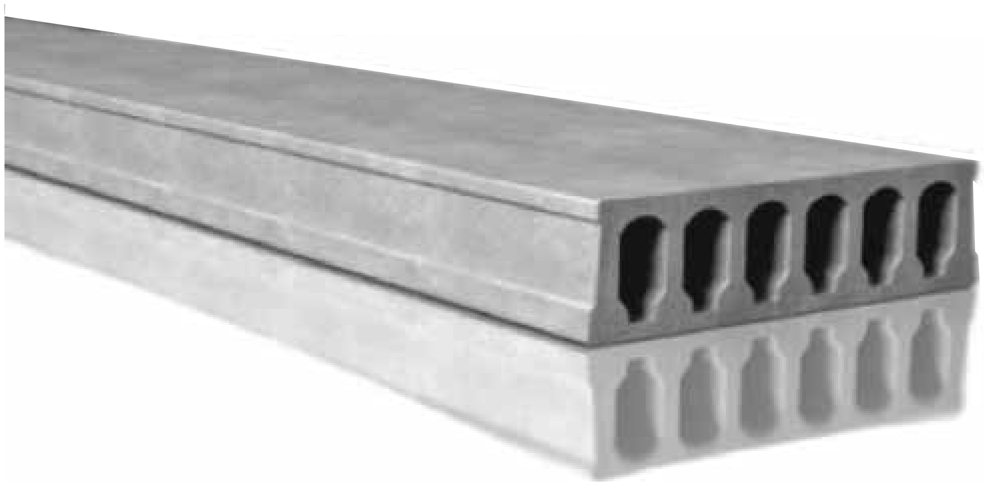
IPHA PRODUCTION SEMINAR 2016

October 26–27. Lleida · Mollerussa, Catalonia

PRODUCTION – THE SLIP FORMER CONCEPT AND THE FLOW FORMER CASTING MACHINES.



PRENSOLAND, S. A.

Product Department.

INTERNATIONAL PRESTRESSED HOLLOWCORE ASSOCIATION

in cooperation with Pujol

1 Scope

This European Standard deals with the requirements and the basic performance criteria and specifies minimum values where appropriate for precast hollow core slabs made of prestressed or reinforced normal weight concrete according to EN 1992-1-1:2004.

This European Standard covers terminology, performance criteria, tolerances, relevant physical properties, special test methods, and special aspects of transport and erection.

Hollow core elements are used in floors, roofs, walls and similar applications. In this European Standard the material properties and other requirements for floors and roofs are dealt with; for special use in walls and other applications, see the relevant product standards for possible additional requirements.

The elements have lateral edges provided with a longitudinal profile in order to make a shear key for transfer of vertical shear through joints between contiguous elements. For diaphragm action the joints have to function as horizontal shear joints.

The elements are manufactured in factories by extrusion, slipforming or mouldcasting.

SUMMARY:

SLIP FORMERS AND FLOW FORMERS

- Definitions.
- Background.
- Principle of Operation.

PRE-STRESSED CONCRETE VALUE CHAIN

PRODUCTIVITY

- Concrete feeding.
- Production cycle: operations and quality control.
- Handling of the finished product.

PRODUCT:

- Versatility
- Integration in the building system.

SLIP FORMER CONCEPT:

EXPLANATION:

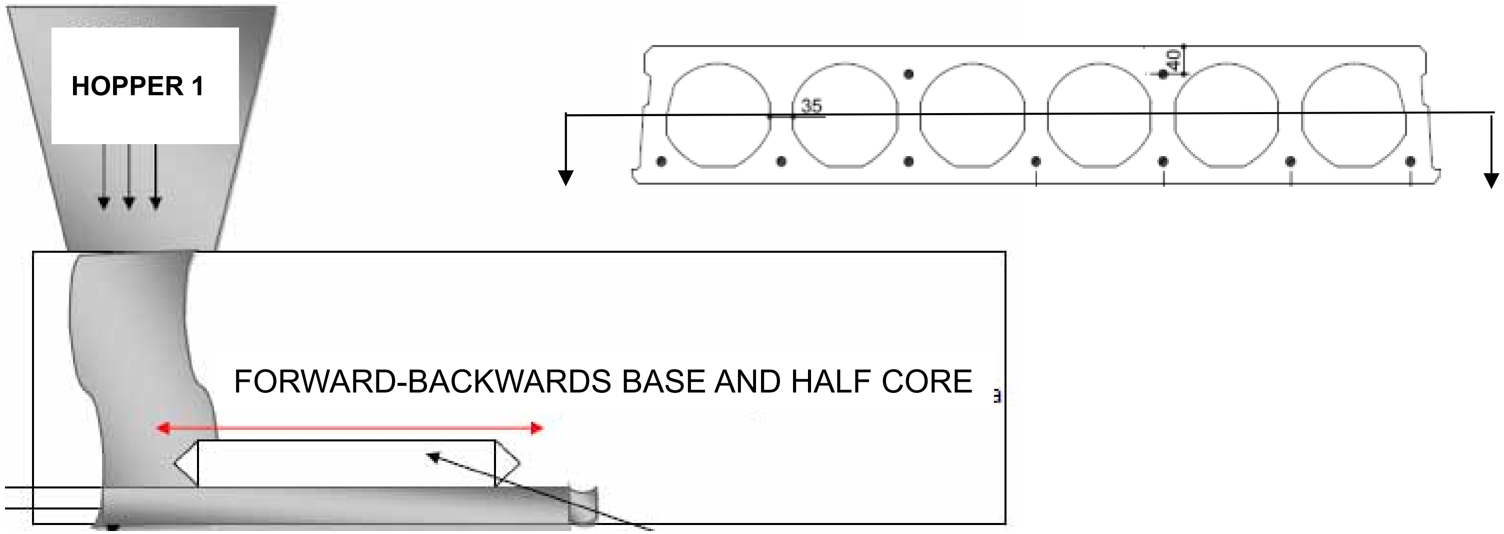
‘The Slip Former machines uses the combination of compaction and vibration to enhance the moulding in two or more steps of the concrete on a mould mounted at the bottom of the casting machine’.

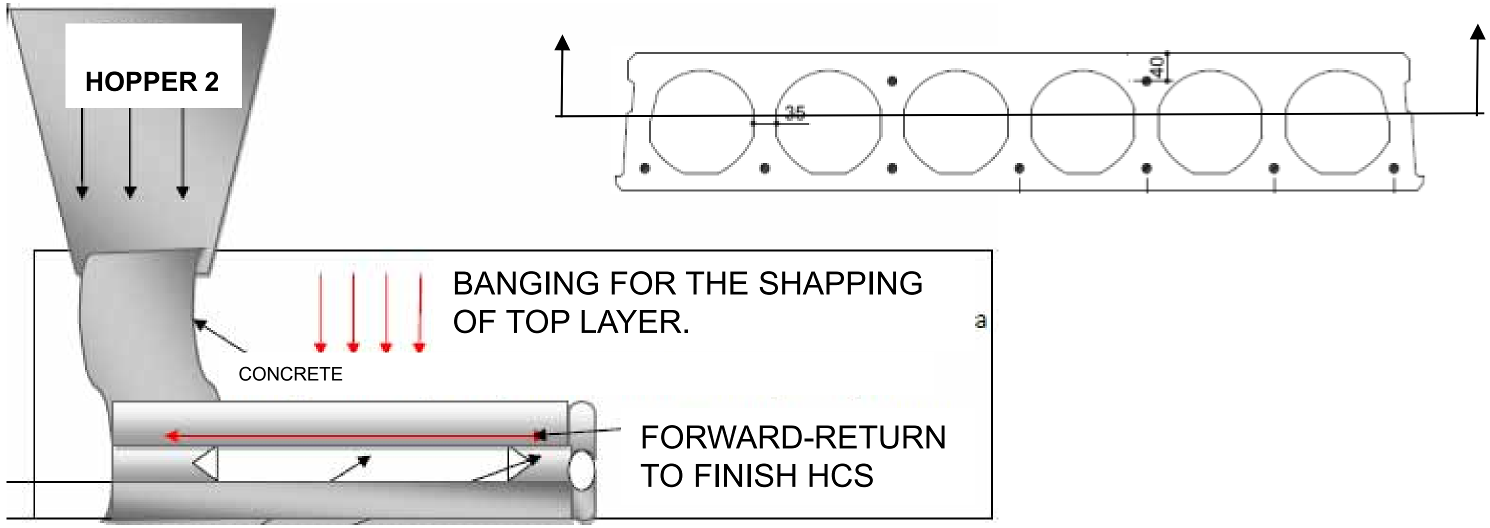
‘It does involve moving mechanical elements to compact or to shape the concrete through the mould’.

‘There is constant friction between the concrete and the mechanical parts’.

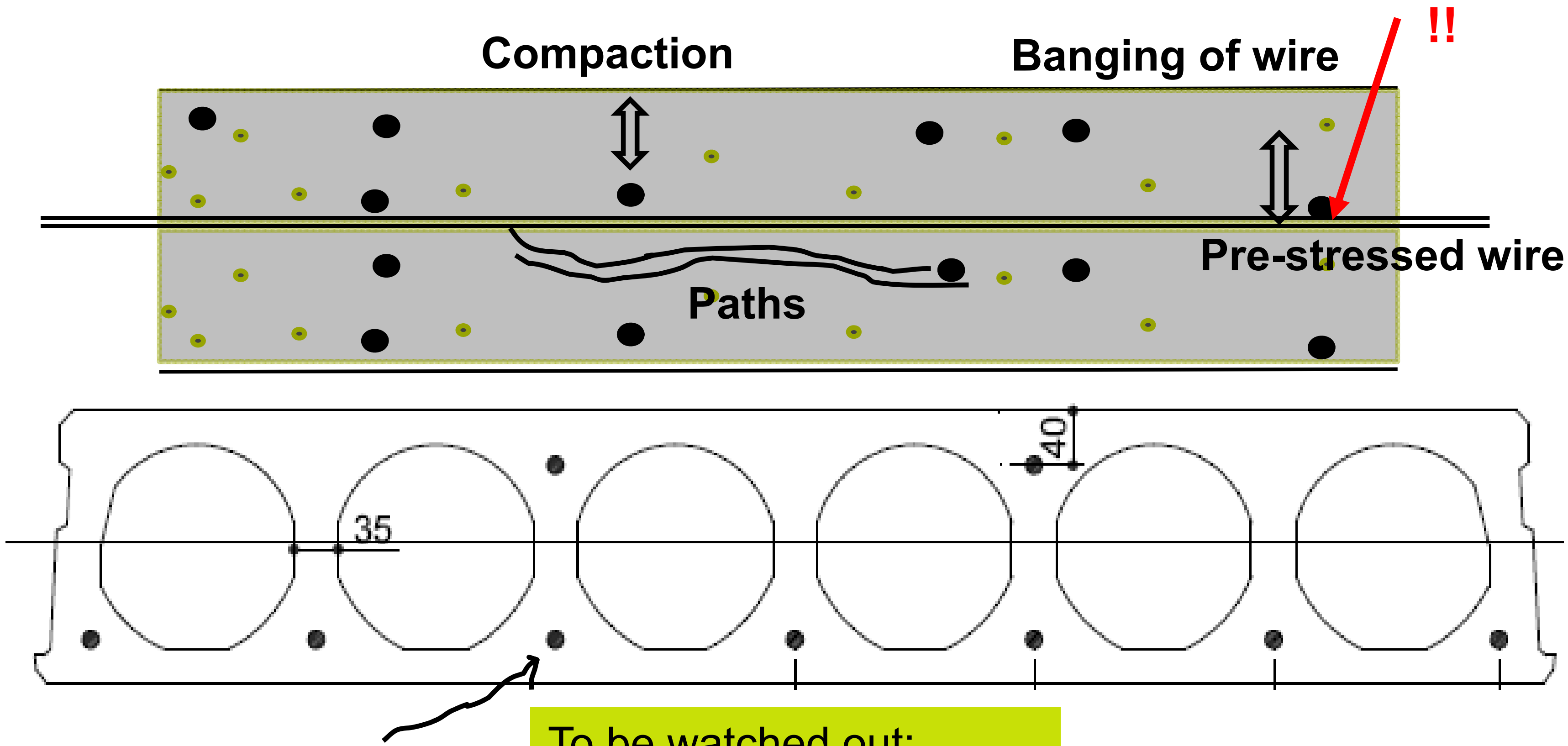
Many different profiles are possible apart from HCS.

THE SLIP FORMER CONCEPT:





TWO / THREE LAYERS CASTING



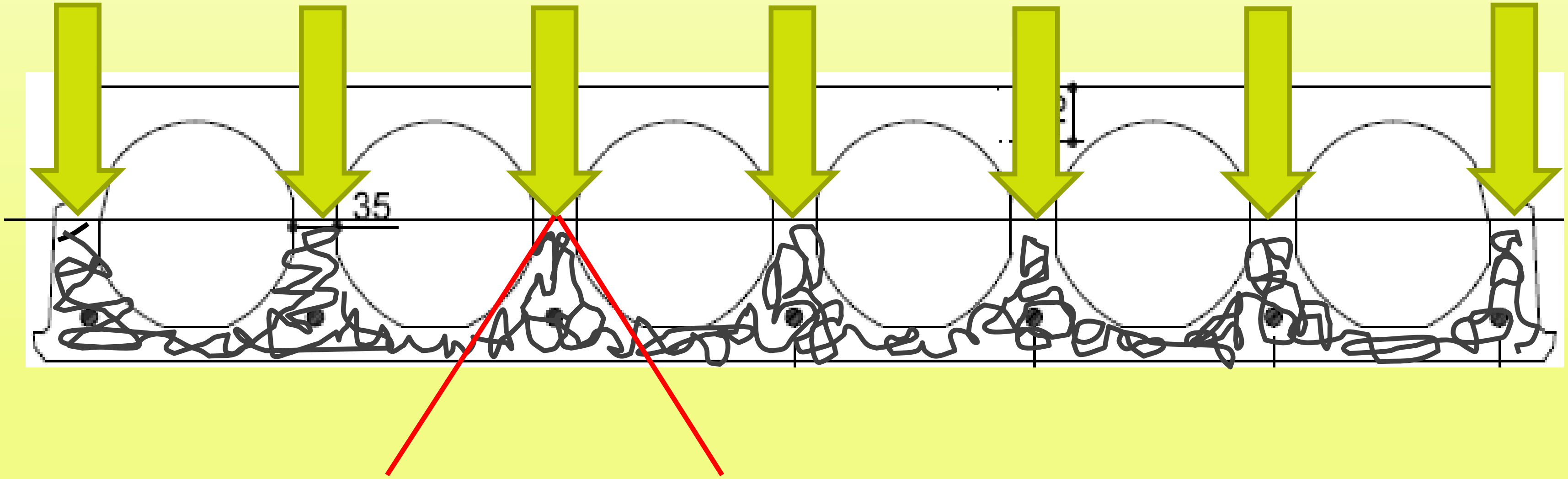
To be watched out:
- Bond slip
- Exposure of the wires
- Bonding of layers.
- Pore paths

TWO / THREE LAYERS CASTING

MIX DESIGN:

- The mechanical shaping requires a half dry concrete
- The use of plasticizers helps to smoothen the surfaces.

Vibration and compacting force



Stress cone of concrete

FLOW FORMING TECHNOLOGY:

EXPLANATION:

‘The Flow Forming technology uses the combination of gravity and vibration to enhance the moulding in just one step of the concrete through a mould mounted at the rear of the casting machine’.

‘It does not involve moving mechanical elements to push or to shape the concrete through the mould’, therefore it is not a ‘slip former’ nor an ‘extruder’ machine.

Possibility of casting many different profiles apart from HCS.

FLOW FORMING TECHNOLOGY:

DEFINITIONS:

Concrete: Plastic (*)

Water to cement ratio 0,30 to 0,35.

Abraham cone 0,5 to 1,0.

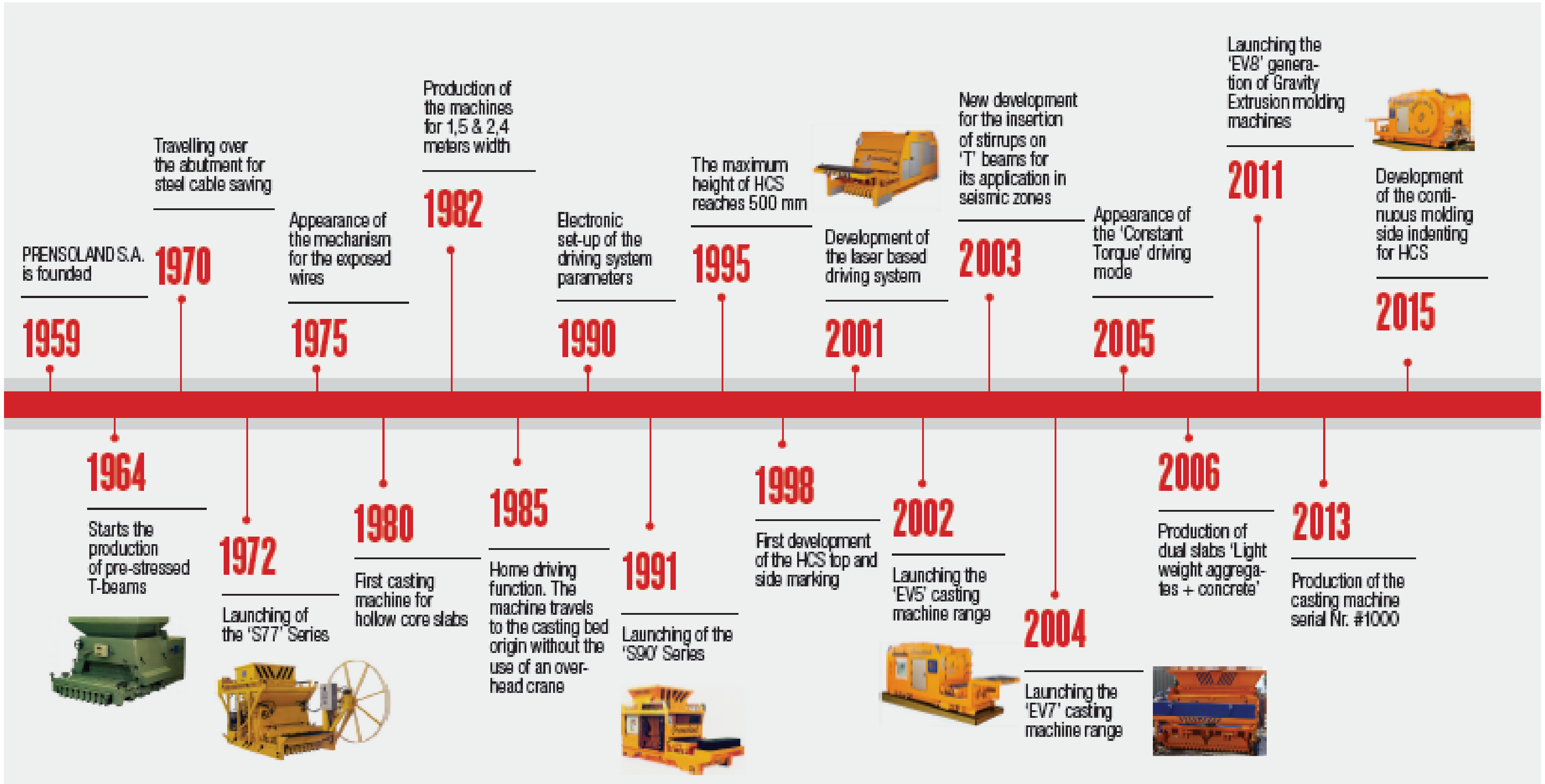
Admixtures: Plasticizers (water reducer).
Other as per factory requirements.

(*) ‘Wet’ concrete applies to pre-casting in static molds, tables, columns, beams, staircases, with a water to cement ratio around r = 0,40.

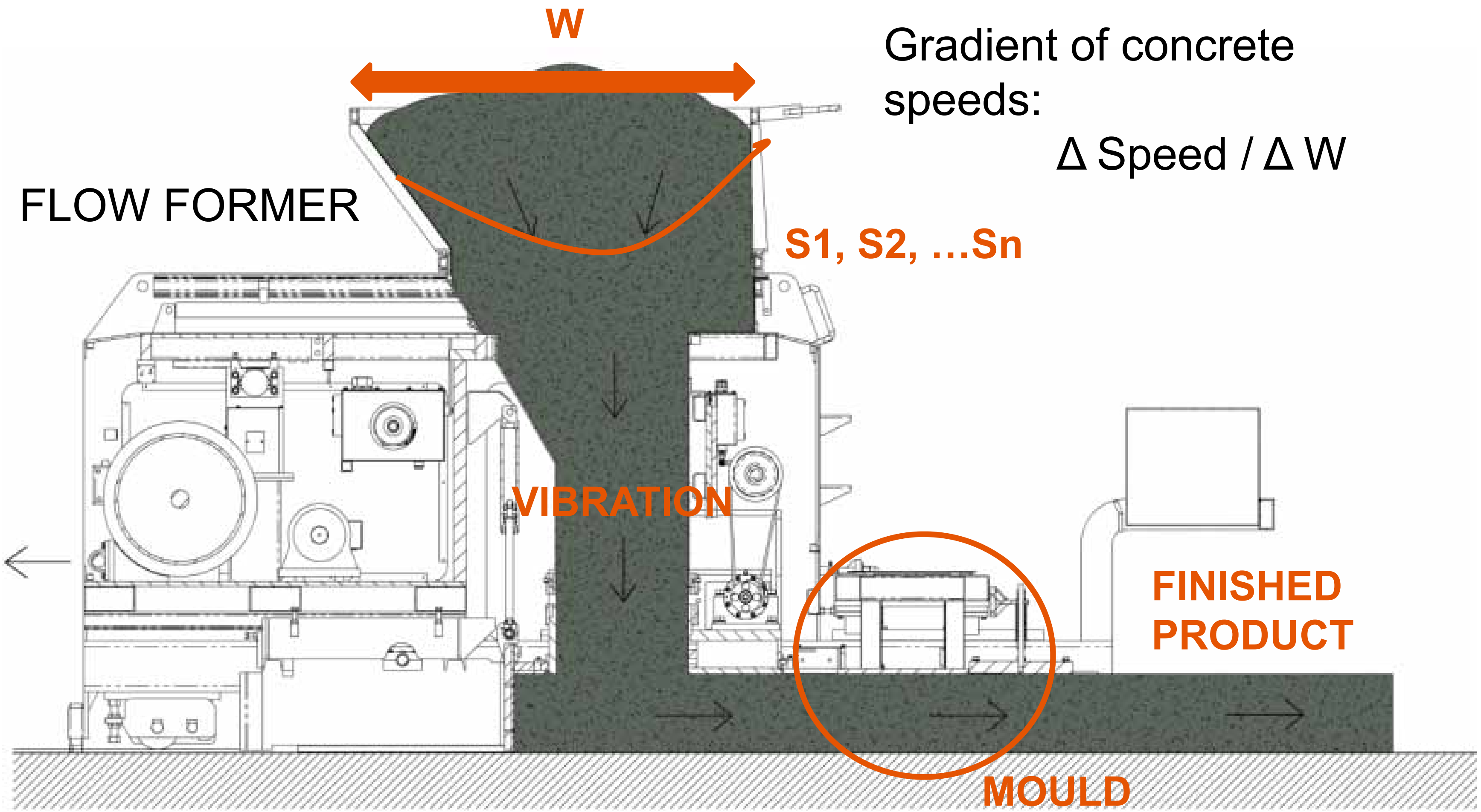
BACKGROUND: Over #1000 units installed.

Tensyland | Evolution 1959-2015

Prensoland
MAQUINARIA INDUSTRIAL



PRINCIPLE OF OPERATION: Gravity + Vibration



Machine forward:
Nominal casting speed: 3,0 m/min.

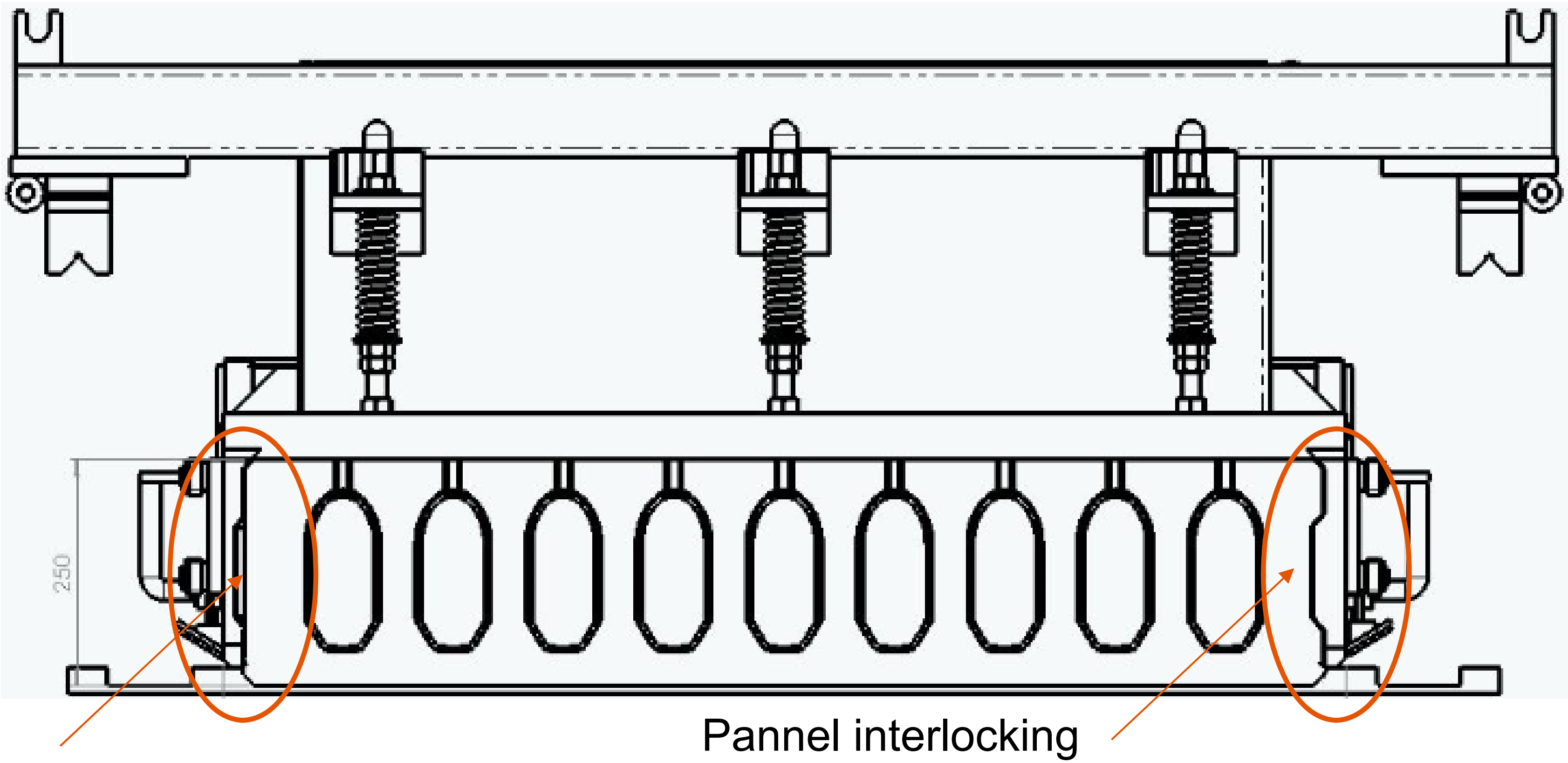
APPLICATION MINIMUM HCS THICKNESS 80 mm.:

APPLICATION FRACTIONAL SLABS:

APPLICATION HOLLOW CORE SLABS:

APPLICATION HOLLOW CORE SLABS:

Floor slabs → Wall slabs: mould sides changing



APPLICATION WALL HOLLOW CORE SLABS:

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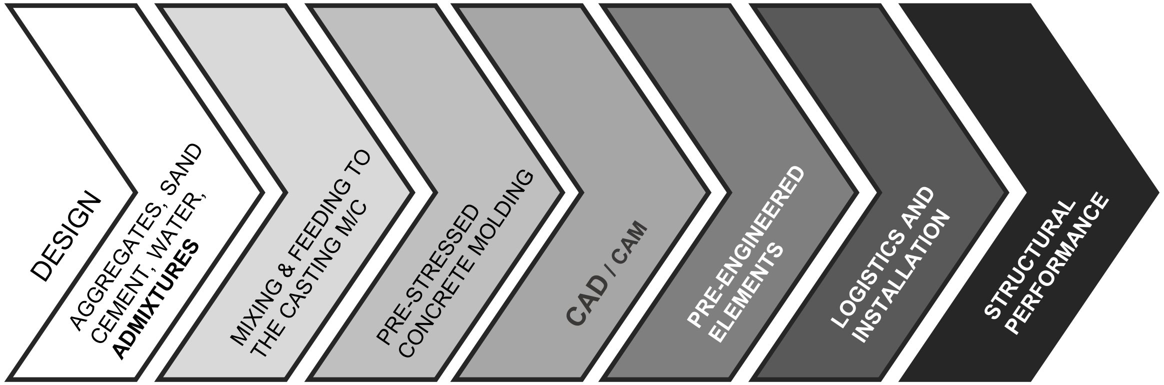
APPLICATION HOLLOW CORE SLABS:

PRE-STRESSSED CONCRETE VALUE CHAIN



TERMS:

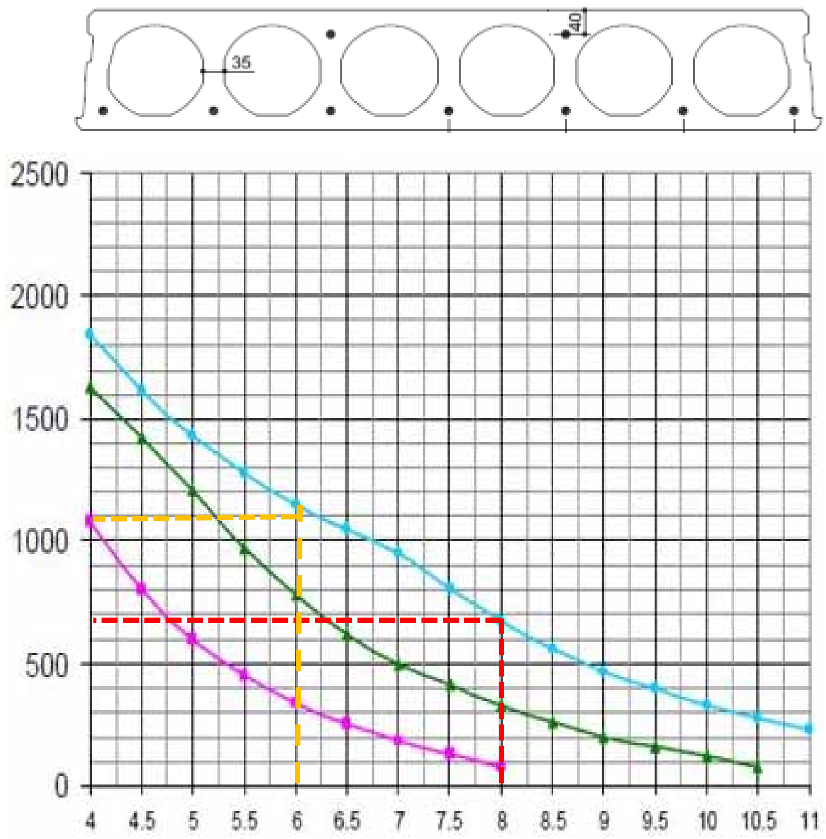
- **Crusher**
- **Mix design**
- **Humidity control**
- **Grade of cement.**

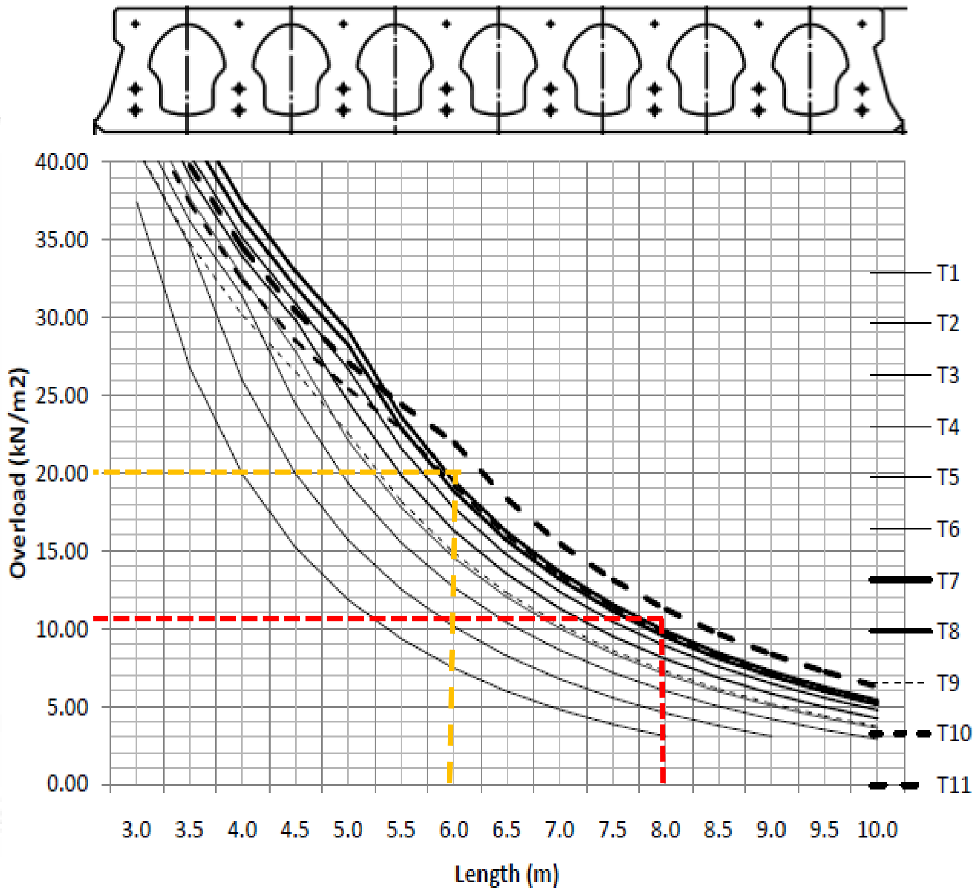
- **Concrete feeding.**
- **Weight**
- **Wire/strand**
- **Strength**
- **Curing.**

- **Cut-out**
- **Filled cores**
- **Fractional slabs**
- **Hooks, jigs.**

- **Load bearing capacity / Shear**
- **Seismic zone**
- **Diaphragm.**

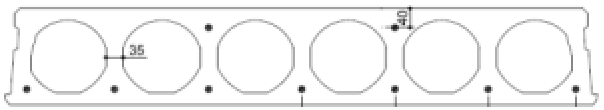
OBJECTIVE BENEFITS: Precaster Vs Developer.

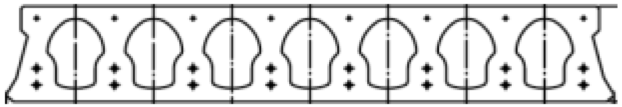




HCS thickness, weight of the slab, cement/m^3, use of steel, load bearing capacity.

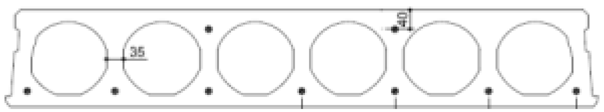
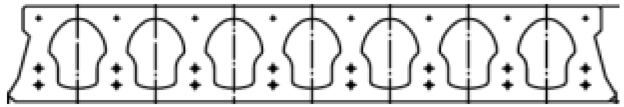
Pre-stressed concrete elements: SALIENT DATA



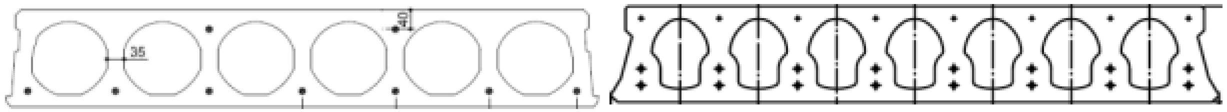


Slab thickness:	**HCS 200 max.**	**HCS 200 max.**
Weight / m²:	**242 kg/m2**	**270 kg/m2 (!!)**
Cement / m²:	**36,3**	**42,75**
Reinforcement:	**7(1/2”)+2(3/8”)=8,03cm²**	**8(1/2”)+6(5mm.)= 9.07 cm²**
Load bearing capacity kg/m²: (8,0 meters span)	**670**	**1100**
Contribution of cement:	**18,5 kg/m² per kg.**	**25,73 kg/m² kg.**
Contribution of steel:	**83,4 kg/m² per cm²**	**121,28 kg/m² per cm²**

Pre-stressed concrete elements: SALIENT DATA

		
Slab thickness:	**HCS 200 max.**	**HCS 200 max.**
Weight / m^2:	**242 kg/m2**	**270 kg/m2**
Cement / m^2:	**36,3**	**42,75**
Reinforcement:	**7(1/2")+2(3/8")=8,03cm^2**	**8(1/2")+6(5mm.)= 8,08 cm^2**
Load bearing capacity kg/m^2: (8,0 meters span)	**670**	**800**
Contribution of cement:	**18,5 kg/m^2 per kg.**	**18,71 kg/m^2 per kg.**
Contribution of steel:	**83,4 kg/m^2 per cm^2**	**99,01 kg/m^2 per cm^2**

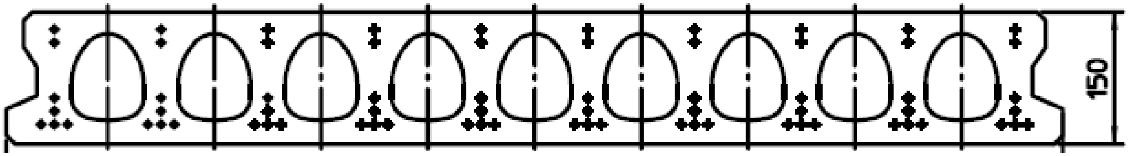
Pre-stressed concrete elements: SALIENT DATA



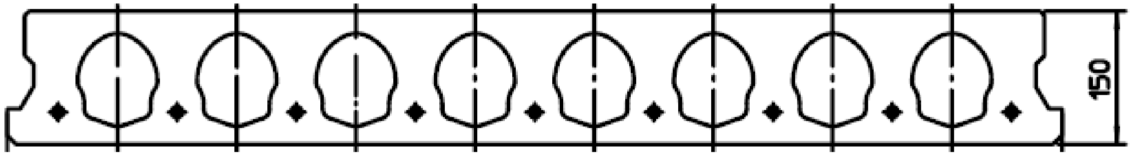
Slab thickness:	**HCS 200 max.**	**HCS 160 max.**
Weight / m^2:	**242 kg/m2**	**226 kg/m2**
Cement / m^2:	**36,3**	**35,8**
Reinforcement:	**7(1/2”)+2(3/8”)=8,03cm^2**	**10(9,3)+4(5mm.)= 6,28 cm^2**
Load bearing capacity kg/m^2: (8,0 meters span)	**670**	**670**
Contribution of cement:	**18,5 kg/m^2 per kg.**	**18,71 kg/m^2 per kg.**
Contribution of steel:	**83,4 kg/m^2 per cm^2**	**106,69 kg/m^2 per cm^2**

Balance core / web

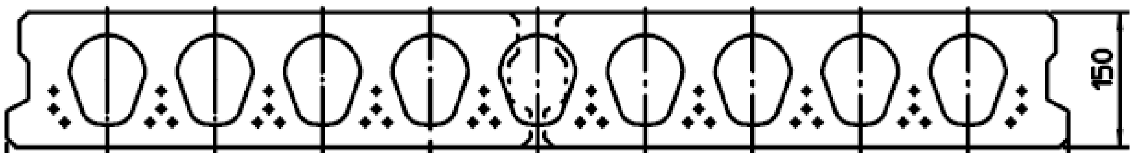
Wire reinforcement: dia. 4,0 mm. – 5,0 mm. - 6,0 mm. (top reinforcement mainly for transport and handling purposes)



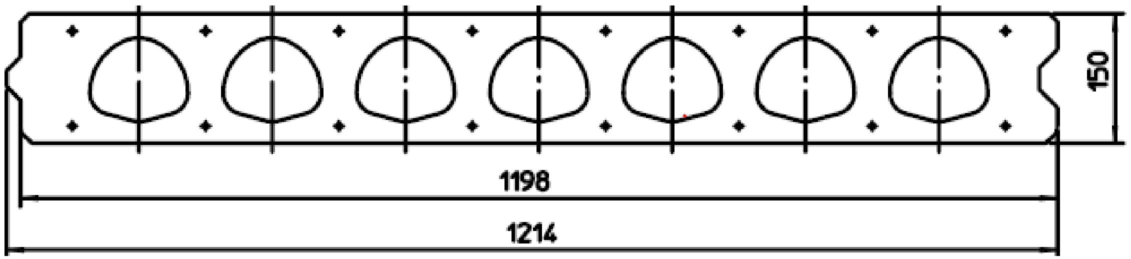
Strand 3/8 inch, 1/2 inch,



Half slabs



Slabs for cladding applications



PRODUCTIVITY: time / materials.

CONCRETE FEEDING:

- Manual buckets: from 1,0 to 2,0 m3
- Dual bucket system: overlapping loading and transfer.
- Flying bucket with dedicated bridge crane for the moulding machine.

PRODUCTION CYCLE

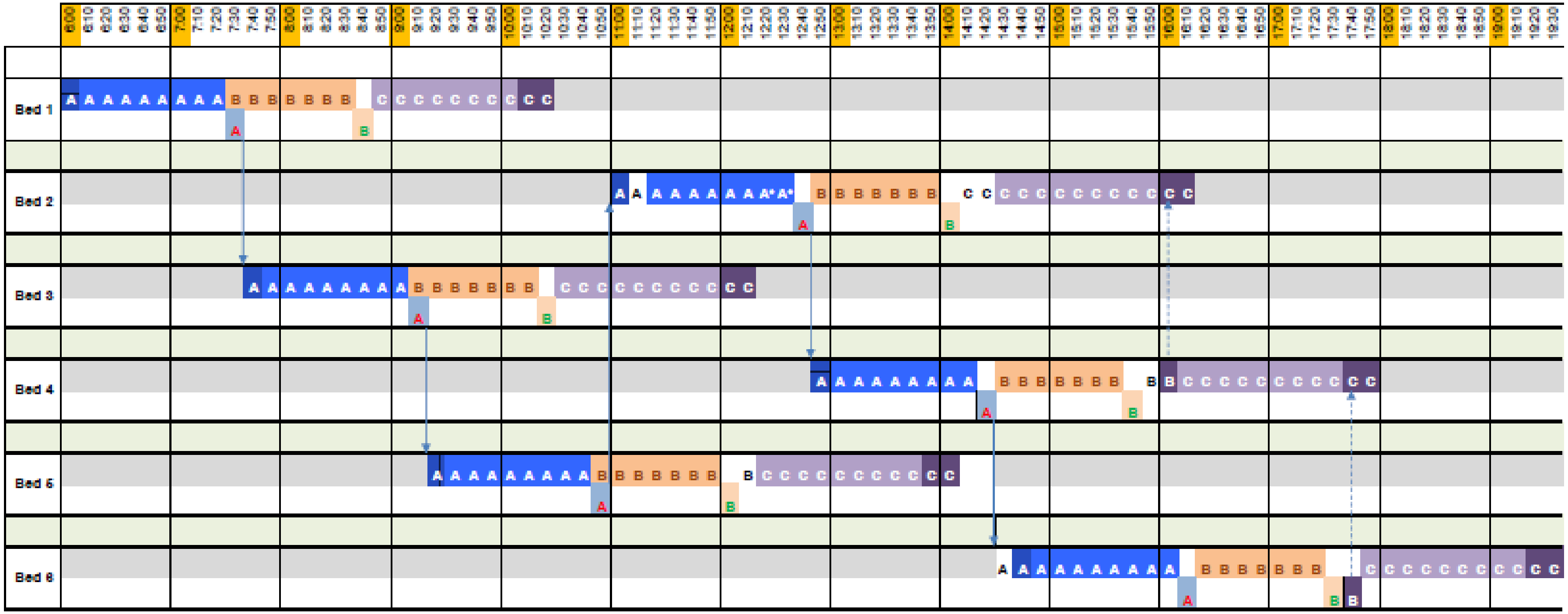
- The process: preparation – casting – curing – cutting.
- Plant engineering: Curing systems, water treatment, H&S.
- Quality control: materials and finished product.
- Integration in the CRM: from CAD/CAM to shipping bills.

HANDLING OF THE FINISHED PRODUCT

- Product removal: clamps.
- Stacker lifter machine.

Cycle time = process + handling + curing

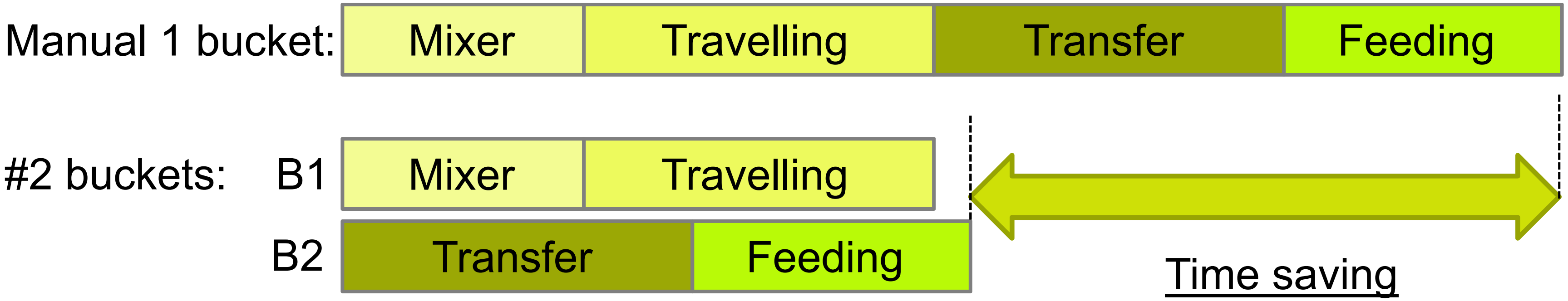
FACTORY #6 CASTING BEDS 150m: 1 MOLDING MACHINE, 1 CUTTING M/C, 1 MULTIPURPOSE: CLEANING + WIRE PULLING.



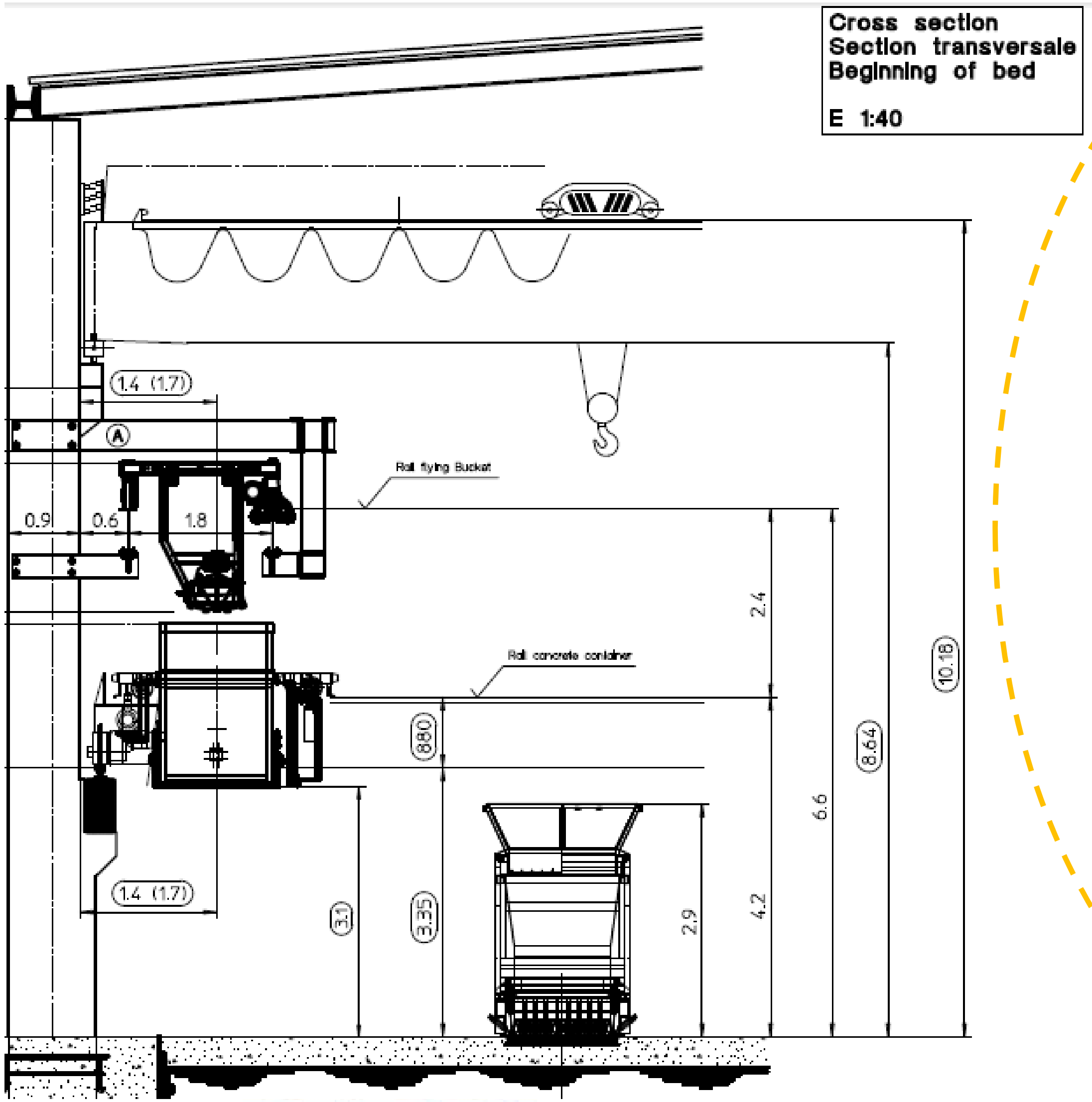
- A — DE-TENSIONING, CUT, MARKING AND REMOVAL OF FINISHED PRODUCT;
- A* — COORDINATED WITH TEAM 'B';
- A — CLEANING, MAINTENANCE & GENERAL TASKS;
- B — CLEANING OF BED AND WIRE PULL;
- B — MAINTENANCE & GENERAL TASKS;
- C — MOLDING;
- C — CLEAN OF MOLDING MACHINE, BATCHING PLANT AND CONCRETE BUCKET;
- A — BREAK TIME TEAM 'A';
- B — BREAK TIME TEAM 'B';
- C — BREAK TIME TEAM 'C';
- B → C — TEAM 'B' HELPS TEAM 'C';
- A — STRENGTH TEST AT THE LABORATORY.

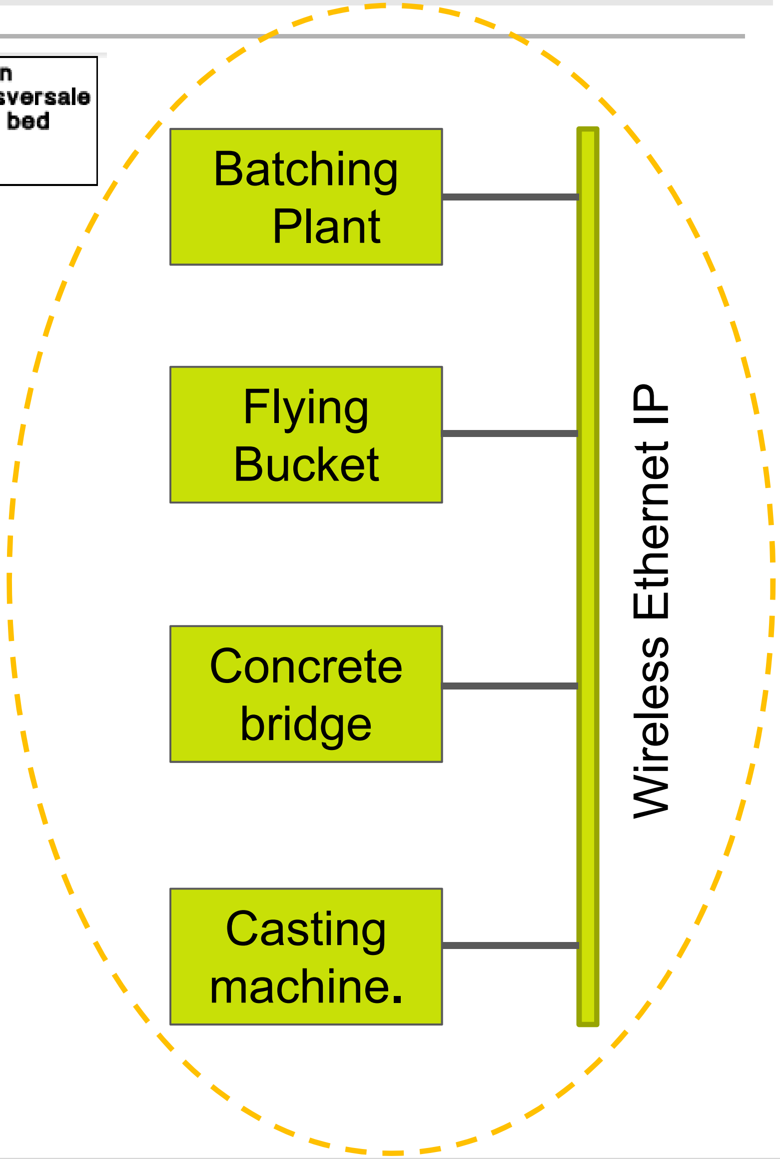
Team A: 2 operators.
Team B: 2 operators.
Team C: 2 operators.
#1 Machine
#1 Batching Plant

Concrete feeding system: semi-automatic

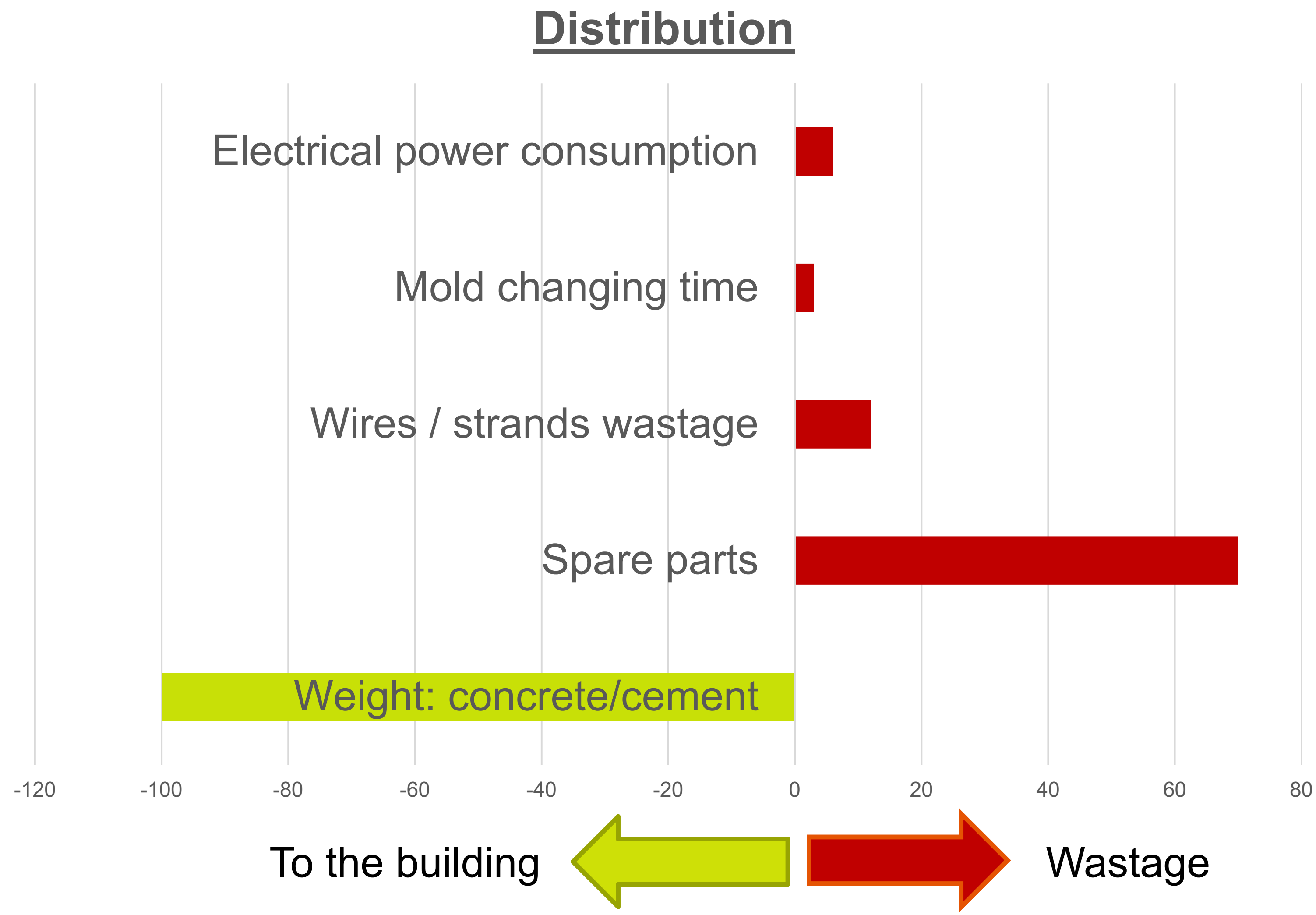


Concrete feeding system: Automatic





Some production costs variables:



Efficiency in the use of the wires or strands:

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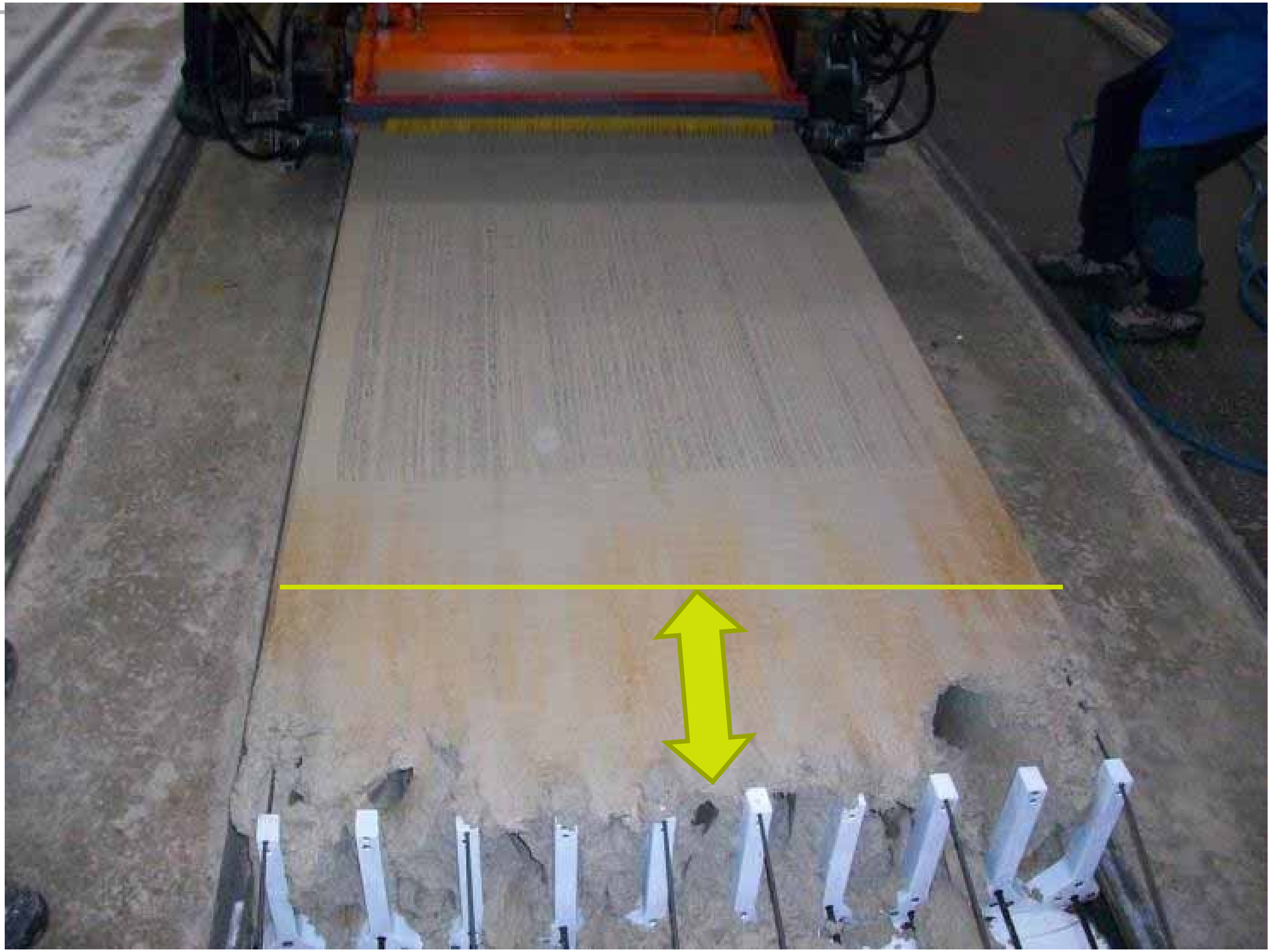
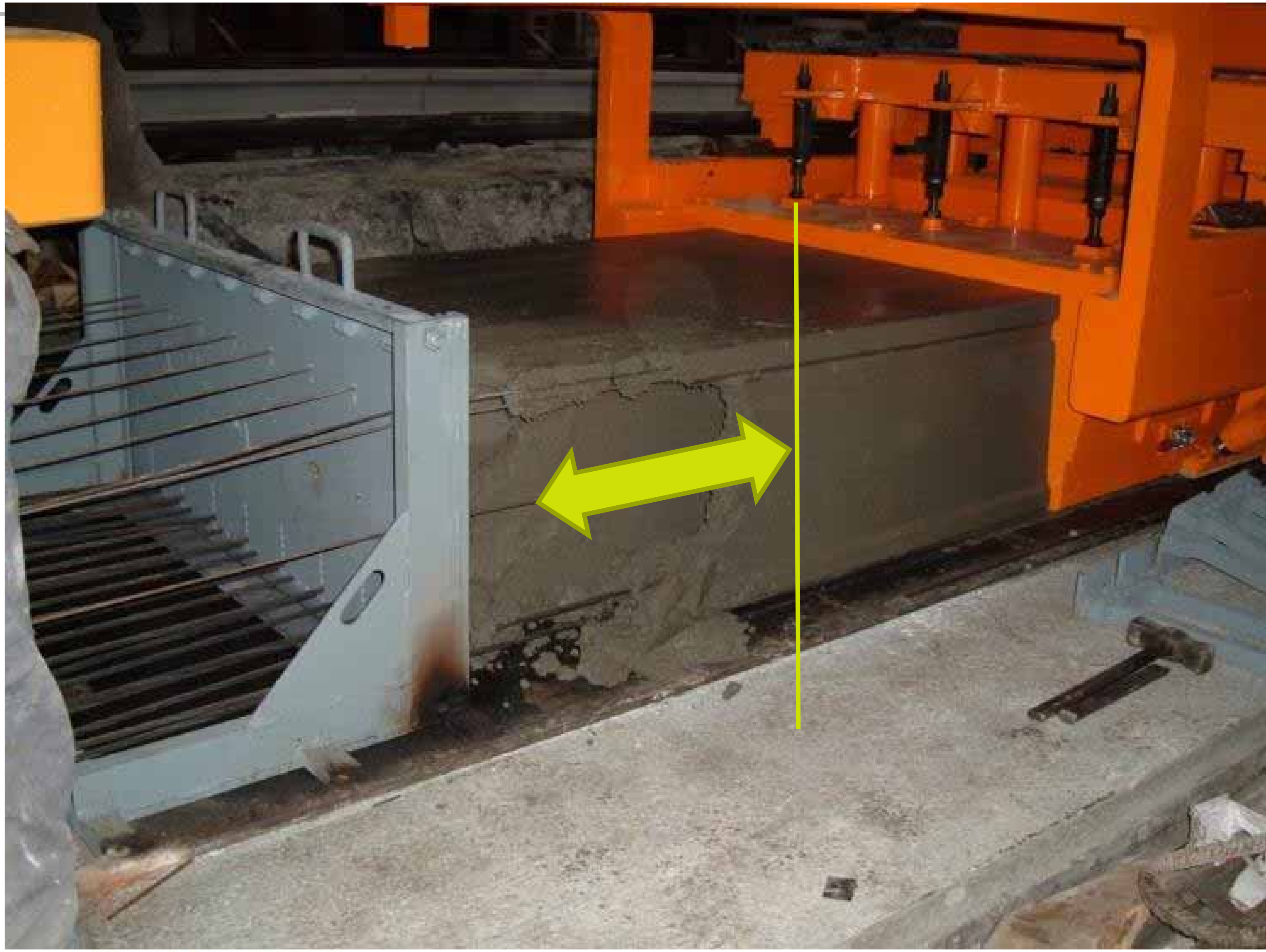
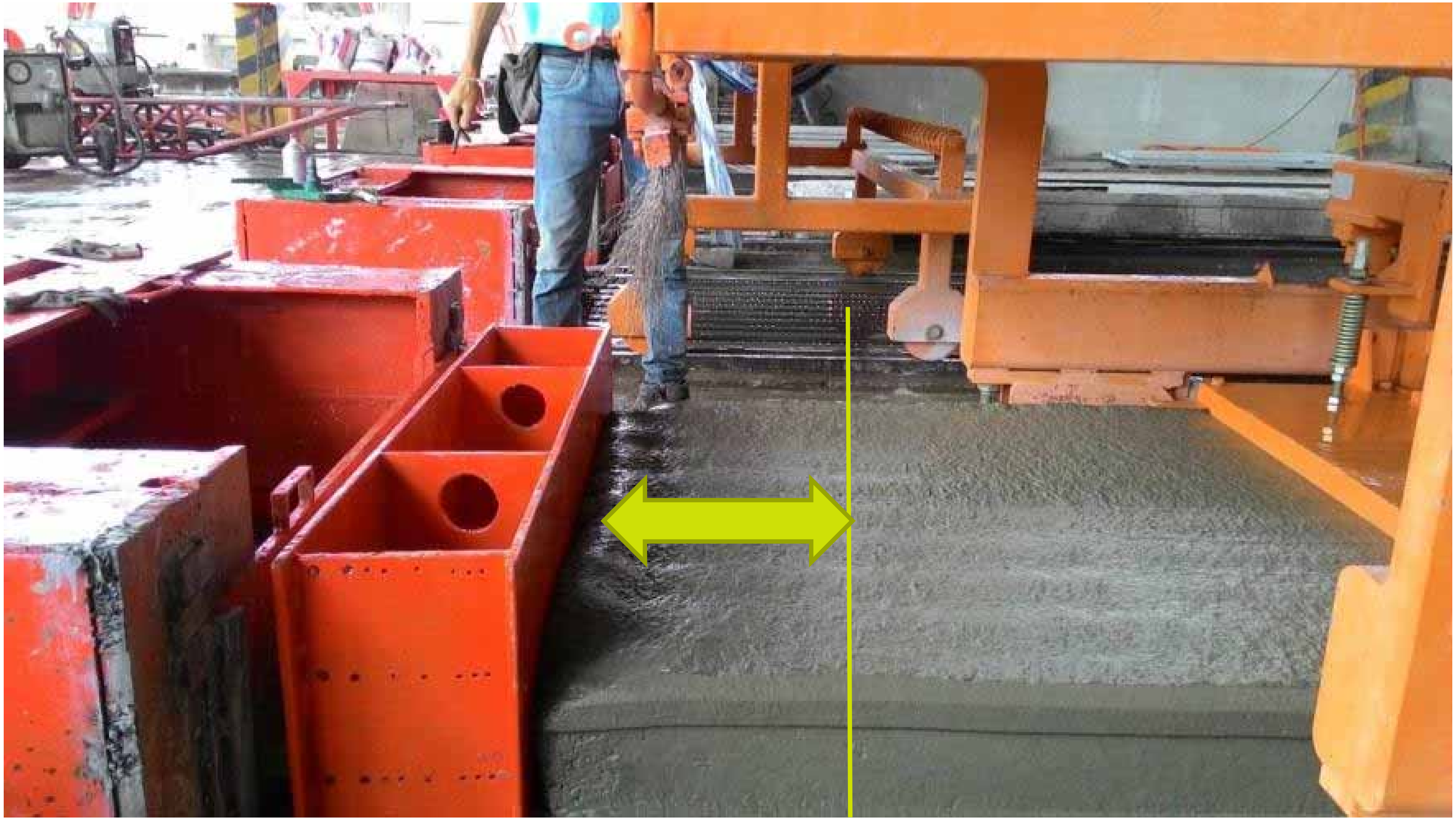


Efficiency in the use of the wires or strands:



Efficiency in the use of the wires or strands:

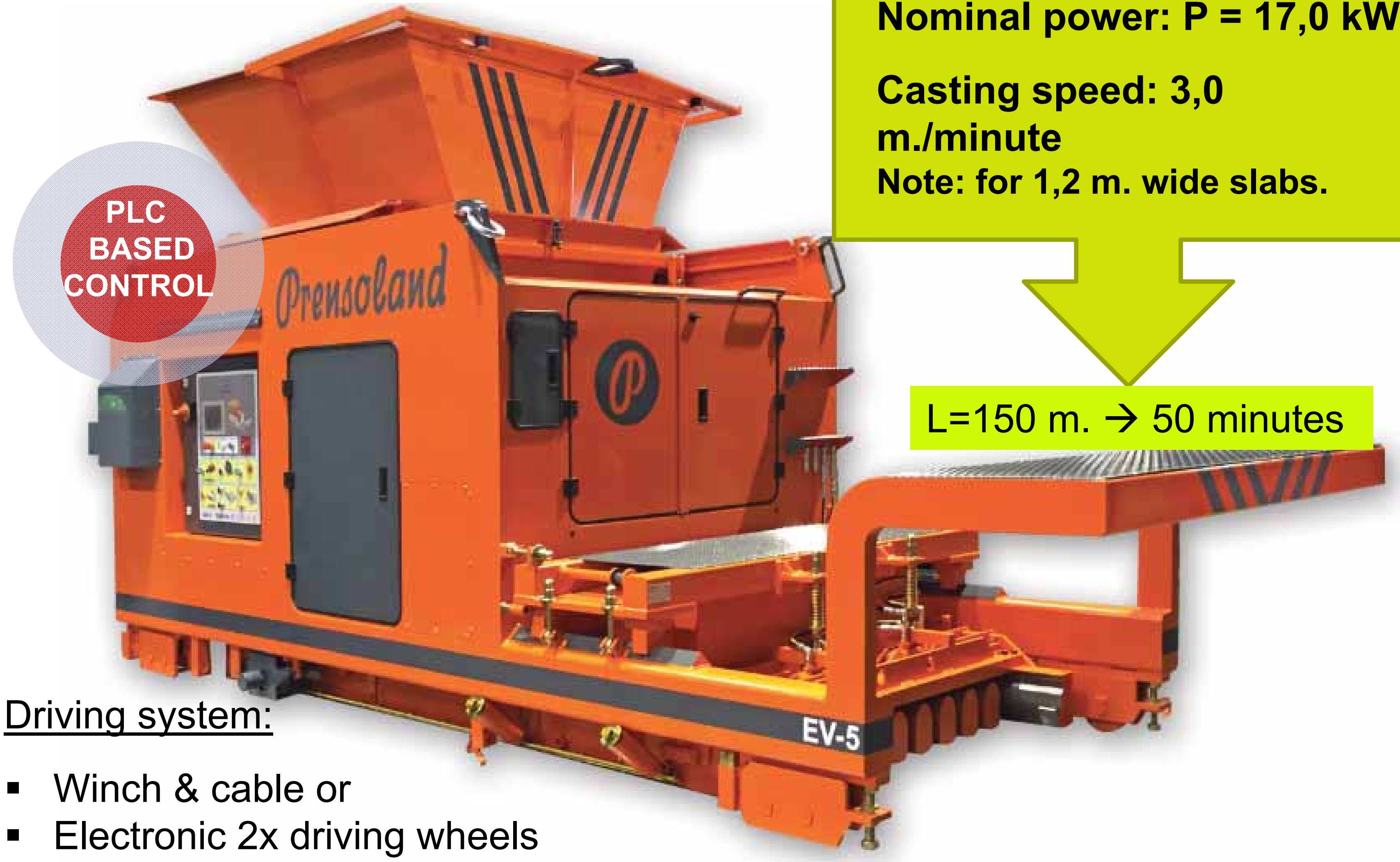


Cycle time: FLOW FORMER

Nominal power: P = 17,0 kW

Casting speed: 3,0 m./minute
Note: for 1,2 m. wide slabs.

L=150 m. → 50 minutes

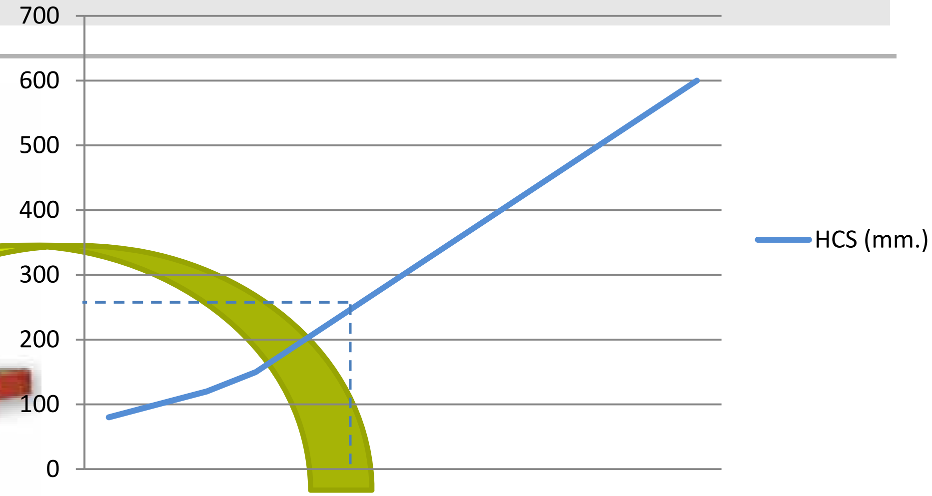


Driving system:

- Winch & cable or
- Electronic 2x driving wheels

FLOW FORMER

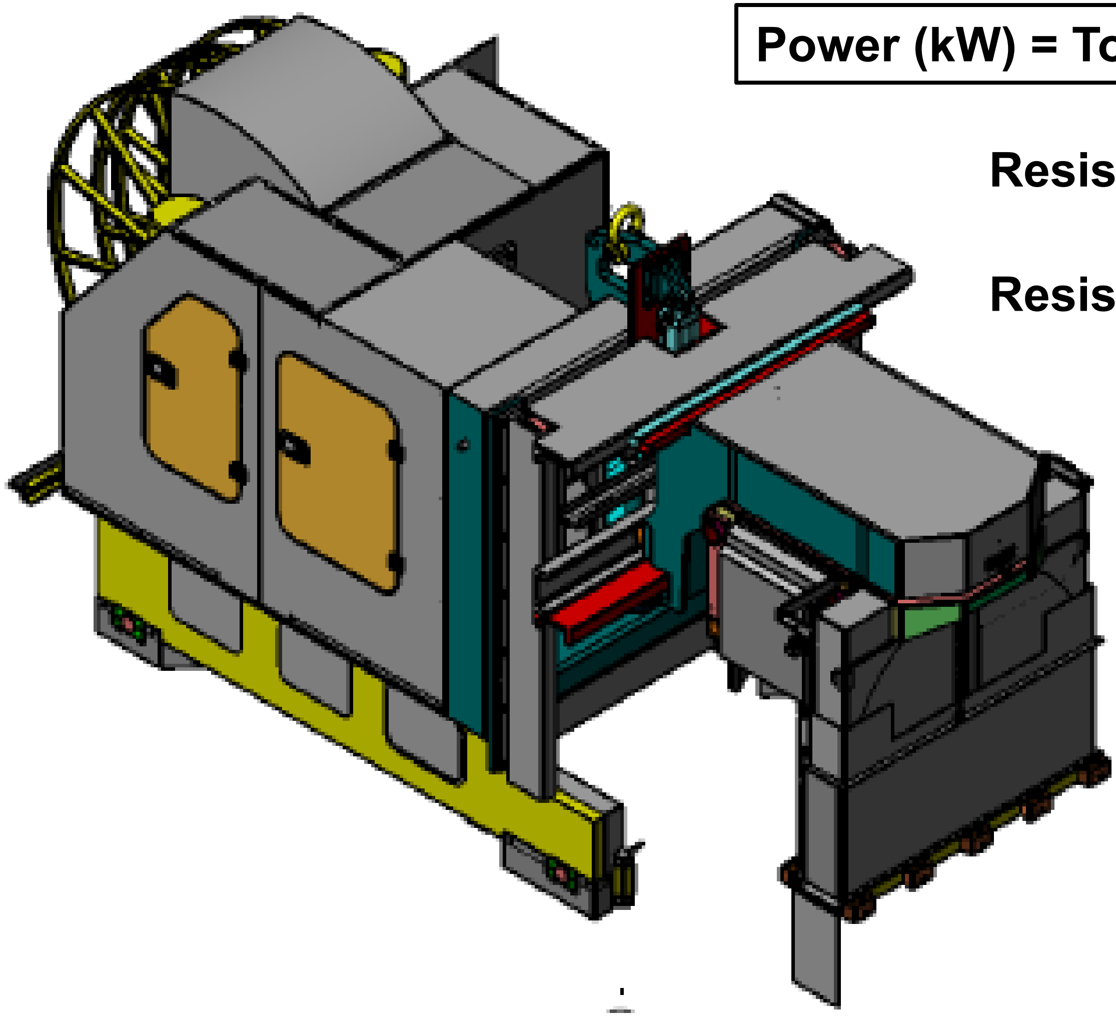
Available thickness HCS (mm.) by FLOW FORMING:



- **Fixing + Alignement: #6 bolts.**
- **Changing mould time: 10 min.**
- **Minimum mould <u>life time</u>:**

  5 years, 2 shifts
  or
  1.500.000 m2 carpet area,
  whatever comes first.

Cycle time: MULTI-ANGLE cutting machine.



Power (kW) = Torque (Nm) * Speed (rpm)

Resistant torque ↑ ; Speed ↓

Resistant torque ↓ ; Speed ↑

SPEED UP CUTTING

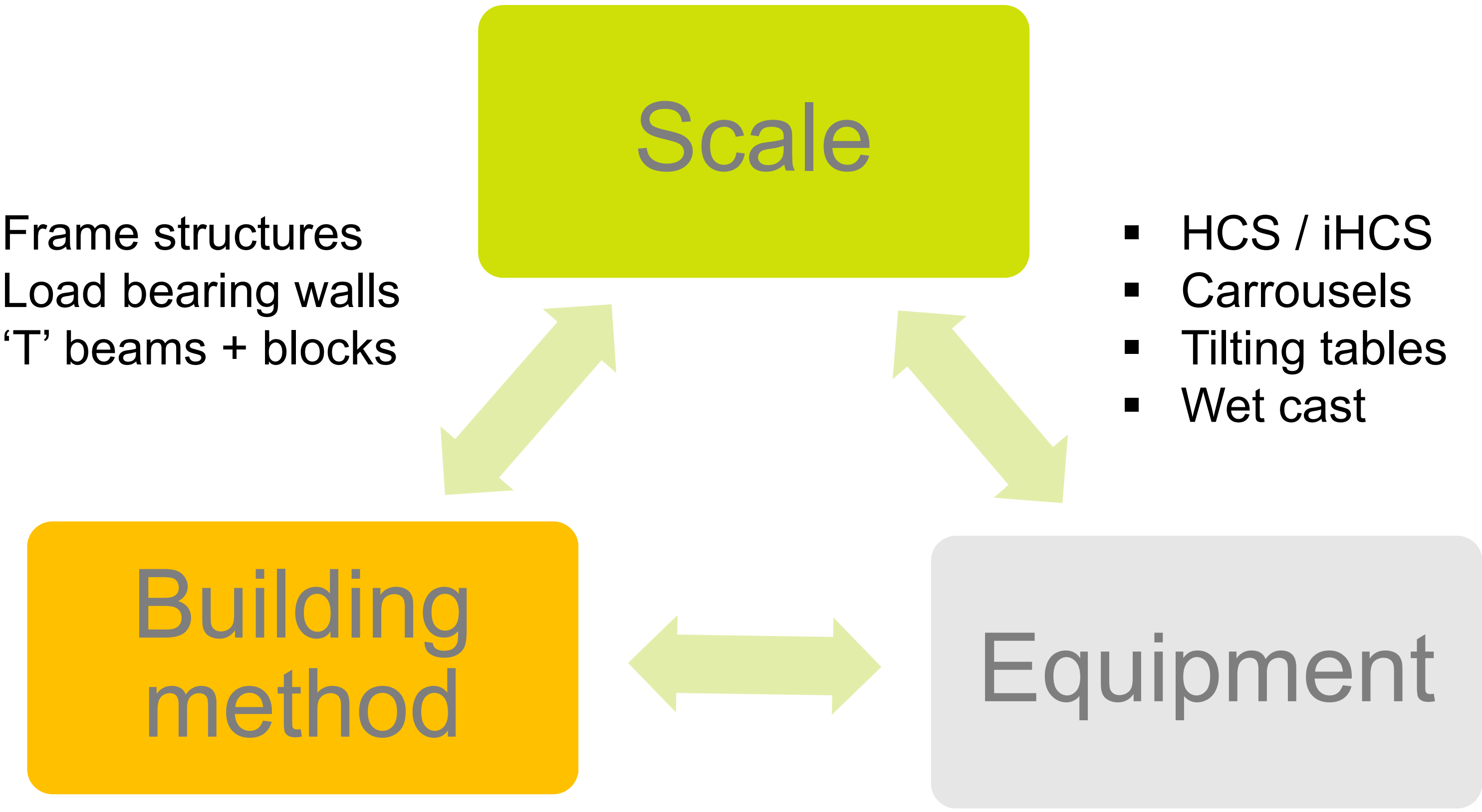
Handling of the finished parts:




Handling of the finished parts:

INTEGRATION IN THE BUILDING SYSTEM:

- Frame structures
- Load bearing walls
- ‘T’ beams + blocks



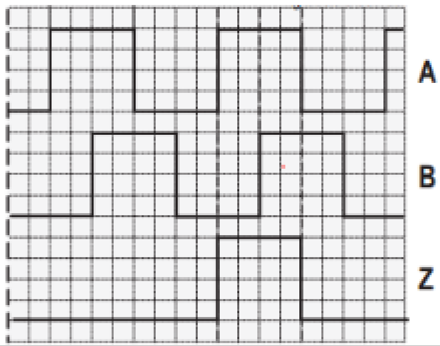
- HCS / iHCS
- Carrousels
- Tilting tables
- Wet cast

Equipment to produce pre-engineered precast concrete elements.

Automated production of hollow core slabs:

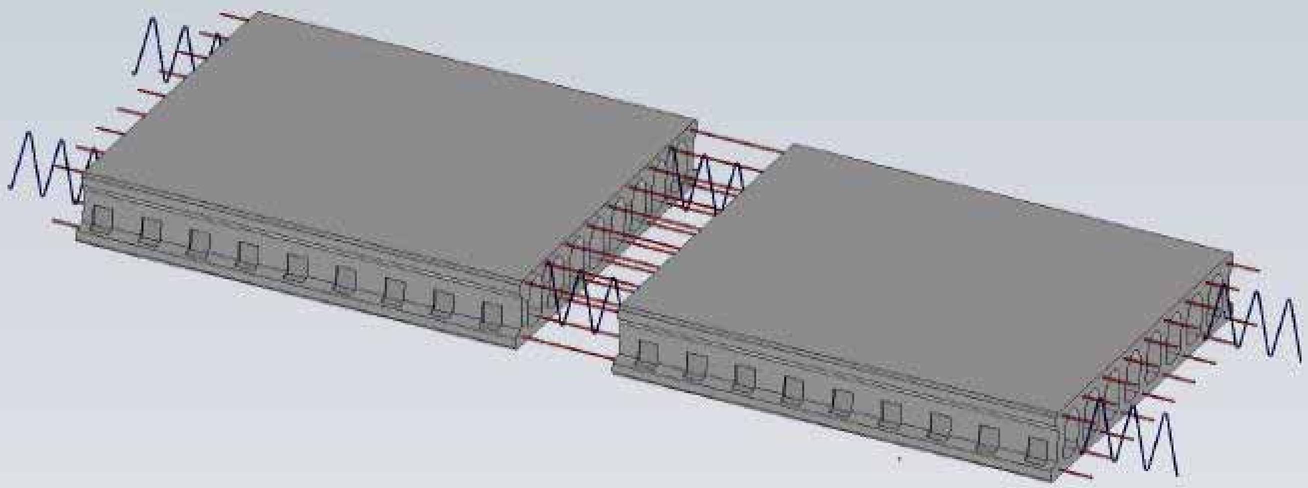
Automation enables:

- ❑ **Exposed wires.**
- ❑ **‘Carantage’.**
- ❑ **Side Indenting.**



Building with indented hollow core slabs iHCS

The origin of the iHCS:



The PRENSOLAND ‘seismic slab’

The need of side indented slabs:

The study of the iHCS:

		fcd [MPa]	fctd [MPa]
Hollowcore concrete :	C45/55	30,00	1,80
Grouting (joint) concrete :	C25/30	16,67	1,20
Topping concrete :	C30/37	20,00	1,33

	h [mm]
Effective height of joint :	230

	h1 [mm]	h2 [mm]	depth [mm]	height [mm]	pitch [°]	c [-]	μ [-]	
Dimensions of indentions :	50	50	5	150	30	0,5	0,9	Top view

	Indented	Rough	Smooth	Very smooth
Surface :	✔	✖	✖	✖

EN 1992-1-1:2004, 6.2.5 (2

	N_Ed [kN/m]
Force through the joint :	15

$$V_{Rdi} = c \cdot f_{ctd} + \mu \cdot \sigma_n + \rho \cdot f_{yd} \cdot (\mu \cdot \sin\alpha + \cos\alpha) \leq 0.5 \cdot \upsilon \cdot f_{cd}$$

EN1992-1-1:2004 (6.25)

Capacity without indentions and without topping

V_Rdi = 105,6 kN/m

Capacity with indentions and without topping

V_j = 98,8 kN/m

V_1 = 36,7 kN/m

V_Rdi = 135,5 kN/m

How much topping is saved with the indentions?

ΔV_Rdi = 29,9 kN/m

h_topping = 53,5 mm

(Formula only valid for thicknesses smaller than 200mm of unreinforced topping)

The European Norm about side indenting on HCS:

https://law.resource.org/pub/eu/eurocode/en.1992.1.1.2004.pdf

6.2.5 Shear at the interface between concrete cast at different times

(1) In addition to the requirements of 6.2.1- 6.2.4 the shear stress at the interface between concrete cast at different times should also satisfy the following:

$$v_{Edi} \leq v_{Rdi} \qquad (6.23)$$

v_{Edi} is the design value of the shear stress in the interface and is given by:

$$v_{Edi} = \beta V_{Ed} / (z\, b_i) \qquad (6.24)$$

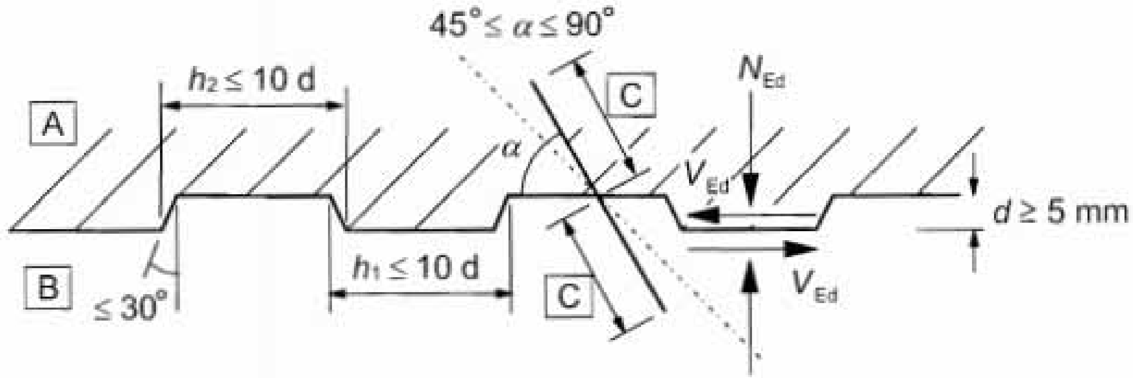
where:

- β is the ratio of the longitudinal force in the new concrete area and the total longitudinal force either in the compression or tension zone, both calculated for the section considered
- V_{Ed} is the transverse shear force
- z is the lever arm of composite section
- b_i is the width of the interface (see Figure 6.8)
- v_{Rdi} is the design shear resistance at the interface and is given by:

$$v_{Rdi} = c\, f_{ctd} + \mu\, \sigma_n + \rho\, f_{yd} (\mu \sin \alpha + \cos \alpha) \leq 0{,}5\, \nu\, f_{cd} \qquad (6.25)$$

The European Norm about side indenting on HCS:

https://law.resource.org/pub/eu/eurocode/en.1992.1.1.2004.pdf



A - new concrete, B - old concrete, C - anchorage

Figure 6.9: Indented construction joint

(2) In the absence of more detailed information surfaces may be classified as very smooth, smooth, rough or indented, with the following examples:

- Very smooth: a surface cast against steel, plastic or specially prepared wooden moulds: c = 0,025 to 0,10 and μ = 0,5
- Smooth: a slipformed or extruded surface, or a free surface left without further treatment after vibration: c = 0,20 and μ = 0,6
- Rough: a surface with at least 3 mm roughness at about 40 mm spacing, achieved by raking, exposing of aggregate or other methods giving an equivalent behaviour: c = 0,40 and μ = 0,7
- Indented: a surface with indentations complying with Figure 6.9: c = 0,50 and μ = 0,9

The European Norm about side indenting on HCS:

BS EN 1992-1-1:2004
EN 1992-1-1:2004 (E)

(8) Precast units with a topping of at least 40 mm may be designed as composite members, if shear in the interface is verified according to 6.2.5. The precast unit should be checked at all stages of construction, before and after composite action has become effective.

(9) Transverse reinforcement for bending and other action effects may lie entirely within the topping. The detailing should be consistent with the structural model, e.g. if two-way spanning is assumed.

(10) Webs or ribs in isolated slab units (i.e. units which are not connected for shear transfer) should be provided with shear reinforcement as for beams.

(11) Floors with precast ribs and blocks without topping may be analysed as solid slabs, if the insitu transverse ribs are provided with continuous reinforcement through the precast longitudinal ribs and at a spacing s_T according to Table 10.1.

(12) In diaphragm action between precast slab elements with concreted or grouted connections, the average longitudinal shear stress v_{Rdi} should be limited to 0,1 MPa for very smooth surfaces, and to 0,15 MPa for smooth and rough surfaces. See 6.2.5 for definition of surfaces.

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The European Norm about side indenting on HCS:

EN 1168 Recommendation:

In seismic zones, the design should be carried out considering the diaphragm behaviour of the hollow core floor with the longitudinal shear stress given in 10.9.3 (12) of EN 1992-1-1:2004, if one of the following requirements is satisfied:

— with a cast-in-situ topping of at least 40 mm for which shear at the interface is verified according to 6.2.5 of EN 1992-1-1:2004;

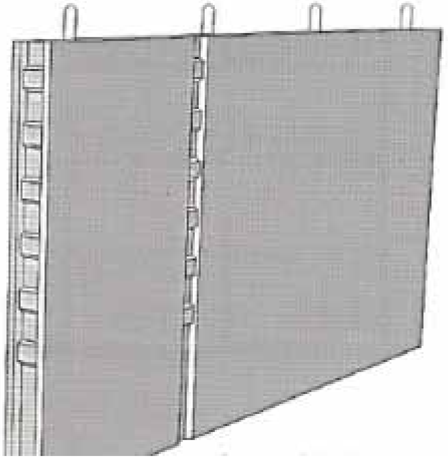
— in the absence of a cast-in-situ topping and all the hollow core slabs are provided with adapted indented lateral edges, as described in 6.2.5 of EN 1992-1-1:2004 (Figure 6.9);

— a system of horizontal appropriately designed ties is provided.

The search for side indenting slabs:



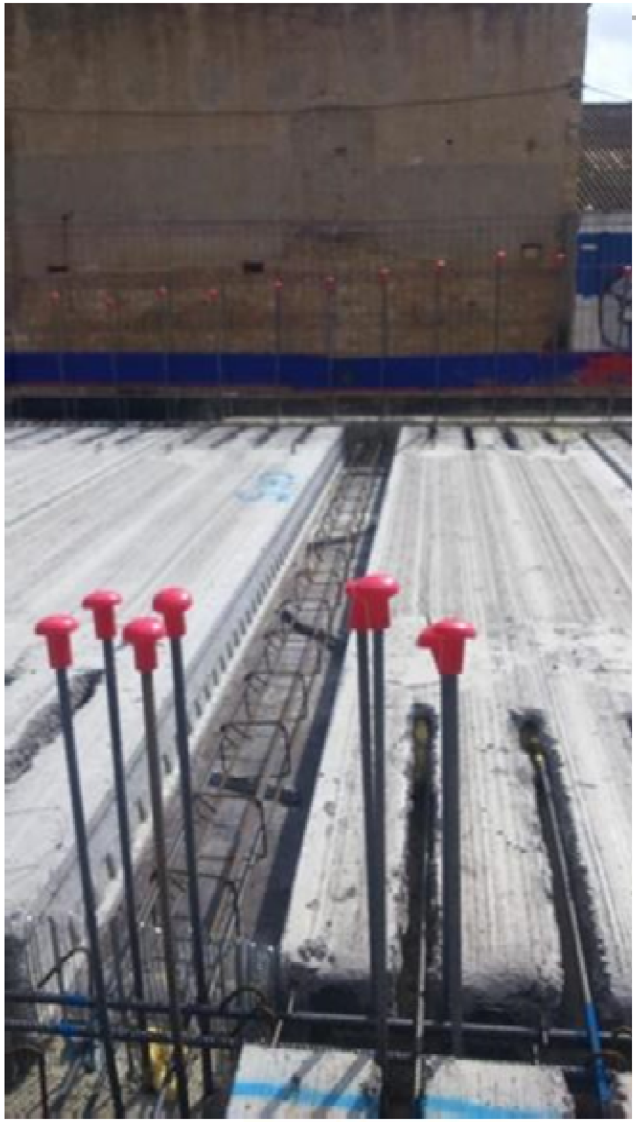


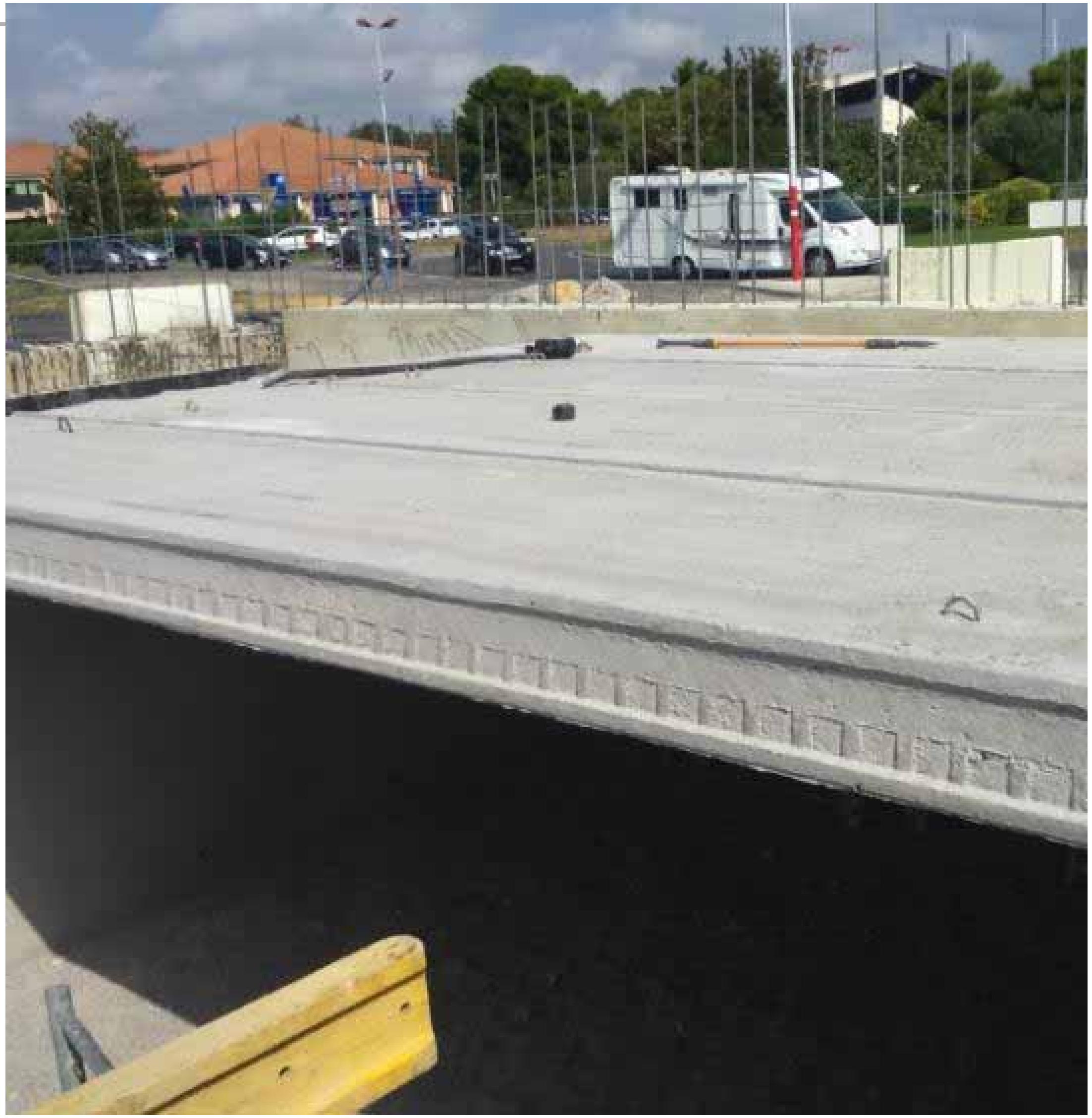


The development of side indenting slabs:

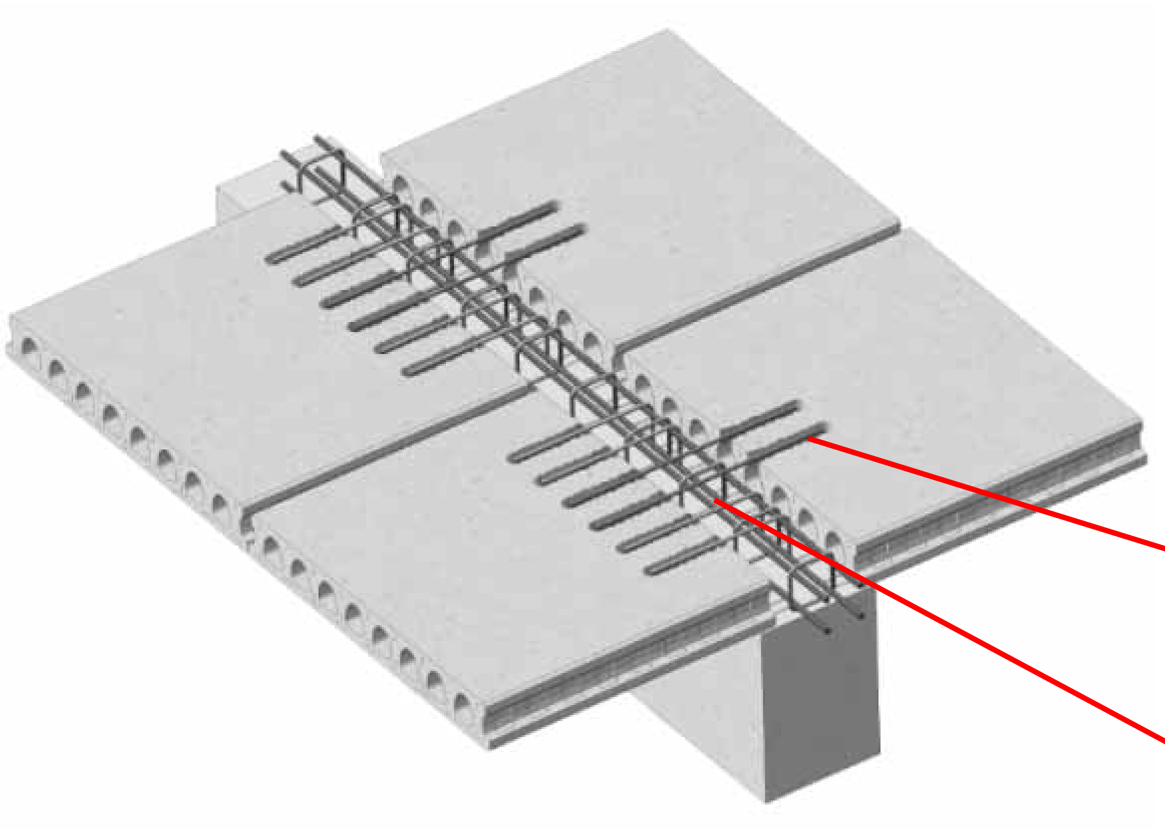
The side indented hollow core slabs (EuroCode 2)

The reality of the side indented hollow core slabs:





Using the side indented hollow core slabs (iHCS):



Untopped floors with iHCS:

Video: fabrication of indented HCS

Fabrication of iHCS