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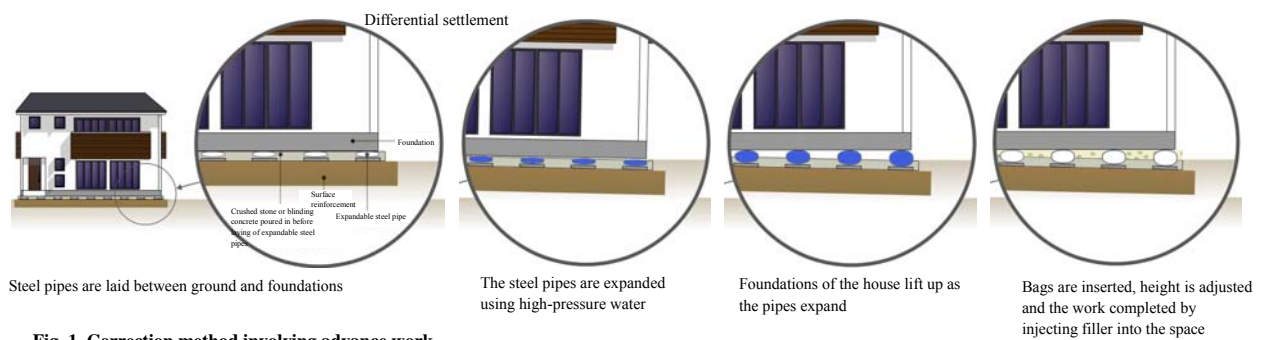
Sumitomo Forestry Co., Ltd.  
Nisshin Steel Co., Ltd.  
Nisshin Kokan Co., Ltd.

Environmentally Friendly Method Effective for Soft Ground Areas  
**Sumitomo Forestry Develops Differential Settlement  
Correction Method for Housing**  
—Cost of Correction Reduced Compared to Existing Methods—

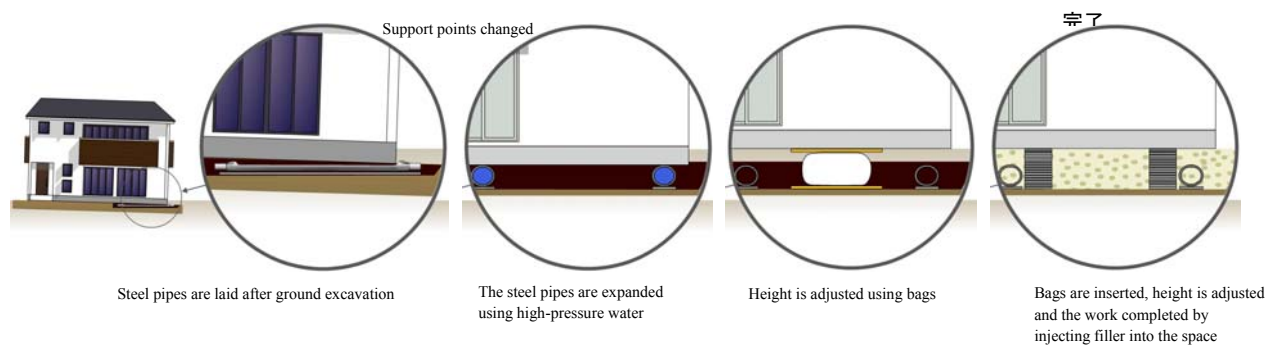
Sumitomo Forestry Co., Ltd. (President and Representative Director: Akira Ichikawa; Head Office: Chiyoda-ku, Tokyo), Nisshin Steel Co., Ltd. (President and CEO: Toshinori Miki; Head Office: Chiyoda-ku, Tokyo), and Nisshin Kokan Co., Ltd. (President: Tatsuji Tomiyasu; Head Office: Chiyoda-ku, Tokyo) have jointly developed a differential settlement correction method for housing. The method, which involves raising the actual foundations of a house, can be used to correct differential settlement of houses built in areas where the ground is soft.

The method entails either advance work at the time of a house's construction—ZAM® expandable steel pipes (rock bolts) are laid down beneath the foundations to allow remedial work if differential settlement occurs (Fig. 1)—or post-construction work after differential settlement occurs (Fig. 2). If work has been carried out in advance, the correction method involves injecting water into the rock bolts to create space, inserting watertight, pressure-resistant bags into the space created and adjusting height by adding water pressure, and then injecting a material like urethane foam into the space as a permanent measure. Post-construction correction work additionally requires excavation of the reinforced ground surface and laying of expandable steel pipes. The method is kinder to the environment than conventional chemical grouting, provides better corrosion resistance than raising the house with hydraulic jacks, and has a major advantage of being low-cost. A patent application for the method has been filed.

A building might settle for a number of reasons, including as a result of an earthquake, drawing of water, or consolidation settlement due to ground-raising. This correction method allows people to live in comfort and safety with peace of mind even if differential settlement does occur.



**Fig. 1. Correction method involving advance work**



**Fig. 2. Post-construction correction method**

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ZAM®: A hot-dip coated steel sheet developed by Nisshin Steel with a coating layer of zinc, aluminum (6%) and magnesium (3%). Boasting high corrosion resistance and workability, ZAM® hot-dip coated steel sheet is environmentally friendly and can be used to replace post-galvanized products.

## ■ Description of the Technology

The differential settlement correction method for housing employs expandable steel pipes that are manufactured using ZAM® raw material and boast high corrosion resistance because they lie in the ground, as well as workability. The expandable steel pipes are pipes usually used for tunnel excavations which have undergone special processing. This method, with either advance or post-construction work, can be applied on the condition that surface reinforcement, or reinforcement using columns, is carried out to establish a repelling force for expanding the rock bolts; that the house has a mat foundation divided into uniform sections by foundation walls; and that the house has no more than two stories and has no basement.

This method is very safe since laying of the rock bolts does not require actually going beneath the foundations, and it is low-cost because, unlike methods employing hydraulic jacks, installation of steel-pipe piles is not needed. The burden on the house is also minimized as it is raised from beneath the foundations in a straight line. Thus, the method is kind on people, the environment, and houses.

## ■ Expandable Steel-Pipe Rock Bolts

Expandable steel-pipe rock bolts are supports used to bind together (stabilize) ground loosened during tunnel excavation. Nisshin Steel Group uses its ZAM® highly corrosion-resistant, hot-dip coated steel sheet as material for the steel pipes, realizing long-term durability. After insertion into radially-arranged holes in the interior walls of a tunnel, the steel-pipe rock bolts are expanded by injecting high-pressure water of 200-250 bars into the steel pipes. When the water is drained from the steel pipes, the pipe sticks fast to the wall of the hole, quickly becoming part of the surrounding ground, contributing enormously to the safety and progression of tunnel excavation. Steel pipes are expanded in the same way, using high-pressure water, in the differential settlement correction method developed on this occasion, which employs the jack-up function achievable with expandable steel pipes (Fig. 3) on a flat surface, thereby safely and reliably separating the ground and foundations.

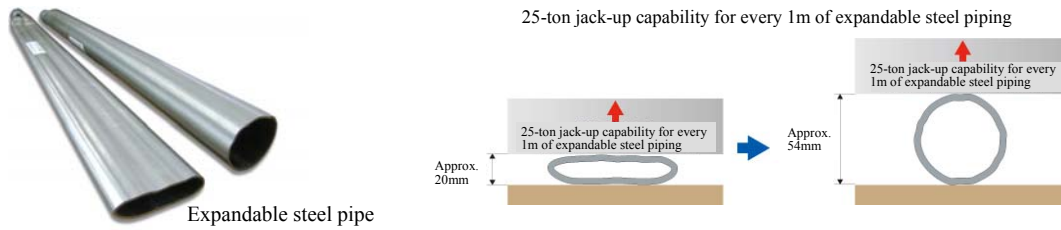


Fig. 3. Jack-up function of expandable steel pipes

### ■ Background to Development

Methods for correcting differential settlement of buildings, such as detached houses, in areas where the ground is soft include injection of grout into the ground (Fig. 4), and underpinning, which involves installation of steel-pipe piles under the foundations in order to raise the house using hydraulic jacks (Fig. 5). The former requires environmental considerations regarding adjacent land. The latter is difficult where there is no bearing layer in the ground, and even if it is possible, costs tend to be high. The method also involves operation of hydraulic jacks beneath the existing house, which necessitates safety management.

Sumitomo Forestry saw potential in the powerful and consistent jack-up capability of the expandable steel-pipe rock bolts developed and launched by the Nisshin Steel Group in 2003 for a safe, environmentally friendly and low-cost differential settlement correction method. The three companies commenced joint development in 2006, leading to success with this method.