Pneumatic formwork with variable elevation for concrete shells production technology

Vitalijs Lusis, *Riga Technical University*

Abstract: **There is evaluated fibro concrete shell production technology in pneumatical formwork with changeable lifting in the article. There is analyzed both the current situation and future visions of this field.**

There are considered shell development technology features in the article. There is evaluated technical and economical effectiveness of concrete shells with thin walls. Now pneumatical systems from flexible materials are developing and improving, there is a great potential followed by modern events in concrete technology, for instance, fibro concrete and self-sealing concrete development.

Keywords: **Concrete shell, pneumatic formwork, fibro concrete.**

Introduction

Nowadays one of the main constructive materials in the building sphere is a precast concrete and cast-in-place concrete. It is well influenced by scientific research basis, development and implementation of progressive technologies. The concrete it is an ideal material with practically unlimited number of shapes. A nomenclature of concrete articles increases, it is working on different shape formation and processing. Obviously that is the reason for concrete to be the most widespread constructive building material all over the world.

A rapid development of concrete sphere is affected by various interconnected factors. One of them is manufacturers' efforts to achieve a bigger material strength, to decrease concrete weariness. In the result there appear thinner concrete structures in building sphere, lighter panels, shells used in bearing structures or elements, which to be served in rather complicated environmental conditions.

Shell production technology in pneumatic formwork with changeable lifting

One of the most successful of fibro concrete usage samples in Latvia could be found in Ventspils, Kalija parks, whereas warehouses are made of fibro concrete, in shape formation there are used pneumatic formwork. (fig.1).

An important argument it is economy of fibro concrete – there is a real cost economy, when you don't need ordinary fittings, and employees' wages – you don't need to pay to fitters.

Nowadays at building different kind of concrete and ferroconcrete shells are made of hard material formwork, which are usually composed of various small form plate or cylindrical elements.

Traditional formwork technologies are rather labour-consuming, plane and cylindrical curved form elements are badly adjustable in two directions for creating surfaces of curved shells.

Forms composed of plate elements don't allow to get shell surfaces curved in both directions the same about small areas, and thus for hiding its concrete footprints it is necessary to make extra finishing works that makes building more expensive.

A restricting factor connected with accepting concrete's free form in designing it is capacity and system forms adjustment, but any changes of formwork forms or surface structure can be considered as complicated, time-consuming, work-consuming and as a result financially unprofitable.

New form architecture has got a thin concrete shell created in the form of cylinders, circles, paraboloids and hyperboloids.

In order to achieve required geometrically complicated forms and surfaces of textured concrete it is necessary a flexible and adjustable formwork system [4].

Pneumatic formwork with changeable lifting form adjustment and adjustment abilities allow using them effectively as complete flexible and adjustable formwork systems, in order to create geometrically complicated architecture forms, at the same time not losing the strength indexes of constructed surfaces.

The offered new technology is foreseen for plain wall structures, that allows to create and have different shells, including domelike structures, in one direction curved shell, in two directions curved shell etc., for example, for building roof covering structures (fig.2). Its field of usage is manufacturing and building of concrete and fibro concrete precast and monolith shells.

Fig.1. Ventspils, Kalija parks, whereas warehouses are made of fibro concrete, in shape formation there are used pneumatic formwork

Usage of pneumatic formwork in concrete surface plain wall building allows us to reduce labour-intensiveness (formwork preparing, reinforcing and concrete works), thanks to simple constructive solutions.

Current technological processes of concrete shell:

1. Technological process of concrete shell creating [2] according to which, first of all, there is attached, pressurized and filled with air a pneumatic formwork and there is attached on it metal reinforcing cage corresponding to the shell form. Then there is laid small-grained concrete mix on the formwork layer by layer. Each next layer is laid after the previous one has been hardened. The formwork keeps the pressure which is necessary for concrete layer weight carrying without any deformations and it is kept during all concrete hardening process. After concrete being hardened the air is let out from the formwork and the shell is demolded.
2. It is known a shell creating technological process, when there is laid reinforcing cage on unfilled by air pneumatic formwork, then the formwork and construction are risen to the desired height and there is a start of concrete works.
3. It is known also fibro concrete creating technological process [1], where there is no laid reinforcing cage on filled pneumatic formwork, but lays fibro concrete layer by layer. The same as in the previous analogue sample [2], it is being hardened without any deformations and the shell being demolded.
4. It is known concrete and fibro concrete shell creating process, which is fulfilled on pneumatic formwork [5], and according to which filled pneumatic formwork interior cover is laid by adhesive small-grained concrete mix layer by layer.

Then the formwork is not taken out, it is kept together with the shell and in future it serves like damp course and exterior finishing layer.

Fig 2 Shells building roof covering structures

There are the following weaknesses of technological processes:

1. While doing concrete works it is not possible to control and provide efficiently the thickness of laid concrete mix neither layer by layer, nor the whole shell in general.
2. The lack of the method is reinforcing tight connection to pneumatic formwork material and therefore there is a high its damage possibility, it is also creates obstacles for creating concrete protective layer of reinforcing cage and affects increased concrete and reinforcement consumption.
3. After finishing concrete works it is rather complicated to smooth and polish the last layer, because shell surface is usually curved in two directions, for instance, paraboloids, circle or ellipsoid surface.
4. For shell concrete works usage of known methods allows to apply only concrete mix laying methods, for instance, humid or dry filling method.

The use of a pneumatic mold reduces employee expenses significantly and widens architecture choice in creating complicated surfaces. It can be used for creating structures with thin walls in order to create curved architecture shaped arches and domes.

Usage of pneumatic formwork most of all allows to industrialize dimensional building concrete structures, its usage advantages is as follows:

1. Flexible shapes (being curved created surfaces are of architecturally and technologically complicated shapes);
2. Smooth concrete surface quality;
3. Transporting: formwork weight and volume of tissue is very small comparing to wooden or steel formwork.

PNEUMATIC FORMWORK

Pneumatic formwork made of air-proof material which takes a desirable shape creating an air pressure.

The most often used pneumatic formwork material is of special rubber (rubberized material) or synthetic fibro material, which fulfills constructions by features for usage in different temperatures (the chosen material should correspond to the purpose of the definite task and there should be provided work capacity in a wide exploitation range of work regime).

Despite the purpose of pneumatic formwork and their usage conditions, the material of pneumatic formwork structures should have a sufficient tensile strength (calculated) and low weight, should be resisting to weather impacts, flexible, with a minimal gas permeability, fireproof (at least the material should be fire extinguished), heatproof and frost-resisting. The requirements are fulfilled when using composite materials (created on synthetic fibro basis).

The pneumatic formwork structures have got obligatory technical requirements: air tightness, ability to take tension forces, a high tensile strength (formwork's second time usage depends on it), a high Young's module (to reduce formwork material deformations after concrete works), a good fitted quality that allows separating off the concrete.

In order to separate easily the formwork material sticked to the shell's internal surface, it is necessary to mount valve in shell concrete.

In order to reduce or avoid concrete sticking to formwork material and simplify concrete shell and concrete structure separating off, there are laid special lubricants on pneumatic formwork surfaces before starting concrete works.

Lubricants must correspond to the following requirements:

1. They can be laid by brush or spray;
2. Fire-resistance;
3. Economy and accessibility.

In 2010 there are completed pilot experiments in the Riga Technical university laboratory in order to create such a concrete shell production technology process which wouldn't have any described faults.

In this case there was produced a pneumatical formwork with changeable lifting. Formwork construction: veneer 1000×1000×15mm, rubber sheet 1000×1000mm, height of frame borders is 15 mm.

Tasks of laboratory experiments: production and achievement of different kind shells, including dome-shaped constructions, clearing up the shell production technological features and technological process advantages, effectiveness, a visual attraction and advantages of products

THERE IS COMPLETED AN EXPERIMENT IN THE LABORATORY TECHNOLOGICAL PROCESS OF CONCRETE SHELL PRODUCTION FOR PNEUMATICAL FORMWORK WITH CHANGEABLE LIFTING [4]

Fig.3. Pneumatic formwork construction

1. There is laid unfilled flexible material on a flat and hermetically sealed surface, pneumatical formwork. Its sides have been fixed to the perimeter of the next shell, if a formwork is composed of one hermetical layer, its side connections are sealed with the formwork basis surface. Formwork surface is planed and stretched out so that it doesn't have any folds (fig.3);
2. The shell's lower layer can be reinforced by a flexible material, for instance, glass or synthetic material net. In this case before concrete works it is laid on a flat formwork surface (fig.4);
3. There is laid a concrete or fibro concrete mix on prepared formwork flat surface and it is smoothed (fig.5);
4. During the technological process of concrete shell creating it is possible to reinforce shell's upper layers by flexible material net before formwork blowing up there is laid and pressed in a flexible material reinforcement on a new concrete surface, for instance, glass fibro net;
5. If it is necessary the upper layer laid on unfilled formwork concrete layer is polished;

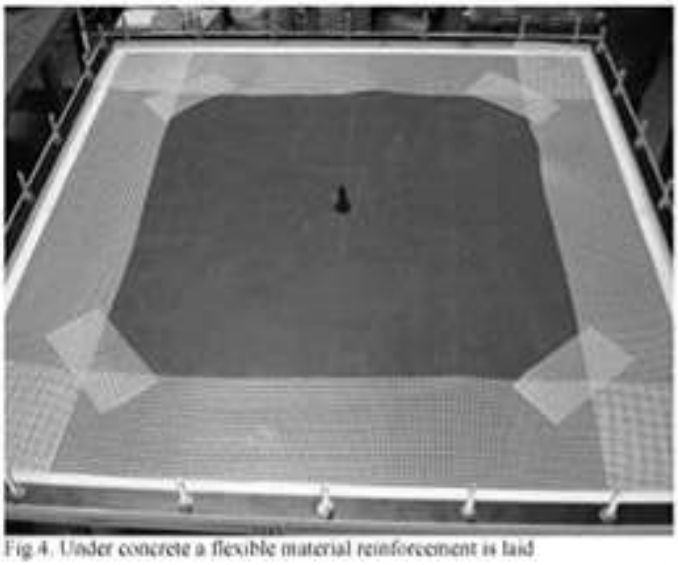

Fig.4. Under concrete a flexible material reinforcement is laid

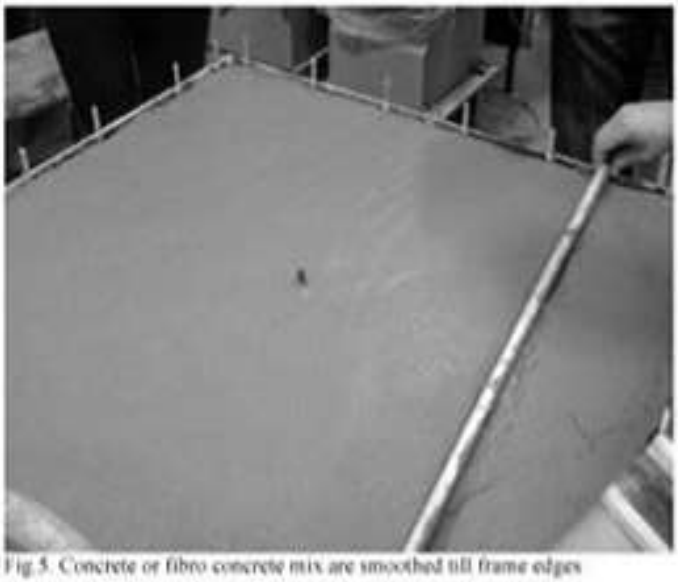

Fig.5. Concrete or fibro concrete mix are smoothed till frame edges

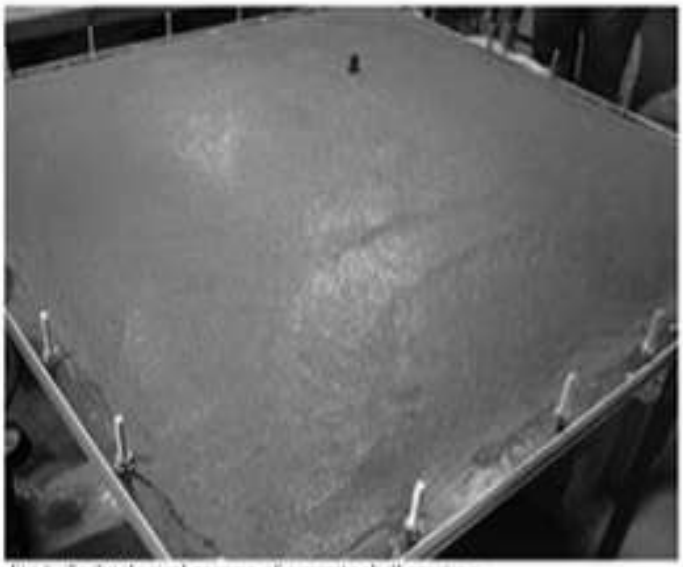

Fig.6. Technological process of concrete shell creating

6. Lifting pneumatic formwork should be finished before starting concrete mix hardening (fig.6). Not allowing the concrete mix hardening start, the air is pumped into the formwork, the formwork surface is curved and lifted till defined shell dimensions. A fresh concrete shell lifting is done by such speed, when tension pressure in a fresh concrete mix can be relaxed so that mix tension deformations wouldn't increase its limits of deformations, so that there won't appear technological cracks on shell surface. For increasing limits of deformation of a fresh concrete there are used special supplements in its mix, for instance, various desired water-soluble polymers or waterproof polymer emulsions. There are also used different kinds of material fibro reinforcement in concrete mix, which after concrete hardening improves its constructive features.

To avoid concrete rapid hardening the shell surface immediately after creating desired layer thickness is covered by protective coat (or spraying) protective layer which prevents an intensive water vaporization. For this purpose there are used special water-soluble polymers or waterproof polymer emulsions.

7. The shell is hardened preventing formwork deformations and therefore during concrete hardening the air pressure in formwork is controlled, as well as it should be unchangeable, the best is to make it automatically using contact manometer, pressure relay and compressor;

8. If it is necessary in order to achieve concrete technological strength the shell is demolded and the air is released from pneumatic formwork (fig.7).

In order to separate easily the formwork material sticked to the shell's internal surface, it is necessary to mount valve in shell concrete through which pumping air, the formwork material is removed from hardened concrete internal surface or it is remained as steam insulation or as a finishing layer;

9. The formwork can be used time after time for a long time, but shells for concrete hardening can be used only for necessity, for instance, transport of necessary strength, or also till achieving necessary constructive strength indexes (fig.8).

Technological process of concrete shell creating, including concrete mix preparing, laying on pneumatic formwork surface, hardening and demolding, is different from that concrete or fibro concrete mix layer is laid on unfilled and laid pneumatic formwork, concrete layer surface is smoothed and then before concrete hardening the air is pumped into formwork and it is lifted till definite shell dimensions, during concrete hardening the constant pressure is saved in formwork, after hardening the air is released from formwork and the shell is demolded.

The results of laboratory experiments have proved that the technology can be used for both concrete and fibro concrete shell production and construction

New concrete shell construction technology using pneumatic formwork provides shell with a smooth internal and smooth and polished external surface.

It can be used in manufacturing and building of concrete and fibro concrete shells.

The offered technology is also flexible, because changing flexible formwork shapes it is possible to get concrete shells of different shapes – different kind of domes and arches, which geometry can be composed so that shell's curving moment in both directions would be minimal or prevented at all. Therefore it is possible to compose shells with minimal thickness, even lighter and cheaper, comparing to traditional building technologies.

As an advantage can be mentioned pneumatical formwork composed of flexible materials for creating concrete shells with thin walls and both building materials and equipment manufactured in Latvia usage.

The factor that affects concrete development is economy. Searching for more cost effective and qualitative solutions the manufacturers as concrete raw materials use various industrial wastes, try to save money on the account labour force.

In this way the offered technology with pneumatic formwork usage reduces several times labour-intensity and time of construction works, reduces concrete and steel consumption, building expenses.

Fig.7. Shell demolding

Fig.8. The concrete shell hardening is continued till necessary technological strength

CONCLUSIONS

Economical effectivity for a wide invention of progressive constructions with a modern design at new construction building principles where as formwork are used pneumatic systems composed of flexible materials.

Pneumatic formwork with changeable lifting give new opportunities in modern architecture, which is impossible using traditional formwork.

Using building practice of pneumatic systems from flexible materials allows to speak about its advantages, emphasizing the most effective usage sphere of pneumatic systems, nevertheless its labour-intensity, small weight, possibility of multiple usage affects positively its usage in building sphere.

Usage of pneumatic formwork develops usage of resource saving methods in building of both dimensional and plane constructions.

Existing views about techniques and technology of constructions building from monolith concrete mostly is based on plane construction building experience. Pneumatic formwork with changeable lifting provide an ideal concrete solution for formwork adjustment without any restricting factors connected to complicated geometry.

Nowadays pneumatical systems from flexible materials are developing and improving, new technologies are created.

The technology has got a big potential followed by modern events in concrete production and development.

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Vitalijs Lusis, M.Sc.Ing.

Vitalijs Lusis was born in Riga, Latvia. In 2010 he received his professional master degree (M.Sc.Ing) in Civil Engineering at the Riga Technical University. He graduated as a civil engineer and held a professional bachelor degree in Civil Engineering (B.Sc.Ing) at the Riga Technical university in 2009. Currently he works as a consultant in the company Grinders. Since 2011 he is member of Latvian Concrete Union.

E-mail: vitalijs.lusis@rtu.lv

Vitālijs Lūsis. Betona čaulu izgatavošanas tehnoloģija pneimatiskos veidņos ar maināmu pacēlumu

Rakstā izvērtēta betona un fibrobetona čaulu veidošanas tehnoloģija pneimatiskos veidņos ar maināmu pacēlumu un radīto izstrādājumu priekšrocības.

Tehnoloģija paredzēta plānsienu konstrukcijām, kas ļauj izveidot un iegūt dažādas čaulas, tai skaitā arī kupolveidīgās konstrukcijas, devos virzienos izlocītas čaulas. Izanalizētā patreizējā situācija kā arī nākotnes redzējums šajā jomā, izvērtēta plānsienu čaulu tehniskā un ekonomiskā efektivitāte. Darbā apskatīti pneimatiskie veidņi ar maināmo ģeometriju čaulu veidošanas tehnoloģijas īpašības un tehnoloģiskā procesa novitāte. Rakstā tiek analizētas pneimatisko veidņu tehnoloģijas ar maināmu pacēlumu priekšrocības, efektivitāte, iegūto izstrādājumu vizuālā pievilcība, patēriņa maksas. Pneimatisko sistēmu no elastīgajiem materiāliem izmantošana būvniecībā ļauj atspoguļot to priekšrocības, atzīmēt pneimatisko sistēmu visefektīvāko pielietošanas apgabalu, bet zema darbietilpība, neliela masa, iespēja daudzkārtīgai izmantošanai atļauj plaši izmantot to būvniecībā.Pneimatiskie veidņi ar maināmu pacēlumu rada jaunas iespējas modernajā arhitektūrā, kuras ir gandrīz neiespējamas ar tradicionālo veidņu izmantošanu. Tehnoloģiskais process izmantojot, pneimatisko veidni, ļauj iegūt čaulu ar gludu iekšējo un arī gludu, sprieķā nošlīpētu, ārējo virsmu.

Analizējot iegūtos rezultātus, var izdarīt secinājumus, ka, pneimatiskie veidņi ar maināmo pacēlumu čaulu veidošanas tehnoloģijai no tehniska un ekonomiska viedokļa ir efektīvs risinājums. Mūsdienīgajā, modernajā arhitektūrā pneimatiskie veidņi rada ļoti plašas, jaunas iespējas betona elementu ar sarežģītām formām veidošanā. Tehnoloģijai ir liels potenciāls kurš ir veicināts ar jaunākajiem notikumiem betona ražošanā un attīstībā Pneimatisko veidņu izmantošanas nelielā pieredze noteikti prasa tālāko pētniecisku darbu šajā virzienā.

Виталий Лусис. Технология изготовления бетонных оболочек на пневматической опалубке с изменяемым подъёмом

Целью работы является исследование появившихся в последнее время технологий для создания пневматической опалубки с изменяемым подъёмом и преимуществ создаваемых с использованием описанных технологий изделий из бетона и фибробетона. В статье проанализирована текущая ситуация, реализуемые проекты и видение развития пневматической опалубки с изменяемой геометрией, рассмотрена экономическая и техническая эффективность, а так же новизна данной технологии. В статье проводится анализ пневматической опалубки с изменяемым подъёмом для выявления таких качеств, как, эффективность, затраты на установку, визуальная привлекательность получаемых изделий. Технология позволяет создавать бетонные оболочки различных форм, в том числе куполообразные, волнистые и изогнутые в двух направлениях. Технологический процесс использования пневматической опалубки приводит к получению бетонной оболочки с гладкой внутренней и гладкой предварительно выровненной внешней поверхностью.

Анализируя полученные результаты можно утверждать, что пневматическая опалубка с изменяемым подъёмом с экономической и технической точки зрения является эффективным решением для конструктивных и современных архитектурных решений. Пневматическая опалубка с изменяемым подъёмом открывает новые возможности для современной архитектуры, которые практически невозможно воплотить с использованием традиционных опалубок. Новая технология имеет большой потенциал для развития, которому способствует развитие в области производства новых видов бетона. Несмотря на хорошо структурированную технологию, которая обеспечивает четкие критерии выполнения работ, есть еще нерешенные вопросы. Учитывая малый опыт изысканий проведённых в этой области, новая технология требует более пристального внимания и проведения дальнейших исследований.