DANISH TECHNOLOGICAL INSTITUTE

CONCRETE CENTRE NEWSLETTER – October 2010

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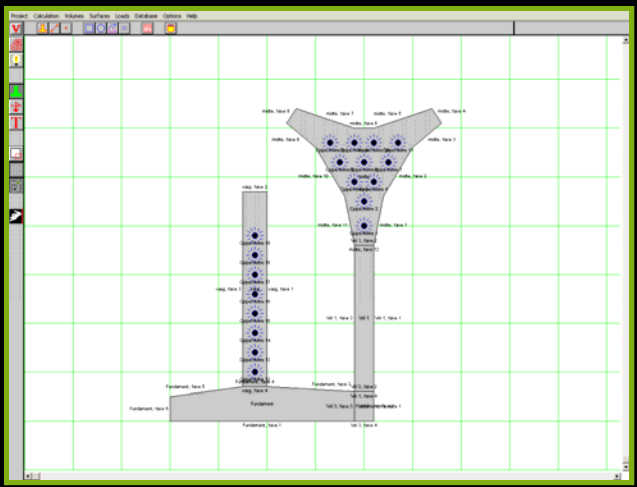

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Tailormade Concrete Structures

Introducing and combining robotics and concrete production allows for the construction of much more architectural interesting structures because robots are able to create far more flexible and complex formwork geometries with very high precision and reproducibility.

In order to develop and mature this technology, the TailorCrete project was launched in 2009 and will run for 5 years. In this project the total value chain of the concrete industry is represented. The goal of the project is to industrialize the production of complex concrete structures while keeping production costs at an acceptable level. The role as project manager is taken on by the Concrete Centre at the Danish Technological Institute.

Read more: www.tailorcrete.com

An example of where these new methods could be directly applied can be found by looking at the addition to the Ordrupgaard museum just north of Copenhagen. This building is constructed of numerous concrete shells, which have been cast and joined together on site using self compacting concrete (SCC) that was dyed black. The casting process was especially complicated as each shell is unique and had to fit perfectly with conjoining shells. To make it even more difficult, all shells are curved and needed to appear with sharp edges.

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Tomorrow's unique concrete structure. Displayed is the addition to the Ordrupgaard museum constructed in 2005.

Example of expensive manual construction process, instead robot manufactured formwork could have been used with advantages.

Example of standard industrialised concrete buildings.

Industrial robot cell at the Concrete Centre, milling out a double curved formwork shell guided by CAM software.

Topologically Optimized Concrete Pavilion

The pavilion was cast as a full scale demonstration at the completion of the national Danish research and development project "Unique Concrete Structures". The pavilion is situated at the premises of Paschal-Danmark A/S in Copenhagen, and is believed to be the world's first topologically optimized concrete structure.

The pavilion is 12m long, 4.5m wide and 4m high and was cast using white SCC. Different requirements were imposed on the flow properties of the columns and superstructure. SCC with lower filling ability was used for the superstructure as the finished surface had to have a slope of up to 3%.

The concrete was produced at a central batch plant using a $3m^3$ counter-current mixer. The transport time to the construction site was 30 minutes. Only one small truck load was needed for the casting of the columns, whereas two normal sized loads were needed for the superstructure. The casting was performed using a pump dropping the concrete into the column and superstructure formwork from above. Control measurements of flow properties and air content were performed at the construction site on each delivery.

The topologic optimization is a computer exercise intended to reduce dimension to a minimum without affecting the load bearing capacity. The resulting 3D digital drawings of the pavilion were translated into milling programs for a 5-axis industrial robot that subsequently "carved" out the 30 individual pieces of formwork needed in Expanded Polystyrene (EPS).

Concrete properties:

- D_{max}: 8mm
- w/c: 0.34
- Air content: 6.5 ±2%
- Target Slump Flow superstructure: 550 ±30mm
- Target Slump Flow columns: 630 ±30mm
- Plastic viscosity: 100-200 Pa·s (4C-Rheometer)
- Compressive strength: 55-60 MPa at 28 days maturity

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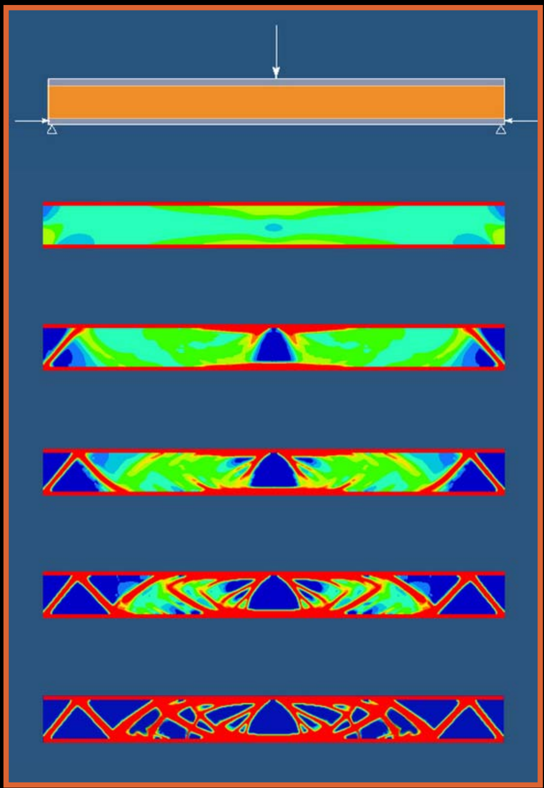
The pavilion seen from below.



Example of topologic optimization, which shows the stress distribution in a structure.

Danish Expert Centre on Infrastructure

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The Concrete Centre has a strategic focus on infrastructure and together with the Technical University of Denmark (DTU) a new expert centre on infrastucture has been formed based on a 3 year performance contract starting ultimo 2010. The primary focus area of the centre will be durability of reinforced concrete structures in harsh environments, e.g. tunnels, bridges, quays.

The expert centre will combine complementary competences and laboratory facilities at the two knowledge centers. As an example the Concrete Centre has a brand new hightech concrete laboratory for batching, mixing and casting concrete, i.e. handling fresh concrete, while DTU has advanced equipment and knowledge within crack formation and statics, i.e. hardened concrete properties.

The expert centre is expected to provide a considerable contribution to the efforts of using infrastructure improvements to create growth in the construction industry in the coming decade.

The following research areas will be covered by the centre:

- long time durability evaluation using micro and macro analysis of existing bridges in seawater.
- contribution to models for chloride transport and binding.
- influence of micro defects on durability.
- influence of chloride concentration values on corrosion initiation and corrosion rate in different exposure environments.
- models for crack formation caused by corrosion.
- influence of casting defects on durability.
- influence of rheology and casting method on durability.
- development of models for prediction of service-life.

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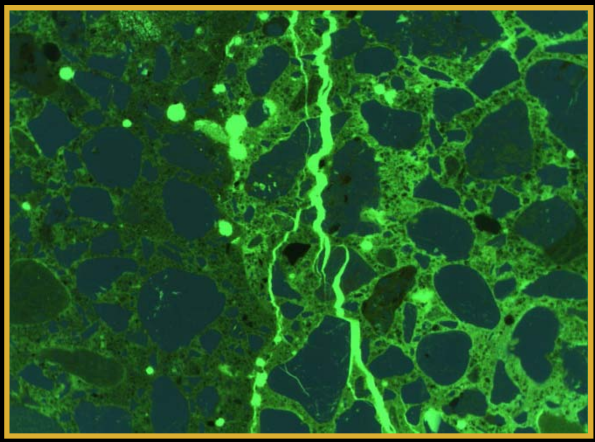

Microscopy evaluation of crack formation.

Setup for controlled crack formation in concrete block. Both path and width of crack are controlled.

Highway bridge in Western Denmark cast using only self compacting concrete.

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4C-Temp&Stress

The Concrete Centre offers assistance within hardening technology in form of training of engineers and documentation/simulation of the hardening process in concrete structures. The simulation is done using 4C-Temp&Stress, which is a computational tool to calculate temperatures and stresses in hardening concrete structures.

By means of 4C-Temp&Stress the hardening period can be simulated on a pc in order to avoid or minimize early-age thermal cracking during the first few days after casting. The parameters affecting early-age cracking are the casting rate, formwork, insulation, cooling pipes, heating wires, ambient weather conditions, etc.

The results of a calculation may be presented as:

- diagrams showing temperature, maturity, strength and stress as functions of time.
- isocurves of temperature, maturity, strength and stress at a given time.

Since the mid-1990s 4C-Temp&Stress has been used to document curing and early-age requirements on several large civil structures around the world, including:

- The Øresund Link between Copenhagen and Sweden.
- Copenhagen Minimetro, bored tunnels and deep stations.
- Malmø Citytunnel, Sweden.
- Marmaray Railway crossing, Istanbul, Bosphorus Strait, bored tunnel, cut and cover, deep stations, Gama-Nurol JV.
- Sitra bridges, Bahrain, Gamuda Berhad Contractors.
- Funder highway bridge, Denmark, Züblin-Dyvidag JV.

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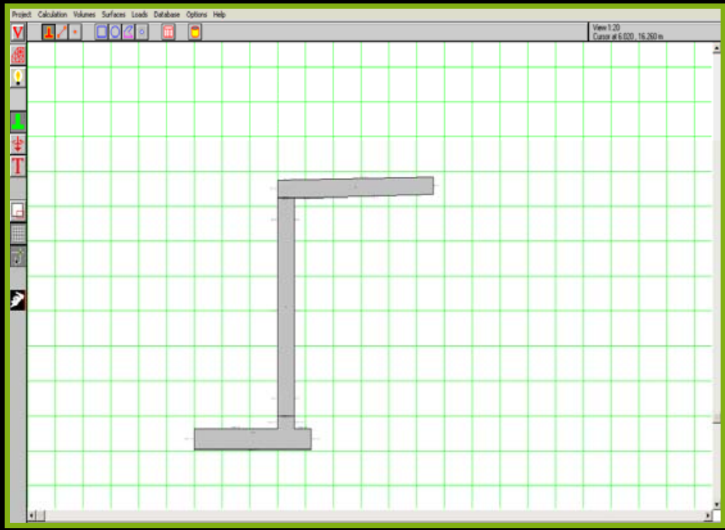


Example of structure drawn in 4C-Temp&Stress.

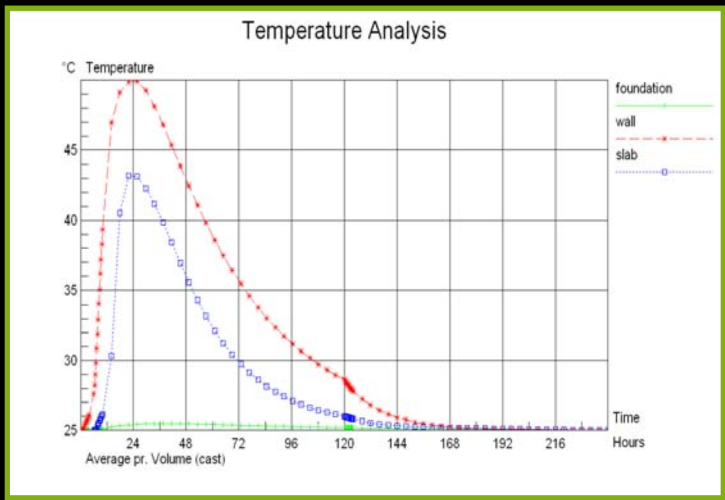
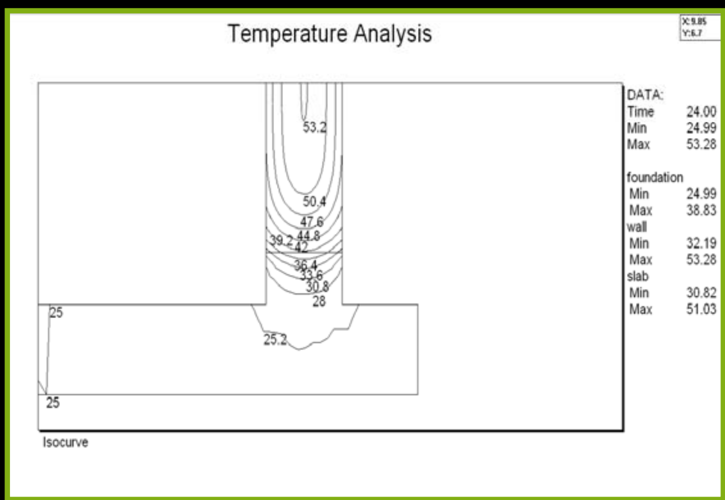


Diagram showing temperature as function of time in different parts of the structure.



Temperature isocurves in the structure at a given time.