

DEVELOPMENT AND APPLICATION OF THE LIGHT WEIGHT MANIPULATOR FOR INTERIOR FINISH WORK

Kenji Nanba, Masayuki Takasu, Tutom Sato, Sigeyuki Kojima
Mechatronics Research Dept. Institute of Technology
Tokyu Construction Co., LTD
3062-1, Soneshita, Tana, Sagamihara, Kanagawa, 229, Japan

ABSTRACT

Interior finish work of a building under construction, which is work in a closed space, is behind the times in labor saving by mechanization. This made us develop a light weight multi-purpose manipulator applicable to different places and types of construction work as well as to various types of interior work, by changing the construction of the unit only. This unit has already been introduced to more than ten construction sites, through which the improvement in the speed, efficiency, and safety of interior finish work has been confirmed. Though the details of the Light Weight Manipulator was reported at the Fourth Symposium on Construction Robotics in Japan held in 1994, this paper presents the improved points for application of the units at construction sites, and reports the examples for ceiling work.

1. INTRODUCTION

Though many robots for construction work have been developed until now, most of them are monofunctional robots, which can not fully demonstrate their functions for various and different interior finish work, and are not in common use at present.

Under such a background, the Light Weight Manipulator has been developed as a multi-purpose type robot for construction work applicable to various interior finish work. This unit can be used both as a handling machine and a mobile scaffold, and is highly applicable to each type of interior finish work.

2. OUTLINE OF UNIT

2.1 COMPOSITION OF UNIT

The outline plan and specification of the Light Weight Manipulator are shown in Fig. 1 and Table 1 respectively. The unit is composed of the body consisting of a manipulator and a traveling truck, and the attachments, adapters, and working stage that are connected to the body.

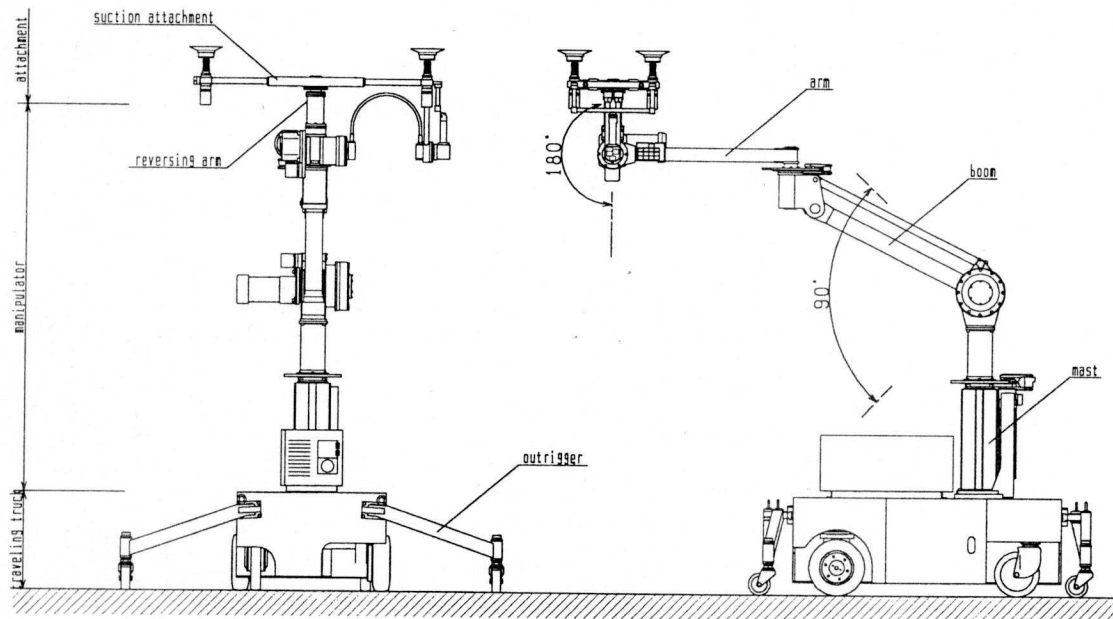


Fig. 1 Outline of The Light Weight Manipulator

Table 1 Specification of The Light Weight Manipulator

Size for storing	* With outrigger: 1,594 (L) × 774 (W) × 1,500 (H) mm. * Without outrigger: 1,304 (L) × 774 (W) × 1,500 (H) mm.
Weight	* Weight of body: 585 kg. * Weight of suction attachment: 30 kg. * Weight of work stage: 45 kg each.
Operational size and range	* Reach of tip : Maximum height: 2,580 mm (at the center of the reversing device). : Minimum height: 870 mm (at the center of the reversing device). : Maximum radius: 1,750 mm (at the center of the reversing device).
Movable weight	* Movable weight of manipulator: 150 kg. * Movable weight of reversing device: 120 kg.
Power supply	* Traveling truck: 24 VDC. * Manipulator: 100 VAC.

1) Body

The manipulator is of a manual operation type, and is moved up/down by an electric motor, and moved freely in horizontal directions by a slight force.

The traveling truck is driven by a motor powered by batteries, and can move in three patterns (going ahead/backward, traversing, and turning).

2) Attachments and adapters

There are a suction attachment that holds interior finish materials by four suction pads and a table attachment that is used for loading small interior finish materials, such as finish boards, and for fitting fan coils, ducts, and the like.

For wall and floor work, an exclusive adapter is fitted between the suction attachment and reversing arm. There are two types of exclusive attachments, those for wall work and those for floor work. The former is provided with a rotating shaft so that the suction plane of the suction attachment may be parallel with the wall surface, and the latter can extend the length of the reversing arm so that the suction attachment may reach the floor surface.

3) Work stage

Connected with the body, the work stage is used as a mobile scaffold. The layout of the work stage can be altered freely according to the details of the work or floor conditions.

2.2 IMPROVED POINTS OF UNIT

After the introduction of a trial unit into the site, the following improvement has been made for safer and more efficient application.

1) Reduction in assembling and disassembling work

- * The compressor fitted outside was mounted on the traveling truck of the body.
- * The connection between the work stage fitted to the body and the traveling truck was simplified.

2) Safety devices attached

- * An alarm buzzer was newly provided to avoid the danger of falling interior finish materials due to insufficient adhesion by suction.
- * A safety device was provided that can maintain the adhesion by suction even in case of a power failure during handling interior materials by suction.
- * A safety device was provided that disables the manipulator while the outrigger for preventing falling down is not used.

3) Improvement on operationality and workability

- * The power supply for the manipulator block was changed from general-purpose 200 VAC to 100 VAC.
- * A simple step was provided for fitting work of wall materials.
- * An up/down switch was provided additionally to the suction attachment to enhance operational workability in fitting work of wall materials.
- * The maximum working height was increased from 3,000 mm to 3,800 mm by providing an adapter for extension of the mast.

3. EXAMPLE OF WORK TO FIT CEILING BACKER BOARDS

3.1 OUTLINE OF WORK

Application: A station building and shops.

Construction scale: Steel structure (part steel enhanced reinforced concrete and reinforced concrete construction).

One story under the ground, and six stories and a one-story penthouse above the ground,

Total floor area: 39,056.7 mm².

Since this building was big in floor area because it was to be used as shops and the ceiling is of two-play application, the manipulator was introduced to enhance work efficiency.

3.2 COMPOSITION OF WORK

Introduction was planned taking the size and shape of the floors and details of work into consideration. The composition of the equipment for fitting ceiling backer boards is shown in Fig. 2.

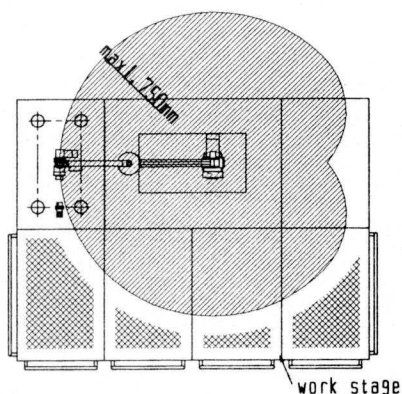
The objective interior finish material is gypsum boards, 910 mm in width, 1,820 mm in length, and 9 mm in thickness. The suction attachment was used for handling gypsum boards.

For ceiling work, the work stage is connected to the body to form the mobile scaffold, and the layout of the work stage was decided taking the working range and workability of the manipulator into consideration.

3.3 WORKING STATUS

It took about two hours each for work preparation and guiding interior finish subcontractors after the introduction of this unit into the site.

The working status using this unit is shown in Photo 1, and the working range and order in Fig. 3.



Attachment	*Suction attachment
Work stage	* Quantity: 6 sets. * Constructional size : 3,000 × 4,000 mm. * Height of work floor : 1,000 mm.

Fig. 2 Composition of Equipment

Fitting work of ceiling backer boards was carried out by a gang of two workers, and one of them operated the unit and the other fitted boards by screws. Fitting work of ceiling backer boards around columns and near the wall that requires processing was carried out manually.

Since pretty much pitch of columns in this site did not disturb the move of the unit, continuous operation could be carried out.

3.4 RESULTS OF WORK

The results of fitting work of ceiling backer boards using the Light Weight Manipulator are shown in Table 2. The introduction of the manipulator increased the work speed by 30% in comparison with that of traditional work. This is because the use of the manipulator in handling ceiling backer boards not only improved the efficiency of the work but also eliminated preparative work, such as moving temporary scaffold. This increased time for which workers dedicated themselves to fitting ceiling backer boards.

Lifting up and holding heavy ceiling backer boards by the manipulator reduce physical load and eliminated accumulated fatigue of the workers.

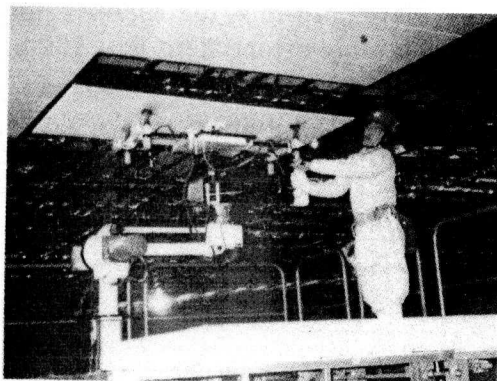


Photo 1 Work Status of Ceiling Backer Boards

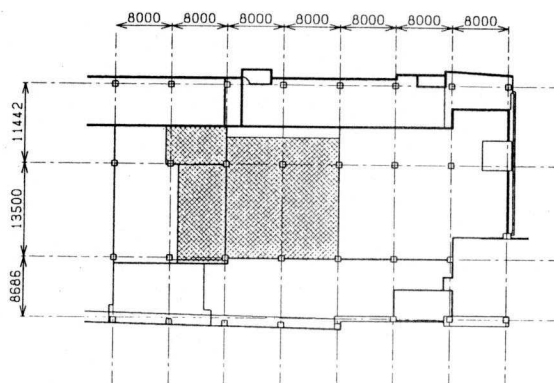


Fig. 3 Range of Work

Table 2 Results of Work in Fitting Ceiling Backer Boards

Objective work	Fitting work of ceiling backer boards Ceiling backer boards: 910×1,820 mm.
Type of work	The Light Weight Manipulator: 1 set. Operator: 1 person. Workers (for screwing): 1 worker.
Days for measurement	About 3.5 days (16.8 hours in total).
Work area	423 m ² .
Work speed	75.5 m ² /man-days in average (12.6 m ² /man-hour). Calculated assuming 6 hours of work a day in average.
Conventional work speed	60.0 m ² /man-day in average.
Work speed ratio	About 1.3 times conventional work speed.

4. EXAMPLE OF WORK TO FIT CEILING BOARDS

4.1 OUTLINE OF WORK

Application: Shops and a car park.

Construction scale: Steel structure (part reinforced concrete construction).

Five stories with a one-story penthouse above the ground,

Total floor area: 38,649.9 0m².

Since this building, which is a large shop, was much in floor area, requires much time for relocating scaffold if traditional temporary scaffold is employed, the Light Weight Manipulator was introduced as mobile scaffold to improve the work. For this site, three manipulators were introduced for ceiling work, and they were used all together.

4.2 COMPOSITION OF WORK

The composition of the Light Weight Manipulator in fitting ceiling boards is shown in Fig. 4.

Table attachments were used since they were suitable for loading and processing ceiling boards. The loading capacity of a table attachment was 100 kg, which corresponds to about 20 sheets of ceiling board in 910 mm x 910 mm.

Since the position and height of the attachment are changeable by operation of the manipulator, it is possible to stock ceiling boards in a position where it is easy to take them all the time.

Twelve work stages to be connected to the body were arranged, and the work area was made long in the direction of fitting boards.

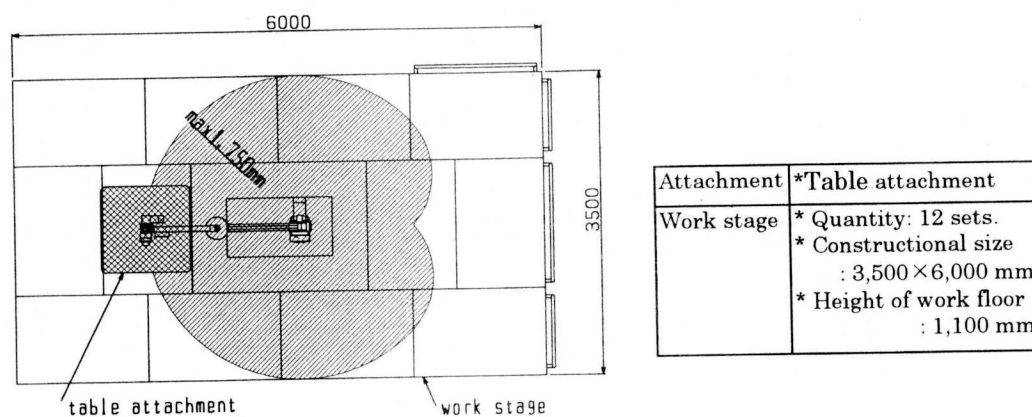


Fig. 4 Composition of Equipment

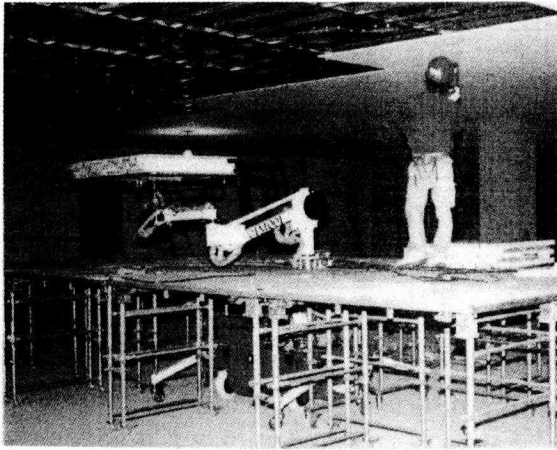
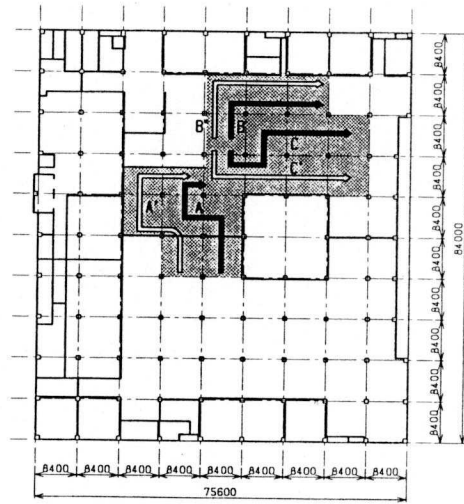


Photo 2 Work Status of Fitting Ceiling Boards



A, A' → B, B' → C, C'
Fig. 5 Range and Order of Work

Table 3 Results of Work in Fitting Ceiling Boards

Objective work	Fitting ceiling boards Ceiling board: 910×910 mm, 9 mm thick.
Type of work	The Light Weight Manipulator: 2 sets. Workers: 3.4 workers a day in average (17 man-days in total).
Days for measurement	5 days (30 hours in total).
Work area	1,190 m ² .
Work speed	70.0 m ² /man-days in average.
Conventional work speed	55.0 m ² /man-days in average.
Work speed ratio	About 1.3 times conventional work speed.

4.4 RESULTS OF WORK

The results of work using the Light Weight Manipulator are shown in Table 3. The introduction of this unit increased the work speed by 30% in comparison with that of traditional work. This is because the reduction of relocating work of temporary scaffold increased the time dedicated to fitting ceiling boards.

In fitting work of ceiling boards, though the manipulators were used as loading units, the results were the same as those for fitting work of ceiling backer boards handled by the manipulator, which is supposed to be the effects of the work carried out by use of two Light Weight Manipulators at the same time.

5. CONCLUSION

Though the effects of the introduction of the Light Weight Manipulator were confirmed by construction works at sites up to now, we are going to enhance further its completeness to achieve improvement in efficiencies, labor-saving, and safety.

From now on, we are going to aiming at a reduction in a term of construction work and cost saving for entire interior finish work by means of the introduction of the Light Weight Manipulator.

We are very grateful to persons of each construction site for the guidance given to us in our development of the Light Weight Manipulator.

REFERENCE

- 1) Takasu, M and Hukuda, S et al. "Development of the Light Weight Manipulator for Interior Finish Work" Proceeding of The Fourth Symposium on Construction Robotics in Japan, July, 1994.