

## PRACTICAL TILE-SETTING ROBOT FOR EXTERIOR WALLS

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### Abstract

Hazama Corporation, the Japan Ceramic Tile Association and Komatsu Ltd. have been and are developing tile-setting robots to automatize the process of tile-setting operations on the exterior wall of building. This paper describes an improved tile-setting robot and reports the observations in the indoor and outdoor experiments of its operations.

### 1. Introduction

Faced by a need to improve the durability of concrete surface and to add the beauty of its appearance, tiled exterior walls of buildings are very popular in Japan. Tiles, which are set on exterior walls, most likely are very thin such as 108 or 227mm long, 60mm wide and 8 to 15mm thick. Tile-setting operations required tile-workers high dexterity. The number of experienced tile setters has been and is decreasing, in spite of increasing the demand for tile-setting operations on the exterior wall of building in Japan.

To improve the quality and productivity of tile-setting operations, tile-setting robots for exterior walls has been and is being developed by Hazama Corporation, the Japan Ceramic Tile Association and Komatsu Ltd.. The process of the development of the tile-setting robots is outlined as follows:

Stage 1: design the concept of tile-setting robot and specify its indispensable functions ;

Stage 2: develop a specialized tile-setting robot and evaluate its availability ;

Stage 3: evolve further refinements of the tile-setting robot.

Tomaru, H., Haino, H. and Ishikawa, S. did research on the development of a tile-setting robot at the stages 1 and 2, and reported the findings of the research<sup>1</sup>. The tile-setting robot has been further improved at the stage 3.

First, this paper presents the improved tile-setting robot. Second, this paper reports the observations in the indoor and outdoor experiments to evaluate the operability of the improved tile-setting robot. Finally, we conclude with a summary of this study and discuss further research.

## 2. Evolving Further Refinements

Further refinements of the tile-setting robot have been achieved at the stage 3, focusing on the improvement of mobility and operability. The distinctive refinements are summarized below.

- (1) Get smaller 40% in its size and lose 80% in its weight.
- (2) Increase 50% in its productivity more than before.
- (3) Simplify its operations so that unskilled workers can easily operate it just by pushing the ON/OFF switches. The previous version of tile-setting robot required tile-worker some computer works which they were unfamiliar with.
- (4) The guide rails for a horizontal carriage of the tile-setting robot are mounted on scaffolding instead of being fastened by anchor bolts on the exterior wall. The disappearance of these anchor bolts enables to avoid manual works for tile-setting on the areas for anchor bolts of exterior wall.

The configurations of the improved tile-setting robot are shown in Photo 1. The specifications of the improved tile-setting robot are summarized in Table 1. Figure 1 shows the system components of the improved tile-setting robot.

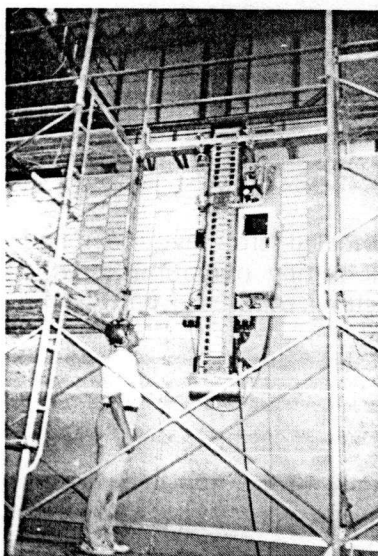


Photo 1. The improved tile-setting robot

Table 1  
Specifications of the improved tile-setting robot

Items		Specifications
Body of the Robot	Types of Joints	Lengthwise Horizontal Orientation Square Joint and Cross Joint
	Joint Width	Vertical Joint : $8 \pm 2\text{mm}$ Horizontal Joint: $9 \pm 2\text{mm}$ Expansion Joint: As possible as avoid
	Unit Execution Area	Approx. $0.4\text{m}^2$ (for 1 setting)
	Method of Movement	(Horizontal) Guide Rails (Vertical) Chain Block, etc.
	Power Source	AC100V
	Established Place	Space between building and scaffolding (width 30-33cm)
	Outer Frame Dimensions	height 2.8 x width 0.8 x depth 0.26m
Equipments	Weight	Approx. 260kgf
	Guide Rails	height 60 x width 30 x length 1800mm
	Air Compressor	Above 2.2kw class(AC200V)
Appropriate Materials	Setting Mortar	Pre-mixed Mortar
	Tiles	227 x 60 mm tiles (thickness 8-15mm) Flat Surface Smoothness

A tile setter supplies the mortar hopper with mortar. The capacity of the mortar hopper is approximately 5 liters of which the volume is sufficient to process about 50 tiles (227mm x 60mm). The mortar trowel places the correct dose of mortar on the reverse side of the tile. A tile setter successively supplies the tile-holding unit with tiles.

As the tile-holding unit is carrying tiles, the tile-setting unit automatically and accurately places the tiles one next to the other to attain a continuous surface on the exterior wall. The tile-setting unit has an electric powered vibrator to firmly place tiles on the exterior wall, and has an air actuator with potentiometer that measures the finishing thickness of mortar required to accurately place tiles on the exterior wall.

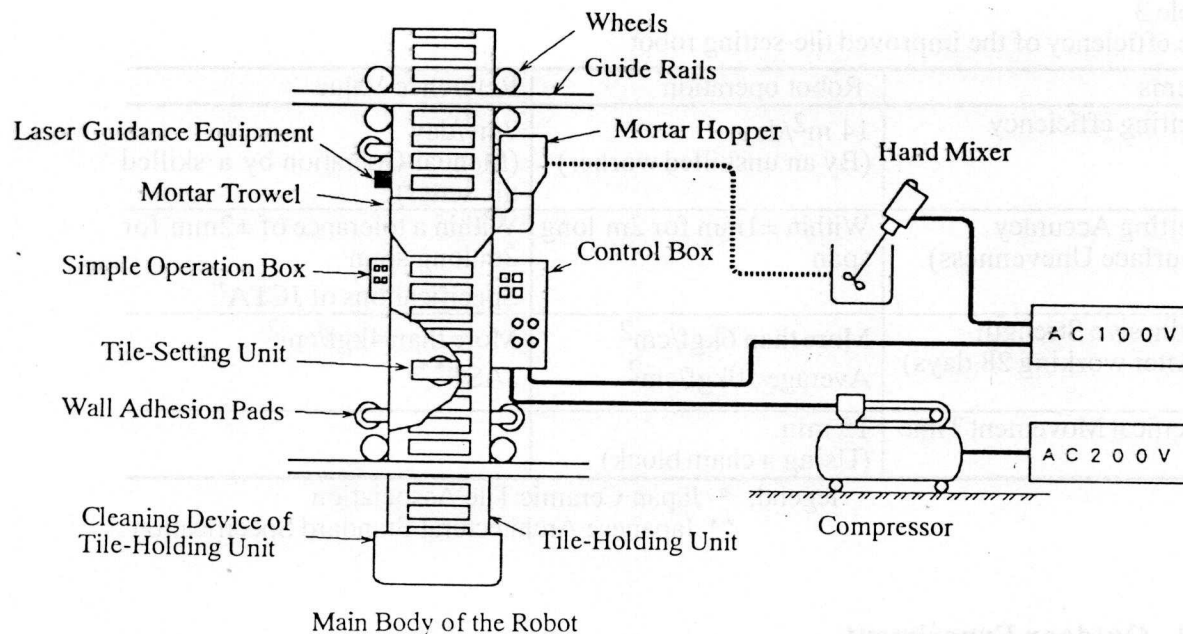


Figure 1. The system components of the improved tile-setting robot

This tile-setting routine is programmed off-line into the control box. The conditions of tile-setting, for example, the number of tiles in a line, joint width, a type of joint, location of expansion joint, were instructed on the control box by tile setter. Besides, the control box has a self-inspecting function to detect existing failure modes, to stop the operation of the improved tile-setting robot and to inform the tile setter of the potential causes as shown in Table 2.

Table 2  
Failure modes and the potential causes

Item	Failure Mode	Potential Cause
Tile-setting unit	<ul style="list-style-type: none"> <li>Motion as unintended</li> <li>- Not being in compliance with preprogrammed instruction.</li> <li>- Although a tile is being pushed toward the exterior wall, the tile can not be reached to the exterior wall.</li> </ul>	<ul style="list-style-type: none"> <li>- the snapping of wire</li> <li>- fail to supply the tile-setting unit with the correct dose of mortar</li> <li>- get mixed with alien substances</li> <li>- the distance between the tile-setting unit and the exterior wall may be longer than expected</li> </ul>
Tile-holding unit	The sensor of the tile-holding unit can not fetch a tile.	forget to supply the tile-holding unit with a tile

### 3. Observations in Experiments

#### 3.1. Indoor Experiment

Using a model wall, which is 7.5m long and 3.6m high, an indoor experiment of the operation of the improved tile-setting robot was carried out. The main items being tested were: (1) setting efficiency, (2) setting accuracy, (3) adhesive strength and (4) vertical movement time (i.e., between floors). The observations in the indoor experiment are summarized in Table 3.

Table 3  
The efficiency of the improved tile-setting robot

Items	Robot operation	Reference Value
Setting efficiency	14 m <sup>2</sup> /day (By an unskilled worker)	7m <sup>2</sup> /day (Manual Operation by a skilled tile setter)
Setting Accuracy (Surface Unevenness)	Within $\pm 1$ mm for 2m long span	Within a tolerance of $\pm 2$ mm for 2m long span Specifications of JCTA *
Adhesive Strength (After working 28 days)	More than 6kgf/cm <sup>2</sup> Average 10kgf/cm <sup>2</sup>	More than 4kgf/cm <sup>2</sup> JASS**
Vertical Movement Time	15 min. (Using a chain block)	-

legend: \* Japan Ceramic Tile Association

\*\* Japanese Architectural Standard Specification

### 3.2. Outdoor Experiment

To evaluate the operability of the improved tile-setting robot at an actual job-site, an outdoor experiment of its operation was carried out on the exterior wall, which is 9m long and 7.5m high, of Acoustics and Electric Wave Laboratory of the Technical Research Institute, Hazama. The numbers of setting tiles are about 2400 pieces. Photo 2 shows the existing conditions of the outdoor experiment. Photo 3 shows the exterior tiled wall, which the improved tile-setting robot produced.

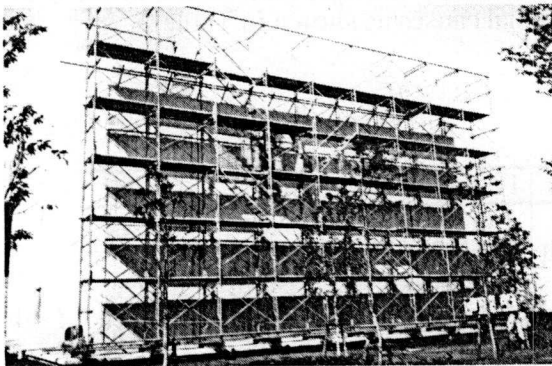


Photo 2 The existing conditions of the outdoor experiment

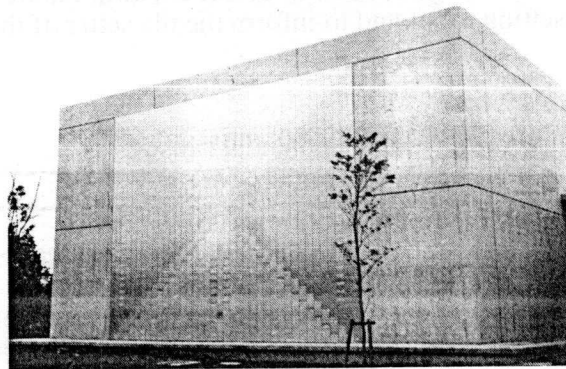


Photo 3 The surface of the exterior tiled wall

It was seen from the outdoor experiment that the setting efficiency was more than 14m<sup>2</sup>/day and that the adhesive strength (after working 28 days) was 17.2kgf/cm<sup>2</sup> in average and 2.1kgf/cm<sup>2</sup> in standard deviation.

From these observations, it can be seen that the improved tile-setting robot, which is operated by an unskilled worker, can realize the better quality and higher productivity of tile-setting operations than a skilled tile setter.

#### **4. Conclusion**

As can be seen from the observations in the indoor and outdoor experiments of the improved tile-setting robot, it could improve the quality and productivity of tile-setting operations and thus could overcome the shortage problem of skilled tile setters.

Further research problem is to evolve further refinements of the improved tile-setting robot so that it could also be available for tiles, 108mm x 60mm.

#### **References**

1. Tomaru, H., Haino, H. and Ishikawa, S., "Tile Setting Robot for Exterior Wall", in Proc. of 8th. I.S.A.R.C., pp.929-936, 1991.