TECHNIQUES FOR SEISMIC ISOLATION RETROFIT WORK WHILE A BUILDING IS BEING USED

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Recently, construction by which the building is made strong without stopping the function of it increases. Attention has especially gathered to seismic isolation retrofit work in that. It has the advantage that can be constructed differing from other methods, and changing neither the design nor the function of the building. For constructing while using the building, a very important task is to eliminate or reduce noise and vibration generated during work, and to secure strict safety for building users and site workers.

Keywords: Seismic isolation retrofit, Seismic safety, Laminated rubber bearing, Low noise and vibration, Cutting method, Manipulator, Steel pipe pile

1. INTRODUCTION

The earthquake-proof safety in a building is reviewed by means of the Hanshin-Awaji great earthquake that occurred in 1995, and seismic retrofit works by which a building is reinforced are increasing.

Recently, seismic isolation retrofit work has become a focus of attention. It substantially reduces the earthquake force transmitted from the ground through incorporation of some laminated rubber bearings into a building. Unlike other seismic retrofit methods, seismic isolation retrofit work can be executed without changing both design and space of a building.

Customers have been requesting constructors to carry out retrofit work in such a way that a building can still be used as usual without any adverse effects on an usual activities and living environment. Customers who must use buildings on twenty-four hour basis, such as computer offices, hospitals and government agencies make similar requests.

From this situation described above, the seismic isolation retrofit work while using a building as usual is being forecasted, and it will be increased in the future. It is necessary to establish the seismic isolation retrofit method with higher value than other companies to win the competition in this market.

This paper describes various techniques developed to execute seismic isolation retrofit work while a building is being used in its usual style. Specifically, these techniques include methods to cut piles and columns quietly, and the mechanization of engineering skills such as a prototype manipulator which handles a laminated rubber bearing. In addition, two projects of base seismic isolation retrofit work while using a building as usual are described.

2. SEISMIC ISOLATION RETROFIT

2.1 Methods

Seismic isolation retrofit methods are classified into base isolation and column isolation. Base isolation can be further divided into two methods. In one method, laminated rubber bearings are installed onto the tops of piles that have been cut to provide a space while an upper structure is being supported. In the other, laminated rubber bearings are installed between an existing base and a newly constructed base. In base isolation, because a building will move by the earthquake, it is necessary to make dry area around a building. Column isolation is a method where laminated rubber bearings are inserted to fit into the space generated after a middle portion of columns has been cut. Generally, they are conditions that the rigidity in a building must be large and the ground is not extremely weak. If the condition is satisfied, decreasing seismic force to about 1/3 becomes possible. Therefore, advancing a plan carefully after the earthquake performance in an existing building including a base is accurately understood becomes important.

2.2 Execution procedure

Figure 1 shows a general execution procedure of base isolation method in which piles are cut. After the periphery has been surrounded by retaining walls, excavation is performed to expose piles and base mat slab is cast. After hydraulic jacks and temporary steels to support upper structure are installed, jacking-up work is performed. While temporary steels are supporting vertical load of upper structure, piles are cut horizontally twice to create a space, and a cut block is pulled out. Subsequently, a laminated rubber bearing is inserted into a space and is fixed. Finally, vertical load of upper structure is shifted to a laminated rubber bearing with jacking-down. Hydraulic jacks and temporary steels are removed, and the work is completed.

It is necessary to prepare some safety functions to suppress the movement of horizontal direction of a building because there is a possibility that the earthquake occurs during a construction period. Function is to join an upper and lower portions by means of plates to reinforce against the earthquake after installing laminated rubber bearings, and another function is to place hydraulic jacks to control the horizontal deformation of a building.

3. TECHNIQUES FOR SEISMIC ISOLATION RETROFIT

3.1 Technical tasks

Table 1 shows technical tasks that should be solved. On management side, it is important to secure the safety of persons who are using a building and also workers, and to maintain the quality of an existing building. On working side, it is necessary to mechanize dangerous work to treat some heavy materials, and secure safety. For instance, working of removing a cut block and carrying a laminated rubber bearing.

3.2 Pressing-in steel pipe piles

To do pressing-in and jointing of steel pipe piles which did by a narrow space of an existing building bottom efficiently and safely, the system of pressing-in steel pipe piles which showed in Figure 2 was developed. The system is composed of a hydraulic jack and a base machine. Some ribs for the pressing-in have placed to a hydraulic jack. A base machine has high mobility and greatly improved entire work efficiency in narrow space of about 3 m in height. Procedure installs a steel pipe pile with the base machine. A next steel pile and the paling that has already been pressed-in are welded. And an initial press fitting is done while taking the reactive force in a basic beam. And, steel pipe pipes are pressed-in by using spacers.

3.3 Supporting the structure

A technique employed to support the vertical load of an upper structure stably in place of piles and columns that have been cut must not impart harmful deformation to a building. This is an important task to secure maintenance of the quality of a building. A method of supporting a structure as shown in the Figure 1 is a general way. However, if load-supporting capacity of the beam or base mat slab is not enough, this method may damage the beam or base mat slab.

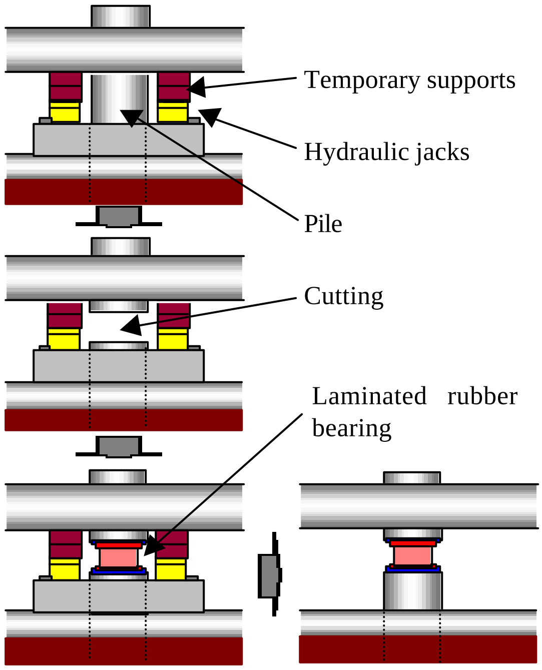


Figure. 1 General execution procedure

Table 1 Technical tasks

Tasks	Requrements
Pressing-in steel pipe piles	Safety High efficiency
Supporting the structure	Safety Maintain the quality
Cutting	Low noise Low vibration
Pulling out a cut block	Safety
Handling a laminated rubber bearing	Safety

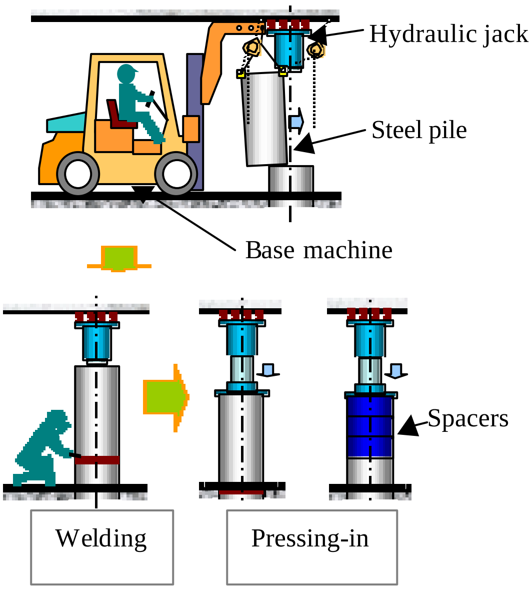
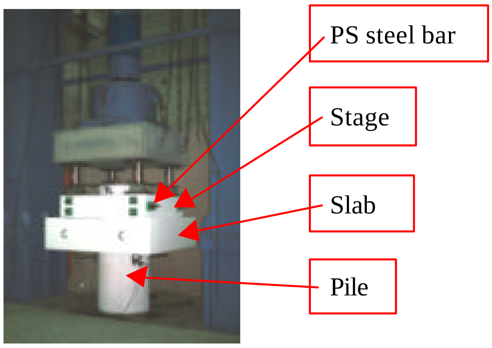


Figure. 2 System of pressing-in steel pipe piles

New method of supporting has developed. It is adopted a pressure force method by means of pre-stressing (PS) steel bars. First, a stage was constructed on newly installed base mat slab. Hydraulic jacks and steel materials were then placed on the stage. Several PS steel bars were then passed through the stage itself. Before jacking-up, a tension force of 1000 N was applied to each bar to integrate the stage with piles. The vertical load of upper structure was supported by means of jacking-up. The vertical load of upper structure is transmitted from the steel materials through hydraulic jacks and the stage to piles rather than base mat slab because of the integration of the stage and piles. This preliminary experiment verified that the stage could bear approximately three times designed load (Photograph 1). This new technique is an excellent supporting method attained through a large effect of pressure force and an ability to retain high rigidity.



Photograph. 1 Structural experiments

3.4 Low noise and vibration cutting method

1) Cutting by pushing wire saw

The wire sawing method is frequently applied to cutting of piles and columns in general. This method is used because noise and vibration are low compared with other cutting methods. Vibration level is satisfactorily low, but noise level must be reduced to below the presence level, because an environment of the occupants who are using a building is affected. Noise and vibration generated during work is transmitted to upper and lower floors via the air and the building's structure. The air-borne sound transmission can be prevented to a certain extent by means of insulation covers. However, the structure-borne sound transmission cannot be prevented when the present technique is employed. To prevent this type of transmission, the most effective countermeasure is to reduce the sound source.

A new cutting method has been developed which can reduce noise. Figure 3 shows this new cutting method which is referred to as "cutting by pushing" and conventional wire sawing method. In cutting by pushing, two arms of movement-cutting device pinch a column. Two arms move in the direction of a column. And the work of cutting progresses toward from the front to the back in a column. In contrast, in

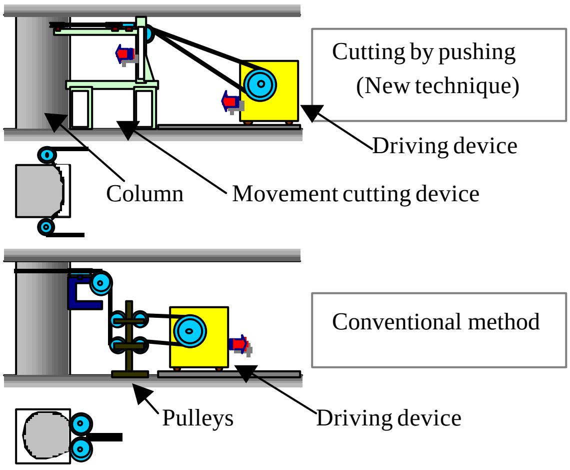
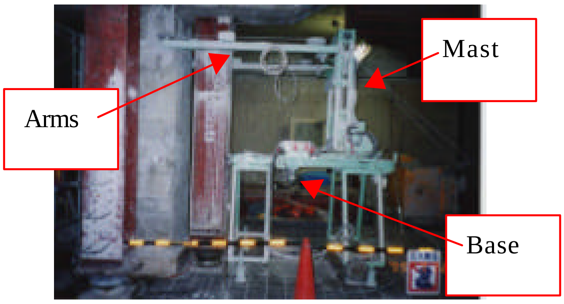


Figure 3. Cutting by wire sawing

the conventional method, wire-saw is wrapped around surroundings in a column. And while being pulled by a driving device, the work of cutting progresses toward from the back to the front. The reason why the cutting by pushing generates less noise is because the wire saw in actual contact with a column is shorting in length. The wire saw has a mechanism of cutting by means of beads that are mounted onto the wire. Many beads are installed in 25 mm. The sound generated when cutting has been generated from a place where beads have come in contact with a column. For this reason a level of sound generated can be suppressed by decreasing the number of beads.

The movement-cutting device (Photograph 2 and Table 2) is composed of a base, arms, and mast. A line to be cut can be set freely to more than FL +700 mm by mounting a stage capable of adjusting its height to the lower portion of a base.



Photograph. 2 Movement-cutting device

Table 2. Specifications unit=mm

Maximum cut section	W1200×D1200
Height of cut position	More than FL +700
Standard size	W1000×D2280×H1650
Minimum size	W790×D1400×H1650
Operation	Operation panel
Weight	550 kg
Power	3Φ 200v

A mast has an ability to go up and down by means of a chain-sprocket system and allows for arms' position to be finely adjusted within a range of 800 mm. An operator can safely cut a column by means of remote control while being able to verify in real time the tension and circulation speed of the wire saw as measured by sensors. Removing parts of a base and two arms allows the device to be conveyed in any elevator of an existing building. Because arms run on a base, cutting can be performed without a large offset from a line being cut and the cut surface is very smooth. This allows a work of removing a cut block and inserting a laminated rubber bearing to be smoothly carried out.

Further, by being able to lower arms to cut a lower position after making an upper cut, without having to stop an operation, means that a time taken to perform a work can be reduced. In addition, there is no necessity to fix pulleys using anchor bolts, and any work generating big sound can be eliminated.

2) Experiments

To confirm the noise and the vibration decreased, the cutting by pushing and the comparison experiments of the conventional method were done. A test piece used was SRC column of 900 mm×900 mm.

When a column had been cut by the same condition, the noise was measured in a place 0.5m away from a column. The cutting by pushing was 81 dB(A), and the conventional method was 90 dB(A). The sound generated from the position where a column was cut confirmed the cutting by pushing was smaller than the conventional method. In addition, it was confirmed that the cutting accuracy was high in cutting by pushing. After these experiments, some improvements were carried out, such as making the movement-cutting device more rigid and improving the performance of arm-moving motor to enhance cutting efficiency.

3) Site test

The cutting by pushing was applied to a seismic isolation retrofit work of an office building completed in 1972 (Photograph 3 and 4). Under the condition that the usual activities of a building would be maintained from the 1st basement to the 8th floor, laminated rubber bearings were mounted to twenty-eight columns on the first floor. Cross-section of a column was 1000 mm x 1000 mm. The cut positions were FL +2500 mm of an upper position, and FL +2000 mm of a lower one. Time to cut a column was 45-50 minutes. This was equal to the cutting time of a conventional method. In the cutting by pushing, arms were lowered after cutting of an upper position was complete and immediately cutting of a lower position was begun. As a result, total working hours by which one column was cut two times was about 3-4 hours including the preparation work. About one hour could be shortened more than a conventional method.

Photograph. 3 After the column cutting ends

Photograph. 4 After the laminated rubber bearing installation ends

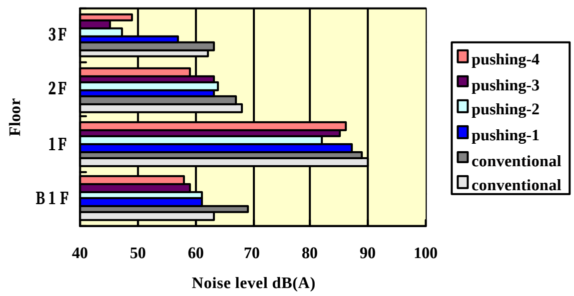


Figure. 4 Noise level during cutting columns

The noise level from the 1st basement to the 3rd floor was measured during cutting a column (Figure 4). The noise levels on the first floor when using the cutting by pushing were approximately 80-85 dB(A). Compared with the conventional method, the new technique allowed noise to be reduced by approximately 5-10 dB(A). On the third floor, noise was much lower. For all floors, vibration levels were less than 40 dB, a level that does not present any problem at all.

3.5 Pulling out a cut block

In order to remove a block safely, a pulling-out device for heavy materials has been developed. Photograph 5 shows an overall view of the device. The wire rope was wound around the periphery of the cut block to be pulled out. The rope connected with the block is pulled with two hydraulic jacks installed in the back of the device. The block is pulled out sliding down on the rail. The device was able to pull out the block safely and efficiently.

Photograph. 5 Pulling-out device

3.6 Prototype manipulators which handles a laminated rubber bearing

1) Mechanism

Usual way of handling a laminated rubber bearing is by means of heavy machinery such as forklift truck. However, the use of heavy machinery is often limited due to the low load supporting capacity of floors. Figure 5 shows the mechanism of a prototype manipulator, which handles a laminated rubber bearing. The mass of one manipulator is approximately 400 N and is not affected by the floor strength because it is mounted onto temporary supports to support the upper structure. The biggest advantage is to be able to move the material of 15 KN in weight by only 300 N force. When a laminated rubber bearing is put on a regular place, a detailed positioning can be easily done. Because two manipulators hold top plates of a laminated rubber bearing while providing upward support from a low position, it is possible to transfer the laminated rubber bearing horizontally through the minimum space that will permit them to pass. Manipulators can also remove a cut blocks through the replacement of holding portion attachment.

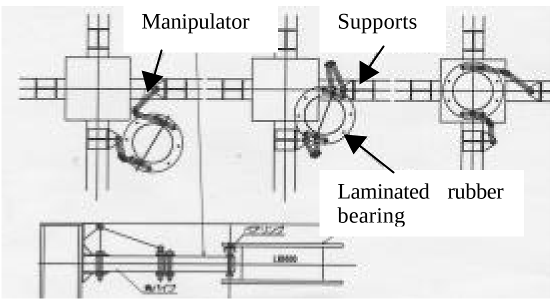
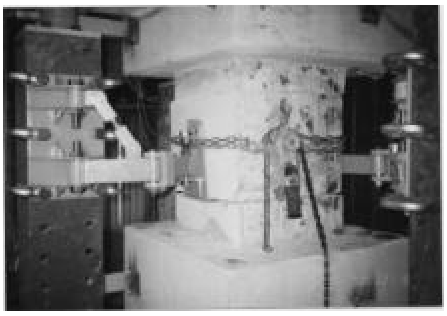


Figure. 5 Prototype manipulators which handles laminated rubber bearing

2) Experiments

In experiments, manipulators were used to pull out a cut block and to move a laminated rubber bearing. The nails mounted on the tip of manipulators



Photograph. 6 Pulling out a block

Photograph. 7 Handling a laminated rubber bearing

were inserted into a gap of approximately 15 mm between the bottom surface of a cut block and the cut surface of a column, and then a block was held and transferred horizontally to be pulled out by manipulators (Photograph 6). A laminated rubber bearing was held and transferred horizontally to a position of fixing (Photograph 7). Just two workers as specified in an initial plan performed all steps.

4. SEISMIC ISOLATION RETROFIT WORK WHILE THE BUILDING IS BEING USED

4.1 Project A building

Seismic isolation retrofit of "A" building is a base isolation in which laminated rubber bearings are installed at the tops of piles. The mass of a building is approximately 1000 MN. The number of laminated rubber bearings to be installed is two hundred and sixty-four. This work scale is the largest in Japan and is the second largest in the world. The purpose of this work is to dramatically enhance safety against strong earthquakes without stopping a computer's functionality. The works are being executed while using a building as usual.

The aforementioned pressing-in joint system was applied to an execution of steel pipe piles that bear the load of the base mat slab. Photograph 8 shows an execution status. Pressing-in joint equipment that uses flash butt welding technique was developed to further reduce the time required for joining steel pipes. And it was applied to a part of an execution. The time required for jointing by means of such welding was approximately four minutes, and the equipment allows the work to be done efficiently compared to that of a typical case of welding.

In analysis done beforehand, supporting of structure and cutting work were modeled. Axial forces and stress deformations of a basic beam in each step were forecast. From these data, a pre-load value and cutting order were decided. A pressure method using the aforementioned pre-stressed steel bars was applied to support the upper structure. After pre-loading, three or four piles were simultaneously cut by the wire sawing method and blocks of approximately 30 KN tons were removed by developed device. Laminated rubber bearings were transferred to positions where they could be installed by a low ceiling forklift truck modified to allow it to be used at a height of 1,800 mm. The bearings were settled by filling high-flow mortar into the clearance between plate of bearing and pile (phtogragh 9).

4.2 Project B building

Before installing laminated rubber bearings on new piles and existing piles, a building was horizontally moved, and construction by which a building was made strong was done. Such construction exists for the first time in Japan. The weight of a building was 20 MN, the distance moved was about 8.2 meters, and the overall work was completed without shutting down any functions of a building. Photograph 10 and 11 show the execution status. To move a building horizontally, forty-one rolling devices were used. The movement devices had steel bars of a diameter of 60 mm arranged on rails that placed on damping plates, which were used for adjusting the horizontal level. The existing base was supported by temporary stage and hydraulic jacks. In order to drive a building, the eight 500 KN hydraulic jacks with strokes of 200 mm were used. A building was moved 80 cm an hour. Three encoders continued to measure horizontal distances moved automatically. Measurement work during working were done to move the building safely, which led to the completion of a seismic isolation retrofit work of moving a building.

5. CONCLUSION

In the paper, it was described to construct seismic isolation retrofit work without stopping any function of a building. Content were techniques developed for the achievement of construction and two projects actual construction. When actually seismic isolation retrofit work will be done, it is important to examine the earthquake performance and the scheme of execution in detail in the master plan stage. A lot of techniques will be accumulated while piling up the improvement while piling up a lot of construction results in the future. Seismic isolation retrofit method with a high additional value will be established.

Photograph. 8 Pressing-in steel pipe pile

Photograph. 9 Status that laminated rubber bearing is fixed

Photograph. 10 Building B panorama

Photograph. 11 Status of movement device

REFERRENCE

[1] T. Miyazaki, T. Suzuki, “13TH. Construction Robot Symposium”,PP.59-64, 2000