Construction Industry: SMAS (Solid Material Assembly System)

In this project a reinforced concrete wall system was re-designed in terms of structure, component design and variation control to allow for efficient robotic assembly. In a test of the system, a 6-articulation-type industrial robot was fixed on the test floor and the newly developed end-effector was installed to this robot. The robot was planned to erect an L-shaped structural wall. The foundation of the wall was steel channels fixed on the floor and solid components were stacked on it. It was expected that the accuracy of the foundation greatly affects the total accuracy of the wall, especially in its vertical direction. The steel foundation was selected in order to avoid the distortion of the wall. In practice, almost all of the foundation was made of cast-in-place reinforced concrete, so the accuracy might present a problem. A sloped rail was installed on the test floor for supplying solid components, and a delivery pallet which was loaded with eight components moved on the rail and drove to the intended stock position (*Figure*). The test procedure can be split down in sub-operations as follows:

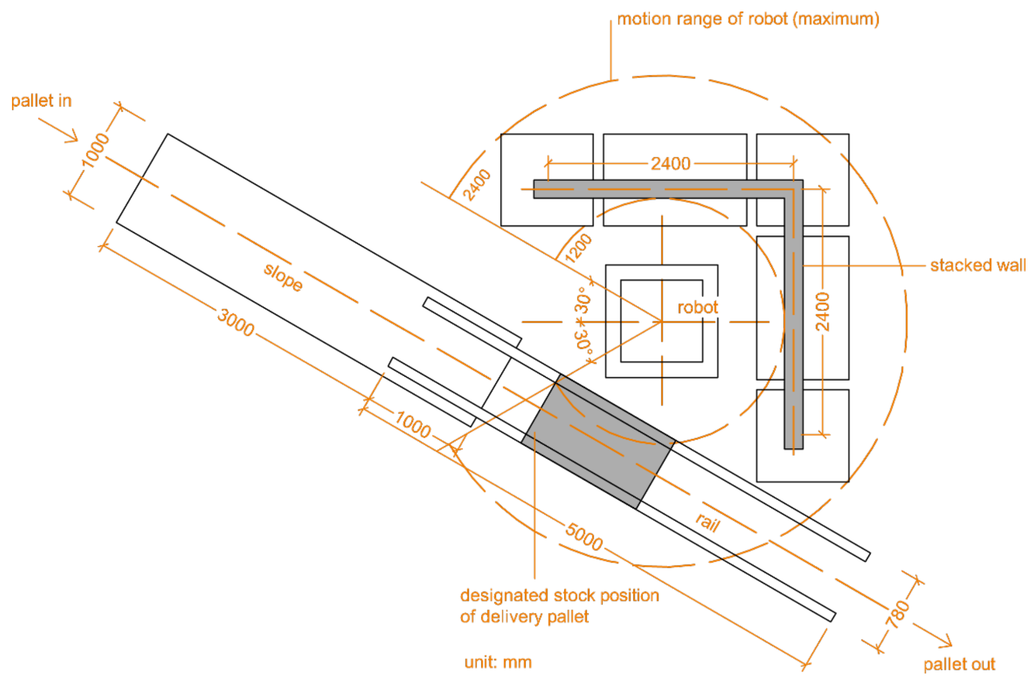


Figure: Layout of test floor.

1. A pallet loaded with eight components arrives at designated position. Loading solid components on the pallet and setting the pallet on the sloped rail were carried out by test staff.
2. The arm of the robot moves to the pallet, picks up solid components, transports the parts to the designated stacking position, and stacks it. Then the arm moves back to the pallet and repeats this series of work according to the computer program input beforehand. In the work of picking up in order, a de-palletizing program was used, that has been developed for general use in manufacturing factories. The robot moves automatically according to this program when the operator teaches some critical points for positioning. When the hand reaches closely to the next component on the pallet, the claws of the hand begins to grasp the steel fixture embedded in the

component, with the signal from the optical sensor. Synchronously, the nut-runner installed in the hand gears with a nut that is fixed to the top-end of vertical reinforcing bar.

3. Motions of the robot are controlled by a computer. Approaching to a stacking position, the arm of the robot moves in high speed to close the position (10 cm side, 10 cm above from the previously stacked component), then slides slowly to the designated position. After the robot releases and stacks the solid components on the designated position, it begins to screw a bolt of vertical reinforcing bar into a nut of the under-laid component. The reinforcing bar also serves also as a guiding pin for the end effector (during component pick-up and component positioning, adjusting and fixing) compensating inaccuracies. The shape of those guiding pins was stepwise improved by experimental trials.
4. When the pallet becomes empty, it is automatically kicked out and the next pallet is supplied.

These continuous actions (1-4) are repeated, and finally an L-shaped structural wall (5.2 m long with a height of 2.1m) was constructed with 17 x 7 components. Steel bars for the reinforcement of the components were fitted up at the factory. For the verification of adequacy of the proposed over-lap type joint in lateral direction, wall specimens were that the strength of the proposed joint is comparable to the ordinal lap-joint, when properly designed.

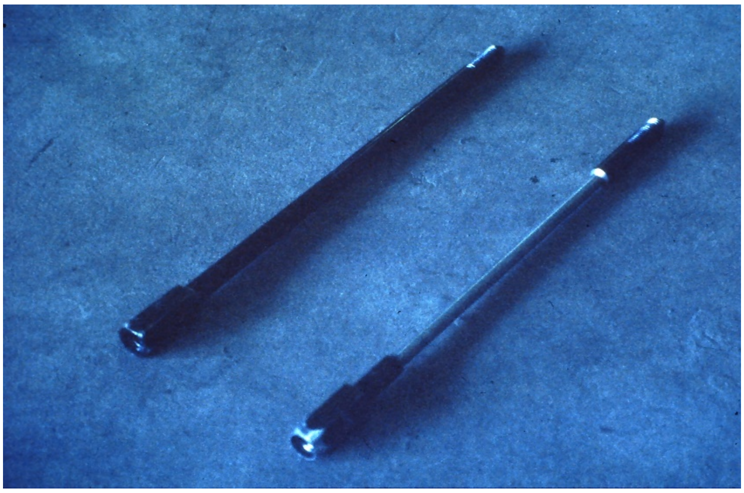


Figure: Experiments with different reinforcing bars serving as guiding pin of the end-effector The shape of those guiding pins was stepwise improved by experimental trials (upper pin: step 1, lower pin: step 2)

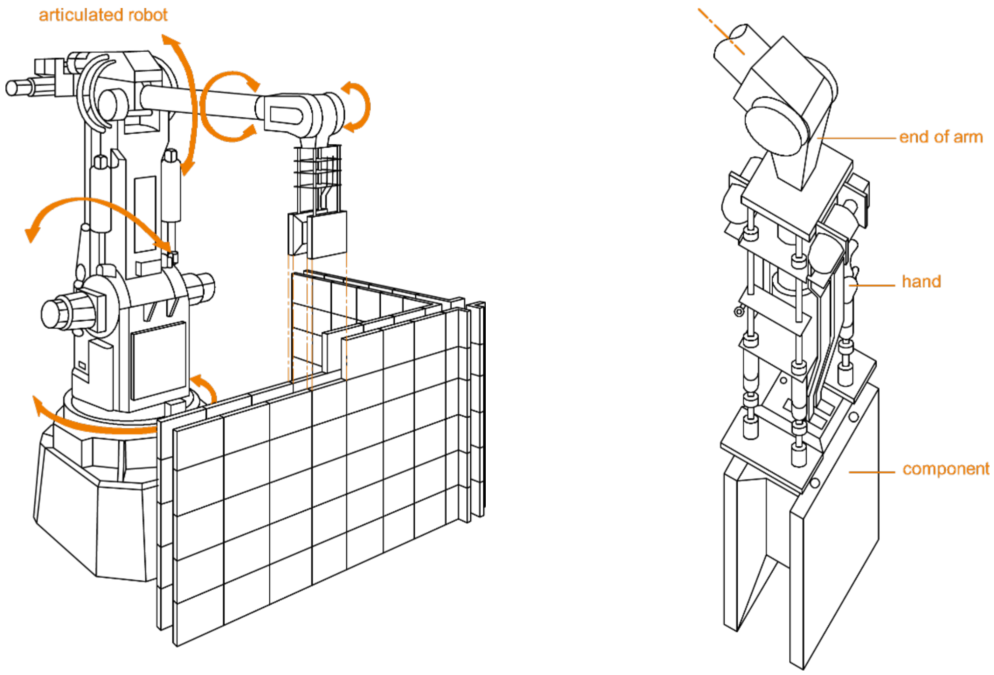
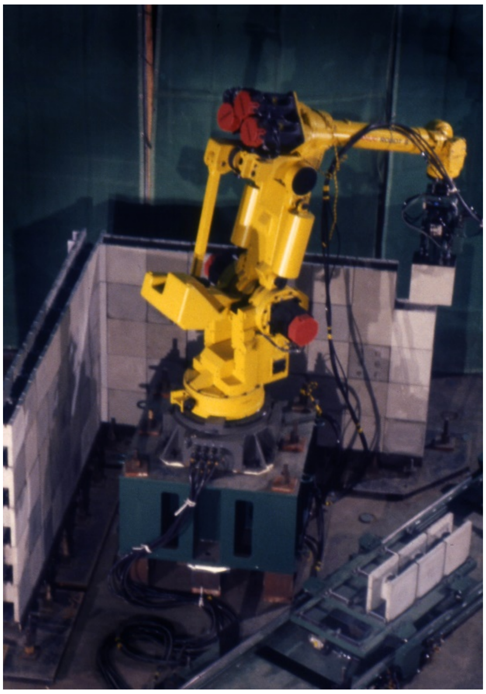
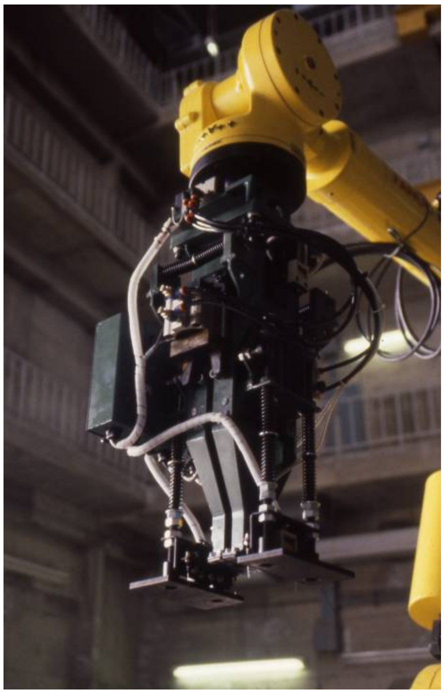


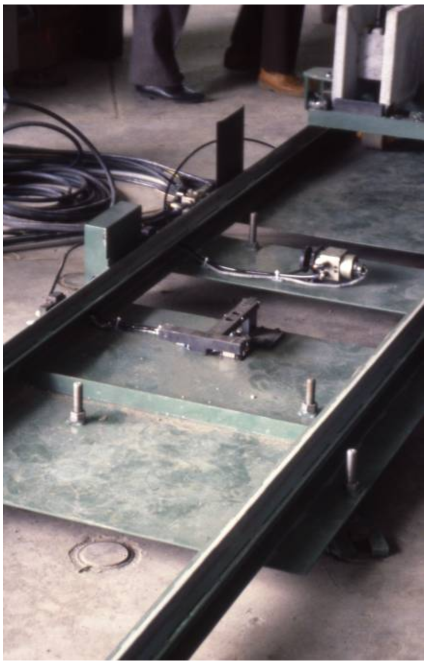
Figure: SMAS robotized wall erection system and detail of robot hand.



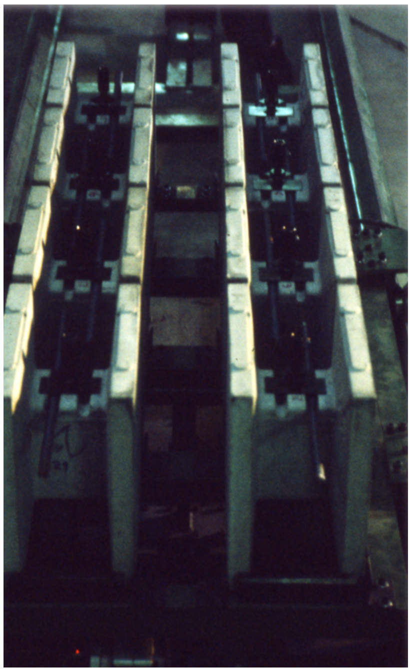
View on total system in action



End-effector gripping a component



Pallet for handling and presenting 8 elements on standardized slots to the robot



Building components designed according to ROD guidelines delivered on the pallet

Figure: Pictures of Solid Material Assembly System (SMAS).