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# A SELF-ASSEMBLING CURTAIN WALL SYSTEM

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## ABSTRACT

Robots are only incidentally used to assemble wall panels in high-rise buildings, even though robotic technology is available for various applications. These applications can improve construction site safety and increase the productivity of the assembly process. A research project initiated at Eindhoven University of Technology (TU/e) in the Netherlands aims to develop an integral design for a curtain wall. The curtain wall's assembly, disassembly and user functions are integrated into a single concept. The focus lies on the assembly/disassembly process and the use of new robotic technology.

This paper presents the further results of a concept design based on the requirements found in an earlier survey of currently available strategies for the assembly of curtain wall systems. The purpose of this research project is to explore the limits of currently available robotic technology in designing a curtain wall for its entire life cycle by integrally designing a feasible concept.

## KEYWORDS

Curtain Wall System, Wall Panels, Robot Technology, Construction Site Safety

## 1. INTRODUCTION

As a rule, the conditions under which the panels of a curtain wall system for high-rise buildings are assembled and disassembled are neither safe nor labour-friendly. Moreover, climate conditions can make production time uncertain. See figure 1.

New robot technology and materials can help to solve the problems identified above, while this technology can also be used for other wall functions such as sunscreens, ventilation and cleaning.

The application of new robot technology requires the integral design of the assembly process, the curtain wall and the wall panels.

In a previous study [1], the design requirements for a curtain wall that is self-supporting during its entire life cycle were developed. The design requirements formulated in the conclusion of that study included the following:

- Safe construction site for assembly workers.
- Curtain wall is appropriate for high-rise constructions involving a steel load-bearing construction.
- The curtain walls are only made of aluminium and glass.
- The curtain wall is equipped for the assembly and disassembly processes. Its components can also be used for user functions (particularly systems) of the façade element.
- Only one remote operator is necessary for the (dis)assembly process.
- Mini- and micro-robot devices are used.

The goal of this study is to develop a concept for a self-assembling curtain wall system that is safe, labour-friendly and can be used in all weather conditions (e.g. wind, rain, snow) without a construction crane being needed and with as few construction workers as possible. The concept is based on the design requirements as formulated above.

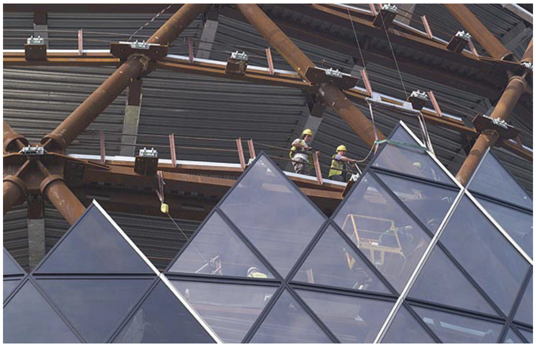

**Figure 1 Curtain Wall assembly can be Extremely Dangerous. Photo showing the assembly of the wall panels for the St. Mary Axe high-rise building in London (Photo: Grant Smith)**

## 2. DESIGN METHOD

The followings steps were carried out to design the new concept:

1. Re-formulating the requirements.
2. Analysing the problem.
3. Designing the concept by using morphologic schemes and Systematic Inventive Techniques (SIT) [2].
4. Engineering the concept.
5. Creating a 3D virtual simulation of the assembly process.
6. Reflection by experts.

## 3. RESULTS

### 3.1 Re-formulated Requirements

Curtain wall:

- Application of panels that are produced in the factory,
- Standard frame with customised filling,
- Wind and water sealing,
- Every panel can be individually assembled and disassembled,
- The drive can also be used for other functions.
- Even design.

Transport of panels to assembly location:

- Self-transporting,
- Self-positioning,
- Motor-driven,
- Constructed from the ground floor of the construction site.

Assembly panel:

- No labour,
- Assembly onto an existing structure

### 3.2 Analysing Some Aspects of the Problem

Before forming a concept, some specific aspects required special study:

- Transport of the panels. After studying various alternatives, a choice was made to only transport (during assembly and disassembly) the panels vertically.
- The mounting of the panels at the structure. There is no connection between the panels other than some loose connections for water and wind sealing; it must be possible to mount and dismount any panel at any time.
- The start of assembly. There must be a basis with which to start the automatic assembly process. The first row of panels will be placed with the help of a crane. See figure 2.

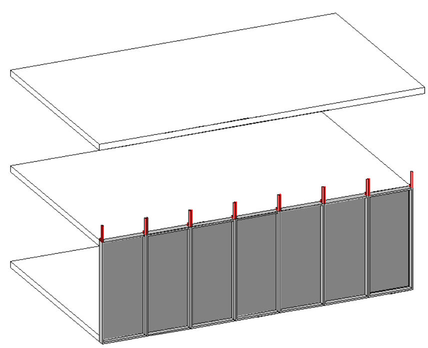

**Figure 2 The First Row of the Curtain Wall will be Placed with the Help of a Crane**

### 3.3 Assembly Concept

The assembly concept comprises six steps:

1. Assembling the first row as mentioned in the previous paragraph. A mounting component is also placed on every floor of the structure.

2. A crane will place a new panel onto a panel in the first row. To keep the panels in position, a guide mechanism and a T-profile are mounted beside the panel.
3. The vertical transport of the panel occurs with the help of a gearwheel driven by a motor and a gear rack.
4. A guided stand is mounted on top of every panel to keep the panel in place.
5. The panel can now be transported horizontally to the structure. The gear rack moves via the mounting component.
6. The element is now in its final position. An operator will fix the panel.

Table 1 describes the six steps of the assembly concept.

### 3.4 Engineering

A series of details have been designed to solve engineering problems. This paper will explain some of them.Water and wind sealing is solved with the help of synthetic profiles, which are mounted in the factory and automatically close the spaces between the panels after placement. See figure 4.

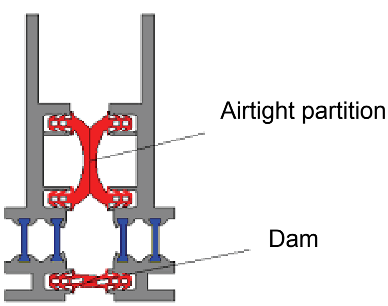


**Figure 4 Upper Profile for Air Sealing and Lower Profile for Water Sealing**

A mounting component is placed at the edge of the floor-slab. This component will realise the horizontal transport of the panel by a gear rack, placement by a buckle and locking by a pin. See figure 5. The driving section. An electric motor, shaft, chains and gear wheels are mounted in the panel. See figure 6.

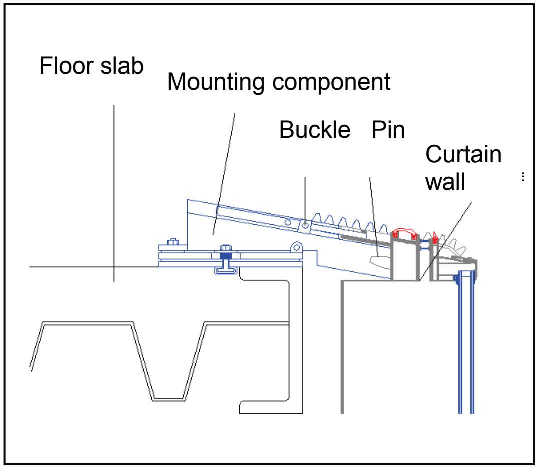


**Figure 5 The Mounting Component**

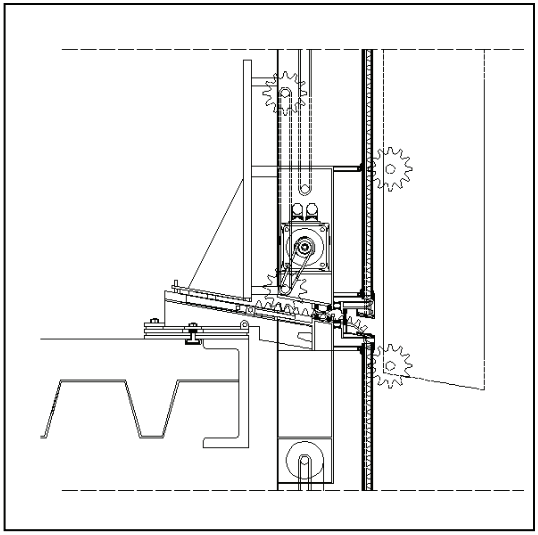

**Figure 6 The Driving Section of the Panel**

Frame and filling. The wall panel consists of a frame and a filling.

All the mechanisms for transport and placement are built into the frame. This enables mass production and mass customisation.

**Table 1 The Assembly Process in Six Steps**

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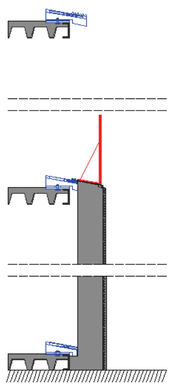
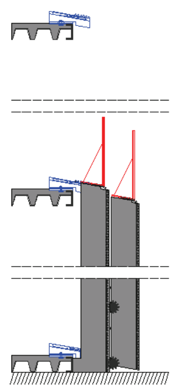
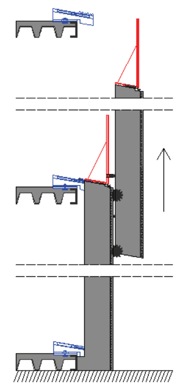
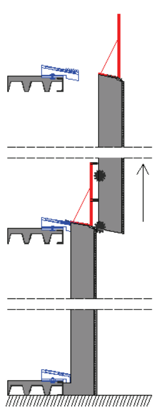
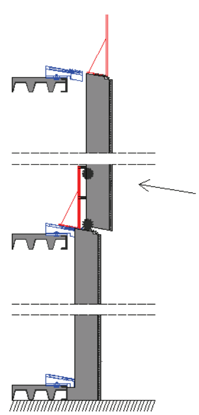
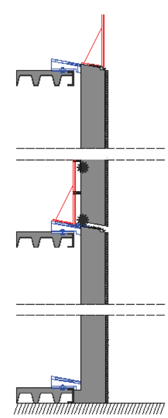
|  |  |  |
| **1.** Assembling the first row. A mounting component is also placed on every floor of the structure. | **2.** A crane will place a new panel on a panel in the first row. To keep the panels in position, a guide mechanism and T-profile are mounted on the panel. | **3.** The vertical transport of the panel occurs with the help of a gearwheel driven by a motor and a gear rack. |
|  |  |  |
| **4.** On top of every panel is a guided stand that will keep the panel in place. | **5.** The panel can now be horizontally transported to the structure. | **6.** The element is now in its final position. The stand remains as part of the façade. |

The filling can be chosen by either the client or the architect and can be designed as a modular system.

### 3.5 Simulation

To get more of an idea of the assembly process and how it will work in reality, a 3D virtual simulation has been made.

### 3.6 Reaction from Experts

The concept was presented to two professionals in the field of façades.

One reaction was that 'One of the plus points of this concept is the guided transport system, which ensures that wind has no influence on the mounting process, which is an advantage when building very tall buildings. Instead of a built-in electric motor, a little crane could also be a solution'.

However, there was doubt as to whether there is a market for robotic technology for such façade facilities as ventilation.

The firm found the integration of the electric drive and the positioning very interesting, but the question remains as to when the costs are acceptable for the client and the architect.

The Dutch knowledge centre of façade builders found the concept both interesting and innovative, but some aspects, such as the reliability of the guidance system and water and wind sealing, remain uncertain. Using the drives for transport is a positive factor, as is the user functions facility, because this gives greater façade flexibility, especially in case of renewal.

## 4. DISCUSSION

The results have shown that most of the requirements have been fulfilled, although some requirements with regards to self-assembly of the entire curtain façade have not.

The ultimate goal of eliminating the work of the construction worker was not feasible, as they are still needed to mount the panels on the ground floor and to undertake some simple mounting operations during the assembly process as a whole.

Various parts of the concept have not yet been tested, such as wind and water sealing, gear transmission and guide rails.

The cost of the driving motor is relatively high and has too much power output for such wall functions as ventilation and sunscreens. One solution would be to use a replicable motor.

## 5. CONCLUSIONS

The introduction listed various problems concerning the assembly and disassembly of curtain wall panels. With this concept, (dis)assembly work is safer and more labour-friendly, and weather conditions have less influence on the progress of the construction work.

Furthermore, the concept allows for using the electric drive for sunscreens and ventilation.

The concept has the potential to solve the problems of labour safety and bad weather conditions that occur when mounting panels.

The concept gives us more insight into how to use robotics and robot technology as for assembly at the construction site and for other wall functions such as ventilation and sunscreens.

## 6. REFERENCES

[1] Van Gassel, Frans, Pascal Schrijver and Jos Lichtenberg (2006) Assembling wall panels with robotic technologies, Proceedings of the 23rd International Symposium on Automation and Robotics in Construction, Tokyo, Japan, October 3-5.

[2] Goldenberg, J. and D. Mazursky (2002) Creativity in Product Innovation. Cambridge University Press.