Automatic production of concrete structural elements

Control and instrumentation at the precast element plant – the backbone of a modern high-tech system

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Erecting buildings using precast concrete elements is no longer limited to Central Europe. The number of modern plants for producing the appropriate elements is also increasing throughout the world and the time when an automated production machine outside Europe was considered unusual are over. The evidence was there at Bauma 2004 at Munich – the demand from all parts of the world for systems for the production of precast concrete elements is enormous.

During discussions with international prospective customers, however, it became clear that there are also some differences to the Central European precast concrete element industry:

1. The plants are usually operated by construction companies to cover their own needs.
2. Substantially more buildings of the same type are being erected. The strong tendency towards individualization, which is particularly common in Germany, is almost absent outside Europe.
3. Centralised production plants are erected with high outputs. Longer transportation routes are therefore accepted.

These characteristics produce a type of system with one target parameter in particular: maximum output with minimum resources. Outputs of more than 1,000 m² per shift with different products are the conditions for cost-effective operation.

A production machine of this type was put into service at the end of last year at Katrineholm in Sweden. This plant will be used as an example to show the importance of control and instrumentation for processes in a production plant such as this.

High-tech system in Sweden

At Katrineholm in Sweden, the construction company Peab AB has set up its own precast concrete element production system. The plant, which is operated by its subsidiary Skandinaviska Byggelement AB, produces solid walls and semifinished elements such as precast floor elements and double walls. The aim of Peab is to erect multi-storey residential buildings at lower cost. Precast concrete elements are ideal for achieve the necessary modularity for the buildings.

SBE at Katrineholm in Sweden

The production machine was designed by Prilhofer Consulting from Freilassing in Germany. The circulation system and machinery were built by Unitechnik, Vollert and Weckenmann. The production machine has 56 circulation stations which are arranged at two levels. The pallet transport system and the processing stations are largely decoupled from each other and the system can therefore process different products simultaneously without the pallets getting in the way of each other.

The most important components and machines are as follows:

- 10 high elevating platform trucks for transfer to the upper level
- Cleaners/oilers and plotters using two colours
- Formwork robots over two stations with interchangeable grabs
- Magazine robots for solid-wall formworks
- Mesh-welding machine
- Automatic concrete distributor over two stations
- 1 tandem trowel and 1 blade trowel
- Suction turning equipment using vacuum technology for double walls
- Hardening chamber for 78 pallets
- 1 hardening chamber 'prehardening before trowelling'
- Tilting station for lifting walls
- Pre-stripping station for solid element formwork
- Automatic travel-out elevating platform truck

Production logistics – the key to success

The more complex production systems are, the more important it is to have a logistics system that works – the right pallet must be in the right place at the

right time. Expensive machines such as formwork robots and concrete distributors must be constantly kept working. Every period of waiting reduces the output of the plant. The UniCAM NT master computer and circulation control system are responsible for co-ordinating all the movements in the system.

Product specific work schedules determine which stations have to be started and in what order. The UniCAM NT master computer optimises the routes so that all the machines are operating equally at full capacity. The highest priority is of course to keep to the planned delivery date for the elements produced.

Control station with master computer

Bottom: Elevating platform truck at transport level. Top: Processing level 02

The journey of an order

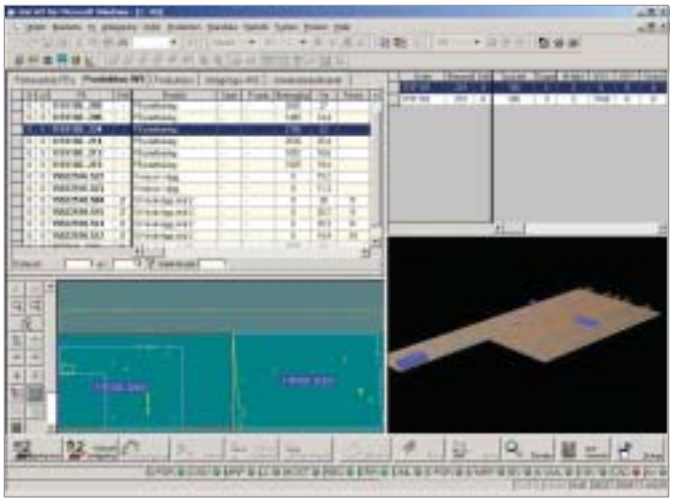
A new order, determined by the construction project, is placed in the ERP system. Order master data are transmitted to the UniCAM NT master computer. At the same time, the building and resulting wall and floor elements are planned on the IDAT CAD system. The CAD data are transmitted to the master computer via the Unitechnik CAD-CAM interface.

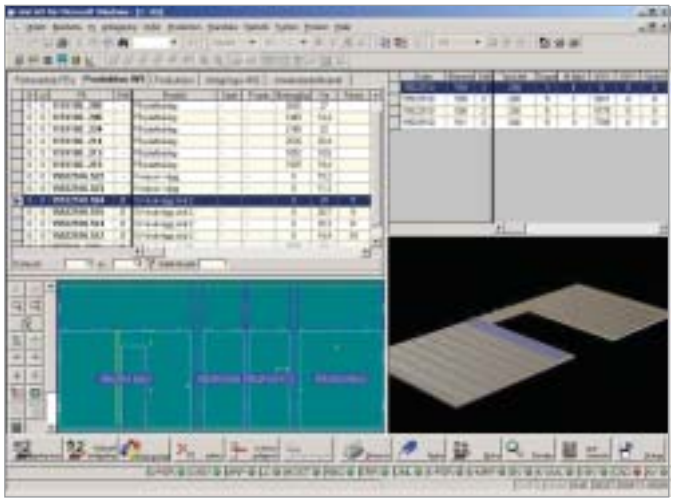
Unitechnik CAD-CAM interface:

The Unitechnik CAD-CAM interface has grown into an industry-wide communication standard. It not only provides data communication between CAD and CAM systems, but also supplies all machines and components participating in production with information relating to the elements which are being produced. As well as the geometrical dimensions, the system describes the reinforcement, concrete type and coating, special fittings, edge designs and much more besides. Each machine extracts the information it needs for its work from the Unitechnik CAD-CAM interface: The mixing plant needs to know the required volume and type of concrete, the mesh-welding machine extracts the reinforcement information and the plotter is told the location of the special fittings.

Pallet loading

The first step in the process on the UniCAM NT master computer is pallet loading. This usually takes place automatically. Pallet loading is optimised according to several criteria: ▶





Screen mask of master computer

1. Suitable elements must be chosen for the type of pallet being loaded (there are 3 different types of pallet)
2. Optimum use must be made of the space on the pallet
3. The weight on the pallet must be distributed evenly
4. All the elements on the pallet must be subjected to the same process steps
5. Optimum use must be made of the available formwork

Occasionally, it may be necessary to change the pallet loading manually if, for example, a defective element has to be replaced at short notice. In this case, the operator can move the elements between the pallets by drag & drop. While doing this, the master computer monitors the minimum distances between neighbouring elements and makes suggestions for optimum placement.

Magazine robot and formwork robot

Magazine robot for solid-wall formworks

Once loaded, the pallets are displayed graphically and the elements can be inspected via a rotating 3D model. This all helps to provide the operator with maximum control of the production process during work preparation.

Placing the formwork

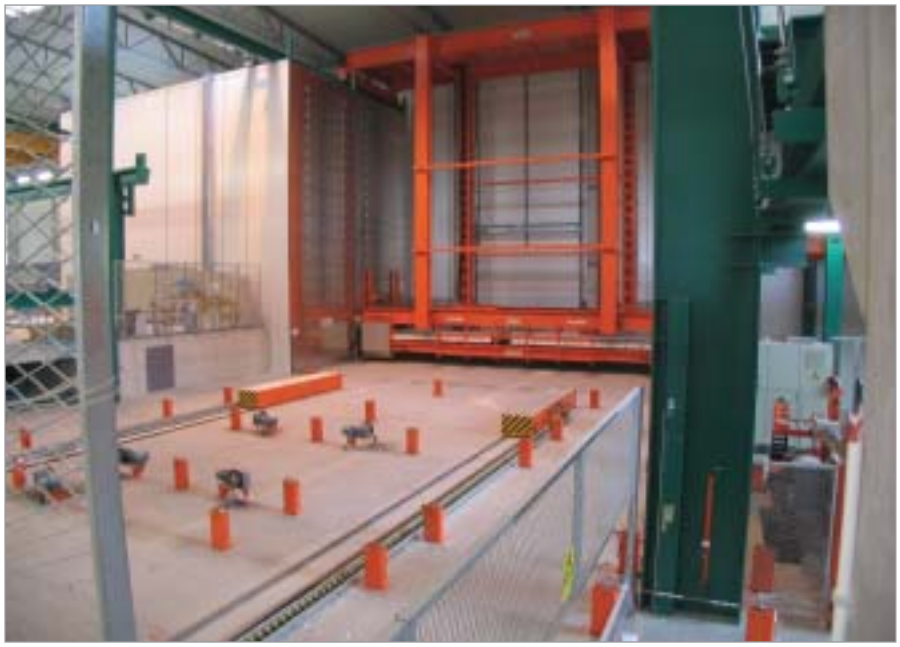
Transmission of the geometrical information from the master computer to the pallet is largely carried out by the formwork robot. Magnets and channel formwork is used for precast floor elements and double walls. Formwork with integrated magnets are used for solid walls. The requirements which the formwork robot has to meet here, are as follows:

1. The formwork must be accurately positioned
2. The formwork must be properly matched and placed without any gaps
3. The outline of the element must be enclosed as completely as possible
4. Optimum use must be made of the available formwork
5. The robot must use the optimum travel

The efficient and, to some extent, patented formwork algorithm makes sure that the requirement for re-shuttering is reduced to a minimum and that the service life of the formwork is significantly increased.

Concreting

Concrete is very difficult to batch because of the large variation in consistency depending on the mix and the



Rack-operating unit

Trowelling the solid elements

Finding the right trowelling time is a problem which cannot be solved using semi-mathematical methods. For a space-saving solution to this problem, a method was chosen which provides the optimum support for the operator to use his experience.

After concreting, the operator assesses the concrete and therefore the expected time before trowelling. If there were no changes on the retention time in the skip. In order to achieve good concreting results consistently, the discharge quantity is recorded using three precision measurement cells. The special circuitry of the measurement cells and the fast closed-loop control system make sure that only the purchased quantity of concrete is placed on the pallet. The concrete distributor also operates over two parallel circulation stations. This eliminates the pallet changeover times and guarantees maximum utilization of the production component.

previous pallet, the operator presses the dispatch button or corrects the pre-hardening time according to his experience.

With the dispatch signal, the pallet is automatically stored in a pre-hardening chamber and then transported automatically to the trowelling station once the selected pre-hardening time has elapsed. Control intervention in this automatic operational sequence is rarely necessary. The operator also has a control terminal at the trowelling station in order to call up any important information. ▶

Circulation control station

Hardening chamber and rack-operating unit

The hardening chamber has a total of 78 places and is provided with segmented lifting gates. The rack-operating unit operates in combination with a pair of elevating platform trucks in order to manage the large number of storage and de-storage tasks in the optimum time. The storing strategy can be configured freely by the user for each product. Experience from production can therefore easily flow back into the production process.
The target and actual hardening times, order number, product and element geometry etc. for each place in the hardening chamber can be called up by a click of the mouse. The entire production process is therefore transparent and avoids time-consuming inquiries.

Since, with this system, several production machines can be semi-interlocked, there are four product-related delivery lines which the master computer has to operate:

1. To the tilting table for double walls and solid elements
2. To the floor unloading system for floor elements and special elements
3. To the turning equipment for the first formwork
4. To the pre-stripping area for solid elements

Circulation switch cabinet

Turning

The vacuum turning unit has 116 suction cups. Because of the high number of suction cups, even difficult slab geometries can still be held securely. Complex setting-up work for the suction cups is eliminated. The control system automatically recognises the slab geometry and visualises the state of each suction cup.

Control technology

All controllers and the master computer are networked via a bus system. A decentralized control circuit was selected to keep the cable runs short. The danger of a cable break is therefore minimised and the availability of the production system is maximised.
Pallet transport takes place automatically at the transport level and in the area of the rack-operating unit. For safety reasons, the manual work stations are operated in dead-man mode. Here, transport is controlled via an agreement button with hardware disconnection of the drives. This complies with the latest recommendations of the safety authorities and guarantees maximum industrial safety.

Trends in control technology

Decentralisation of peripherals
The input and output modules and drive regulators are moved as close as possible to the machine or equipment. Connection to the central controller is via bus systems.

The worlds grow together
The division of tasks between the control level and the circulation control system is shifting. The co-ordination of material flow can be programmed to a large extent on the PLC using a high-level language.

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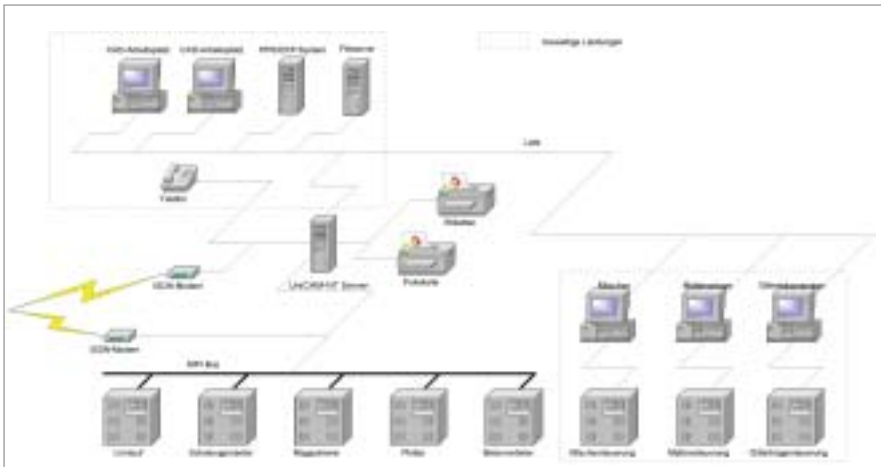

System configuration

Key specification of the control technology:

2 Siemens S7-400 type controllers
3 Siemens S7-300 type controllers
150 decentralized bus participants
880 sensors
516 drives
47 km cable
32 control stations
20 running m switch cabinets

Mobility
This is achieved by linking mobile control terminals via WLAN or by calling up the daily statistics via the Internet. Mobility is also playing an increasingly major role in automation.

Concluding remarks

Control and instrumentation in this type of system is neither an end in itself nor a technical plaything. Rather, it guarantees optimum use of the system's resources for the operator with maximum flexibility and transparency in the production system. It therefore makes a substantial contribution the economical success of the company. ■

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