Use of Construction Machinery in Earthquake Recovery Work

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OVERVIEW: In addition to use in conventional civil engineering work, the power of construction machines and the range of uses to which they can be put make them vital to disaster recovery work. The Great East Japan Earthquake resulted in unprecedented damage, and the role being played by construction machinery is large, starting with reopening roads to emergency vehicle traffic and extending to recovery work such as removing large quantities of rubble, as well as the reconstruction that has yet to get fully underway. Unmanned construction techniques developed during and after work on recovery from the damage caused by the Mount Unzen-Fugen eruption in Japan have proved effective in dealing with the nuclear power plant accident triggered by the earthquake, and Hitachi Construction Machinery Co., Ltd. has contributed to the cleanup work at the site through the supply of approximately 20 machines. The company is preparing for ongoing disaster recovery work with a product range that includes advanced double-arm working machines and disassemblable hydraulic excavators capable of remote operation.

INTRODUCTION

IN recent years, hydraulic excavator and other construction machines have become an essential part of recovery and reconstruction work after major disasters. With demand for construction machinery in Japan in FY2012 anticipated to increase by 11.3% over the previous year to 605.8 billion yen as a consequence of the Great East Japan Earthquake in March 2011, all the factories of Hitachi Construction Machinery Co., Ltd. are making an effort to increase production.

This article describes conventional construction machinery used in post-earthquake reconstruction along with the assistance provided using advanced double-arm working machines, emergency assistance for Fukushima Daiichi Nuclear Power Station, and disassemblable hydraulic excavators suitable for disaster recovery work.

INVOLVEMENT IN EARTHQUAKE RECONSTRUCTION

Role of Construction Machinery

When television screens showed the huge amount of rubble resulting from the Great East Japan Earthquake, far too much to move using manual labor, the cameras also captured a variety of construction machines at work. It can be thought of as a real demonstration of what construction machinery can do. This section recounts the time since the earthquake and tsunami and describes what is expected from construction machinery in the post-disaster reconstruction.

Fig. 1 shows the progress over time of reconstruction carried out since the earthquake. In practice, the

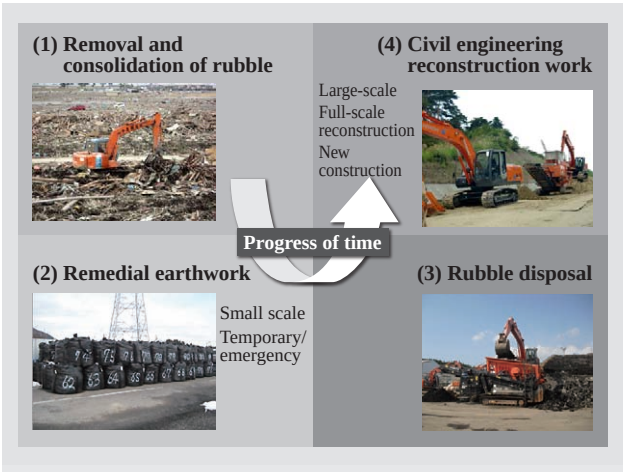


Fig. 1—Progress over Time of Recovery and Reconstruction Work.
First hydraulic excavators are used to remove and consolidate rubble and complete temporary remedial earthworks, then hydraulic excavators and recycling machinery undertake rubble disposal and embark on full-scale civil engineering reconstruction work.

removal and consolidation of rubble was mostly done in parallel with remedial earthworks. Amid horrific scenes, periods when construction machinery was operated to allow for the rescue of survivors was the time for removal and consolidation of rubble. The Tohoku branch of Hitachi Construction Machinery also suffered tsunami damage, and although staff were themselves victims of the devastation, they did their utmost to meet the requests of customers who were pouring their efforts into disaster recovery.

Rubble Disposal Plant

While there have been delays in dealing with the huge quantities of rubble, plants for disposing of this rubble are currently being constructed at various sites, or are already in operation. Although the methods vary between locations and in accordance with other circumstantial factors, recycling machinery are used for some of this work. For example, hydraulic excavators are used to feed concrete demolition material into track mounted crushers that break it up to produce recycled aggregate.

One example of a rubble disposal plant is the "Tagajo City Project for Interim Disposal of Rubble and Other Waste Material from the Great East Japan Earthquake" that Tagajo City in Miyagi Prefecture contracted to the Tohoku branch of Konoike Construction Co., Ltd. (see Fig. 2). The plant helps provide employment in the wake of the worsening of the job market after the earthquake. It also went through a variety of startup problems, not only because some staff had little experience and was unfamiliar with the operation, but also because the rubble was non-uniform. Despite facing many uncertainties about how to get the machinery operating smoothly, the company is taking steps to achieve a high level of plant utilization.

Fig. 2—Tagajo City Project for Interim Disposal of Rubble and Other Waste Material from the Great East Japan Earthquake. The work utilizes all types of recycling machinery, such as track mounted wood grinders and track mounted screens, as well as hydraulic excavators, wheel loaders, and also forklifts made by TCM Corporation, a subsidiary of Hitachi Construction Machinery Co., Ltd.

Fig. 3—Track Mounted Soil Recycler and Other Construction Machinery Used for Civil Engineering Reconstruction Work. It is anticipated that the track mounted soil recycler and other machines will be used for tasks such as stabilization of soft ground, roadbed construction, and repairing of washed-away riverside embankments.

Civil Engineering Reconstruction Work

Plans for civil engineering reconstruction work include the construction of embankments and new expressways or highways for which funding has been allocated in the government's supplementary budget. In particular, it is expected that considerable use will be made of machines such as track mounted crushers able to recycle destroyed coastal embankments and other concrete structures into construction material, and track mounted soil recyclers that can be used for stabilization of soft ground, building roadbeds for new roads, and repairing washed-away riverside embankments (see Fig. 3).

PROVISION OF ASSISTANCE USING DOUBLE-ARM WORKING MACHINES

Deployment of Double-arm Working Machines

Following the Great East Japan Earthquake, double-arm working machines were twice (in May and June of 2011) brought to the disaster zone to support rubble clearance. This machine was developed under a contract with the New Energy and Industrial Technology Development Organization (NEDO) as part of a project to develop strategic and advanced robotics technologies. Equipped with a small auxiliary

Fig. 4—Removal of Refrigerated Vehicle Containers (Ishinomaki City).
The machine's arms were used to separate out the different materials used in the containers, which included steel frames, aluminum, and wood.

Fig. 5—Rubble Clearance (at Minamisanriku-cho).
The main arm holds up steel framing and pulls it away from building foundations so that the cutter attached to the auxiliary arm can cut it free.

arm as well as its conventional main arm, the machine is able to perform complex operations that would not be possible using a conventional hydraulic excavator, such as using the main arm to hold material while the auxiliary arm cuts it[(1)].

Container Removal

The first site was Ishinomaki City in Miyagi Prefecture. Fig. 4 shows the machine in action clearing refrigerated vehicle containers washed into shops by the tsunami. The site was close to Ishinomaki Port and a number of containers of processed seafood had been carried to the shops by the flooding. The work involved using the two arms to separate out the different materials used in the containers, which included steel frames, aluminum, and wood. To allow the material to be removed from the site, it was also broken up into pieces small enough to be loaded onto a trailer.

Cutting and Removal of Steel Framing

Fig. 5 shows the clearance of rubble and scrap in Minamisanriku-cho in Miyagi Prefecture. This harbor-side town suffered enormous damage in the tsunami, with steel framing from factory buildings left scattered about in a complex tangle. The nature of the debris made clearance using just a grapple or other grasping machinery impractical. As steel framing and building foundations had been left fused together in many places after the damage from the tsunami, the work was conducted by using the main arm to hold up steel framing while a cutter attached to the auxiliary arm was used to cut it.

EMERGENCY ASSISTANCE FOR FUKUSHIMA DAIICHI NUCLEAR POWER STATION

System Proposal for Recovery

While achieving a cold shutdown was an urgent task on the recovery roadmap for the Fukushima Daiichi Nuclear Power Station, there was also an urgent need to clear the debris left scattered around the site and to remove as soon as possible the exploded reactor building so that the state of the containment vessel and other internal parts could be ascertained. Hitachi Construction Machinery worked with other Hitachi Group companies to directly or indirectly offer Tokyo Electric Power Co., Inc. the associated materials and systems needed for the recovery.

To begin with, working through the Unmanned Construction System Association (a society for unmanned construction with 18 member companies, including construction companies), it was decided that emergency cleanup of the debris around the site would require use of radio-controlled hydraulic excavators and radio-controlled carriers for removing rubble and other material. Accordingly, Hitachi Construction Machinery modified a crawler carrier for radio-controlled operation and brought it to the site (see Fig. 6).

Next, as the details became clearer, it was determined that the exploded building contained a large amount of scattered debris and structural material (including steel H beams), and that removal work would need to be carried out at heights of 30 m or more and under high levels of radiation.

Fig. 6—Radio-controlled Crawler Carrier.
This EG110R crawler carrier was modified for radio control and supplied to the site together with the remote controller (specified low-power 429-MHz band).

TABLE 1. Main Technical and Commercial Aspects of Emergency Response
The table lists the main challenges in the way of achieving a resolution by the in-house Fukushima Nuclear Power Station Project established by Hitachi Construction Machinery.

Challenge	Response
Confirm ability of electronic equipment to tolerate radiation.	Conducted durability testing of actual electronic equipment (at JAEA).
Prepare radio control components.	Emergency component stockpiling and procurement
Establish video transmission system for remote control.	Collaborate with construction companies and experts (build a system using commercially available parts).
Construct automatic fuel supply system.	Generate ideas and develop rapidly (outsource manufacturing to specialist companies).
Develop lead-lined protective cab (for manned operation).	Build local ventilation system for radioactive fumes based on in-house design.
Build suspended steel frame demolition system.	Proceed with in-house development based on prior testing of cutter capabilities.

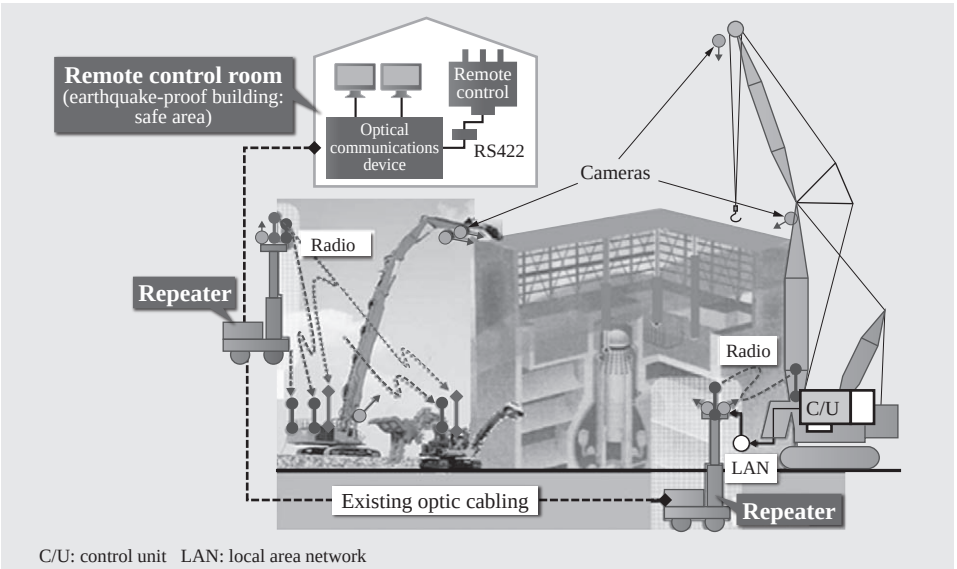
JAEA: Japan Atomic Energy Agency

In response, because of its strengths in fields such as demolition machines and large cranes, Hitachi Construction Machinery embarked on the development of machinery and radio control systems in cooperation with related parties (see Fig. 7).

Technical Development and Emergency Response

To ensure a rapid response to the accident at Fukushima Daiichi Nuclear Power Station, Hitachi Construction Machinery established its own in-house Fukushima Nuclear Power Station Project and included sales departments in its activities. Table 1 lists the main challenges in the way of achieving a resolution.

As many aspects of these challenges could not be overcome by the company on its own, Hitachi Construction Machinery actively sought to cooperate with specialist agencies and suppliers. To assess the radiation tolerance of electronic equipment, Hitachi Construction Machinery conducted testing at the Takasaki test facility of the Japan Atomic Energy Agency (JAEA) to determine suitable standards for cumulative exposure. Machinery such as the remotely operated demolition machine and large crane that Hitachi Construction Machinery offered the site is being used for removal of debris from reactor No. 3 (see Fig. 8).



C/U: control unit LAN: local area network

Fig. 7—Proposed Remote Control System for Large Machinery.
Hitachi Construction Machinery was quick to propose a remote control system using equipment such as demolition machines and large cranes to the relevant authorities, and started work on preparing the machinery and radio control system.

Fig. 8—Remotely Operated Upright Demolition Machine. Hitachi Construction Machinery's remotely operated demolition machine (center rear of photograph) in action at reactor No. 3 where it is used for tasks such as removing beams from the collapsed building.

DISASSEMBLABLE HYDRAULIC EXCAVATORS

Previous disassemblable hydraulic excavators were developed for small-scale civil engineering work in mountainous locations that lack access roads for heavy equipment, such as the construction of power pylons. In recent years, however, demand has emerged for the development of large disassemblable hydraulic excavators capable of performing conventional-scale earthworks to prevent further damage, and able to be helicoptered into the site in the initial stages of the response to a major disaster without waiting for heavy equipment access roads to be opened up (see Table 2).

Based on experience with use of a 0.45-m^3-class disassemblable hydraulic excavator in recovery work after the 2008 Iwate-Miyagi Nairiku Earthquake, Hitachi Construction Machinery received an order from the Tohoku Regional Bureau of the Ministry of Land, Infrastructure, Transport and Tourism of Japan to develop a larger 1.0-m^3-class model in 2010 (see Fig. 9 and Table 3).

The Tohoku Regional Bureau trialed the excavator in six prefectures of Tohoku to confirm that it was suitable for use in disaster recovery work.

TABLE 2. Deliveries of Disassemblable Hydraulic Excavators
The table lists the numbers of excavators delivered by Hitachi Construction Machinery between 1966 and 2011.

Bucket size	No. of excavators	Main uses
0.25-m^3 class	43	Small-scale civil engineering work in mountainous locations (such as construction of power pylons in locations lacking access roads)
0.45-m^3 class	15	
0.7-m^3 class	6	Conventional-scale civil engineering work (disaster response work when roads are closed)
1.0-m^3 class	1	
Total	65	

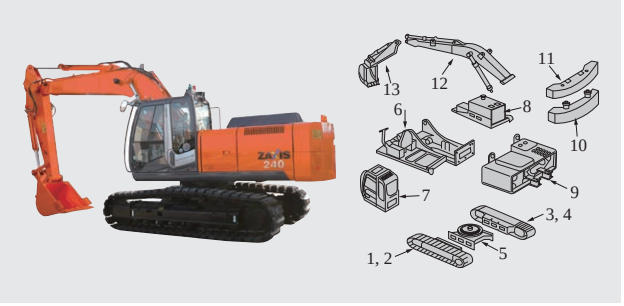


Fig. 9—1.0-m^3-class Disassemblable Hydraulic Excavator in Assembled and Disassembled Forms (Excluding Accessories). The design includes use of flanges on detachable parts of structural components, one-touch hydraulic couplings, electrical connectors, and a weight that can be split into upper and lower halves.

TABLE 3. Specifications of 1.0-m^3-class Disassemblable Hydraulic Excavator
In addition to being operated by a driver, the excavator is also fitted with a radio system to allow remote operation.

Item	Specification	Remarks
Machine type	ZX240-3 2.7-t disassemblable excavator	Complies with regulation stage III for construction use. Splits into 14 units.
Bucket capacity	1.0 m^3	New JIS
Machine mass	25,800 kg	
Rated engine output	132 kW/2,000 min^{-1}	
Operation	Driver-operated	Also supports remote operation.

CONCLUSIONS

This article has described conventional construction machinery used in post-earthquake reconstruction along with the assistance provided using advanced double-arm working machines, emergency assistance for Fukushima Daiichi Nuclear Power Station, and disassemblable hydraulic excavators suitable for disaster recovery work.

Through its involvement in reconstruction assistance, Hitachi Construction Machinery has seen firsthand the state of the affected areas, right back to the immediate aftermath of the earthquake. While we have done what we could to assist, the effort made by the local people remains a humbling memory. We would also like to take this opportunity to extend our

condolences to the families and associates of all those who fell victim to the disaster.

With reconstruction work set to begin in earnest, Hitachi Construction Machinery Co., Ltd. intends to adopt a more customer-oriented perspective and to share its operational know-how with the people on the ground as it takes steps to provide a one-stop shop for the required equipment and materials.

REFERENCE

(1) T. Omata et al., "Development of Double Arm Working Machine for Demolition and Scrap Processing," 2011 Proceedings of the 28th ISARC, pp. 76–81 (2011).

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