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Selected innovative solutions and overview of molds for precast concrete

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Abstract

Precast concrete products are widely used for infrastructure, construction sites, roads, retaining walls, river erosion control and drains all over the world. In order to obtain a proper shape and surface of the prefabricated elements it is required to use not only durable and rigid molds but also easily adjustable solutions according to different shapes and dimensions of products. Intensive development of concrete technology in recent years, including broadening of Self Compacting Concrete applications, has contributed to the progress in mold planning and manufacturing. Nowadays an innovative software, as for example 2D/3D CAD Systems or Finite Element Method (FEM) simulation are used commonly in the process of designing the molds. The paper presents solutions increasing productivity and efficiency of molds when demolding, setting and cleaning. Moreover the Authors of the paper focus on automation in mold change system, reliable and flexible mold systems. The examples described include, among others, molds for drainage systems, manhole base shells and retaining walls. The summary of the paper contains future needs and potential applications in the field of molds technology for precast concrete.

Keywords: innovative solutions, mold manufacturing and planning, precast concrete.

1. Introduction

One of the most important market conditions that should be met by a precast concrete plant is providing a high flexibility in terms of the range of products offered. Implementation of this condition is possible with the proper organization of production, including the shortest possible time of mold changeovers. For many years the precast industry is characterized by the synergy of the traditional manufacturing industries and the precast industry, while still requiring production lines and project sites [5]. A great part of innovations has been transferred from science and other industries into concrete manufacturing plants, as for example CAD Systems for designing the molds. In addition, it should be emphasized the use of multifunctional robotic production cells that were first applied in the prefabrication of concrete floor panels and later for wall and roof panels [6]. Despite the technological progress in Architecture, Engineering and Construction Industry (AEC), including for example: Contour Crafting [7], [8] or Concrete Printing [9] that significantly reduce the use of molds and formworks in construction, mold manufactures still get involved in working on innovative solutions. Some of these solutions are described in this paper.

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2. Overview of molds for precast concrete

Steel molds are used in a production of reinforced and unreinforced precast concrete elements. Design and shape of the molds depend mainly on the production technology in the plant, type of concrete, weight and shape of the element and number of elements in one casting. In flow production, in which elements move through the subsequent production stations, the molds are usually light and non-separable and have small dimensions. Precast concrete elements that are prepared on the stationary production lines require massive and separable molds. Concrete technology affects leak-tightness of the molds. Self-compacting concrete (SCC) can be poured into the molds of a high level of leak-tightness. In addition, the lack of vibrations influences a higher durability of molds. Concrete reinforcement technology also influences the massiveness of molds. Prestressed elements due to the need of transferring large tensioning forces are designed with larger cross-section of steel with high mechanical strengths. Casting of several elements at the same time requires a usage of a battery molds, which can be non-separable, separable and partially separable. General classification of molds used in precast production plants is presented in table 1 [1].

Table 1. Classification of molds for precast concrete elements.

Mold cross-section shapes depending on the element shapes		Mold cross-section shapes depending on the mold structure		
Rod elements	Plate elements	Partially separable molds immediately after casting	Molds with elastic sides	Battery molds
Non-separable	Non-separable	Straight surface side	Mold with one elastic side	Non-separable
Partially separable with one side moveable	Partially separable with one side tilted	Complex surface side	Mold with two elastic sides	Partially separable with fixed partitions and tilted sides
Partially separable with one side tilted	Partially separable with one side moveable	Untypical for the elements such as:		Partially separable with two sides moveable
Partially separable with two sides tilted	Partially separable with two sides tilted	columns with multidirectional consoles etc.		Partially separable with removable partitions
Separable with tilted low height sides	Partially separable with two low height sides and raised hinges			

Mold design in terms of strength is carried out under consideration of static loads that include the weight of element, mold and mold equipment. In addition, the mold must carry dynamic loads, mainly due to the vibration generated during the compaction of a concrete mix. Currently molds are designed using 2D/3D CAD software Systems, on the basis of Finite Element Method [2].

3. Fully automated mold change system

In order to meet the requirements of the market, the concrete manufacturers need to reconcile flexibility, productivity and safety, while offering an ever-larger of high quality products. Mold changeover operation has a significant meaning for productivity and safety in the precast manufacturing plant. It is also a necessary consequence of the wide range of incoming orders.

A good example of the company that has taken on the challenge of fully automating this operation is Quadra. The company is a manufacturer of equipment for the concrete industry. The first tailored automatic stacker crane has been set up in the Plattard factory with which Quadra has been in close cooperation for many years [3].



Figure 1. Automated mold rack storage [3].

The mold rack storage has been located in a closed area. A special route has been created from the rack storage area to the block machine, enabling the stacker crane to move between both areas. The stacker crane moves and handles molds from the rack to the block machine and from the block machine to the rack while production is still in operation. As a result of this, the transfer time does not affect the production since it is not stopped. A space between the block machine and the face mix unit has been implemented to enable moving the molds directly from and to the block machine. Regarding automation of the operation an accurate referencing of the mold and the tamper head is recorded [3]. Adjustment of the tamper head, the mold and the vibrating table of the press ensures accurate and automated positioning. Positions are adjusted automatically to the type of manufactured products and according to the recipes.



Figure 2. Stacker crane ready to incorporate the new mold [3].

The operator uses the control screen to select the mold required for the next production. Without interrupting the current production, the automatic stacker crane withdraws the required mold from rack and transfers it to the block machine area for placing it within a temporary situated close to the machine [3].

As soon as the production is ready, the stacker crane moves between the block machine and the face mix unit in order to withdraw from the block machine the mold to be changed. The stacker crane puts this mold and latter places the new one. Pestle and mold adjustment with securing is carried out automatically. After resuming production the stacker crane transports the mold, which has been used to the washing station.



Figure 3. Washing station set up outside the building [3].

As soon as the washing is completed the mold is located in the storage rack and waits for further use.

4. Shuttering magnet system

Precast concrete manufactures in order to maintain a leading position in the construction market need to offer a very diverse range of products. Obtaining complex shapes of products requires the use of a reliable and flexible mold systems. One of the most important factors that influence the production efficiency in the manufacturing plant is quick and precise assembly and disassembly of molds. An innovative solution in this regard are ultra-light shuttering magnets. Their use as an equipment for molds assembly eliminates the use of time-consuming molds screwing on one hand, on the other hand the total weight of the mold is reduced.



Figure 4. MagFly AP ultra-light shuttering magnet [4].

The magnet is light and therefore also particularly simple to handle. It is simple to position to align together with the shuttering and that makes the shuttering particularly precise [4]. With an adhesive force of 22 kN and a mass of just 5,40 kg, including levers and adaptors, the magnet has a very favorable force/mass ratio.

5. Mold for integral drainage

In the last few years water-permeable roads have been often constructed in Japan. A new designed drainage has the ability that allows the permeated water from the road to be flowed into drainage through its side holes. One of the conditions to obtain a high productivity and a proper manufacturing of this type of the internal drainage is to ease the operation of the inner core assembly and disassembly.



Figure 5. Inner core examples able to be collapsible in one-touch by hand [10].

Inner cores showed in figure 5 are able to be collapsible in one-touch by hand. The main advantage of this solution is the ability to separate the inner core from concrete and make a demolding operation as easy as possible. The inner core can be moved away from the concrete product in many ways, such as: roll-back type (by human hand), automatic type (by a special machining) or gooseneck type (by a crane depending on the individual customers' requests). The molds presented in figure 6 and 7 are with the roll-back type inner core.



Figure 6. Mold with roll-back type inner core, hung from one side with sliding rail [10].

The inner core is hung from one side with sliding rail. As a result of it, cleaning and demolding operation are clean and safe [10].

The inner can be opened and closed with one-hand without usage of any hydraulic device, as it is shown in figure 7. In this case elimination of automation on one hand and the human involvement, on the other, result in reducing a risk of overlooking a potential clogging, caused by the poor cleaning of the mold.



Figure 7. Opening and closing of inner in one-touch by hand [10].

In order to prevent the concrete from leaking the molds are equipped with rubber gaskets. Replacing the gaskets material are the only maintenance operations for this type of mold.

6. Conclusion

The paper presents selected innovative solutions in the field of steel molds for precast concrete elements. The main objective of these solutions is an improvement of production process. In case of fully automated mold change system, due to the fact that molds are transported by means of stacker crane during production, manufacturing has to be stopped for only 5 minutes. The loss of production is therefore minimized and enables the manufacturer to switch production more frequently, enabling it to be flexible and varied. In addition, the automation of this operation is beneficial for the health and safety of the operators. Indeed, no manual intervention is required [3].

The use of magnetic shuttering system significantly influences the improvement of productivity and increase flexibility in the assembly of precast concrete mold for an element. The molds for integral drainage due to the use of roll-back type inner core are easily demolded. Demolding, which means overcoming of adhesion forces between concrete and mold material is very important in terms of the prefabricated element surface quality. In many cases, especially in large precast concrete elements of a complex shapes, the process of demolding needs to be carried out in stages. As a result of it, the whole activity consumes more time.

Automation in the precast concrete industry improves the production process. Retraining of workers towards operation of highly efficient machines increases the level of safety in the manufacturing plant. At the same time quality of products and efficiency increase, resulting in greater competitiveness of production. Due to the fact that molds cover often more than 50% of the whole production line costs, it is rather not possible to skip them in the process of automation the production in precast concrete industry.

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