headquarters in Tokyo © Kajima

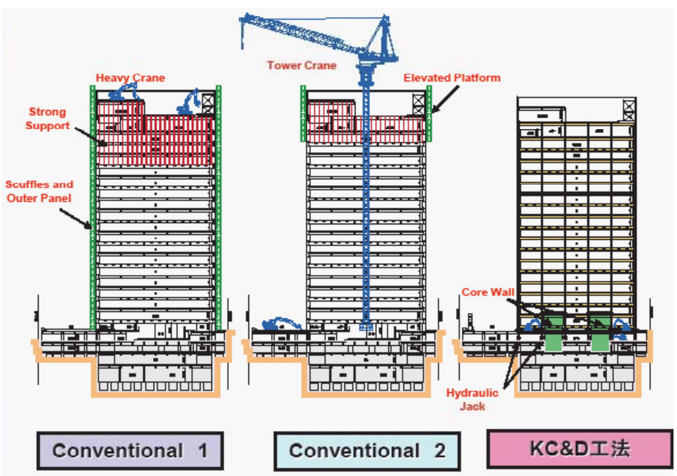


Figure 2. Comparison between demolition methods © Kajima

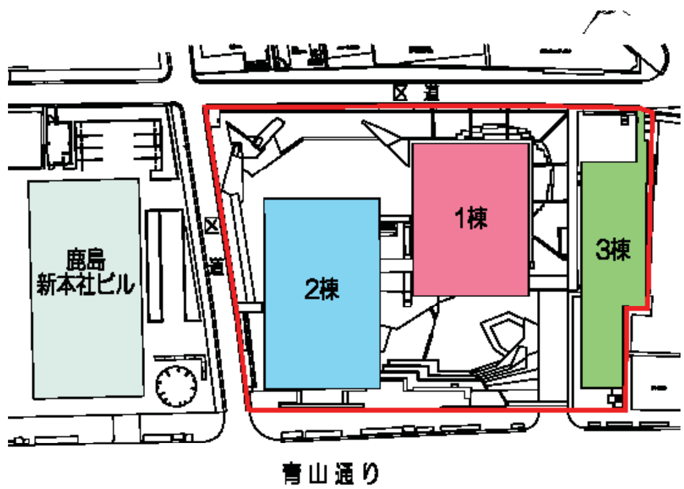


Figure 3. Kajima Corp. former headquarters site layout © Kajima

flows down to the lower floors, which requires additional effort to drain the waste water. One also needs to prevent the water from spreading around the neighborhood. Another concern is sparks caused by gas cutting equipment used on steel, which may ignite a fire when in contact with combustible materials.

C+TD Case Study: Kajima Corp. Headquarters

Kajima's former HQ was housed in three buildings (See Figure 3). The site on which the towers stood is 85 meters (279 feet) wide and 60 meters (197 feet) long, with a 2.4-meter (8-foot) altitude difference across the site. An office building is located directly to the east of the site, and a residential building can be found to the north of it. There are public pedestrian paths along the site perimeter, which require extra caution for noise, vibration and safety issues.

Out of three buildings, it was decided to apply the new method on the buildings No. 1 and No. 2, which are the two high-rise buildings. These buildings were also selected due to their steel structure, which makes it easier to cut the columns. Building No. 3 was a low-rise building, to which was applied a conventional demolition method.

The load bearing structure of building No. 1 consisted of a grid of 5 x 4 columns with 4 x 3 spans of 7.5 meters (24.6 feet) and weight of 7,139 tons. Building No. 2 had a 6 x 4 column structure and hence a grid of 5 x 3 span, weighing 9,973 tons.

Demolition Cycle

In a nutshell, the basic cycle of the C&TD method is to place temporary columns near a structural column, take out the column, place a hydraulic jack to support the second floors and up, use the hydraulic jacks to lower the building, and demolish the floors and walls (see Figure 4).

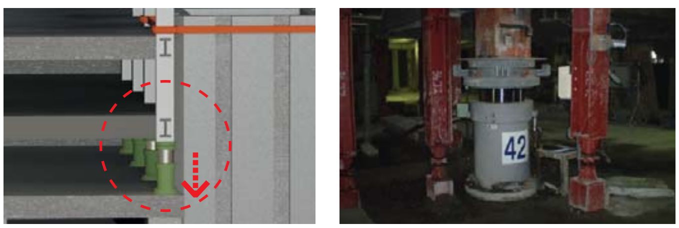
Hydraulic jacks

Based on the structural study, custom hydraulic jacks were ordered with a lifting

1. **Cut the column.** Cut length of 70 centimeters for a column and take off

2. **Extend the jack stroke.** Extend length of 70 centimeters for jack stroke

3. **Take down all jacks.** After doing step 1 & 2 for all columns, all jacks were taken down



4. Take out beams and floor slab of the floor above

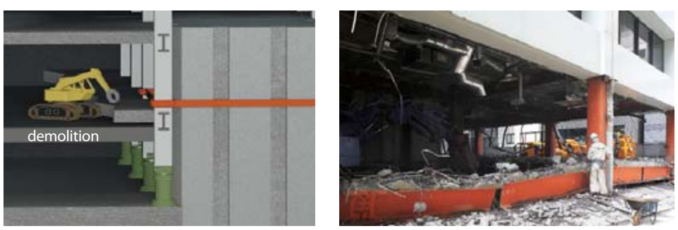


Figure 4. Demolition process © Kajima

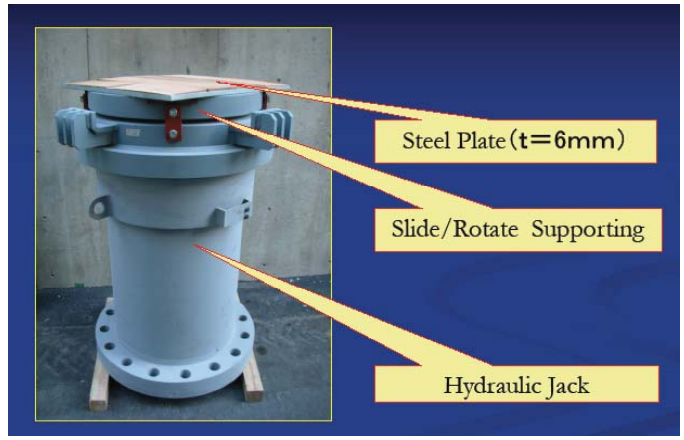


Figure 5. Hydraulic jacks © Kajima

Figure 6. Temporary support columns © Kajima

capability of 800 tons and load carrying capacity of 1,200 tons each. Each jack weighs 3 tons and has a diameter of 725 millimeters (28.5 inches). A supporting plate with the ability to slide and rotate was placed on top of each jack in order to adjust the length of columns, as their length may vary depending on the marginal error when it was manufactured, or how they were cut during the demolition. This plate also absorbs any horizontal and rotating movement of columns in the event of an earthquake. To protect the top portion of the hydraulic jacks, 6-millimeter (0.24-inch) thick steel plates were placed in between the supporting plate and cross section of a column (see Figure 5). Before cutting the columns, temporary support columns are installed on both sides of a steel column and placed under the structural beams of the second floor (see Figure 6).

Cycles

One cycle consists of: (1) cutting the column; (2) extend the jack; and (3) lower all jacks to bring down the second floor. Floors are lowered 675 millimeters (26.5 inches) per cycle. These steps are repeated five times in order to completely lower a floor of 3.375 meters (11.1 feet). It takes 2.5 days to lower one floor, and another 3.5 days to demolish the beams, floors, and walls. In all, it requires six days to completely demolish one floor. A monitoring system was installed to check the movement of every single jack and to measure the level and position of the building. The system was monitored at a central control room.

Dealing with Lateral Movement during Earthquakes

Since this method separates the upper portion of the building from its foundation, the structure is left vulnerable to earthquakes. To cope with the potential danger of lateral load movements, a method was developed which includes a core wall which is connected to a load transferring frame by a wedge control device.

Core wall

The core wall is comparable to the cores which are typical to tall concrete structures. In

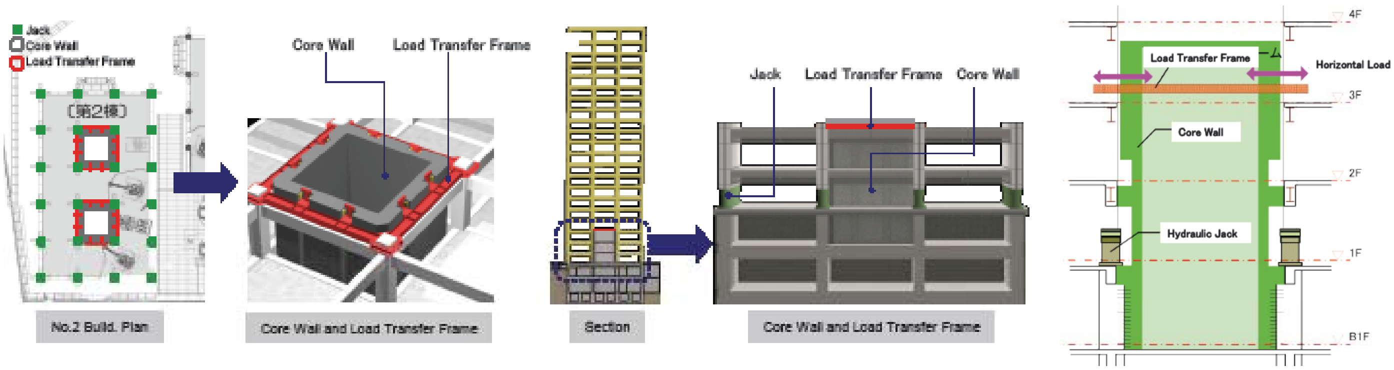


Figure 7. Core wall and load transfer frame © Kajima

Figure 8. Wedge control device © Kajima

this case, a 12.5-meter (41-foot) tall core wall was constructed inside the first three floors. It is made of reinforced concrete boxed walls, with a thickness of 400 to 900 millimeters (15.7 to 35.4 inches). It is located in the center of the floor plan of the building.

Load transferring frame

In order to transfer the lateral loads caused by horizontal movements of the upper building structure to the core wall and the building base, a number of detachable temporary steel frames (BH-585x350x25x25) were installed between the core wall and the surrounding columns, forming a square of steel around the core wall. This is called the load transferring frame. Tongues attached to the frame fit into the grooves of the core walls. During an earthquake, steel wedges fall in place in between the grooves of the core wall and the tongues of the load transferring frame. This connects the core wall with the frame, which allows transferring the lateral movement of the building in the event of an earthquake (see Figure 7).

Wedge control device

While jacks are lowering the structure, the core wall and load transferring frame need to be disconnected in order to achieve a smooth operation. However, if an earthquake

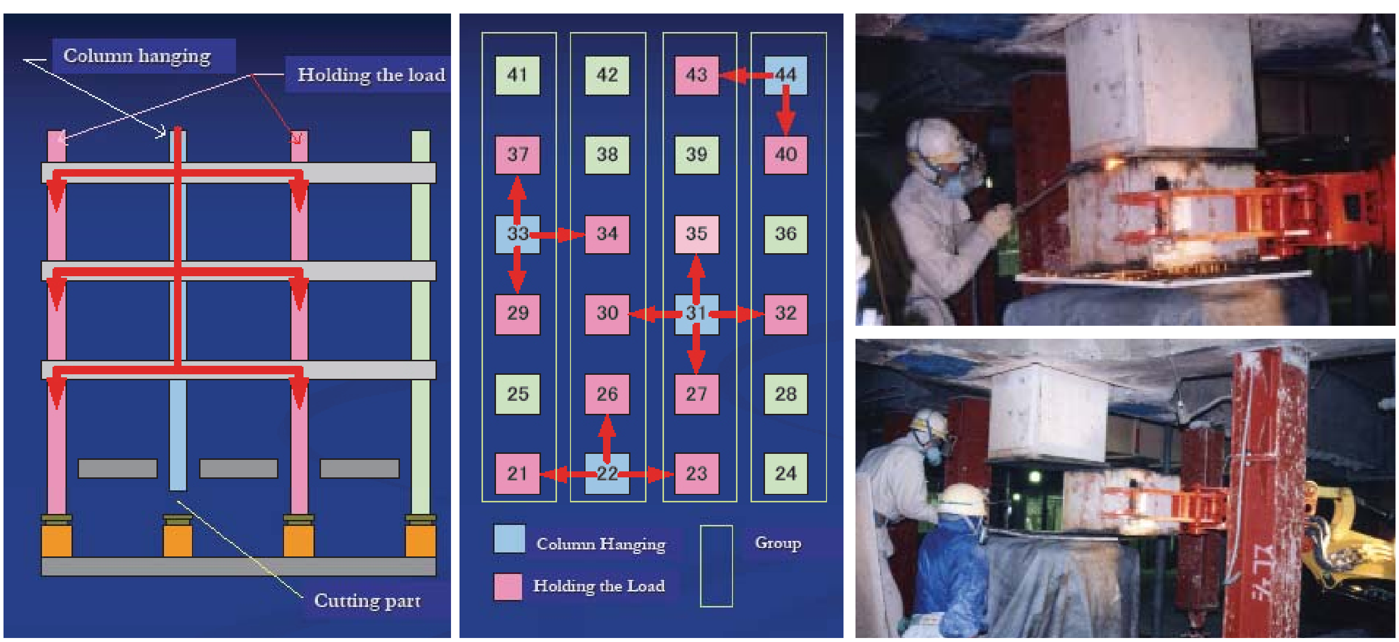


Figure 9. Cutting Columns © Kajima

occurs while the building is being lowered, the connection must be locked in place immediately. An early warning system for earthquakes was installed, which automatically triggers the steel wedge. Each steel wedge weighs approximately 80 kilograms (176 pounds) and automatically deploys to instantly make the connection once it receives the signal (see Figure 8).

Cutting Columns

When the jack is removed in order to take out the column, the floor above tends to bulge somewhat, while other columns are holding the load. During this moment, the floor deforms and lowers about 10 millimeters (0.4 inches). However, deformation of the entire structure is minimal. This also does not affect the precast concrete panels on the outer façade (see Figure 9).

Dismantling the interior materials

The ground floor level is where the jacks are installed and columns are cut. Disassembling of the outer skin, beams and concrete floor of the lowered building floor area (referred as floor N) is done on the second floor using heavy equipment. Disassembled and sorted concrete and steel reinforced bars were shipped out from the second floor very efficiently (see Figure 10).

Working simultaneously, the load transferring frame is installed on the N + 1 floor above while taking out concrete slab around core wall area on floor N+2. Interior demolition is done on floor N + 4 while asbestos is being removed on floor N + 3 floor, after preventive measures have been taken to abate the asbestos. This work is done as part of the cycle of the C&TD method and continues to work via the same process from the ground floor and up (see Figure 11). Doing the same work on the same floor, the cycle resembles a demolition factory.

Results of Cut and Take Down Method

In comparison to the conventional method, the Kajima Cut and Take Down Method has the following merits:

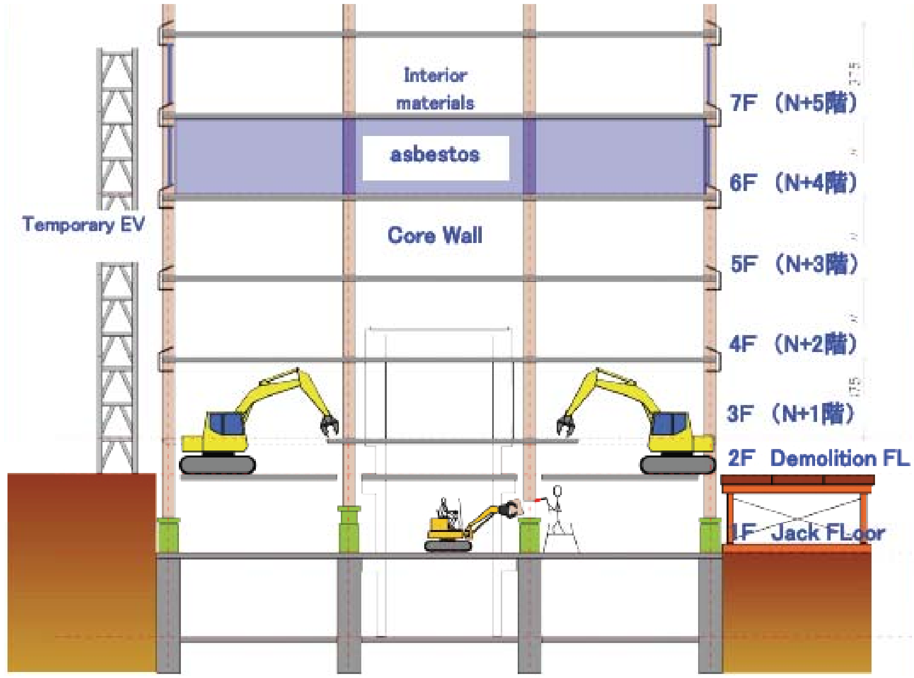


Figure 10. Interior and building demolition © Kajima


Figure 11. Interior and building demolition © Kajima

- It reduces dust and noise, and minimizes impact on the environment.
- There is no need to set up scaffolding for the upper floor, and there is less concern for the surrounding neighbors.
- Materials are easy to process and recycle since all the work is done close to the ground.
- Less work is done on higher levels, which results in less risk for falling down or dropping materials from higher floors, which results in a safer job site.

- Using conventional demolition methods, ten different materials could have been recycled on the job site, returning a recycling rate of 55%. The C&TD method allowed recycling of 20 kinds of material with a 93% recycling rate. When the building structure is included, this number increases to 99%.
- The costs of demolishing a building using the C&TD method are 5 to 10% higher compared to convention demolition methods. On other hand, the work can be completed 15% faster, which shortens interruption time and allows for the speeding up of new replacement construction.

Summary and Future Outlook

Through study and conducting pilot projects, Kajima has gained relevant experience in construction automation processes, and specifically regarding hydraulic jack control technology, such as the Lift Up-Method, which was used at the Seibu Dome and the Haneda Airport's Boeing 747 hanger projects.

Also Kajima has developed an Automatic Up-Rising Construction by Advanced Technique (AMURAD)-method. This can be considered as a reverse of the C&TD Method as the construction of a building starts with the roof, while adding floors from the ground level as the building is jacked up. Several other advanced construction methods have been developed (see Figure 12).

Although the C&TD-method was intended for a 20-story tall, and rigid steel frame structure, this method could be applied to any structural material or combination. However, each building has its own unique structural features, which may require its own suitable demolition method.

We have not been able to test this method on a second project yet. However, as pointed out in the introduction, we expect to see more large-scale building demolition like this in the near future. We will continue to develop this technology based on the experience of the demolition of our former HQ buildings, and try to make it more environmentally friendly, more efficient and cost effective. ■

Figure 12. Automatic Up-Rising Construction by Advanced Technique (AMURAD)-method © Kajima

… lifetime

"In the past, if American architects could participate in the building of two or three skyscraper projects in their lifetime, that was a great achievement. But in China today, a designer can work on two or three skyscraper projects in a single year."

Zhou Xuewang, head of China operations at SOM on China's skyscraper boom. From "The Political Aesthetics of Skyscrapers," China Youth Daily, June 2011.