Textile Formwork

Introduction

Fabric formwork uses a flexible textile membrane in place of the rigid formwork panels usually used in concrete construction. The use of the textile as concrete formwork allows to obtain structural elements with variable geometry. The fabric formwork is an interesting link between the structural, architectural and artistic aspects. On the architectural side, the use of flexible formwork introduces a new horizon for architectural form and expression. The work is proposing a global approach for the design of this kind of elements by means of a case study – a column selected from the Glaspaleis of Heerlen. This 5m high reinforced concrete column with a variable section at the top has been studied in different phases, which include the numerical analysis of the textile formwork loaded with the wet concrete, the finite element study of the concrete column under representative loading, a proposed design for the framework and a proposal for the successive steps for the concreting of this column with respect to the specific column's geometry. The textile formwork technology can be used to create structural elements like columns, walls, beams, slabs or shells.




1 *Column, Mark West, The Center for architectural structures and Technology, University of Manitoba*
2 *Twelve meter fabric cast beam prototype, Mark West, The Center for architectural structures and Technology, University of Manitoba*
3 *Exterior concrete walls of Unno's Stone renaissance house, Funabashi City, Chiba (2005)*
4 *Shell application, Mark West, The Center for architectural structures and Technology, University of Manitoba*

Characteristics and advantages of fabric formwork


Surface
The textile permeability allows wet concrete to bleed out air bubbles and excess mix water. This action gives to the concrete an amazing surface finishes unobtainable by any other methods of concrete construction.

5 *Surface produced, Mark West, The Center for architectural structures and Technology, University of Manitoba*
6 *Typical surface produced, Kenzo Unno*


Geometry and Structure
Fabric formwork can be easily use to create structures with variable section. This is really interesting to build lightweight structure because you only form thick section at strategic point of the structure regarding to the stresses. This could really change our vision of what reinforced concrete can be like.

7 *URC house with grass, Kenzo Unno, Edogawa-ku, Tokyo (2003)*
8 *Fabric formed column, Mark West, The Center for architectural structures and Technology, University of Manitoba*


Lightweight formwork
The textile actually used are not only 100 to 300 lighter than classic wood formwork, but also 10% of the price/m². Of course this kind of formwork are a lot less voluminous than all the other type of formwork, and that make it interesting for the transport.

9 *Fabric columns formwork awaiting concrete placement, Mark West, The Center for architectural structures and Technology, University of Manitoba*
10 *Lightweight fabric formwork for 13 individually dimension and detailed columns were shipped by air to Culebra, PR in three small duffle bags, Mark West, The Center for architectural structures and Technology, University of Manitoba*

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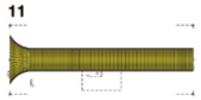
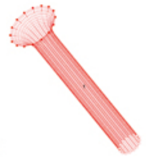
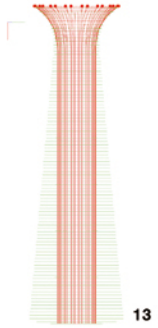
Study of a 5 meter high column
with a variable section at the top

The approach is proposing to study this kind of element on different point of view. The possibilities of forms created by this technology are nearly unlimited.

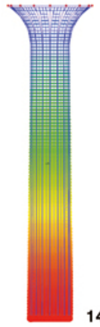
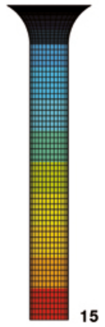
First step: Resistive study of the textile
Formfinding and Statical analyse
Two modelisations are realized for the study of the fabric. The first one is created on EASY that is representing the textile by an orthotropic articulated cables network. The second one is created on the finite element program Samcef that is representing the material with orthotropic membrane element without flexional behavior where the unknowns are the nodal displacements.

11 *Textile represented by membrane elements, Samcef*
12 *Cable network of the column's global geometry, EASY*



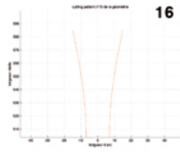
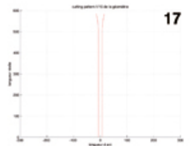
The pressure due to the concrete is calculated for different heights and apply perpendicularly to the elements in the EASY modelisation. In the Samcef modelisation, it is calculated more precisely with a function that is asking for a volumic density and a height arbitrary defined from wich the pressure is calculated.

13 *Representation of the load case due to the wet concrete, EASY*

We consider that the textile is attached at the top and free at the bottom.The results given by the two modelisations are really similar. The results are the membrane stresses, the displacements, and the reactions at the boundary conditions.

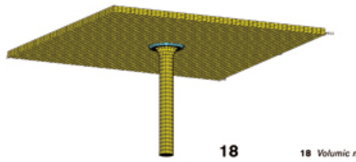
14 *Circumferential stresses of the statical analyse given by EASY*
15 *Circumferential stresses by the statical analyse given by Samcef*

The cutting pattern
The cutting pattern is calculated analytically by dividing the revolution surface in 16 modules. The module is divided in segments. The first step is to calculate the circumferential length of each segment and the real width of these segments. We project the results on the cutting plan.

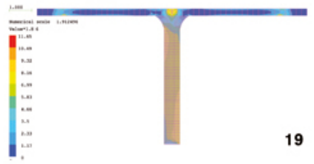
16 *Cutting Pattern of the 1/16th global surface at the top, Matlab*
17 *Cutting Pattern of the 1/16th global surface, Matlab*

Second step: Structural study of the column
Regarding to the form, we are able to verify the finite element modelisation by analytical calculation. We chose a volumic modelisation because the modelisation with shell and beam elements should be difficult to use regarding to the variable section of the column's top and should not be representative of the reality regarding to the interaction between the column and the slab.

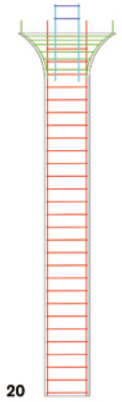
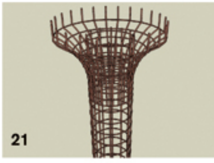
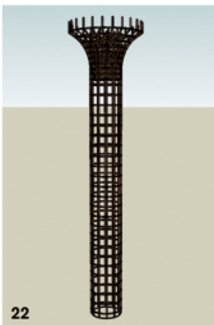


18 *Volumic modelisation of the column and the upper slab, Samcef*

The structure is calculated on representative vertical and horizontal load. The column is fixed at the bottom and fixed in the slab by a relation master-slaved. The Von Mises criteria is used to check the amplitude of the principal stresses.

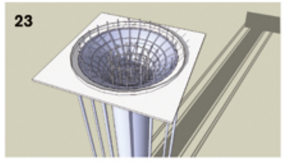


19 *Equivalent stresses on representative loading, Samcef*

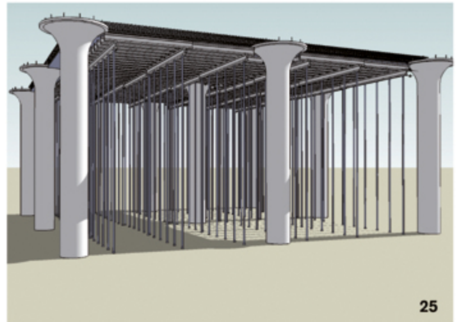
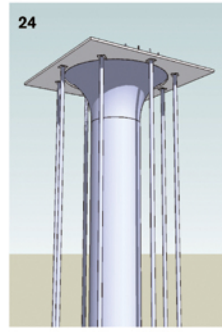




Third step: Proposition of the framework
The proposed framework for the column is calculated following the recommendation of the eurocode. It is constituted by two principal modules. The first one is in red and is the longitudinal framework of the column. The second in green is the top module and its role is to avoid crack in the concrete.

20 *Principle of the proposed framework*
21 *3 dimensional representation of the framework's top*
22 *3 dimensional representation of the global framework*



Fourth step: Realization steps
The different steps of the realization are explained in the next figure. The important points are the primary structure that support the textile and the concreting of the upper slab. The 3D representation is realized on the free Google program Sketch up.

23 *3 dimensional representation of the primary structure*
24 *3 dimensional representation of the primary structure*
25 *3 dimensional representation of the upper slab's concreting*