

Product Introduction

Development of Oil Damper System for Seismically Isolated Structures with Lock Mechanism

ITO Yoshihiro, SUZUKI Takio

1 Introduction

When we experience massive earthquakes, safety measures are reinforced and earthquake measures are further developed based on the data. After the Hyogo Ken Nanbu Earthquake in 1995, the dissemination of buildings with seismically isolated structures was rapidly promoted. Due to the recent Great East Japan Earthquake in 2011 as well as our response to expected massive earthquakes in the future, etc., the expression “seismic isolation” is now widely recognized in society.

Seismically isolated structures generally have a seismic isolation layer between the ground and the building, reduce the oscillation transmitted to the building by using an isolator (such as rubber bearing), and damp oscillation with damping equipment. Damping equipment includes steel dampers^{Note 1)} and lead dampers^{Note 2)}, but oil dampers have been regarded as the leading equipment since the Great East Japan Earthquake from the perspective of durability to allow continuous use even after large earthquakes. In this report, we would like to take the example of the oil damper system with a lock mechanism (maximum damping force: 1,000kN) which reduces wind shake in case of strong wind and introduce these systems.

Note 1) Hysteretic damper utilizing energy absorption through plastic deformation of steel materials

Note 2) Hysteretic damper utilizing energy absorption through plastic deformation of lead materials

2 Oil Damper with Lock Mechanism

Habitability of regular seismically isolated structures may be damaged due to wind shake caused by strong wind, such as typhoons.

Seismically isolated structures using the oil damper with a lock mechanism (Photo 1) are installed as shown in Photo 2. It functions as an oil damper for seismic isolation in the normal mode (lock: OFF), and the damper’s telescopic movement can be locked (lock: ON) in case of strong wind. This function allows us to improve the habitability of buildings in case of strong wind better than regular seismically isolated structures (Fig. 1 and 2).

Although KYB TECHNICAL REVIEW No. 23 also introduced the concept of locking dampers to respond to

wind shake for individual houses, the oil damper with a lock mechanism introduced in this report is for large buildings, such as high-rises.



Photo 1 Oil damper with a lock mechanism



Photo 2 Installation example of the oil damper with a lock mechanism

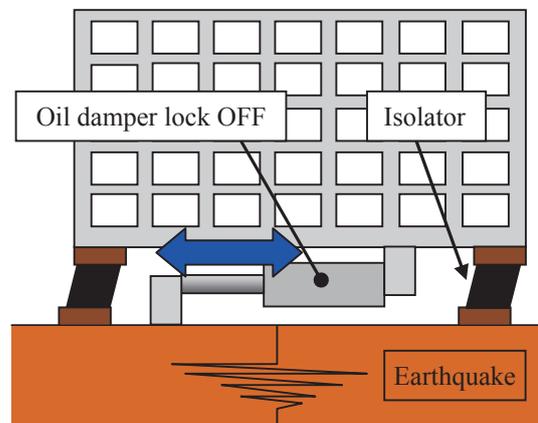


Fig. 1 The damper makes telescopic movements to attenuate oscillation in case of an earthquake

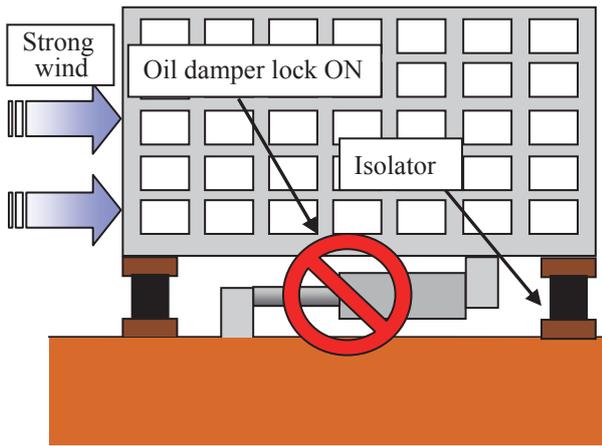


Fig. 2 The damper is locked in case of strong wind in order to reduce wind shake

3 System Development Background

The Japan Society of Seismic Isolation issued the “Guidelines for wind-resistant design of base-isolated buildings” in 2012 (in 2016 for English version), in which wind resistance performance of buildings was clearly indicated in different ranks. Acquiring high evaluation on wind resistance performance also increases building added value, so demand for oil dampers with a lock mechanism has been increasing.

Due to such circumstances, we reviewed the construction workability, cost, and functions of the existing locking control system. We would like to introduce a new-standard control system, which was developed as the foundation for the product lineup.

In addition, the background for the development of the oil damper with a lock mechanism itself is discussed in KYB TECHNICAL REVIEW No. 29 (Oct. 2004), so please refer to it.

4 Structure and Functions of the Oil Damper with Lock Mechanism

4.1 Structure and Functions When the Lock is OFF

As Fig. 3 shows, in this oil damper with a lock mechanism, the damping valve to gain damping characteristics, the lock valve and solenoid valve to control the lock mechanism, and the safety valve to prevent damage due to excessive load when locked are all contained within a valve block.

The oil damper with a lock mechanism functions as an oil damper for seismically isolated structures when the lock is OFF. Due to the fact that this is a “uniflow” type, in which working fluid passes a common damping valve when the damper makes telescopic movements, it operates as shown in Fig. 4 and Fig. 5 during these telescopic movements. In terms of damping characteristics, this system utilizes a linear type, in which the damping force is controlled solely through the damping valve without using relief valves, etc. and the damping force increases along with the velocity.

As Fig. 3 shows, the ratio of “inner tube inner diameter cross-sectional area (chamber A: 2)” and the “value obtained by subtracting the rod’s cross-sectional area from the inner tube inner diameter cross-sectional area (chamber B: 1)” is 2:1. This structure maintains the equal pressure and the working fluid flow volume flowing to the damping valve with telescopic movements. Since the working fluid’s flow volume is converted into the oil damper’s velocity and the pressure is converted to damping force, the oil damper’s damping characteristics during telescopic movements can be maintained equally by maintaining the equal pressure and the working fluid flow volume during telescopic movements.

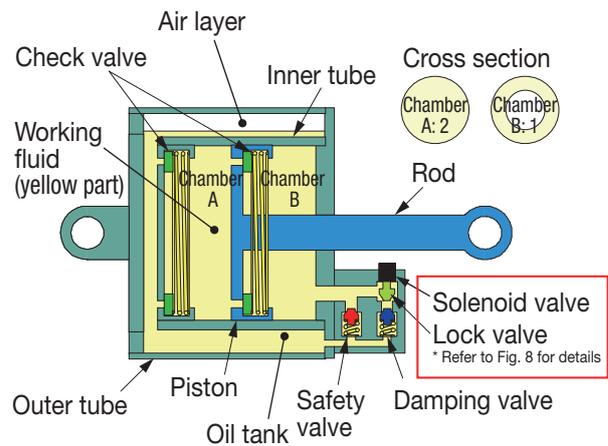


Fig. 3 Damper structure

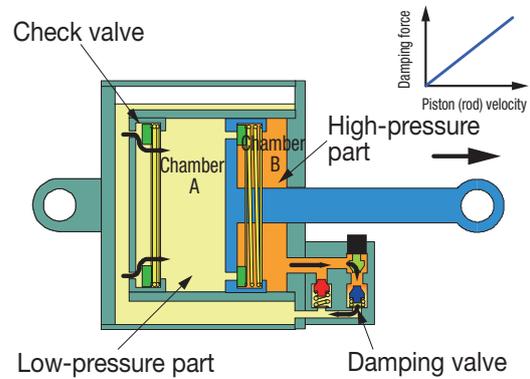


Fig. 4 Damper function (extension direction)

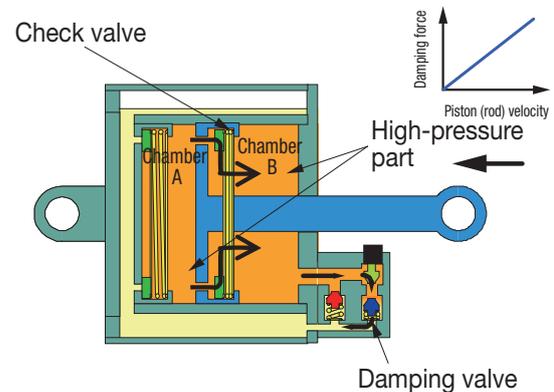


Fig. 5 Damper function (contraction direction)

4.2 Structure and Functions When the Lock is ON

When the lock is turned ON, the lock valve closes as shown in Fig. 6, closing the passage to the damping valve. As previously mentioned, the oil damper with a lock mechanism is a uniflow type. Due to this, when the passage to the damping valve is closed, it cannot make telescopic movements and becomes locked.

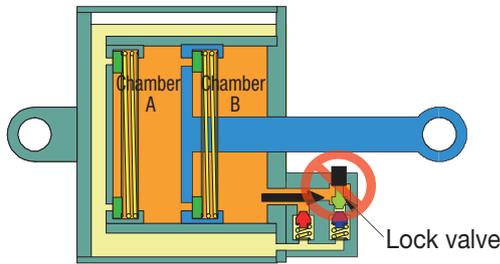


Fig. 6 Damper function when locked

4.3 Safety Valve

The maximum damping force of the oil damper with a lock mechanism is 1,000kN. When the load exceeds this and reaches 1,100 to 1,200kN due to an earthquake, etc. while the lock is ON, the safety valve operates as shown in Fig. 7 and prevents the damper from being damaged due to excessive load.

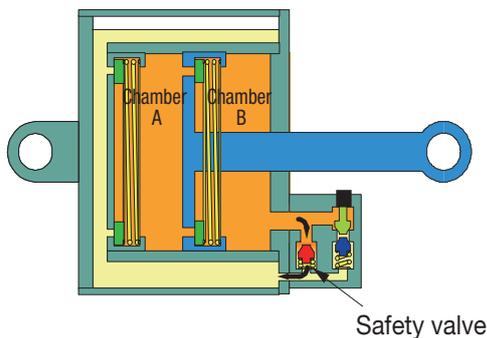


Fig. 7 Safety valve function

4.4 Lock Valve and Solenoid Valve

Lock valves and solenoid valves are structured within valve blocks as shown in Fig. 8.

When the lock is OFF, the solenoid valve is open, keeping the passage to the oil tank open. Due to this, the inner pressure due to the damper's telescopic movements is applied to the cross-section ① as force to open the lock valve. It is also applied to the cross-section ② as force to close the valve, but the force to open the lock valve is greater due to the fact that the area of the cross-section ① is greater, thus opening the passage to the damping valve.

When the lock is ON, the solenoid valve is closed, and inner pressure due to the damper's telescopic movements is applied to the cross-sections ①, ②, and ③. However, in this status, the force to close the lock valve is applied to the cross-sections ② and ③, so the force to close the lock valve is greater, thus closing the passage to the damping valve.

4.5 Solenoid Valve and Connector

Solenoid valve opening and closing are controlled through electric signals. There are 4 valve blocks, which contain solenoid valves, installed on the rod side of the damper, as shown in Photo 3.

A connector (shown in Photo 4) is attached to each solenoid valve, and the damper is connected to the control system with it.

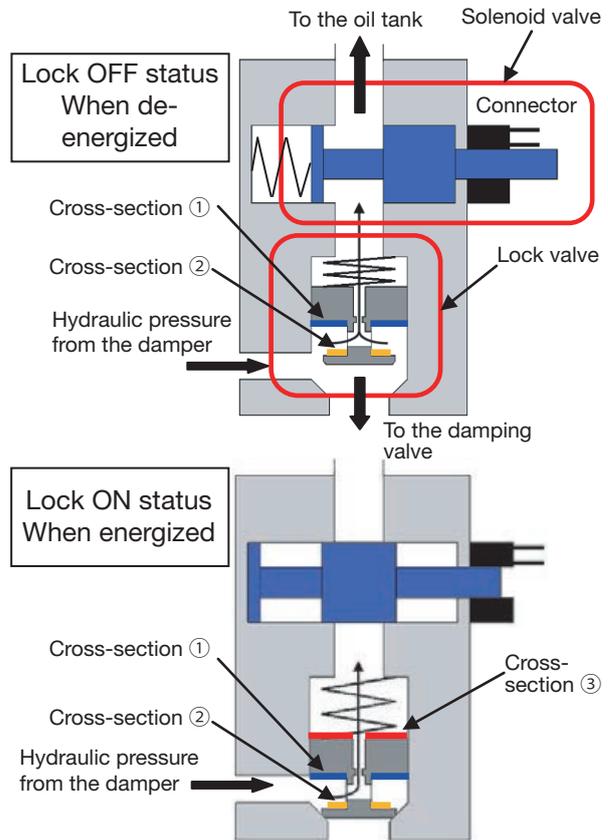


Fig. 8 Lock mechanism

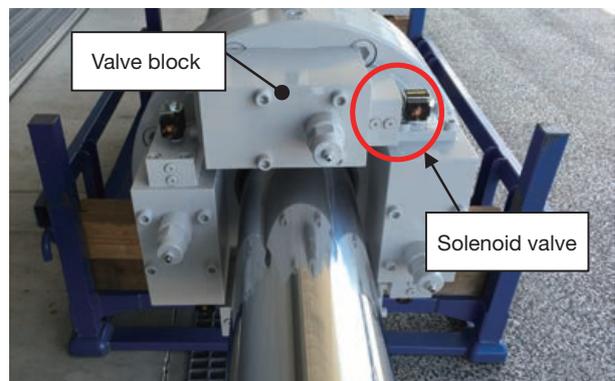


Photo 3 Valve block

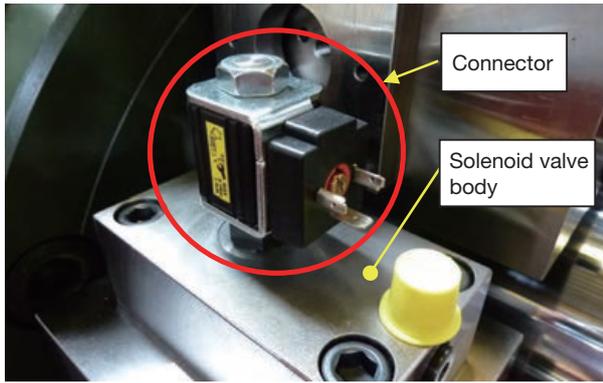


Photo 4 Valve block connector

the seismic isolation effects of the oil damper with a lock mechanism in case of earthquakes, and acceleration data is recorded during earthquakes.



Photo 5 Accelerometer

5 Control Method

In terms of the control method, we have established the standard control method, which uses both wind information and earthquake information, and the simplified system (2 types), which considers the building's usage condition and cost and uses either wind information or earthquake information for the control.

The standard control method description is as follows.

5.1 System Configuration for the Standard Control Method

Fig. 9 shows the system configuration of the standard control system. This system uses accelerometers (Photo 5) to detect earthquakes, anemometers (Photo 6) to detect strong wind, a control panel (Photo 7) to control the electric signals to solenoid valves based on information from each detector, and the junction box (Photo 8) to split 1 cable from the control panel into 4 cables due to the 4 solenoid valves used in each oil damper with a lock mechanism. We recommend that customers use at least 2 units of each detector as a failsafe measure.

We also install an accelerometer on top of the seismic isolation layer to respond to customers' requests to verify



Photo 6 Anemometer

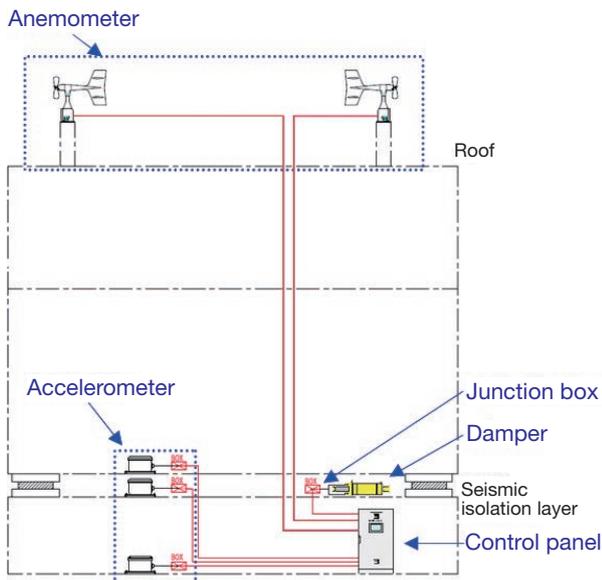


Fig. 9 System configuration



Photo 7 Control panel



Photo 8 Junction box



Photo 9 Control screen

5.2 System Control

Fig. 10 shows the flow chart for the standard control method. The oil damper's lock is OFF in the initial state, and it has an automatic mode and manual mode. However, the automatic mode is normally used. When the wind velocity signal exceeds the set value, the automatic mode automatically locks the oil damper with a lock mechanism. When the acceleration signal exceeds the set value during the lock status or after a certain time period, the lock is turned OFF, and the system returns to the seismic isolation damper status.

In manual mode, the user selects lock ON or OFF by operating the touch panel switches on the control panel (Photo 9). However, the condition to automatically turn the lock OFF is the same as in automatic mode.

The set value for each detector and the set value for each timer can also be easily changed after starting the operation through the same touch panel (Photo 10).

Power failure is a problem in electric control. However, this system uses normal open solenoid valves, meaning that no electricity runs through the solenoid valves. Due to this, the lock is turned OFF in the oil damper with a lock mechanism to make the damper function as an oil damper for seismically isolated structures, thus securing the building's safety.

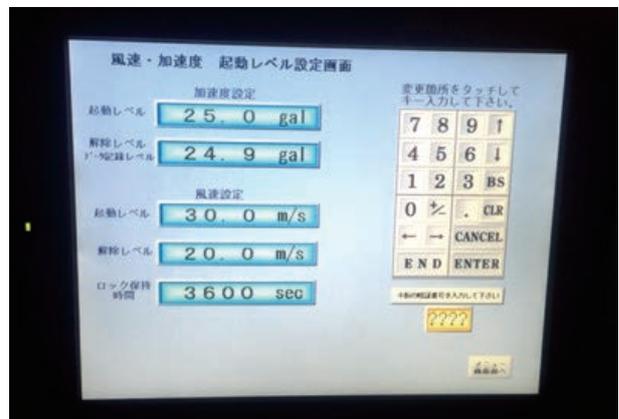


Photo 10 Wind velocity/acceleration startup level setting screen

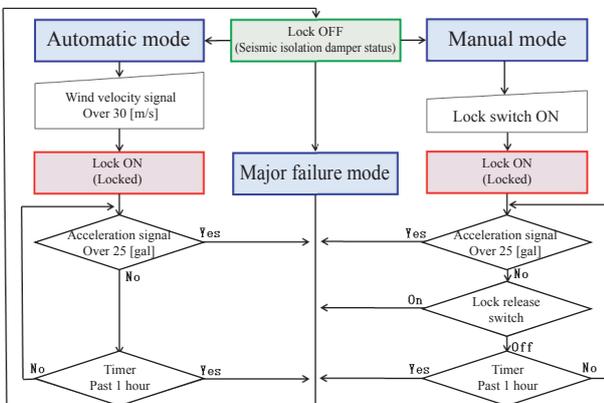


Fig. 10 Standard control system flow chart

6 Introduction Example

We would like to introduce some of the buildings to which this system was introduced.

6.1 Roppongi Grand Tower

In this building with 2 underground floors and 43 above-ground floors, we introduced a standard control system with 2 anemometers, 8 accelerometers (2 for both control/recording, 6 exclusively for recording), and 4 oil dampers with a lock mechanism (Photo 11).

6.2 Tekko Building

In this building with 3 underground floors and 26 above-ground floors, we introduced a standard control system with 3 anemometers, 7 accelerometers (2 for both control/recording, 5 exclusively for recording), and 32 oil dampers with a lock mechanism (Photo 12).

In this example, the signals output from the earthquake/wind observation device, which was introduced by the customer, are imported to the control panel, thus controlling the ON/OFF for the lock of the oil dampers with a lock mechanism.



Photo 11 Roppongi Grand Tower



Photo 12 Tekko Building

7 In Closing

By developing the oil damper system for seismically isolated structures with a lock mechanism and establishing 3 types of control systems, we expect that introduction of this system will further increase and that it will contribute to the improvement of habitability in seismically isolated buildings.

We expect that we will be able to enhance the technology to quickly comprehend the oil damper system's status by utilizing the IoT^{Note 3)} technology, etc. in the future.

Finally, we would like to express our sincere gratitude for everyone who has provided us with their cooperation in the course of this system's development as well as everyone who has given us their approval to post photos.

Note 3) Short for "Internet of Things". It refers to communication of measurement data, etc. by connecting things to the internet.

Author



ITO Yoshihiro

Joined the company in 2008.
Engineering Dept., Mie Plant,
KAYABA SYSTEM MACHINERY
Co., Ltd.
Engaged in design and development
of control.



SUZUKI Takio

Joined the company in 2009.
Quality Assurance Dept., Mie Plant,
KAYABA SYSTEM MACHINERY
Co., Ltd.