CONCRETE WITH ADDED VALUE – CONCEPTS FOR INCREASED CUSTOMER BENEFIT

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Abstract

Developing products with added value is crucial for future RMC market. Betongindustri has a long tradition offering not only bulk concrete meeting traditional performance criteria (strength, w/c etc) but also marketing functional concrete products e. g. pre-tested concretes for frost resistance, fast drying time, early surface treatment, winter concreting.

The functionality is now enlarged by also including design tools accessed to the products. Hence, concrete concepts have been developed involving pre-design calculations for the functionality of concern, a choice of optimum concrete product, delivery on site, follow up of function and input to the next casting. The success rate of the functional concretes and concepts is high. At the moment the share of the concretes with added value is larger than 30 % of the total annual production of the company. The paper demonstrates two concepts: BI Dry and BI Ready striving for controlled drying of concrete floors and controlled early surface treatment of horizontal surfaces respectively.

Keywords

Value added concrete, functional concrete, concept, drying, surface treatment

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1. INTRODUCTION

In a historic perspective, the common solution in the building sector has been to provide standard concrete products to fulfill the basic needs of customers; mainly requirements for strength and durability. However, over the last years there has been an increasing demand for properties other than strength and durability. One solution to satisfy the market is by introducing so called value added products.

Developing products with added value is crucial for future RMC market in order to withstand the increasing competition from e. g. the steel and wood industry. Since about 20 years, Betongindustri has thus offered not only standard or bulk concrete, but also functional concrete. Examples are frost resistant concrete, fast drying concrete, concrete for early surface treatment and concrete for winter conditions [1]. For all functional products, pretesting is conducted in order to verify that the considered function is fulfilled. The pretesting implies a testing of the function in laboratory and a quality assurance at production at each concrete plant of the company.

To focus on functional concretes, or value added concretes, rather than on standard concrete has been successful for Betongindustri, with increased benefit of customers while at the same time increasing the income for the company. On the other hand, these concretes require careful development (and often basic research), increased marketing and selling activities and well-controlled manufacturing and delivery.

During the last years, the parent concern Heidelberg Cement, with more than 1300 RMC plants in 40 countries worldwide, has expressed that value added products are an important part of the project portfolio. The value added products should have a high innovative potential and be produced and delivered permanently from the concrete plants, according to the company´s definition. Today, more than 130 value added concrete products are marketed by Heidelberg Cement, whereof Betongindustri offers twelve products of this type for the Swedish market - an interesting reflection as such.

Betongindustri is now taking the next step by promoting products with a further increase of customer benefit and degree of refinement, by the so called concept solutions. A concept means that the functionality is further enlarged by also including computer based tools associated with the product. The general difference as compared with a value added product is demonstrated in Table 1 and Figure 1.

Table1. Product solutions at Betongindustri

	Type of product	**Criteria**	**Comment**
A	Standard (bulk) concrete	w/C, strength	Durability, strength
B	Functional concrete Value added product	A + pretested function	Predefined function e. g. frost resistance, fast drying, surface quality
C	Concept	B + analysis tool	Concept: four stages of commitment. Examples: BI Dry, BI Ready
D	System	C + construction method, design method and similar	System solution developed in partnership with designer, material supplier and/or customer

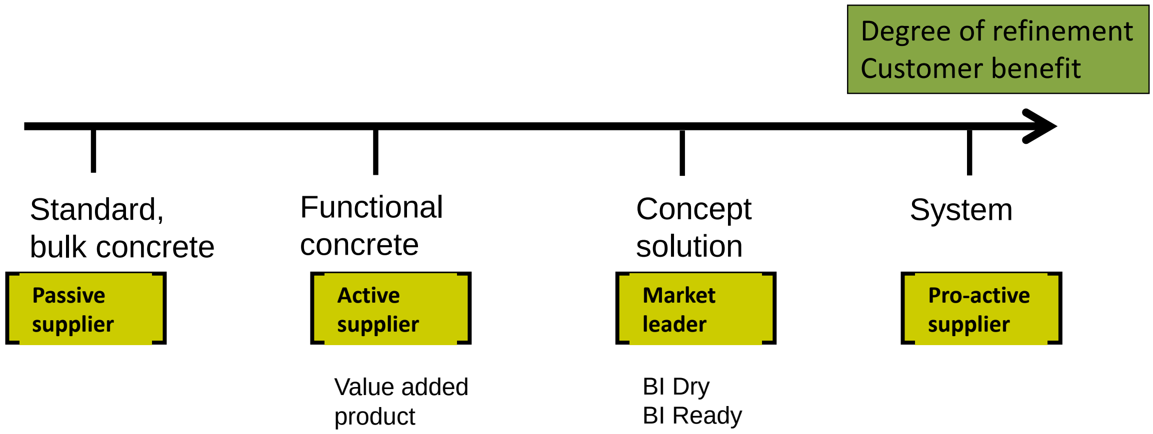


Figure 1. Value added products and concept as well as system solutions increase the benefit of customer.

It is observed from the figure and the table that it is possible to associate the concept with a system solution to further increase the customer benefit. A system solution can be developed for industrialized construction, design method, safe construction and similar,. However, a system solution requires that the RMC company collaborates with other material suppliers, designers and contractors, preferably in a long term partnership. One idea of a system solution on Betongindustri´s agenda is to offer design support where certain reinforcement types are combined with high performance concretes featuring predefined stiffness, creep, strength etc. Another possible idea is to combine the drying concept BI Dry, described later in the article, with a visualization tool for industrialized and moisture safe construction.

2. CONCEPT – GENERAL

As mentioned previously the Betongindustri definition of a concept implies that a computer based tool is used to analyse the function of a value added concrete. Basically, the concept process can be described in four steps:

1) Input data related to the considered function is expressed by the customer.
2) Pre-calculation of inherent parameter of the function
3) Delivery of value added concrete
4) Follow up the function, input to next sequence

The computer program used in step 2 needs to be calibrated to the performance of the associated value added concrete at specific manufacturing conditions, i.e. at the concrete plant of interest with local aggregates, admixtures etc. The development of the computer program, calibration and pre-testing as well as possible adjustments of concrete products are conducted by the R&D department of Betongindustri in long term projects often in collaboration with specialists at universities and testing institutes.

3. BI DRY – CONCEPT FOR MOISTURE SAFE CONSTRUCTION

3.1 Technical Base

Moisture condition in concrete and associated drying process is an important phenomenon to be considered in concrete technology. The moisture influences on many processes in the concrete material such as transportation of gases and ions, frost, corrosion, shrinkage and even strength. For example, the shrinkage process and the related induced cracking, deformations in joints and warping of horizontal structures, requires that comprehensive measures in planning stage and at construction are taken. Nevertheless, shrinkage related damages often create considerable increase of costs due to repair and delay. Measures should thus be taken to reduce the shrinkage, to find proper arrangement of joints and to design sufficient type and amount of crack distribution reinforcement.

The concept BI Dry focuses on another phenomenon associated with concrete moisture. Thus, during the last decades, drying of residual moisture in concrete floors and slabs has been brought into interest. Depending on water/cement ratio and environmental conditions, different quantities of water will be released to the surroundings until moisture equilibrium is achieved. If a moisture barrier is installed e. g. a PVC flooring carpet, residual moisture will be redistributed and increase the humidity at the surface [2], [3]. If the humidity is too high, i. e. if the drying is insufficient when the carpet is installed, there is a high risk of degradation of adhesives beneath the flooring material. This degrading of adhesives is known to emit volatile organic compounds, VOCs, to the indoor environment which may have a negative health impact on people living and working in such environment [4], [5]. In the Nordic countries this is known as the Sick House Syndrome which implies large annual costs in repair and rehabilitation of buildings.

One solution to the problem is to develop rapid drying concretes, in which the internal water is not only dried out but primary consumed by the hydration process, i. e. by self desiccation. The lower the w/C ratio, the larger and faster the self desiccation [2], [3], [5], [6]. Moreover, a low w/C implies a denser pore system which means a large robustness against external water e. g. rain. Figure 2 shows drying of some concrete types, and it is seen that various concrete qualities give significant differences in waiting-time for carpet installation, i.e. time to reach a critical humidity level (usual levels are 85 % or 90 % relative humidity).

Modelling of drying implies an accurate consideration of chemical reactions during hardening, moisture transport in the structural element and concrete constituents (binder, admixtures and additives). Furthermore, the hydration process (degree of hydration) as dependent on temperature must be modelled correctly [7], [8]. The individual sorption isotherm of each concrete, i. e. the relation between relative humidity and water physically bound in the pore system, is also central in the modelling [10]. It is understood that comprehensive laboratory tests are needed for a correct analysis.

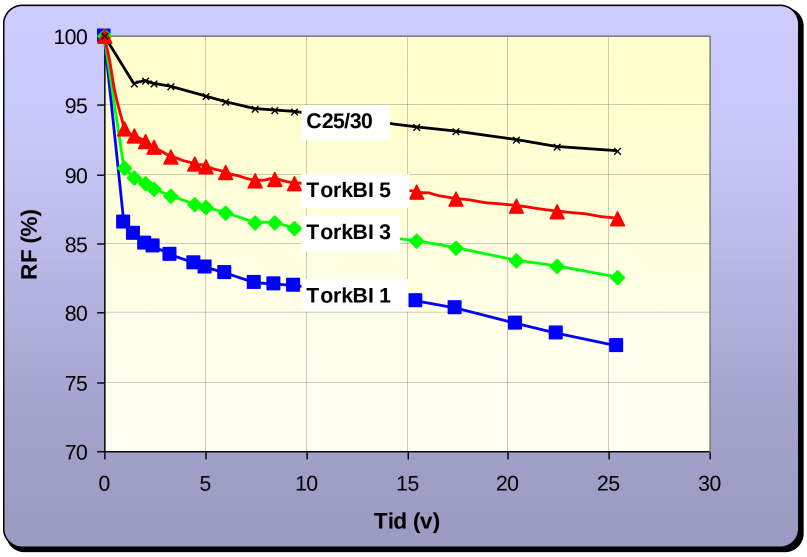


Figure 2. Drying of concrete in laboratory (T = 20 °C, RH = 50 %) for some fast drying (value added) concretes [1] as compared with reference quality C25/30.

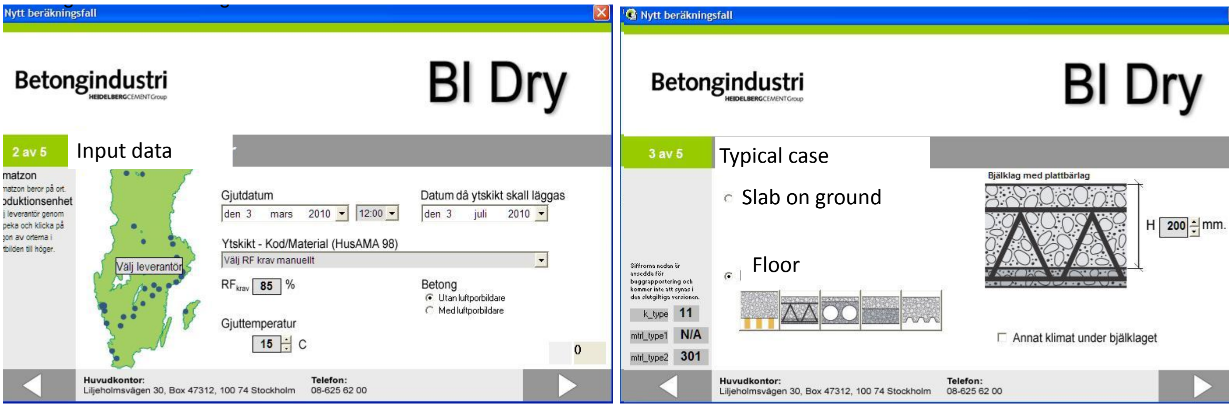
3.2 BI Dry Computations

The concept BI Dry means that Betongindustri offers to take over the responsibility of moisture related problems in concrete structures from the contractor. Delivery of fast drying concretes (also self drying ones) with a pre-defined degree of self desiccation and drying process as well as a computer program to calculate the drying process are two important ingredients of the BI Dry concept. The full concept means that Betongindustri commits to the following steps:

1) Assortment of input data. Geometry of typical case (floor or slab on ground), weather conditions, casting and curing conditions, possible internal heating (embedded heating system), indoor temperature, time for installation of roof, critical relative humidity (85 % or 90 %, mentioned above, are common in Sweden)
2) Drying design using BI Dry. The computer program calculates the required drying time to reach the critical relative humidity for a certain type of rapid drying concrete.
3) Delivery of the certified value added product (TorkBI 1, TorkBI 2 etc)
4) Recording of moisture content and drying process on site. Documentation as demanded for quality control. Input to next sequence.

The concept implies that, once the time-schedule is set for the construction, Betongindustri helps the customer to select the proper concrete type to fulfil the desired critical humidity level at the time of carpet installation. An agreement is also set up, which states what actions that need to be taken by the contractor on site, e.g. agreed indoor climate at the right time.

Figure 3 show examples of input to the BI Dry concept and results from a drying forecast and results from calculations in comparison with follow up at site are shown in Figure 4.



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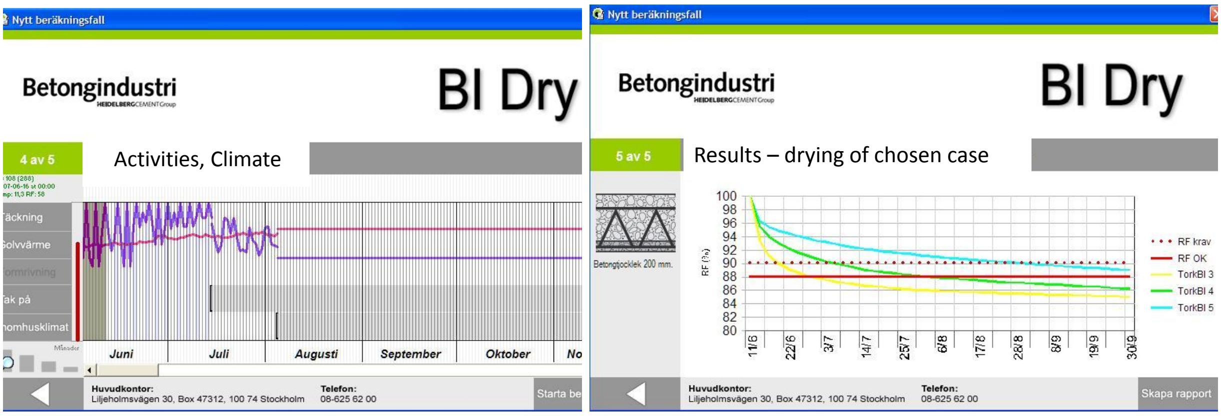


c) d)

Figure 3. BI Dry computations. Examples of input data; location of plant, concrete temperature, time at casting and carpet installation (a), typical case (b), activities at building site; curing, indoor temperature, internal heating etc (c) and drying prognosis for some concretes (d)

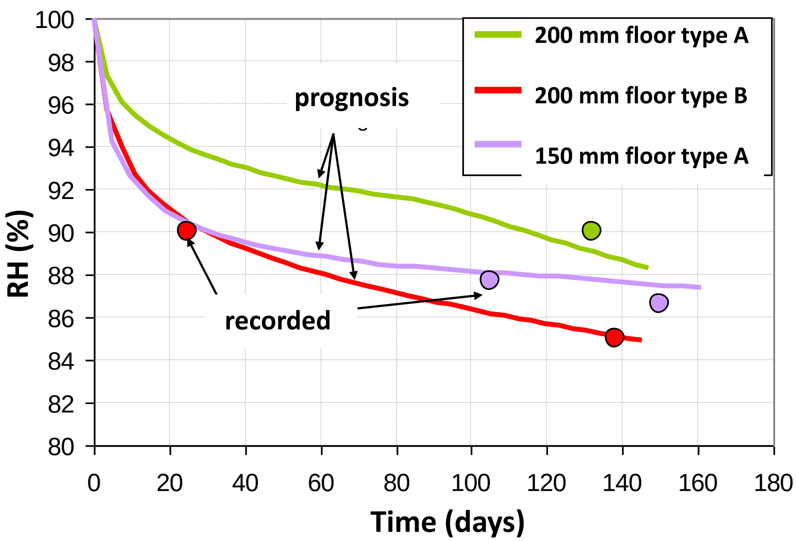


Figure 4. Results from BI Dry computations in comparison with follow up at site for two floor types and two geometries.

4. BI READY – CONCEPT FOR EARLY SURFACE TREATMENT

4.1 Technical Base

The technical base for the second concept marketed by Betongindustri during the last years is the very early setting and strength growth of concrete in the surface layer. The concept has been developed to help contractors to take suitable measures in order to be able to trowel surfaces (Figure 5) at a controlled age after casting. Too early surface treatment leads to an uneven, deformed and more or less damaged surface and too late treatment may imply that cement paste and particles are broken away from the surface.

Research indicates that the possible time of trowelling is related to certain strength levels [9]. It has been shown that the first trowelling (coarse trowelling) can be initiated when the strength of the surface layer reaches approximately 0.12 MPa and that a second fine trowelling can be started at a strength level of approximately 0.25 MPa but should be finished at a surface strength lower than about 0,60 MPa [9], Figure 6. These limits have been established by testing in laboratory and at full scale projects among other things using a penetration device combined with temperature logging (Figure 7) where the penetration is related to compressive strength as exemplified in Figure 8.

Figure 5. Surface trowelling at controlled age after casting

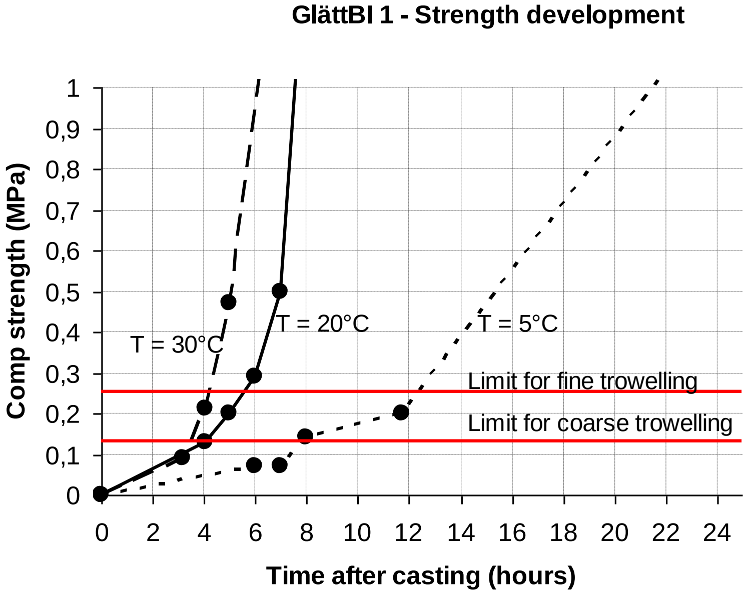


Figure 6. Early strength growth for value added concrete GlättBl1, specially developed for early trowelling. Limits for start of coarse and fine trowelling.

Choosing strength as inherent parameter indicating surface treatment implies that well known models for maturity function can be calibrated for the certain value added concrete to be delivered. Thus, the compressive strength growth can be captured from the temperature measurements on site using maturity models that have been extended for very early ages. Prior to marketing the concept, Betongindustri has performed laboratory tests to map the early strength growth for all functional concretes with regard to surface trowelling. Thus, maturity, local conditions etc. have been documented for each concrete plant of the company.

Figure 7. Penetration test device (left) and temperature logger (right).

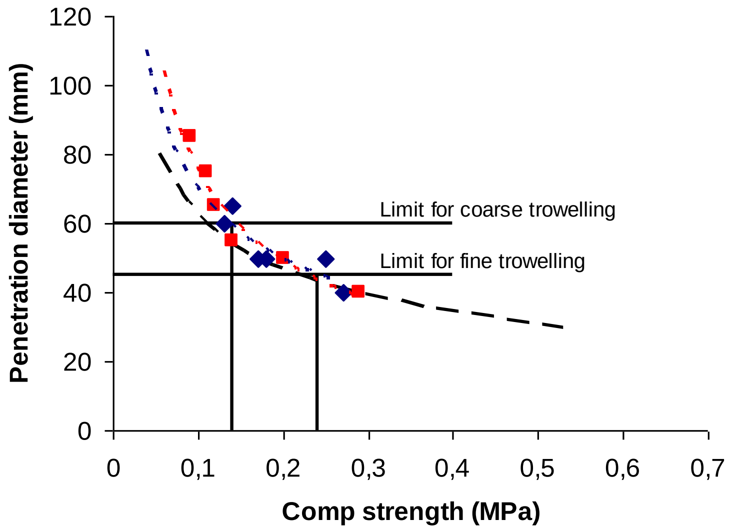


Figure 8. Penetration test: Relation between penetration, expressed as cone diameter, and compressive strength as well as limits for start of coarse and fine trowelling.

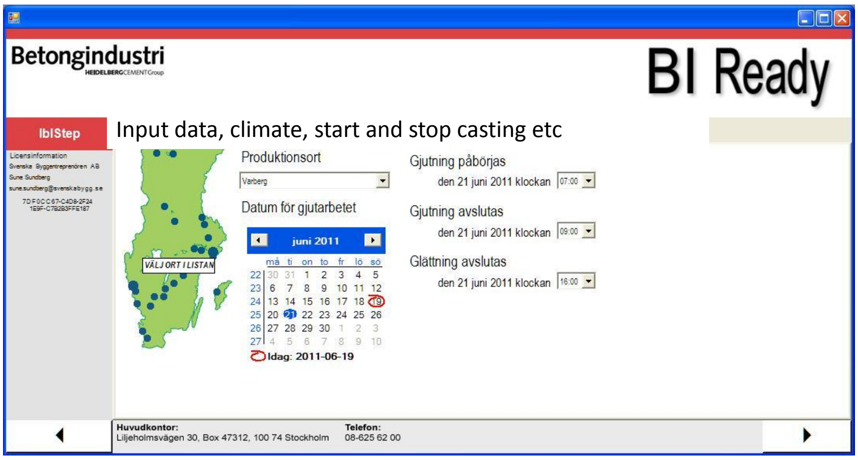
4.2 BI Ready

For the contractor, it is important to reduce the waiting times on site. The time when troweling can be initiated is of interest indeed, but the time when the surface treatment can be finalised is often even more important, in order to limit overtime. The concept BI Ready gives the contractor a tool to optimise a combination of concrete and measures to be taken in order to finalise trowelling on time at the day, i. e. “Be Ready On Time”.

Similar to BI Dry, a computer program, BI Ready, has been developed to calculate the early strength growth of the surface layer of concrete in floors and slab surfaces. The program is based on recent modelling of very early age maturity [10] – [12] and the concept includes the following four step commitments:

1) Assortment of input data. Geometry of typical case (floor or slab on ground), weather conditions, air temperature, casting and curing conditions etc.
2) Forecast of strength growth as computed with BI Ready. Strength at very early ages has been calibrated to functional concretes.
3) Delivery of the certified product (GlattBI1, GlattBI2 etc)
4) Follow up: Documentation of temperature, strength and sometimes penetration of surface concrete. Visual inspection of surface treatment etc.

Figure 9 shows example of input to the BI Ready concept and results from a strength growth forecast. It is seen that with the actual concrete, depending on weather, the trowelling can start at 3 h or 6 h after ending casting and that the surface treatment ends 6 h or 9 h after casting. Figure 10 shows influences of wind and active surface insulation on strength growth.



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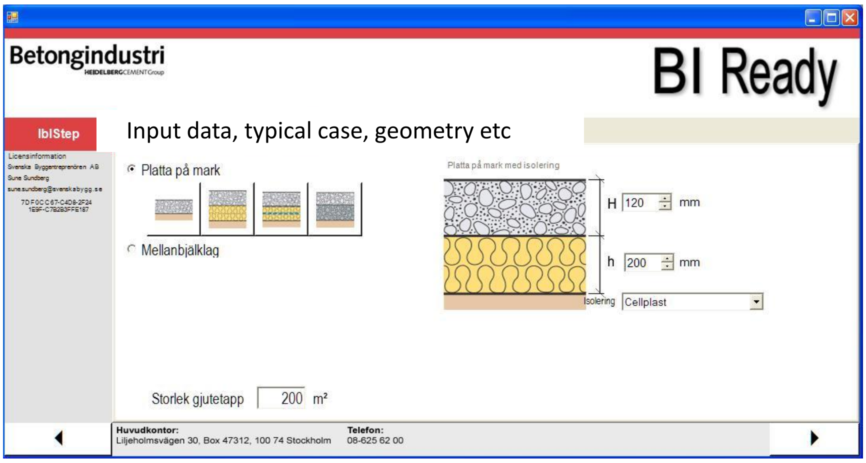

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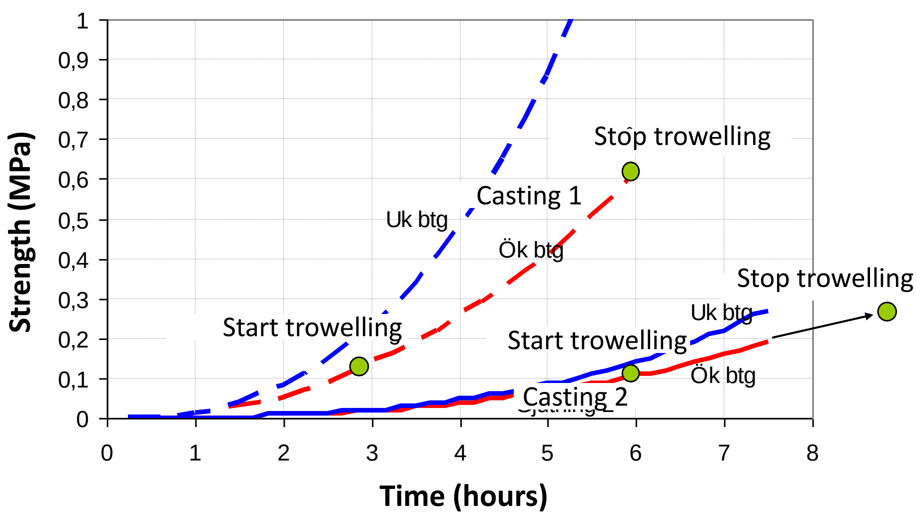

c)

Figure 9. Examples of input data (a) and (b) and results (c) obtained by the BI Ready computer program. Casting 1: T_{air} = 22 °C , casting 2: T_{air} = 12 °C, ök = upper surface layer, uk = lower surface layer.

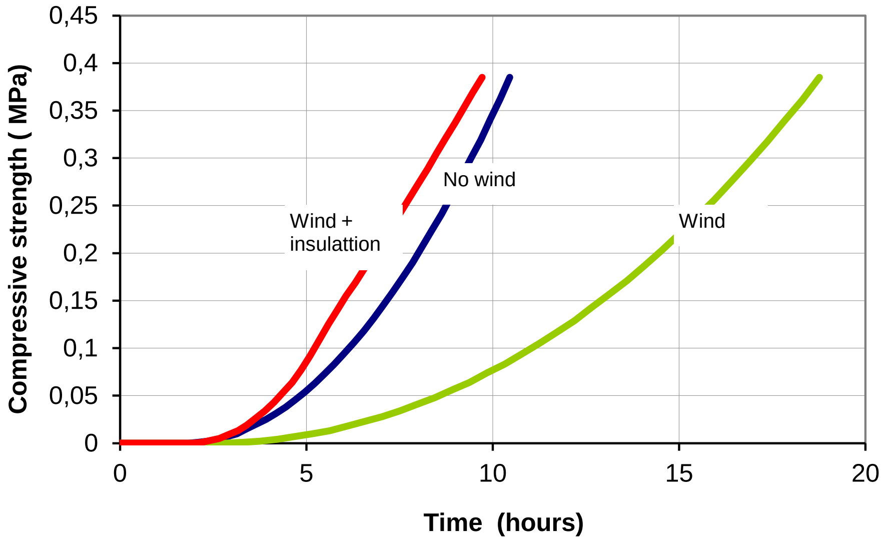

Figure 10. BI Ready computations. Effects of wind and active insulation of surface on compressive strength growth.

5. CONCLUSIONS

The concept solutions demonstrated, promoting two of the value added products, have been very successful for Betongindustri. The concepts require careful development and basic research, clear marketing and selling activities as well as highly controlled manufacturing and delivery on site, i. e. a demanding issue for the company.

The increased benefits of customer are evident: plans are achieved securing drying and early trowelling of sections to be cast, pretested functional concretes are delivered fulfilling criteria set up by clients and relief from duties are obtained in areas where Betongindustri has long experience and knowledge. In fact the RMC company can take over critical risks in concrete construction and get paid for that.

Furthermore, the concepts qualify for higher margins of the added value products. Several important parameters are raised at the negotiating with customer; i. e. the focus on price is eased. The company is considered as working on the front-edge with closer customer relations as a result. Moreover, the salesmen at Betongindustri have obtained a more interesting job that is highly appreciated by the customer.

At the moment Betongindustri have initiated several research and development projects aiming for new concepts and system solutions are on the agenda. One vision in future marketing is that consultants and designer writes the concept name directly on the drawing.

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