Production cycle of hollow core slabs (excl. casting)

Olli Korander
Introduction

Olli Korander

- Involved in precast business since 1978
  - Designer
  - R&D engineer
  - R&D director
    - R&D, productivity, transfer of knowledge, safety
  - Managing director in Consolis Technology
  - Member of Consolis Executive Committee
  - Board member in several Consolis companies
  - Retired 2012 from Consolis
  - Board member in international organisations (BIBM, IPHA)
  - Board member in Finnish standardisation organisation (Sfs)
  - Actively involved in fib and national associations

- Board member in Polarmatic Oy
Main topics

- The main factors in production process evaluation
- Some other aspects in technology selections
- Level of mechanization and automation
- Production Process
  1. Bed cleaning and strand pulling
  2. Pre-stressing
  3. Measuring and marking
  4. Hole cutting
  5. Drainage holes
  6. Covering and curing
  7. Sawing
  8. LOGISTICS and HANDLING
- Some future possibilities in production
- Opinions based on 35 + years experience
Importance of business environment

- Market need
  - Products, product mix, specialised business/ multi-product business...
  - Services
- What is the life cycle position of the product in the market
- Used business model
  - Different offering (Full building / sub-systems / single components)
  - Cost driven / Added value driven
- Planning and management principles
  - Used management/ process control tools (ERP)
  - Used engineering principle and methods
    - Individual slabs / Floor design
    - Engineering tools (Modeling, calculations, drawings, input to ERP)
  - Used production planning principle
  - Used assembly planning principle
- Logistics

⇒ INDUSTRIALISED CONSTRUCTION as a TARGET
Features of industrialised construction

- Work is transferred from site to factory conditions
- Efficient production methods are used
  - Mechanization
  - Automation
  - Better quality control
- Efficient use of raw materials
  - Less raw materials
  - Less waste
  - Sustainability
- Modern design methods are used
- Site work more effective
  - Mainly assembly of components
- Less noise, dust to the neighborhood during construction
- More attractive job for competent and talented labor
- Safe site work
Process factors in technology selection

- **Safety**
- **PRODUCTION as a PROCESS**
- **Costs**
  - Manpower
  - Use of raw materials
  - Investment
- **Productivity**
  - Through put time
  - Unit time / m, m², m³
  - Down time
- **Quality**
  - Visual quality
  - Technical quality
- **Waste**
  - Concrete
  - Steel
Process factors in technology selection (cont.)

- Used casting technology
- Factory lay-out, specialised/multi product factory
- Product mix
  - Cross-sections
  - Average size, max length, weight
  - Product types
    - “Normal slabs”
    - Amount of “special slabs” (narrow, angle cuts, openings)
    - Insulated slabs
    - “Added value” slabs (for insulation, heating, cooling)
    - Hollow core as a wall, foundation etc.
- Capacity need / actual utilisation
  - $m^2/m^2$
- Process cycle need / possibilities
  - Casting speed
  - Curing / hardening time
Productivity areas

- **Manpower; typically main emphasis**
- **Materials**
  - Concrete mix design
  - Concrete / steel waste
  - Other waste
- **Process**
  - New methods and process control tools
  - Production planning principles
  - Process waste
  - Maintenance
  - Down time / preventive maintenance
  - Production machinery power (electricity, gas, diesel)
- **Design methods and tools**
- **Quality**
- **Safety**
- **Capital**
  - Capacity utilisation
- **Others**
  - Role of administration
Level of mechanization and automation

- Size of the factory
  - Flexibility according to market needs
  - Specialised/ multi-product
- Available input data for automation
  - Internal / external design
- Level in industry
  - Do we have industrial culture?
- Level of personnel
  - Do we get best people?
- Evolution or revolution
  - Investments mainly in old factories
- Benefits of automation
  - What are the benefits?
  - Do we get more flexibility?
Hollow-core slab, product evolution

Case Finland

- Eurocode requirements
  - 370 mm sound insulation floor
  - 320 mm sound insulation floor
  - Building service floor
  - Integrated floors
- 320 mm slab
- Bathroom slabs
- 500 mm slabs
- 400 mm slabs
- 2400 mm wide slabs
- Foundation beams
- 400 mm slab / 3 voids
- Narrow slabs
- Composite slabs
- Fire slabs
- 150 mm slab
- Insulated slabs
- 200 mm slab
- 265 mm slab

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### Hollow-core slab, production evolution

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<th>Case Finland</th>
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<tbody>
<tr>
<td>System</td>
<td>Extrusion / vibration compaction</td>
<td>Extrusion / vibration compaction</td>
<td>Extrusion / shear compaction</td>
<td>B&amp;M automation, concrete transportation</td>
<td>Multi purpose machinery</td>
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<td>Drainage hole machine</td>
<td>Angle cutting</td>
<td>Improved shear compaction</td>
<td>Extrusion / shear compaction</td>
<td>Lifting loops</td>
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<td>Modular casting machines</td>
<td>Saw</td>
<td>Gluing of insulation</td>
<td>Hole cutting machine</td>
<td>Measuring automation</td>
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<td>Maturity control</td>
<td>Lifting beam automation</td>
<td>Bathroom slab machinery</td>
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<td>Sawing automation</td>
<td>4th gen. casting machine</td>
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<td>Hole cutting automation</td>
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Production Seminar 2016, October 26-27, Lleida - Mollerussa, Catalonia
Cost driven products
Added value products
Production Process

1. Bed cleaning and strand pulling
2. Pre-stressing
3. Measuring and marking
4. Hole cutting
5. Drainage holes
6. Covering and curing
7. Sawing
8. LOGISTICS and HANDLING
1. Bed cleaning and strand pulling

- Manual / mechanised
- Cleaning / waste handling
- Oiling
  - Oil quality
  - Amount
  - Even oil surfaces
  - Strand pulling
    - Individual strands
    - All strands
  - Oiling of the strands / strand slippage
Cleaning and strand pulling, equipment
2. Pre-stressing

- Safety
  - Cleaning of grips
  - Pre-stressing procedure and safety

- Anchor structure
  - What is the usable length of the bed
  - Capacity utilisation

- Control of pre-stressing
  - Power / elongation or both

- Single or bundle pre-stressing
  - Size of the factory
  - Normally differences minor
  - Even pre-stressing easy to test

- Waste
  - Starting length (> 1 m)
  - Ending length (min 1 m-xx m)
  - Use of continuous strands
Pre-stressing, equipment
Use of continuous strands

- Steel waste
- Bed utilisation / production planning principle
- Steel strength / grips
  - Is it allowed?
  - A lot of tests done
- Steel stock value
3. Measuring and marking

- Manual
  - Tolerances
- Automated
  - Tolerances
  - Measuring principle
    - Laser
    - Pulse
  - Ink jet

Is input data available in right format for all products?
  - Different formats in design and machinery, standards?

Labeling, on the slab/ other labels

Height measurement, control/ concrete waste?
  - Use of tolerances; production in minus area
  - Example 270 mm slab
    - 2 mm extra height = 1.4% waste
Automatic measuring, equipment
4. Hole cutting

- Manual
- Mechanised
- Automatic

Fresh concrete
- Shovel principle
- Vacuum principle
- Excavating principle

Hardened concrete
- Diamond tools, drilling, chain saw
- Water jet cutting?

Important topics
- Tolerance and outlook requirements
- Re-use of concrete
Hole cutting, equipment
5. Drainage holes

- Are they needed?
  - In most cases yes, especially in cold climate
  - Water in voids is a very expensive claim
  - Sales contract topic, who is responsible

- Drilling from the top
  - Fresh concrete
  - Quality of holes

- Drilling from the bottom
  - Hardened concrete
  - Quality of holes

- Different drilling methods
  - Normal drills
  - Hammering
  - Water jet
6. Sawing

- Normal sawing
- Angle cuts
- Longitudinal sawing

- Fresh sawing
  - Quality of sawing
  - Tolerances

- Sawing of hardened concrete
  - Manually operated
  - Fully automated, measuring principle
  - Dust and slurry handling
  - Availability of input data in right format
Sawing, cont.

Important topics

- Sawing speed
- Sawing quality, tolerances
- Sawing costs / blade quality
- Noise level
  - Noise protection
  - Blade structure
- Quartz dust
  - Aggregate minerals
  - Saw machine structure
Sawing, equipment
7. Curing and maturity control

Why important?

- To control the rate and extent of moisture loss from concrete during cement hydration
- On-line control of concrete temperature, control of heating
- Calculation of final strength
- Forecast of hardening time
- Tracking of curing process needed in some projects
- Variations in raw materials; aggregates, cement
- Less waste (strand slippage)
- Lower energy consumption, short pay-back time

=> OPTIMISED and CONTROLLED PROCESS CYCLE
Curing and maturity control

Methods of curing concrete

- Minimise moisture loss from the concrete, by covering it with a relatively impermeable membrane.

- Prevent moisture loss by continuously wetting the exposed surface of the concrete.

- Keep the surface moist and, raise the temperature of the concrete => increasing the rate of strength gain.
Maturity control principle

- Heat loss to air model
- Reaction heat model
- Heating model

Production hall temperature
Concrete temperature
External heating energy

Heat loss to air model
Reaction heat model
Heating model
8. Logistics and handling

- Handling in the factory
- Handling in the stock yard
- Assembly at the building site

Main aspects in lifting
- Safety in all phases/ local regulation
- Speed
- Amount of special slabs (narrow slabs, large openings etc.)
- Storage system
- Transportation contract
- Transportation method and assembly order and method

Lifting options
- Individual slabs
- Bundle lifting
- Long lifting
Logistics and handling, production hall

Cranes
Clamps / lifting beams

Collection wagons / cars

Lifting hooks / lifting beams
Logistics and handling, production hall

- **Clamps / hooks**
  - Total production cycle time
  - Manual / mechanised hook assembly
  - Extra concrete for hook casting
  - Handling of special slabs (narrow, large openings)
  - Calculation principle and calculated safety

- **De-molding is the first quality control test**
- **Load bearing capacity of both methods is based on concrete tensile strength**
  - Design principle of hooks, bonding under the strand or not
- **Planning principle is very important, sorting in the hall or stock yard**
Logistics and handling, clamps

- Locking of clamps
- Adjustable beam length
  - One clamp
  - 2 clamps
  - 4 clamps
- Cross section /
  good compaction
- Edge profile
- Safety chain
Logistics and handling, lifting hooks and anchors
Lifting hooks, equipment
Logistics and handling, storage

- **In coming products**
  - Assembly order
  - Load size
  - Available storage area

- **Out going products**
  - Transportation contracts
  - Who is doing loading?
  - Assembly order
Logistics and handling, storage

Single slabs

Bundle handling

Ready loads

Crane on the lorry
Logistics and handling, at site

Fixing of the load

Hollow-core slabs

- Notice the location of stacking timbers
- Fixing behind stacking timber, not from the side of cantilever
Logistics and handling, at site
Logistics and handling, at site

- **Safety**
  - Safety rules

- **Assembly instructions**
  - Easy to understand

- **Assembly speed**
  - Crane speed / lifting height
  - Adjusting of the slabs
  - Extra castings of hooks
## Clamps / hooks

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<th>Clamps</th>
<th>Hooks</th>
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<tr>
<td>Safety</td>
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<tr>
<td>Unit cost</td>
<td>+++</td>
<td>+</td>
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<tr>
<td>Handling speed</td>
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<td>Special slabs</td>
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<td>Local regulation</td>
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<tr>
<td>Extra site work</td>
<td>+++</td>
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Future of pre-cast industry…..

- Evolution will continue
- Larger factories, more flexible production?
- Co-operation with other players and materials
- Environmental challenges are real
- Examples from other industries
- Industrialization of total building process
  - Focus on productivity
  - Design the key area
  - Pre-fabrication as a main tool
  - Automation and mechanization
- More emphasis on material technology
  - Cost, quality / outlook, sustainability

- MORE INNOVATIONS NEEDED
Future possibilities in hollow core production

- Fully automated factories
  - Larger units?
  - Technology is available

- Automation of individual steps
  - Heavy work
  - Better quality

- Simulation as production planning tool

- Faster production cycle / hardening

- Preventive maintenance

- New production concepts
  - Now fixed product, moving machinery
  - Moving product, fixed work stations

- New technologies
  - Water jet, laser
  - RFID, machine vision