Latvia University of Agriculture
Faculty of Rural Engineering

CIVIL ENGINEERING'13

4th International Scientific Conference

Part II

PROCEEDINGS

Volume 4

Jelgava 2013

International Scientific Conference and Proceedings "Civil Engineering 13" – dedicated to the 150th anniversary of the higher agriculture education in Latvia and the Latvia University of Agriculture, and the 275th anniversary of the Jelgava Palace

The 4th International Scientific Conference „Civil Engineering 13" is organized on a regular basis and this year it was held on May 16-17, 2013. More than 80 reports were presented at six conference sections. Reports were presented by scientists and civil engineering professionals from the Latvia University of Agriculture, Riga Technical University as well as scientists from universities of Lithuania, Estonia, Russia, Poland, Netherlands and other countries. The main research directions represented at the conference were: construction and materials, landscape architecture, land management and geodesy, building and renovation, structural engineering, environment and environmental effects, industrial energy efficiency and others. One of the nowadays research priorities – effective usage and saving of energy resources, received a lot of attention - 10 scientific reports were presented at the "Industrial Energy Efficiency" section.

The conference „Civil Engineering 13" international scientific committee is represented by civil engineering experts and academic staff from Latvia, Lithuania, Estonia, Poland, Finland,Sweden, Czech Republic, Netherlands.

The 4th International Scientific Conference „Civil Engineering 13" Proceedings are developed in a notable anniversary year for all of us – the conference and proceedings are dedicated to the 150 anniversary of the higher agriculture education in Latvia and the Latvia University of Agriculture. The home of the Latvia University of Agriculture is the Jelgava Palace - the largest architectural monument in the Baltic States. The Jelgava Palace this year is celebrating its 275 anniversary years. We are proud that this monument is fundamental and outstanding and it definitely influences also modern building tendencies in Latvia and abroad.

It is important to note that scientific papers from previous International Scientific Conference „Civil Engineering 11" Proceedings were included in the AGRIS, CAB ABSTRACTS, EBSCO Central & Eastern European Academic Source and SCOPUS databases.

Scientific Conference "Civil Engeneering" has become very traditional and I hope that in future it will expand and will provide a collection of excellent researches.

Sincerely,
Dr. sc. ing., prof. Juris Skujans
Rector of Latvia University of Agriculture

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LATVIA UNIVERSITY OF AGRICULTURE
FACULTY OF RURAL ENGINEERING

Department of Architecture and Building
Department of Structural Engineering

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The collection of articles provides important ideas for further scientific activities and is dedicated to the 150 anniversary of the Latvia University of Agriculture.

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CONTENT

CONSTRUCTION AND MATERIALS

HIGH EFFICIENCY POROUS CERAMICS WITH CONTROLLABLE POROSITY

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ABSTRACT

The increasingly growing anxiety in society about global warming and interest about construction materials which are less harmful to the environment, encourages manufactures and scientists to think about the use of more effective resources which are available and necessary for production, as well as finding possibilities and solutions for the decrease of primary energy resources depletion by producing ecological materials from local raw materials such as clay – the main raw material for the production of ceramic materials and their products, as well as more widely distributed sediments which mainly form the upper part of the Earth's crust. Notwithstanding the distribution of clay, the current amount of clay usage is similar to that of the second part of the '50s which is equal to the middle of the '30s of the past century.

Besides traditional ceramic materials, porous ceramics has also been widely researched and is becoming a more and more popular material in the world, thanks to its wide possibilities of usage in different applications and technology industries – from construction to mechanical engineering and even cosmic applications.

The chemical-mineral content, type of formation, thermal processing provisions, etc., of raw materials determine the ceramic material's porosity characteristics.

Many researchers have investigated porous ceramics with efficient properties, in order to research factors which influence the microstructure of porous ceramics, using polymer-material saturation with clay slicker and concluding how to produce porous ceramics. During the presented research porous ceramics was produced, by using a polymer material which was saturated with clay slicker.

The obtaining of porous ceramics, using a foam polyurethane pump as a burnable filler, is promoted by the fact that current technology used for producing foam polyurethane allows it to form preferable porous structures within wide ranges, with pore dimensions starting from some micrometers up to 2-3 millimeters.

Porous ceramic materials obtained within this research breathe; they are thermostable, resistant to thermal impacts, corrosion, and are easy to process.

Key words: ceramics, ecological materials, insulation materials, production waste, controllable porosity

INTRODUCTION

Energy, energy efficiency, greenhouse effect and resources are the words which are most commonly used emphasizing the role of heat insulation for buildings, because the inhabited homes are the greatest direct energy consumers in Latvia. Using its own resources, Latvia produces only a small part of consumed energy, and at the same time the cost of energy resources is increasing in geometrical progression.

Heat insulation is an effective way to decrease the costs of heat supply and thus economize. Heating does not assume the waste of energy resources and minimize greenhouse effect gas exudation in the atmosphere. Besides, the smaller the amount of fuel used for heating (but during the summer – for cooling), the less the environment is polluted. Good heat insulation not only improves the microclimate indoors, but also minimizes unfavourable changes in the climate.

The modern building industry offers a wide choice of heating materials, where the range of environmentally friendly, nontoxic materials and the range of materials produced by local manufacturers is slowly increasing, to where one of these materials could be porous ceramics, which can be obtained by the polymer sponge saturation method.

The materials containing tailored porosity exhibit special properties and features that usually cannot be achieved by their conventional dense counterparts. Therefore, nowadays porous materials find many applications as end products and in several technological processes (Studart et al, 2006). Contrary to metallic and polymeric structures, pores have been traditionally avoided in ceramic components because of their inherently brittle nature. However, an increasing number of applications that require porous ceramics have appeared in the last decades, especially for environments where high temperatures, extensive wear and corrosive media are involved.

Such applications include, for example, the filtration of molten metals, high-temperature thermal insulation, support for catalytic reactions, filtration of particulates from diesel engine exhaust gases and filtration of hot corrosive gases in various industrial processes (Rice, 1998, Scheffer and Colombo, 2005, Studart et al., 2006).

Solid sponges (i.e. open-celled foams) belong to the cellular materials. The key characteristics of solid sponges are a high and continuously accessible porosity of typically about 75-95%. (Dietrich et al. 2009, Dietrich et al., 2010).

The nature of the polymer sponge method is that in the scope of this method a thin layer of ceramic slurry is coated on the surface of the struts of a reticulate polymer sponge. After burning out the polymer skeleton, a positive replica of the sponge is obtained. However, the space occupied by the polymer remains as an internal defect in the ceramic body and the thin layer of ceramic slurry coating on the polymer sponge forms very thin walls between pores, which results in a structure of low mechanical strength (Ramay H.R and Zhang M., 2003). This method is in fact considered as the first method deliberately used for the production of macroporous ceramics. The original invention dates back to the early 1960s, when Schwartzwalder and Somers (Schwartzwalder and Somers, 1963) started using polymeric sponges as templates to prepare ceramic cellular structures of various pore sizes, porosities and chemical compositions. Since then this technique has become the most popular method to produce macroporous ceramics and is extensively used today (Studart et al., 2006).

By the use of the polymer sponge saturation method we can get not only samples with particular pore sizes and amounts, but also with different geometrical characteristics and shapes.

The polymer sponge method is not the only one for obtaining such porous ceramics, methods like sacrificial template and direct foaming (Studart et al., 2006), each of the methods has its own merits and drawbacks (Young Yang et al., 2010).

A disadvantage of the polymeric sponge replica technique is the fact that the struts of the reticulated structure are often cracked during pyrolysis of the polymeric sponge, markedly degrading the final mechanical strength of the porous ceramic (Sepulveda, 1997).

The strut flaws reduce the compressive strength of the porous ceramics to levels usually lower than the strength theoretically predicted for open cell structures (Gibson and Ashby, 1997).

As the alternative for the use of such a method, Sherman et al. developed a similar process to the polymeric sponge replica method, where the polymeric sponge is first converted into a vitreous carbon skeleton and is subsequently infiltrated with reactive gaseous species to form macroporous ceramics of many different carbides, oxides, borides, nitrides and silicides (Studart et al., 2006).

As the polymer sponge saturation method was used in the study for obtaining porous ceramics that in spite of its processing simplicity and low processing cost, it is not suitable for production of porous ceramics with small pore sizes (< 200 μm), due to the difficulty of obtaining an efficient slurry impregnation into the polymeric sponge (Lange and Miller, 1987), samples of porous ceramics will be obtained from macropores.

Predominantly open porous structures are produced by this method, as the original cellular sponge has to be accessible for the impregnation of the ceramic suspension or precursor. However, the ratio of open to closed pores in the final ceramic material may be adjusted to a certain extent by controlling the suspension viscosity and shear thinning behavior (Studart et al., 2006).

Such types of macroporous ceramics with interconnected open structures are widely used in everyday life and modern industries because of their inherent characteristics such as low thermal mass, low thermal conductivity, controlled permeability, high surface area, low density, high specific strength and low dielectric constant (Ishizaki et al., 1998, Young Yang et al., 2010).

Worldwide several researches for obtaining porous ceramics have been performed, using the replica method for production of porous ceramics. For example, Silva with his colleagues did research, using vegetal sponge for the production of a reticulated ceramic that combines the morphology of a vegetal sponge with ceramic properties, such as thermal stability, resistance to chemical attack, elevated porous degree and reticulation (Silva et al., 2009). Reticulated ceramics are materials made up of interconnected voids surrounded by a ceramic net, perceived to have high permeability and low density, thus rendering them suitable for many applications (Saggio et al., 1992). These include filters, catalysts, sensors, implants, among others (Peng et al., 2000).

The polymeric sponge method was used to obtain a reticulated ceramic in milimetric scale degree (5-10mm) using a vegetal sponge, L. cylindrica species as a template. The combination of the clay, K – feldspar and sand promoted an ideal plasticity to the slurry, leading to the morphology of the reticulated ceramic was identical to the vegetal sponge used as templating. Like the template structure, the reticulated ceramic has a tridimensional structure, where the ceramic fibers randomly link to each other (Silva et al., 2009).

The Electro-Chemistry Institute of Belgrade University performed a study for stating the factors which have an influence on the microstructure of porous ceramic. A clay slip saturated polymer material was used in the above mentioned study and it was concluded that the viscosity of the mixture has an essential role in the production of porous ceramics using the polymer sponge saturation method (Tripkovic D., et al. 2006).

Samples of porous ceramics were produced within the scope of the research, using the polymer-sponge saturation method thus obtaining samples with particular physical characteristics and strength parameters.

The goal of the given research is to obtain a porous ceramic material with specific features of strength and density thus achieving a material that could be used to insulate buildings.

MATERIALS AND METHODS

At the beginning of the research two different types of polymer sponges were selected (Fig. 1a, 1b) and the main consideration in the selection process of such types of polymer sponges was their wide availability and light saturation with ceramic slurry.

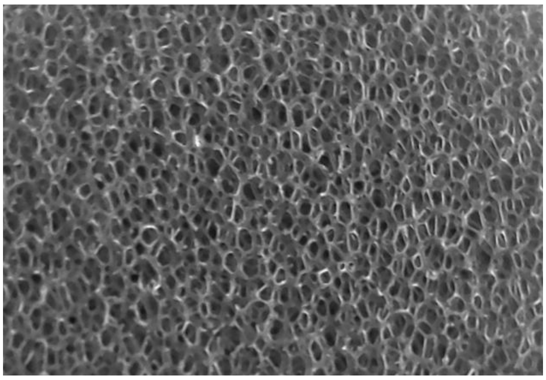

Figure 1a: Polymer sponge with pore size 1 - 3 mm

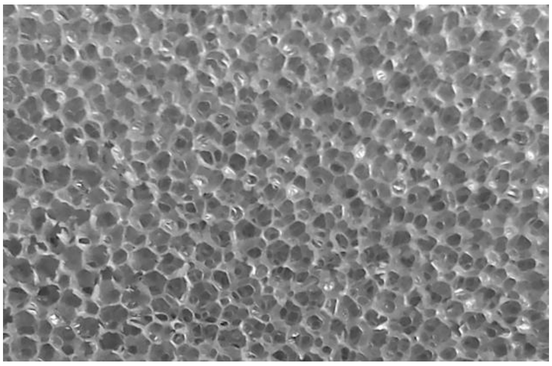

Figure 1b: Polymer sponge with pore size 0,5-2mm

During the next stage of the sample preparation process, a ceramic slurry was made, and the polymer sponges were saturated with chamotte, Lode clay with a humidity level of 24 % as well as ground glass. The chemical structure of the glass is given in Table 1.

The clay for the research was used in dry condition and was ground in a globe mill. The same procedures were done to the chamotte – it was ground in a RETSCH PM 400 mill for 2 minutes.

When the required components were prepared (grinding), they were dosed in the required amount and mixed in dry condition in the RETSCH PM 400 mill for 30 seconds; then water was gradually added until a homogenous mixture was sufficiently obtained.

Table 1

Chemical composition of ground glass

Component	SiO_2	B_2O_3	Al_2O_3	Fe_2O_3
Amount, %	74.20	16.63	1.65	0.16
Component	CaO	Na_2O	K_2O	
Amount, %	2.09	3.82	0.93	

A proportion of dry clay, chamotte and water used in the research varied depending on the pore size and pore type from the polymer sponges used. Components of the dry mixture were dosed according to mass, where dry, milled clay was 60 – 75 %, chamotte 10 - 15 %, but ground glass 20 – 30 %. By the addition of water (30-40%) there liquid clay slip, mixing clay, chamotte and previously ground glass in the mill were made. In the beginning the polymer sponge with pore size of 1 – 3 mm was impregnated with the obtained ceramic slurry and then compressed so that air was squeezed out of it, immersed in the ceramic slurry and then released, allowing it to dilate and obtain the initial form.

Such a step of compressing – dilating was repeated 3 – 4 times in order to reach the desirable density. In the next step the residual clay slip part was removed (25 % – 75 %), thus providing sufficiently high porosity.

The previous polymer sponge dipping in a soapsuds mixture was also used in the sample production, thus providing a better connection with the ceramic slurry during the process of sponge impregnation.

Sizes of sample: square samples with a thickness of 10 mm and edge sized of 100 x 100 mm and round shape samples with a thickness of 10 mm and 100 mm diameter, as well as the thickness of 20 mm and 100 mm diameter.

Conditions of material development: drying in a drying oven for 8 hours at a temperature of 50°C, favourably influenced by the large area of sample surface and the type of penetrating pores. Afterwards the samples were burnt for 11 hours, keeping the maximal temperature at (1090 °C) for one hour. The regime of sample burning is presented in Figure 2.

The regimes of sample drying as well as burning were chosen so that the time and energy resources required for material development are minimal, but sufficient in order to obtain the material with certain properties.

Samples with a thickness of one polymer sponge layer were produced, as well as several layers were combined and two different types of sponges were used. Samples were produced in several layers using several plates of polymer-sponge, then these plates were joined when produced in the ceramic slurry (in the process of sample saturation).One thicker sample composed of several layers was made after the sample was dried and burnt. (Fig.3.).

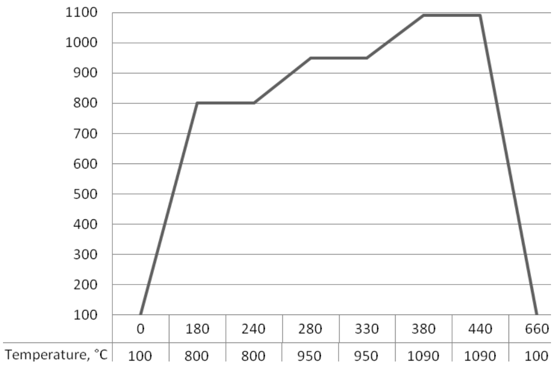

Figure 2: Regime of sample burning, using polymer material sponge

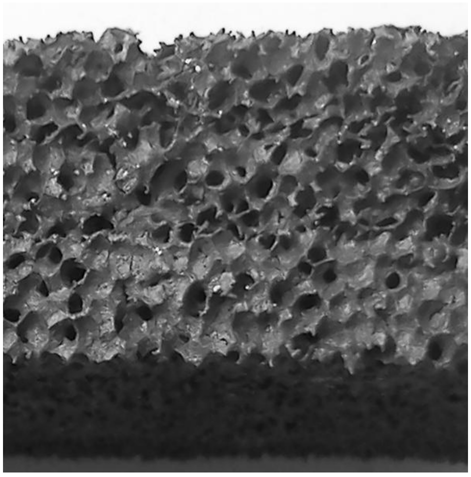

Figure 3: Porous ceramic sample made of 3 layers

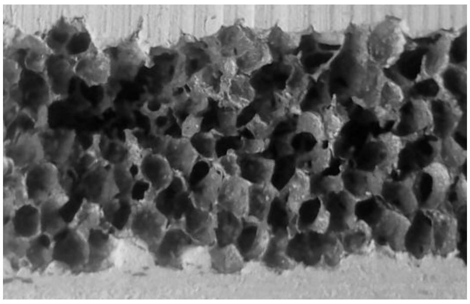

Figure 4: Sample with evened surface

By sample preparation for compressive strength tests, their surface was evened out with a layer of plaster paste (4 - 6 mm) from both sides (Fig. 4), pressing the sample between two parallel, smooth glass surfaces.

Verification of samples developed by the polymeric sponge replica method was carried out by the ZWICK Z100 perpendicular to the formation direction of the samples, thus providing the establishment of mean strength in the cross section, reducing the influence of certain weakening, which could have formed while samples were removed from mounds and a non-homogenous structural density in the direction of the cross-section formation.

RESULTS AND DISCUSSION

Porous ceramic materials were obtained during research. Compressive strength tests were performed, as well as their volume density and water absorption was determined.

Usage of polymeric sponge saturation with ceramic slurry method, by varying quantity of grinded glass in slurry, leads to development of several types of materials. Three basic mixtues have been used in further material production and testing:

1.) 70% clay, 20% ground glass, 10% chamotte;
2.) 65% clay, 25% ground glass, 10% chamotte;
3.) 60% clay, 30% ground glass, 10% chamotte.

The raw materials used, provide the acquisition of necessary properties of porous ceramics where clay serves as a cohesive substance, but chamotte provides the necessary stiffness, by making a stable frame during the burning process of the polymeric sponge, whereas the glass provides higher strength and better cohesion between the mixture and sponge within the sample formation process.

From two different types of polymer sponges the samples with the amount of glass 20-30% were made. Their density was within the scope of 330 to 490 kg/m3, because the main aim of the experiment was to improve the compressive strength parameters (Fig.5.).

Average volume density of the samples (Fig.6.) with 20% of ground glass is 364 kg/m3, 408 kg/m3 for samples with 25% of ground glass and 462 kg/m3 for samples with 30% of ground glass. Comparing the volume density of the samples before and after burning, it decreased per 29.2% to 32.6% for the all types of samples after burning. Average volume density of the samples (Fig.7.) with 20% of ground glass is 380 kg/m3, 416 kg/m3 for samples with 25% of ground glass and 492 kg/m3 for samples with 30% of ground glass.

The size of samples, comparing them before and after burning, decreased from 3-9% per edge length and from 1-4% per thickness.

By comparing the sample compressive strength, a higher strength was observed for the samples where the amount of glass used was 20-30%. The highest compressive strength was 1.84 MPa, using 30% of ground glass and 1.42 MPa, using 25% of ground glass. For the samples, using 20% of ground glass, the highest compressive strength was 1.24 MPa.

Water-absorption of ceramics material varies from 55,97% to 87,12 for the samples with 0.5 - 2 mm pore size, but for the second type of samples with pore size 1-3 mm – absorption is in the range only from 11,11% to 20,15%. It can be explained by the various types and amount of pores if compared with the first type of samples.

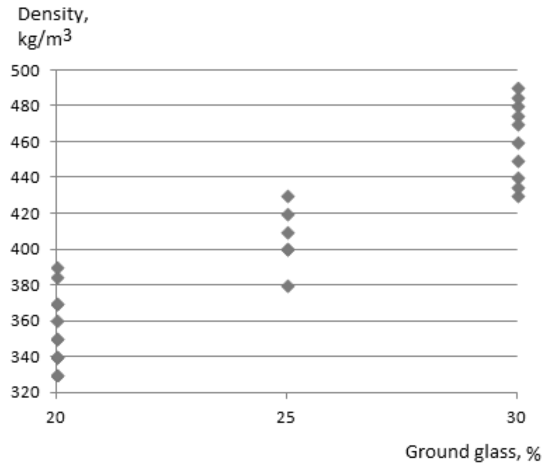

Figure 5: Volume density of the samples (Fig. 1a) with measure of pores 1-3mm and the amount of glass 20-30%

Macropores and micropores can be seen within the structure of porous ceramics, where the measurement of the pores in the obtained polymer sponge samples were 0.5 - 3.0 mm and macropores obtained by burning of polymer material sponge, have a form which copies the structure of the sponge itself and they are shown in figure 6 and 7.

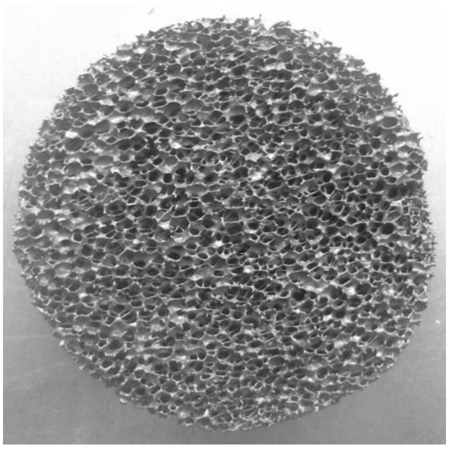

Figure 6: Porous ceramic sample with measure of pores 1- 3 mm. Scale 1:2

In the course of the research the polymer sponge was used for the saturation with the ceramic slurry where the essential role is played by the type of sponge itself and the size of its pores in order to ensure a complete filling of the sponge with the slurry content, as well as the viscosity of the ceramic slurry itself, because in this case the mixture is not sufficiently plastic. Within it, the polyurethane sponge components that are not being filled with the mixture content form empty areas after the burning process, have a negative impact on the physical and mechanical parameters of the material by reducing its strength. As such empty areas which are being formed by insufficiently saturating the polymer sponge, limits the thickness of a producible sample; it is preferable to use a consolidation method of several samples which was performed during the research, by forming one sample from separate layers, thus providing the necessary thickness of producible samples and their saturation with ceramic slurry in the whole volume.
The advantage of the given method for the production of porous ceramics lies not only in the simplicity of the technology but also in the time and cost consumption efficiency, whereas its drawback is linked to the features of obtainable porous ceramic materials dependence on the polymeric sponge quality, as well as the limited dimensions of the producible samples, which is effectively solved by gluing multiple samples together.

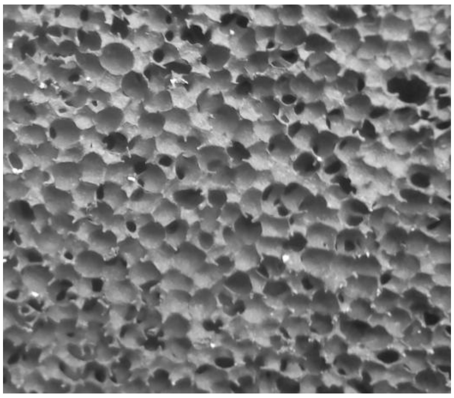

Figure 7: Porous ceramic sample with measure of pores 0.5-2 mm. Scale 2.5:1

By using the polymer sponge saturation method it is possible to make heat insulation elements with particular types and amount of pores, as well as with various sizes and forms, repeating any form which was initially characteristic to the polymer sponge itself.
Within this research during the process of sample production, attention was paid directly to the amount of ground glass, in order not to improve their strength parameters and to reduce the necessary amount of clay and the temperature necessary for burning, but it is also preferable to use glass waste in material production which could be further used in load-bearing low storey structures.
In the following research it would be useful to vary the components which are necessary for making ceramic slurry, and it could also be useful to use a consolidation of this method with some other porous ceramics production method in order to prevent the main drawbacks of the polymer sponge saturation method, thus improving the compressive strength of the samples.

CONCLUSIONS

The use of such porous ceramic materials will allow not only to increase energy efficiency of buildings, by using current and widely distributed clay resources, but will also allow economic development, increase clay extraction and use.

Weight of ceramic samples decreased per 29.2% to 32.6% after burning process. Burning shrinkage of samples was in the range per 1-4% per thickness to 3-9% per edge length.

By increasing contents of glass filler replacing clay in the mix from 20% to 30% the compressive strength for first type of sponge was increased exponentially from 1.24 MPa to 1.84 MPa, though volume density was increased linearly from 364 to 462 kg/m^3.

Average volume density of the second type samples (Fig.7.) increased from 380 kg/m3, with 20% of ground glass, to 492 kg/m3 for samples with 30% of ground glass exponentially.

Water-absorption of ceramics material depends from the size of pores and is in four times more for sample with 0.5 - 2 mm pore size, than for the second type of samples with pore size 1-3 mm .

The samples made within this research where polymeric material was used, allowed us to obtain materials with predefined features which could be competitive, by improving their compressive strength parameters with the materials like aerated concrete blocks.

The obtained porous ceramic materials are breathable, resistant tot corrosion, aggressive environment or heat and thermal impact and do not decay.

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EFFECT OF ELEVATED TEMPERATURE ENVIRONMENT ON ULTRASONIC PULSE VELOCITY IN CURING CONCRETE

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ABSTRACT

Quite often concrete strength parameters have to be determined at an early age. Due to the strong correlation existing between the mechanical and acoustic properties of concrete, ultrasonic devices can be used for this purpose. However, the ultrasonic pulse velocity (UPV) is affected by many factors, and it makes a great difference whether the concrete is subject to test at an earlier age or at a later time of exploitation. Since the elevated temperature of the environment promotes the shrinkage processes in hardening concrete, development of cracks and, therefore, a decrease of the UPV in concrete are to be expected. This paper describes the effect of non-isothermal high temperature (up to +30 °C) on the UPV in concrete. Influence of elevated temperature on the UPV in the concrete mass has been evaluated by determining the depth of the surface layer, at which the development of micro-cracks in the upper layers have no significant effect on the acoustic properties in concrete if an indirect transmission is applied for sounding.

Key words: concrete, nondestructive testing, ultrasonic pulse velocity, effect of elevated temperature

INTRODUCTION

Quite often concrete strength has to be determined at an early age, which happens due to the need to remove the formwork as quickly as possible and to perform an evaluation of the load carrying capacity. For that purpose most often the nondestructive research methods are used. It is known that a strong correlation exists between the mechanical and acoustic properties of concrete, however, the ultrasonic pulse velocity (UPV) is affected by many factors. Results of an earlier conducted research show that the ambient temperature within the range of +5...+30 °C does not produce any effect on the UPV in concrete. Specifically, when UPV is determined within that range, the UPV in concrete of any age will not demonstrate any significant change. Compared to the concrete placed in the environment with a temperature +20 °C, the difference in the UPV both in moisture saturated and dry concrete held at +40 °C is the least significant — up to 2 % (Malhotra and Carino, 2004; Guidebook, 2002). However, it should be taken into consideration that in such cases the discussion is of the concrete that is subject to sounding at the time when the active phase of the hydration processes of hydrated cement paste in concrete is finished. Namely, it makes a great difference whether the concrete is subject to the test at an earlier age or at a later point in time of exploitation.

Formerly, testing of cured concrete at an earlier age in an elevated temperature environment (by using the steaming method) with the help of ultrasonic equipment was performed mainly for the purpose of kinetic control of the compressive strength of concrete (Dzenis and Lapsa, 1972; Korotkov et al., 1963). As a result of concrete steaming, the strength of the massive structures grew at a lower rate, therefore, when the specimens of various bulk are tested, different results may be obtained. At the same time, it should be indicated that such curing method applied to products with similar geometrical parameters that came from the same batch also showed quite versatile results — a wide dispersion of data for concrete mechanical properties. (Dzenis and Lapsa, 1972). Therefore, it can be assumed that if concrete is simply subjected to an elevated temperature at earlier curing stages, determination of the UPV may also show a similar dispersion of data, which leads to an inaccurate interpretation of the measured results.

Similarly, the concrete at an earlier age was examined to determine the influence of isothermal and non-isothermal temperature (of up to +50 °C) in the hydration processes of hydrated cement paste. However, also in this case the main goal of the research was to determine the correlation between the strength and the UPV development kinetics during the first days of concrete hardening. It was determined that due to the effect produced by an isometric temperature of +35 °C during the first twelve hours, the UPV in the hydrated cement paste increases at a higher rate in comparison with the case when concrete curing happens at a lower temperature, whereas in 4-day old concrete the UPV is still lower compared to that in concrete that hardened in normal conditions, the difference in compression strength being ~ 20 % (Sun et al., 2005). Whereas, the results of another research show that in comparison with the temperature and shrinkage processes that develop in concrete, the changes in the UPV values are noticed at a later stage (Voigt, 2005). Therefore, it can be concluded that as a result of the influence of the above described physical processes, subsequent changes in the UPV are observable later, not during the first days of hydrated cement paste hardening.

Research conducted earlier proves that changes in moisture and temperature conditions can have quite a significant effect on the UPV in concrete (Alimov, 2007; Dzenis and Lapsa, 1972; Korotkov et al., 1963). Within the considered temperature range of +5...+30 °C the UPV in concrete decreases with a temperature increase. This may presumably happen because in the process of drying the specimens become increasingly dry and lose a certain percentage of moisture. It should be emphasized that the influence of the moisture factor on the UPV in concrete is much more significant, which was proved by the latest research in this area (Alimov, 2007; Fadragas and Gonzalez, 2011). Under the influence of elevated temperatures minor UPV and strength changes are observable in concrete with the comparatively lower strength as well as in the mixes with a lesser amount of coarse aggregates, which is largely explained by the higher homogeneity and greater porosity of the material (Glinchikov and Makagonov, 1974).

Regulations of the State standards do not contain specific guidance on the influence of temperature on the UPV propagation in concrete.

The currently existing Latvian standard and EU standard (Latvian Standard, 2004) stipulate that upon measuring the temperatures within the +10...+30 °C range, concrete is not supposed to show any significant changes in the strength or elastic properties. According to the regulations of the Standard, adjustments of the UPV measurements should be made only when sounding is carried out beyond a specified range of temperature. Furthermore, during testing the temperature of the concrete needs to be recorded in the test report only in this particular case. This standard does not contain any regulations regarding the influence of the shrinkage process on the UPV in concrete.

The existing Russian Federation standard highlights the possibility of UPV variations and, accordingly, the probability of inaccuracy in interpreting the measured results if the degree of moisture and influence of low temperatures on the tested concrete products are ignored (Russian Standard, 1988). At the same time, the standard does not contain any regulations regarding the influence of non-isothermal positive temperature on the UPV in concrete.

As it is known, during hardening the elevated temperature of the environment promotes the shrinkage processes in concrete, which normally causes development of cracks in the upper layer of the concrete and therefore a decrease of the UPV. It should be added that the influence of the shrinkage processes on the propagation of the UPV in concrete (especially in the upper layers of the material) has not been extensively studied. This work studies the effect, which the non-isothermal high temperature (of up to +30 °C) produces on the UPV in concrete if the ultrasonic testing method, the most frequently applied in practice, is used — the indirect transmission with a longitudinal wave pulse.

For this research it was decided to manufacture concrete specimens that would be subsequently placed in various curing conditions — in a normal or elevated temperature environment. For part of the specimens the curing conditions were simulated to resemble the situation at the building site in hot summer. For the purpose of evaluation of the differences in the UPV and compressive strength up to a certain age, during hardening some specimens were kept in the formwork and some were released from the formwork to harden. The main task was to evaluate the influence of elevated temperatures on the UPV in the depth of the concrete mass and to determine the depth of the surface layer at which, given the respective hardening conditions, the development of micro-cracks in the upper layers of a specimen have no significant effect on the UPV in concrete.

MEASURING DEVICE, SPECIMENS FOR RESEARCH

For this research the ultrasonic tester "UK-1401" (made in Russia) was applied, which is a frequently used device for such kind of testing both in the laboratory and in building objects. This device has two built-in dry point contact (DPC) transducers to achieve the efficient emitting and reception of longitudinal pulses. The main technical parameters of the «UK-1401» device are as follows: path length (constant distance between the contact elements) — 15 cm, working frequency of the ultrasonic vibrations — 70 kHz, measuring error of the ultrasonic time and velocity — not more than ±1 %.

The object of the research — 27 concrete specimens (with the dimensions of 15×15×15 cm).

After manufacturing, the concrete specimens were kept for 2 days at room temperature in a metal formwork; the surface of the specimens was covered with polyethylene film. At the age of 2 days 18 specimens were released form the formwork, while 9 were left inside. 9 dismantled specimens were placed in a standard moist room, while 18 specimens were placed in the climatic chamber (9 dismantled and 9 undismantled specimens). The specimens placed in the climatic chamber were kept in conditions that corresponded to the situation at the building sites during a hot summer. For example, all faces of the undismantled specimens were partially protected to prevent moisture evaporation during concrete hardening (upper surface of the specimens was covered with polyethylene film). In the standard moist room a constant air temperature of +18 °C and a relative humidity of 95...100 % were maintained, while in the climatic chamber with constant ventilation and humidity control the fol-

lowing cyclic conditions were maintained over 24 hours — for 17 hours: at +10 °C, for 7 hours: at +30 °C, with the air humidity changing within a 20...50 % range subject to temperature alterations.
Depending on the environment, in which the hardening of concrete took place, the specimens were grouped as follows: *N* — in a standard moist room; *K* — in a climatic chamber (dismantled); K_V — in a climatic chamber (undismantled). Each specimen group contained 3 specimens.
Along with the three different groups of hardening environment, the specimens were further subdivided into three subgroups. Namely, for certain specimens hardening was discontinued, they were released from the formwork and had the side faces cut off at three different ages — 7, 14 and 28 days (at the age of 28 days the side face of the 3rd group of specimens was not cut off). Each specimen subgroup contained 9 specimens. Therefore, when the specimens reached each of the above indicated ages the following number of specimens were removed from the chambers: 3 — from the standard moist room; 6 — from the climatic chamber (3 dismantled and 3 undismantled). At the age of 84 days approximately a 1 cm thick layer was cut off the upper face of all specimens. Cutting off of the surface layers was carried out to evaluate the possible influence of the shrinkage process on the UPV in the concrete below the cut off layer. Sounding of the surface of concrete specimens was carried out by the ultrasonic tester at the age of 2, 7, 14, 64 and 84 days.

TESTING RESULTS

For each specimen the sounding was carried out in three faces that were marked according to concrete casting direction: *U* — top; *S* — side; *L* — bottom. Prior to sounding the mass of the specimens, weight was determined as well as surface moisture measured (with the help of the measuring device "Tramex Concrete Moisture Encounter"). 9 diagonal measurements of each specimen face were carried out with the tester.
After processing the UPV results on various faces of the concrete specimens, the following was established. For the cubic-shaped specimens due to their casting direction, top faces almost always showed a lower UPV compared with the side and bottom faces, see Table 1. To this day, this feature was mainly explained by segregation of the concrete being influenced by compacting. However, during this research it was established that mainly it was affected by the environment in which the hardening took place. It is known that moisture promotes the hydration processes that occur in hydrated cement paste. Therefore the concrete sections with a higher level of accumulated moisture showed also a higher UPV. However, it should be emphasized that in this case the UPV increase is influenced by the moisture present in concrete, which plays a role of the initiator of chemical processes taking place there rather than as a physical factor. During the research it was established that if the specimens dry up at a steady pace over the whole bulk, the proportion of the UPV determined for various faces is preserved, only the absolute values of the UPV decrease.
It should be noted that, during another research that was conducted earlier, it also was established that distribution of the velocity of ultrasonic longitudinal waves and the surface waves throughout the height of a concrete specimen is not uniform (Staviski, 1982). It was discovered that for concrete specimens that were subject to various steaming conditions the UPV at the top is comparatively lower than the same at the bottom, while in the sections very close to the top face of the concrete it appears to be considerably lower.
A very significant difference between the UPV results for the top and the bottom faces was found for the specimens, which during hardening were subject to a cyclical impact of an elevated temperature (nonisothermal conditions) and which were not released from the formwork — K_V group specimens. Although the upper faces of the specimens of this group were also covered with polyethylene film (thus, emission of heat in the process of concrete hardening caused an accumulation of moisture on the specimen surface), here the fixed UPV appears to be explicitly lower in comparison to the measurements taken at the side and at the bottom faces, see Table 1. Besides, the longer the specimen was subject to such hardening conditions, the larger the UPV difference was. The other two specimen groups did not demonstrate such a strongly explicit tendency in the UPV differences. At the same time it should be noted that as a result of the influence of similar curing conditions the UPV measured for the upper face of the K_V group specimens of various ages is almost identical to that of the *K* group specimens.
As it was already mentioned, the physical influence of the moisture factor on the UPV in concrete is not a determinant in this case. Where initially differences in the amount of moisture present in the upper and bottom sides of the 2, 7 and 14-day old concrete specimens were fixed, then, later, when the 64-daysold specimens were tested, the moisture became evenly distributed almost throughout the whole bulk of those specimens. Measurements performed for certain specimens, which were approximately 3 years old, support the above assumption. Specifically, it was determined that the difference in the UPV fixed for the side and bottom faces of the specimens remained on the same level as it had been fixed at the age of 2 day.
The results obtained for the UPV show a comparatively greater dispersion in the specimens of group *K*. Since these specimens were released from the formwork and hardened at an elevated temperature, the conditions under which the structure of the hydrated cement paste was formed to a certain extent

appear to be similar to the specimens that hardened under steaming conditions, which also demonstrate greater dispersion of acoustic properties (Dzenis and Lapsa, 1972; Gorshkov et al., 1979).

Considering the above mentioned, the following conclusions can be drawn:—it is assumed that during the process of hardening in a hot environment (when the temperature during the day reaches at least +30 °C or exceeds this level) the porosity of the upper layers of hydrated cement paste and/or intensity of the quantity of microcracks in the undismantled concrete would be much higher compared with the rest of the mass, covered by the formwork.

In such cases, for examination of the structures with the help of nondestructive testing equipment, sclerаometric devices as a rule are not useful because quite often the surface that stays free from the formwork has significant asperity. Therefore, quite often the method of acoustic testing is the only possible way to evaluate the degree of homogeneity of the concrete in the structure and, in addition, to determine its strength parameters. Nevertheless, as seen from the results obtained in the course of the experiment, one should be especially careful when carrying out an assessment of general technical conditions of the concrete structures with the help of ultrasonic equipment. This is mainly because the concrete top surface, which in contrast to the rest of the faces (covered by the formwork) that hardened in a different environment, in warm weather conditions is subject to moisture evaporation even if the surface is covered with polyethylene film, which promotes moisture accumulation. Therefore, the UPV measured on the concrete surface freed from the formwork quite often proves to be lower in comparison with the rest of the concrete mass, and based on such results one may rush to the conclusions about the insufficient strength of concrete structure. In turn, when measurements are taken for the bottom faces of the concrete that was released from the formwork, the opposite inaccuracy may be made — here obtained the UPV will be higher than the results shown for the rest of the structure in general. Accordingly, the concrete that was hardened in such an environment should be sounded in all available faces and, additionally, the moisture degree should be determined. Adherence to such a measuring method will lead to more a accurate interpretation of the UPV measurement results with relation to the results of concrete homogeneity and strength.

Table 1

Average results of the differences in the UPV propagation in the top, bottom and side faces of the concrete specimens, which were cured in various environments, at different ages

Speci-mens group	Designation of specimens	Specimen age at the time of testing / the face subject to measurements / UPV differences in relation to the top face							
		2 days		7 days		14 days		64 days	
		side	bottom	side	bottom	side	bottom	side	bottom
N	$10.^{7}$, $16.^{7}$, $17.^{7}$	+2%	+5%	+1%	+3%	0%	+5%	+2%	+5%
	$5.^{14}$, $6.^{14}$, $15.^{14}$	+2%	+6%	+2%	+5%	+2%	+5%	+5%	+6%
	$1.^{28}$, $2.^{28}$, $7.^{28}$	+2%	+8%	+1%	+5%	+1%	+5%	+2%	+6%
	average total*:	**+2%**	**+6%**	**+1%**	**+5%**	**+1%**	**+5%**	**+3%**	**+6%**
K	$4.^{7}$, $13.^{7}$, $18.^{7}$	0%	+5%	0%	+5%	+6%	+5%	+5%	+6%
	$3.^{14}$, $8.^{14}$, $14.^{14}$	0%	+3%	0%	+3%	-1%	+3%	+9%	+5%
	$9.^{28}$, $11.^{28}$, $12.^{28}$	+1%	+4%	0%	+4%	+1%	+3%	+1%	+4%
	average total*:	**0%**	**+4%**	**0%**	**+4%**	**+2%**	**+4%**	**+5%**	**+5%**
K_V	$22.^{7}$, $25.^{7}$, $27.^{7}$	–	–	+7%	+11%	+7%	+11%	+8%	+10%
	$20.^{14}$, $23.^{14}$, $26.^{14}$	–	–	–	–	+9%	+13%	+11%	+12%
	$19.^{28}$, $21.^{28}$, $24.^{28}$	–	–	–	–	–	–	+10%	+14%
	average total*:	–	–	**+7%**	**+11%**	**+8%**	**+12%**	**+10%**	**+12%**

Note:

1. For the purpose of numbering, each specimen is assigned a number in superscript, which shows the age in days at which hardening in the corresponding chamber was discontinued and the surface layer of the side face was cut off (however not at the age of 28 days);
2. * — the average results of the UPV difference in the side and bottom faces compared to the upper face.

In order to determine the possible influence of the shrinkage processes on the UPV in the deeper layers of concrete mass, the surface layers of the specimens were cut off at various ages, and sounding was performed before and after the cutting.

Before cutting off the side face layer, each specimen was inspected by using the below described method. First, the amount of moisture present in the side face was determined, afterwards 18 diagonal measurements were carried out with the help of an ultrasonic tester. Then, the specimens' dimensions and mass were measured to determine the density. Such preliminary work was necessary because the specimen was moistened during cutting, and while it dried it was necessary to control the two parameters — the surface moisture and density. Namely, it was necessary to ensure that these two parameters got back to the initial level fixed before the cutting. (It should be noted that after surface layers were cut off, repeated dimensioning of the specimens was done). When the surface moisture and density reached the required level, measurements of the side faces of the specimens were carried out with the help of an ultrasonic tester. Adherence to such a method is considered as a major prerequisite to ensure accurate comparison of the UPV results obtained before and after cutting off the surface layer.

At first, the average 0.15 cm thick surface layer was cut off the side face of the specimens, then, one day later, repeated cutting was carried out, the total thickness of the surface layer cut off of each specimen on the average constituted 1.5 cm, see Table 2.

Table 2

UPV changes obtained for the surface layers of various thicknesses cut off the side faces of the 7-day old concrete specimens

Designation of specimen	Specimens group	Cut thickness, cm*	UPV before cutting, m/s	UPV after cutting, m/s	UPV difference, m/s | %	Cut thickness, cm*	UPV before cutting, m/s	UPV after cutting, m/s	UPV difference, m/s | %
4.[7]	K	0.31	4258	4337	+78 | +1.8	1.69	4258	4624	+366 | +8.6
13.[7]		0.19	4489	4537	+47 | +1.1	1.45	4489	4524	+35 | +0.8
18.[7]		0.15	4326	4354	+29 | +0.7	1.55	4326	4517	+192 | +4.4
				average result:	**+51 | +1.2**	–	–	–	**+197 | +4.6**
22.[7]	K_V	0.09	4648	4679	+31 | +0.7	1.63	4648	4722	+74 | +1.6
25.[7]		0.15	4620	4617	-3 | -0.1	1.37	4620	4641	+21 | +0.4
27.[7]		0.23	4608	4642	+34 | +0.7	1.78	4608	4750	+142 | +3.1
				average result:	**+21 | +0.4**	–	–	–	**+79 | +1.7**
10.[7]	N	0.05	4598	4564	-33 | -0.7	1.42	4598	4614	+17 | +0.4
16.[7]		0.10	4599	4544	-56 | -1.2	1.39	4599	4545	-54 | -1.2
17.[7]		0.09	4637	4612	-24 | -0.5	1.35	4637	4589	-48 | -1.0
				average result:	**-38 | -0.8**	–	–	–	**-29 | -0.6**

Note: * — thickness of the surface layers cut off the side faces of concrete specimens.

After the 0.15 cm thick surface layer was cut off the side face of the 7-days old concrete, a slight increase in the UPV was fixed only for the *K* group specimens, see Table 2. At the same time, in the cases where the 1.5 cm thick surface layer was cut off, *K* group concrete specimens, which were released from the formwork before the cycling process and hardened in the elevated temperature environment, showed a much higher increase in the UPV results — by ~ 200 m/s or 5 % on the average. Similarly, specimens of group K_V, which hardened in the similar environment although being kept in the formwork, also showed an increase in the UPV, see Table 2. It should be added that, in the concrete that hardened under normal conditions, after the cutting of the surface layer was realized, no increase in the UPV was obtained.

Therefore, it can be concluded that the shrinkage processes, which developed in the upper layers of the concrete under the impact of the elevated temperature of nonisothermal nature hindered propagation of ultrasonic longitudinal waves. Namely, after cutting off the 1.5 cm thick surface layer the concrete specimens of *K* and K_V groups showed the UPV results, which were much closer to the results, obtained for the 7-day old concrete that cured under normal conditions.

When a similar experiment was carried out for the 14-days old concrete, the specimens that were released from the formwork and hardened in the climatic chamber demonstrated even a higher increase of the UPV — approximately by 300 m/s or 7 %.

The above mentioned assumption is confirmed by the changes in the UPV shown in Fig. 1, which in the graphical form presents the data obtained for the specimens of various groups. Namely, after cutting off a ~ 1.5 cm thick surface layer the nature of the UPV curves for the 7 and 14-day old specimens cured in the standard moist room (*N*) and in the climatic chamber in formworks (K_V) is unchanged, while the side faces of the 14-day old specimens released from the formwork (*K*), which hardened in the climatic chamber, register a significant UPV increase. The nature of the UPV curves, as it in Fig. 1, *b*, for all specimen groups did not change also at the age of 64 days. Similar UPV curve changes are determined for the *K* group concrete specimens, when the results for the side face cuttings, i.e., for the data obtained at the age of 14 days are compared with the results fixed in 64 days.

By summarizing the data it was stated that concrete specimens of *K* group, after an approximately 1.5 cm thick surface layer was cut off the side face, for various initial UPV values, fixed before cutting, demonstrated a significant difference in the UPV increase that was measured after the cutting, see Fig. 2. Specifically, the lowest initial UPV (4258 m/s) showed the highest UPV increase — 8.6 % (4624 m/s). And conversely — the highest initial UPV (4489 m/s) corresponded to the lowest increase of UPV — 0.8 % (4524 m/s).

In addition to cutting off the side faces of specimens, all concrete specimens at the age of 84 days had the top face cut off as well.

In that case, the most significant differences in the UPV were obtained only for the 28-day old specimens that hardened in the climatic chamber. Specifically, for the specimens of the *K* and K_V groups, after they had an approximately 1 cm thick surface layer cut off, fixed an increase of the UPV compared to the UPV in the uncut surface: 171 m/s or 4.1 % and 184 m/s or 4.4 %, accordingly. In its turn, the specimens, which for 28 days hardened in the standard moist room (*N* group), demonstrated an increase of UPV by 54 m/s or 1.2 %.

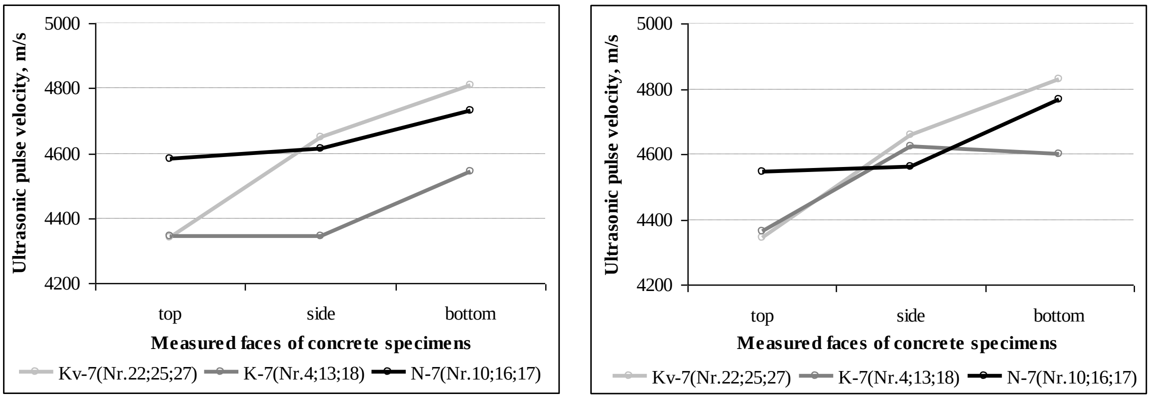

Figure 1. UPV changes obtained for the 7- (*a*) and 14- (*b*) days old concrete hardened in various environments after the surface layer of the side face was cut off

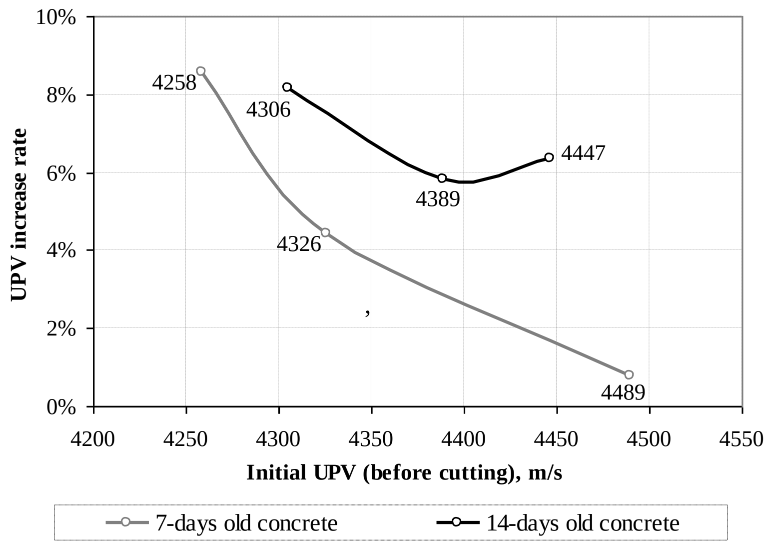

Figure 2. Differences in the UPV increase rate of the *K* group concrete specimens with different initial UPV, after approximately 1.5 cm thick surface layer was cut off the side faces

It should be emphasized that in contrast to the above determined relationships for the side faces of the concrete, in this case, the top faces of the *K* and K_V group specimens were subject to equal hardening conditions. Therefore, the obtained UPV differences also appear to be of similar nature.

For each of the specimens, after measuring and comparing the UPV data in various faces, different resulting trends have been obtained depending on the environment, in which hardening took place. Namely, the propagation of the UPV throughout the whole bulk of concrete specimen is best characterized by the data in its top face, after an approximately 1 cm thick surface layer has been cut off. However, such conditions can be referred only to the specimens, which hardened in the standard moist room or were kept in the formwork even in sufficiently hot weather conditions, whereas, for the concrete that was dismantled and placed in a hot environment, the optimal characteristic UPV value is medium-level, which is obtained by sounding the bottom and side faces.

Thus, it should be concluded that when ultrasonic measurements of concrete are carried out by using the indirect transmission method, the correlation of the acoustic and mechanical properties is to a great extent dependent upon the conditions in which hardening took place. Besides, the data obtained for the upper layer of concrete may not provide the correct characteristics of the concrete condition in general.

CONCLUSIONS

1. In relation to the concrete casting direction the top face of the specimens showed lower UPV in comparison to that obtained on the sides and at the bottom. This feature is the result of the concrete segregation occurring during compacting as well as influenced by the environment, in which hardening took place. Since moisture promotes the hydration processes in the hydrated cement paste, UPV also proves to be higher in the sections where more moisture is accumulated. In this case an increase of the UPV is contributed by moisture not as a physical factor but rather as the initiator for chemical reactions in concrete. In the 3-year old specimens after uniform drying throughout the whole bulk, the UPV for various sides was retained, only the absolute UPV values decreased.
2. A very significant difference between the UPV results for the upper and bottom faces was determined for the specimens that were not released from the formwork and during hardening were subject to the impact of the elevated nonisothermal temperature (K_V group). The UPV fixed in the top layer of the concrete is less by 15 % compared to the values measured at the sides and at the bottom.
3. The concrete that hardened in a hot environment (at the air temperature reaching +30 ^oC) usually has increased porosity of the hydrated cement paste in the upper layers and/or microcracks, which prevented propagation of ultrasonic waves. The average increase of the UPV determined at the depth of 1.5 cm at the side faces of concrete specimens of *K* group at the age of 14 days constituted 300 m/s or 7 %. At such a depth the UPV is much closer to the values, measured on the surface of the concrete, which hardened in normal conditions. The K_V group specimens also showed a noticeable UPV increase. In its turn, no UPV increase at the specified depth was obtained in the concrete that hardened in normal conditions. A similar correlation was determined when sounding of the top faces of the concrete specimens was carried out at a later age.
4. For concrete specimens of *K* group at the depth of 1.5 cm obtained significant difference in the UPV increase in comparison with the initial UPV values. Namely, a higher increase in the UPV corresponds to lower initial UPV value, and conversely — higher initial UPV corresponds to lower UPV increase.
5. It is concluded that when ultrasonic measurements of the concrete are carried out by using the indirect transmission method, the correlation between the acoustic and mechanical properties to a great extent depends on the environment, in which the concrete was cured. Besides, the data obtained for the upper layer of concrete may not provide correct characteristics of the concrete condition in general. The concrete which was hardened at the elevated temperature should be sounded in all available faces and at the same time it is important to determine the degree of the surface moisture. Such measuring methodology is going to significantly improve interpretation of the UPV measurement results in respect of homogeneity and strength parameters of concrete.

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CREEP BEHAVIOR OF HIGH PERFORMANCE FIBER REINFORCED CONCRETE (HPFRC)

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ABSTRACT

The challenge of the present investigation is to evaluate the possibility of using micro- and nano- fillers as active additives in concrete composition for the replacement of cement and elaborating a new concrete. This paper examines experimental test results carried out with the aim to evaluate the long-term deformations – creep of elaborated concrete composition. Two kinds of fiber-reinforced high performance concrete mixes using those additives and a cocktail of polyvinyl alcohol (PVA) fibers have been developed and prepared. The cubes and cylindrical specimens were prepared for each composition and tested. Cylindrical specimens were put into a creep lever test stand and subjected to a uniform compressive load kept constant over a long period in constant room temperature and level of moisture. This study was carried out in two different extreme environments: in one case they were kept in 100% humidity ensured by preventing the desiccation of the concrete and in the other case samples were air-dried. Compressive strength and modulus of elasticity were determined for each concrete composition. The results of the experiments allow the authors to predict long-term deformations of the concrete.

Key words: cement composites, PVA fibers, silica particles, long-term behavior

INTRODUCTION

Scientists and concrete technologists have been working on the development of new types of concrete. One of the most perspective products is fiber-reinforced high performance concrete (HPFRC). Fibers in concrete provide improved mechanical and physical properties for the material.

One type of strain that plays a major role in successful and continuous use of structures is creep – deformations that appear due to long-term loading of a structural element. Under constant mechanical loading, the strain of concrete increases significantly with loading duration, the increase often reaching 2 to 3 times the value of the instantaneous strain (Rilem TC 107-CSP, 1998). The deformation characteristics of concrete are important in the design of sustainable structures. Therefore, designers and engineers need to know the creep properties of concrete and must be able to take them into account in the structure analysis (Neville et al., 1983).

This paper introduces the recent state of research on elastic and time-dependent deformations of new high performance cement composite materials (FRCC) that are reinforced with PVA fiber and subjected to long-term, uniform, constant compressive load. In these composites, part of the cement has been replaced with micro and nano fillers. The experimental studies of creep in compression were performed. The results of the experiments allow us to predict long-term deformations of concrete.

MATERIALS AND METHODS

Preparation of the specimens

The experimental work included the preparation of two HPFRCC compositions with polyvinyl alcohol (PVA) fibers constituting 2% of the total amount of cement with and without nanosilica. For the purposes of this paper, the batches containing microsilica were designated SF, and the ones containing nanosilica – NN. The mix compositions are shown in Table 1. PVA fiber properties are listed in Table 2.

Raw components of the concrete were measured and then mixed in a laboratory conic rotation mixer for 4 minutes. Standard sample cubes 100x100x100 mm and cylindrical specimens 47x190 mm were produced to investigate the mechanical characteristics of the material. Concrete mixes were cast into oiled steel moulds without vibration because the composite is a self-compacting HPFRC. After one day the specimens were removed from the moulds (Fig. 1). Standard curing conditions (temperature 20±2ºC, RH > 95±5%) were provided during hardening until certain concrete ages were reached.

Table 1

Concrete mix composition

Component [kg/m³]	SF	NN
Cement Aalborg white CEM I 52,5 N	1000	1000
Quartz sand 0-1mm	260	260
Quartz sand 0.3-0.8mm	400	400
Quartz sand 0-0.3mm	300	300
Silica fume Elkem 971 U	150	150
Plasticizer Sikament 56	30	30
Nanosilica	0	20
Water	195	195
PVA fibers MC 40/8	10	10
PVA fibers MC 200/12	10	10
W/C	0.19	0.19

Table 2

Properties of PVA fibres

Fiber type	Ø [μm]	L [mm]	f_t [GPa]	E [GPa]
MC 40/8	40	8	1.6	42
MC 200/12	200	12	1.0	30

Figure 1. Demolded specimens

Test procedure

Cylindrical and cubes compressive strength, modulus of elasticity and creep tests were performed. The compressive tests were completed after 7, 28 and 123 days of concrete hardening in conformity with the standard EN 12390-3:2002. The modulus of elasticity was obtained from samples loading during creep tests. The creep was measured for hardened concrete specimens subjected to a uniform compressive load which was kept constant over a long period of time (Rilem TC 107-CSP, 1998; ACI Committee 209.1R-05, 2008). The constant with time stress level of all specimens was 25% of the maximum strength of the concrete, which had been determined during destructive tests carried out on cube specimens. The load was applied gradually in four steps and as fast as possible. Specimens were kept under a constant load for 90 days, and for recoverable creep they were kept without load for 30 days.

Six aluminium plates had been symmetrically glued onto three sides of the creep specimens in order to provide a basis for the strain gauges. The distance between the centers of the two plates was 50 mm. Three ±0.001 mm precision strain gauges were symmetrically connected to each specimen and then the specimens were put into a creep lever test stand and loaded (Fig. 2). The samples were tested in two extreme conditions: in one case they were kept in 100% humidity ensured by preventing the desiccation of the concrete and in the other case samples were air-dried. All specimens were kept in a dry atmosphere of controlled relative humidity in standard conditions: temperature 20±1ºC and relative humidity 48±3% (Gilbert et al., 2011). After creep tests the cylindrical compressive strength of the specimens at the age of 123 days was also determined.

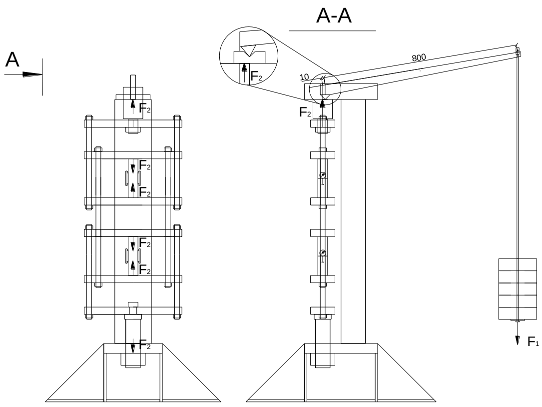

Figure 2. Creep lever test stand

The classification of deformations is shown in Fig. 3 and already described in papers (Gilbert et al., 2011; Sprince et al., 2011).

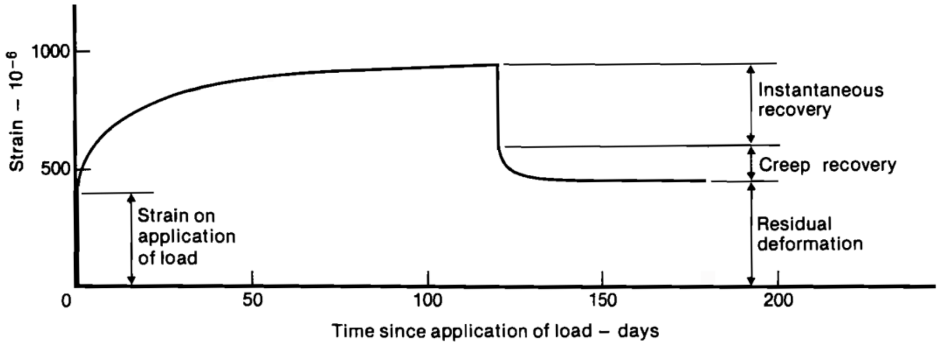

Figure 3. Classification of deformations (Neville et al., 1983)

RESULTS AND DISCUSSION

High cement content and low water/cement ratio provides a rapid concrete hardening process with high strength gain. A slightly higher cubic compressive strength was exhibited by the micro silica specimens after the 28th day. The cube compressive strength for specimens with micro and nano silica after 28 days had reached 100 MPa. After the creep test (123 days later) the cubes compressive strength for both type of specimens was 150 MPa.

During creep tests, the modulus of elasticity was obtained according to Hooke's law by measuring the deformations on the sides of the specimens during the first loading. It was observed that the modulus of elasticity in the both conditions is similar for both mixes and it was 45 GPa.

The total creep strains are given in Fig.4. The creep tests results of the HPFRC indicate that the highest creep strain was observed for micro silica specimens in the dry condition but the lowest ones were for specimens with nano silica in moist conditions. The average difference between specimens with micro silica hardened in moist and in dry conditions was approximately 11%, but for specimens with nano silica hardened in moist and in dry conditions the difference was 34% respectively.

After 90 days of loading, the load was removed. The creep recovery was measured 30 days after the loading period. The largest part of recoverable creep strain is instantaneous. For both mixes the larger difference of irrecoverable creep strain was exhibited by moisture-hardened specimens. The highest residual creep strains were observed for specimens with micro silica. The average difference between specimens with micro silica hardened in moist and in dry conditions is approximately 1% but for specimens with nano silica hardened in moist and in dry conditions the difference is 17% respectively.

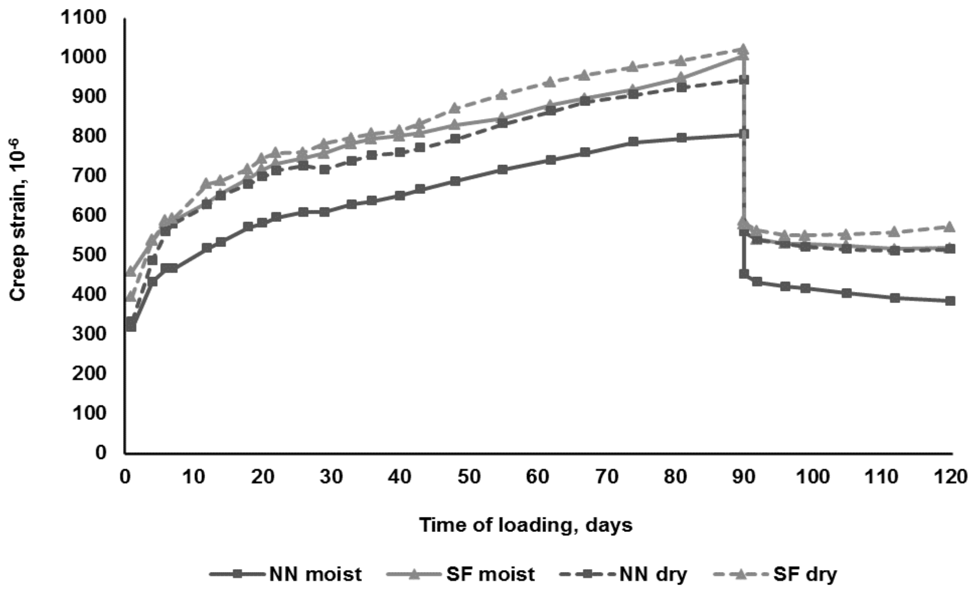

Figure 4. Creep strain of HPFRC at air-drying and moist conditions

The final creep coefficient is a useful measure of the creeping capacity of concrete and increases with time at an ever-decreasing rate. The creep coefficient reduces significantly with the growth of the concrete strength. The highest creep coefficients were established for concrete specimens with micro silica in the both conditions and it reached 3.2. The lowest creep coefficient was exhibited by the specimens with nano-silica. In both conditions it was 2.8.

CONCLUSIONS

Two fiber-reinforced concrete compositions (HPFRC) with micro and nano-silica as active additives were prepared for laboratory examination. The cube compressive strength, modulus of elasticity and creep strain were determined.

The compression strengths before and after the creep test (123 days old) were established.

During creep tests, the modulus of elasticity was obtained. It was observed that the modulus of elasticity in both conditions is similar for both mixes.

Concrete specimens were tested on creep. All specimens were loaded with an equal stress level of 0.25. The load was applied for 90 days and the long-term deformation responses were measured. The highest creep strain was observed for micro silica specimens in dry conditions but the lowest ones were for specimens with nano-silica in moist conditions. The creep recovery was observed over a time period of 30 days. The creep deformations were found to decrease with concrete aging and time. The largest part of recoverable creep strain is instantaneous. For both mixes the larger difference of irrecoverable creep strain was exhibited by moist-hardened specimens. The highest residual creep strains were observed for specimens with micro silica.

The creep coefficient reduces significantly with the increase in concrete strength. The highest creep coefficients were established for concrete specimens with micro silica and the lowest creep coefficient was exhibited by the specimens with nano-silica.

In the future, the physical and mechanical properties of new FRCC containing micro and nano-silica should be investigated in a more detailed way.

The obtained results indicate quite high dispersion of experimental data. In order to decrease the dispersion of results, the number of specimens and tests should be increased.

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RHEOLOGICAL AND STRENGTH PERFORMANCE OF CEMENT PASTE WITH GROUND FLUORESCENT LAMP GLASS WASTE AND ASH

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ABSTRACT

The rheological behaviour of fresh mortars is a key characteristic since it determines the material's workability, having as well a great influence on the hardened product's final characteristics. Portland cement substitution with lamp glass waste (DRL – mercury vapour lamps and LB – fluorescent tubes) in concrete has a significant effect on strength performance and workability. In the present study an experimental program aiming to evaluate the effectiveness of lamp glass waste ground from 10min to 60min and used as a cement component in cement paste mix, has been completed. Viscosity, electrical conductivity and compressive strength of cement paste samples with Portland cement substitution at a level of 30% with ground lamp glass waste and bottom wood/coal ash were determined. The results showed a significant increase of the workability for cement paste mixes with LB and wood ash, and an increase of compressive strength for DRL and coal ash mixes.

Key words: viscosity, electrical conductivity, fineness, compressive strength, lamp glass waste, bottom ash.

INTRODUCTION

The production of Portland cement leads to the release of a significant amount of CO_2 and other greenhouse gases and the environmental issues associated with CO_2 will play a leading role in the sustainable development of the cement-based construction materials and concrete industry during the 21st century. One of the biggest threats to the sustainability of the cement industry is the dwindling amount of limestone in some geographical regions. As limestone becomes a limited resource, employment and construction associated with cement-based construction materials will decline; therefore, those involved with these industries must develop new technique for creating cement-based construction materials with a minimal use of limestone. We must use more blended cement produced by blending with clinker other pozzolanic materials, such as coal or bio-mass fly ash, slag, silica fume, and such other pozzolanic materials as finely ground waste glass (Naik, 2011). The use of glass waste as a coarse aggregate was not successful in the previous years because of the marked strength regression and excessive expansion. But in recent years research has shown that increasing the surface area to the volume ratio of glass will reduce the effects of the ASR reaction and this can be accomplished by using glass with smaller particles. Finer particles tend to accelerate the reaction, which may allow the gel to expand before the concrete hardens and no alkali-silica reaction had been detected with particle sizes up to 100 µm (Corinaldesi, 2005).

With the replacement of cement with other recyclable resources, worldwide CO_2 emissions would be reduced. A replacement of 50% of cement worldwide by other cementitious materials would reduce CO_2 emissions by more than one billion tones. And this is equivalent to removing approximately one-quarter of all automobiles in the world (Malhorta, 2004). Waste management is a very important issue both from the public health perspective and the industrial one. As an increasing amount of hazardous materials need to be disposed of in a safe and economical way, the wastes are to be considered a real opportunity to produce clean secondary raw materials reducing costs and conserving resources (Andreola, 2010). Glass waste corresponds to many types of after-use products and can be completely recycled. Since most of this glass waste is made with soda-lime material, its melting and working temperatures are relatively low, which makes it easy to reprocess. But in spite of this recycling advantage, a large amount of glass waste is still discarded in landfills or simply thrown into the environment, including fluorescent lamps (Morais, 2012). Fluorescent lamps are used widely all over the world due to their long life and energy saving capability. Fluorescent and high intensity discharge lamps contain mercury, lead, and other components of environmental concern. Of that 17,400 tonnes of lamp waste, there was an estimated 2,4 tonnes of mercury and 2,5 tonnes of lead. The fluorescent lamp recycling facility crushes the lamps, separates the metal caps and recovers mercury. The majority of the by-product from the processing is the lamp glass. For 55000 tubes recycled, approximately 30 m^3 of waste glass will be generated. Because of the mercury contamination, the lamp glasses are finally sent to landfill. Similar to the mixed color bottle glass, the waste lamp glass awaits for the assessment of re-use (Shao, 2001). According to the data, from the only one lamp recycling centre in the Baltic States located in Liepaja (Latvia), the accumulated amount of lamp glass waste in the period from 2004 to 2012 is 1.8 thousand tonnes from which 0.5 thousand tonnes were exported outside of Latvia. There have been several investigations conducted in recent years about the application of this glass waste as a partial cement substitution in concrete. (Shakhmenko, 2010; Kara, 2012; Kara, 2013).

In this paper viscosity, electrical conductivity and compression strength of cement paste substituted with finely ground fluorescent lamp glass waste and bottom coal/wood ash are investigated focusing on cement paste workability behaviour.

MATERIALS AND EXPERIMENTAL PROGRAM

The glass powder that was obtained from the fluorescent lamp chippings (named LB) and mercury vapour lamps (named DRL) were received from a local lamp recycling centre (Fig.1). The chippings were then washed and dried before being ground in a laboratory planetary ball mill Retsch PM400 (with rotation speed 300 min-1).

Figure 1. DRL (left) and LB (right) lamps

The DRL and LB chippings were ground for 10, 20, 30, 40, 50 and 60 minutes. The coal and bottom ashes were obtained from a local source and ground for 30 min. The fineness of powders was obtained by the Blaine apparatus Testing Bluhm&Feuerherdt GmbH (50ml) using a method with the prior need of measuring the density of the powder with a pyknometer in accordance with EN 196-6. The fineness of DRL and LB powders is shown in Figure 2. The fineness of coal bottom ash was 840 m^2/kg, wood coal ash was 660 m^2/kg. Ordinary Portland cement CEM I 42.5N was used as a binding agent and its fineness was 390 m^2/kg. Sikament 56 was applied as a polycarboxylates plasticizing agent at a dosage of 1% by weight of cement. The chemical analysis of powders was determined in conformity with EN 196-21 methodology and the results are summarized in Table 1.

In order to reveal the influence of waste glass and bottom ashes on the rheological properties of cement paste, cement paste mixes were prepared. The cement, glass powders and ashes, plasticizer were dosed by mass. Constant w/c ratio of 0.28 was maintained throughout all the tests. Plasticizer was mixed into the water used for the cement paste. In total, 22 cement paste mixes were prepared. *Six mixes* named LB10, LB20, LB30, LB40, LB50, LB60 were prepared with a cement substitution at a level of 30% with LB waste glass (grinding time from 10 to 60 minutes). *Six mixes* named DRL10, DRL20, DRL30, DRL40, DRL50, DRL60 were prepared with a cement substitution at a level of 30% with DRL waste glass (grinding time from 10 to 60 minutes). *Three mixes* named LBp20, LBp40, LBp60 were prepared with cement substitution at level of 30% with LB waste glass (grinding time from 20, 40 and 60 minutes), plasticizer. *Three mixes* named DRLp20, DRLp40, DRLp60 were prepared with a cement substitution at a level of 30% with DRL waste glass (grinding time from 20, 40 and 60 minutes), plasticizer and w/c=0,28. *Two control cement paste mixes* with and without plasticizer. *Two mixes* named CBA and WBA were prepared with a cement substitution at a level of 30% with coal/wood bottom ash ground for 30 minutes.

Table 1

Chemical composition of glass powders, bottom ashes and Portland cement used in the study

Bulk oxide, %mass	**DRL**	**LB**	**Wood ash**	**Coal ash**	**PC**
CaO	1.320	5.110	13.5	20.42	69.01
Al_2O_3	2.600	1.220	16.72	3.59	5.260
SiO_2	71.140	65.520	40.69	56.93	18.74
K_2O	1.702	1.881	1.592	5.636	0.727
Na_2O	3.301	12.354	0.431	1.274	0.382
Fe_2O_3	0.170	0.110	9.5	1.91	2.030
MnO	0.006	0.011	0.193	0.469	0.059
MgO	0.615	2.946	5.132	3.505	1.812
TiO_2	0.006	0.027	0.84	0.193	0.261
SO_3	0	0.143	0.552	0.024	3.004
P_2O_5	0.023	0.038	0.865	1.723	0.151

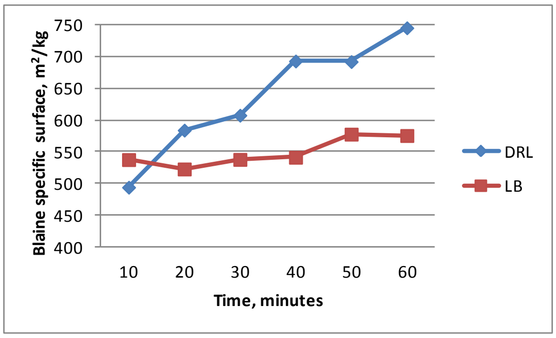

Figure 2. The fineness of DRL and LB powders vs grinding time

The rheological behaviour of the cement pastes was tested after the mix components were mixed for 25 minutes. Dynamic viscosity of cement pastes was tested by Malvern Instruments vibroviscometer SV-10 (Japan), the principle of its operation is based on an electromagnetic force driven vibration of two acoustic plates in a 13ml container. Two cement paste mixes were tested in parallel with a time interval for 5 minutes: A- first pair of two cement paste mixes, B – second pair, C- third pair. Each test had six levels: (i) first cement paste was prepared and tested at vibroviscometer for 5 minutes, in the meantime of running the experiment a second cement paste mix was prepared, (ii) the first cement paste mix was taken off from the vibroviscometer and left to harden, a second paste mix was placed for testing for 5 minutes; (iii) a second cement paste mix was taken off from the vibroviscometer and left to harden, then the first paste mix was slightly remixed in the test container by spoon and placed for testing for another 5 minutes; (iv) the first cement paste mix was taken off from the vibroviscometer and left to harden, the second paste mix was slightly remixed in the test container by spoon and placed for testing for another 5 minutes; (v) and (vi) – repeat of (iii) and (iv). The dependence of the cement paste's (w/c=0.28) viscosity on time when the grinding time of LB waste glass was increased from 10 to 60 minutes is shown in Figure 3. The dependence of the cement paste's viscosity on time when the grinding time of DRL waste glass was increased from 10 to 60 minutes is shown in Figure 4. The dependence of the cement paste's (w/c=0.28) viscosity with plasticizer on time when the grinding time of LB and DRL waste glass was 20, 40 and 60 minutes is shown in Figure 5. The dependence of the cement paste's viscosity on time of wood (WBA) and coal (CBA) bottom ashes is shown in Figure 6.

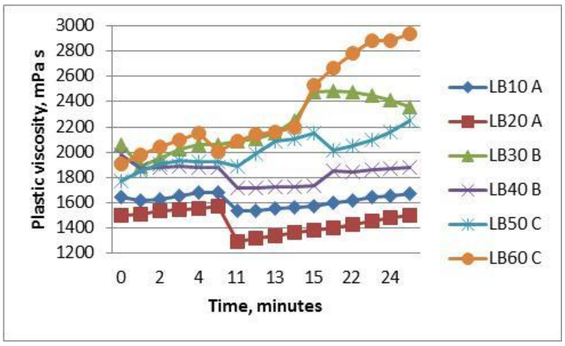

Figure 3. Time dependence of viscosity of Portland cement paste with the increase of LB waste glass powder grinding time

It can be seen in Figure 2 and 3 that the finer the LB glass waste is, the better the viscosity is of the cement paste. The optimal grinding time for LB glass waste is 30 minutes with Blaine specific surface area of 542 m^2/kg. In Figure 3 it is possible to observe the increase of the viscosity of cement paste with LB glass waste with increased time duration. The best result in this experiment set is for the mix LB60C. In comparison with Figure 6 where it is shown the viscosity of the cement paste, cement substitution with LB glass waste reasonably improves the workability and has an impact on the rheological properties of the cement paste. However, after first 10 minutes of the experiment it is observed that there is a slight decrease of viscosity for all cement paste samples with LB glass waste.

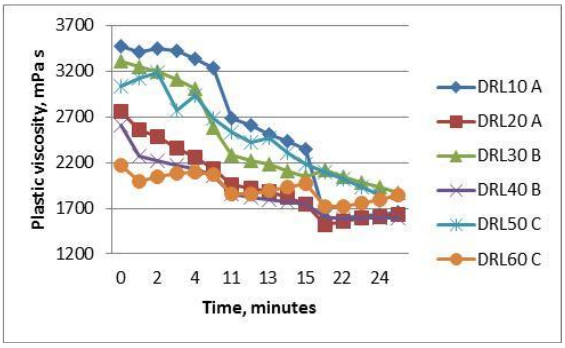

Figure 4. Time dependence of viscosity of Portland cement paste with the increase of DRL glass waste powder grinding time

It can be seen from Figures 2 and 4 that the finer is DRL glass waste the better viscosity of the cement paste in the first 5 minutes of the experiment. The Blaine specific surface area of DRL glass waste is much higher in comparison to LB glass waste with an increase of grinding time as it can be seen in Figure 2. The optimal grinding time for DRL glass waste is 20-30 minutes. In Figure 3 it is possible to observe a decrease of the viscosity of cement paste with DRL glass waste with an increased duration of time. The higher the grinding time of DRL glass waste the lower is the viscosity is of the cement paste. It can be described by the fact that - DRL particles are finer and more active than they are for pozzolanic reactions in the cement paste. The best result in this experiment set was the mix DRL10A from the workability's point of view. In comparison with the control mix, the cement paste with DRL glass waste also performed better.

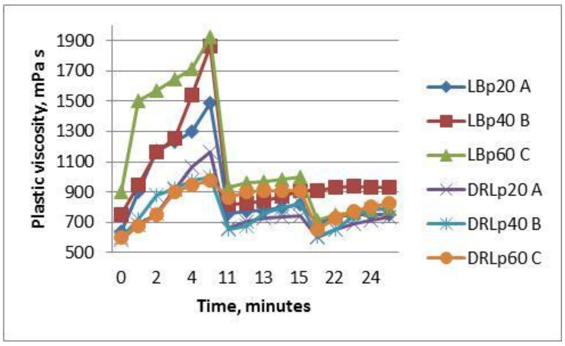

Figure 5. Time dependence of viscosity of Portland cement paste with plasticizer and LB and DRL glass waste powder ground for 20, 40 and 60 minutes

It can be seen in Figure 5 that the addition of plasticizer into cement paste mixes changes the character of viscosity of the mixes with DRL and

LB glass waste. It is observed that in the first 5 minutes the LB mixes have a significant increase of viscosity and in the second 5 minutes of the test – a significant decrease of viscosity with values equal to DRL mixes viscosity.

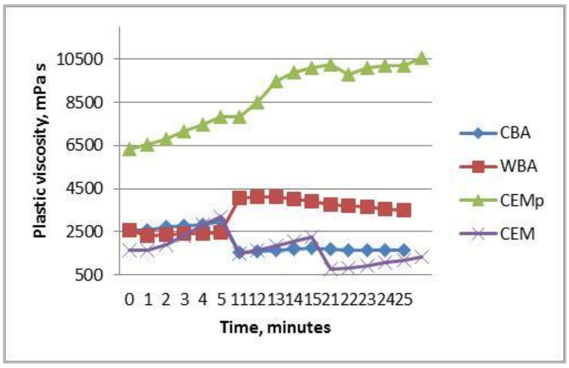

Figure 6. Time dependence of viscosity of Portland cement paste with/without plasticizer and coal and wood ashes

DRL mixes have almost a constant raising of viscosity in the duration of the experiment which is lower than is shown in Figure 4 but the workability of the mix is improved. The best results in this experiment set are for LBp40 and DRLp60. Plasticizer Sikament 56 improves the workability of DRL glass waste cement paste.
It can be seen in Figure 6 that the cement paste with WBA has increased viscosity and with CBA decreased viscosity. It was observed during the experiments that wood ash improves the workability of cement paste mixes, when coal ash absorbs more water. The cement paste mix electrical conductivity was studied immediately after mixing with water and at the 5th, 10th and 15th minute of the test with the device Metter-Toledo MPC 227 (electrical electrode in Lab 730, measuring interval (0-1000)µS/cm). The measurements were obtained at an ambient air temperature 21 ± 0.5°C.

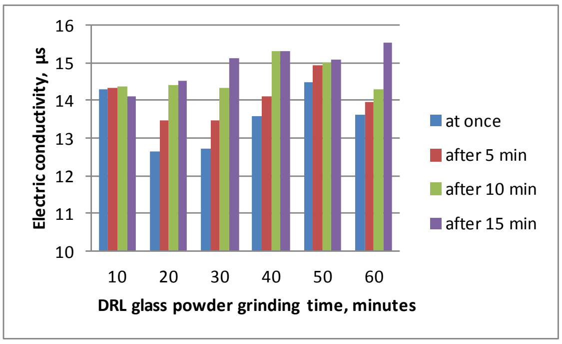

Figure 7. DRL glass and cement mix electrical conductivity

The results are shown in Figures 7, 8 and 9. It can be seen that electrical conductivity increases with time in the experiment for all mixes. In Figure 7 it is possible to see that mix DRL40 and DRL50 has better results and that DRL glass waste particle size influences the electrical conductivity of the cement mixes. In Figure 8 it is possible to observe that the electrical conductivity of LB glass waste cement paste mixes is decreased depending on the grinding time of LB glass waste: LB has finer particles and lower is electrical conductivity. Addition of plasticizer lowers the value of electrical conductivity in both DRL and LB cement paste mixes, but in comparison with Figure 7 and 8 results, in Figure 9 it is possible to observe that the finer the glass waste powder particles are, the better the electrical conductivity is in LB mixes in comparison with the DRL mixes.
In order to determine the compressive strength of cement paste mixes with glass waste and ashes, cement paste specimens were cast in 40x40x40mm steel moulds. The optimal grinding time for 30 minutes was chosen. The cement was substituted at a level of 30% with glass waste or ashes. The moulds were cleaned and lightly coated with form oil before the casting procedure. Samples were compacted on a vibrating table.

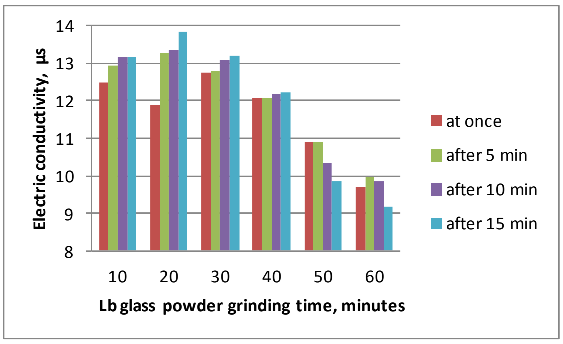

Figure 8. LB glass and cement mix electrical conductivity

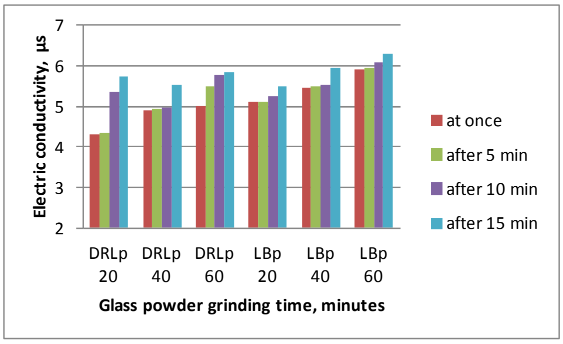

Figure 9. DRL or LB glass, cement and plasticizer mix electrical conductivity

After that the specimens were covered with polyethylene wrap and left to set for 24 hours. Then they were removed from the moulds and cured in water at a temperature of +20±2ºC for 28 days. Compression tests were performed at the age of 7, 28 and 56 days. The results are shown in Figure 10.

As it can be seen the best results were performed by the mixes with DRL glass waste powder with a maximum compressive strength for mixes DRL30 equal to 102 Mpa and DRLp30 equal to 117MPa at the age of 56 days.

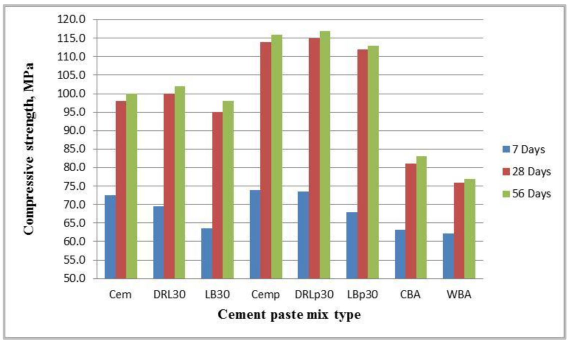

Figure 10. Influence of glass waste and bottom ash and curing time on the cement paste mix compressive strength

CONCLUSIONS

The rheological behavior of cement paste is improved by the application of fluorescent lamp glass waste in the mixes. However, the effectiveness of glass waste grinding time on rheological behavior and strength performance depends on the chemical composition of the glass waste and bottom ash used as a cement component in the cement paste mix. As it was observed, the finer the LB glass waste particles were the higher the value of viscosity was including lower electrical conductivity. The finer the DRL glass waste particles, the lower value of viscosity, and an almost constant electrical conductivity was observed.

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BUILDING AND RENOVATION

NEED TO INNOVATE THE DUTCH BUILDING REGULATION

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ABSTRACT

Increasing dissatisfaction with the regulatory burden, with the (municipal) system of quality assessment and the general loss of knowledge and experience on operational levels led to two Governmental Committees who presented in 2008 their conclusions and proposals. For instance, private certification of the building permit procedure, and to concentrate the knowledge of municipalities in regional intermunicipal bodies for environmental subjects. These proposals will however not change fundamentally the attitudes and behavior of the parties in the building process, owners and users of works. Experiments since show only increased costs and liability.

Also more fundamental questions were raised about quality assurance and responsibility in a market driven construction sector. Should the national building regulation set a minimum standard for all relevant aspects because of market imperfections? Or is self regulation feasible? And if so, will it be effective without supervision by a local authority?

In 2011 three new studies were commissioned by the Government to address the perceived problems. Two subjects were the economic effects of the changed regulations, and the cost effectiveness of the existing building regulations. The third integral study, executed by the Foundation Expert centre Regulations in Building (ERB) was based on the weaknesses in the knowledge circle of the building sector. It led to proposals to redefine responsibility and liability for all parties.

This study states that by an effort of yearly € 100 million, unnecessary costs up to € 1 billion can be avoided and a real quality push will take place in the building and real estate markets.

This paper discusses the three studies and the given proposals.

Keywords: deregulation, education, liability, system innovation

INTRODUCTION

The Dutch Building Decree has been under discussion for decades. Clear building rules and regulations form an important, even an essential link between the building practice and society, aiming primarily at the availability of safe, healthy, usable and sustainable buildings. How effective building rules and regulations are depends largely on their practical applicability, costs and the extent in which they allow building innovations.

With its Building Decree 1992 the Dutch legislation took an important first step, a system that meets these objectives. As opposed to the traditional building regulations, the Building Decree does not prescribe in detail how to build, but indicates the required performance. This system leaves space for the introduction and application of fresh, innovative solutions.

Now, almost twenty years later, the building regulations have been changed three times fundamentally, initiated by deregulation initiatives. The last one is more and more based on the idea that governmental regulation can be skipped in the belief that market forces will ensure good performance, in the whole building sector, also for the long run.

Although the Building Decree has proven to be successful in many aspects, various problems have emerged which appear to be structural in origin.

ERB published its first, overall analysis and vision (Scholten, et al.2008) in 2009. One of its conclusions was that the end user – who, as the owner of a building, is legally accountable for it to meet the rules and regulations set – is represented too feebly in the building process, and often does not even play any role at all in the decision-making, especially not in the formulation of regulations. Because of this, the end user could in practice become the loser. As a result ERB assigned a group of experts and scientists to further investigate this issue and to come with a remedy to this undesirable situation.

Other conclusions were that in the public and private sectors two separated circuits of knowledge development took place, and that the building

regulations in their present form insufficiently warrant that public objectives are realized.
At the end of 2011, a quick scan study was realized commissioned by the Government:
To describe the desired change in public and private roles of the involved parties in the building process and in the management and maintenance of real estate.
To sketch a robust future picture of the development and content of the building regulations and the role of the different parties in that process by focusing on the protection of the non professional end-user.
To change the building control process and the process of assessment of the performance of the existing stock to strengthen the position of the end-user in such a way that the realized performance fulfills the regulations and that at the transfer of real estate by owner or tenants the performance will be transparent and guaranteed.

THE PRESENT SYSTEM

As a reaction to the abominable bad housing of city immigrants in the second half of the 19th century the Netherlands introduced the Housing Act in 1901. From then, the municipalities were responsible for the drawing up and enforcement of regulations in the form of local building codes. In the 20s and 30s of the 20th century, the Housing Act advanced the construction of good - and still attractive - dwellings.
After the World War II building contractors and developers operated more and more nationwide. They were confronted with all kinds of different and inconsistent local regulations. In order to rationalize the building process, countrywide uniformity was required. As a first move the Association of Dutch Municipalities issued the Model Building Bylaw. But many municipalities kept adhering to their own building regulations and the call for national uniformity became stronger.
In 1982 the Lubbers-1 cabinet took the initiative that finally resulted in the 1992 Building Decree. The Housing Act stated that from then on municipalities, fire brigades and utility companies were no longer allowed to issue regulations supplementary to or deviating from the Building Decree.
This first Building Decree had a completely different structure. In the old system, the building regulations described specific solutions to many regularly occurring construction problems; innovative solutions were formally not allowed. As the Building Decree states the performance required of complete buildings, constructors could apply both, the existing standard solutions as well as new, equivalent or better.
Between 1992 and 1998 the government worked on a second edition of the Building Decree which was never enforced. In 2003, the presentation form of the Building Decree was changed at the request of the market into the so-called tables legislation. However, the Dutch government simultaneously introduced a new modeling principle of works that was in conformity with the experience of neither the construction partners nor citizens.
On April 1st of 2012 a revised Building Decree 2012 came into force after a long development struggle. It integrated elements of the Building Decree 2003, of 418 municipal building bylaws, the Decree on fire safety structures in use and the Decree on road tunnels. The political goal was to reduce more than 25% of the volume of all clauses and to diminish the freedom of local authorities to decide about exemption of requirements for renovations.
Since its publication in 1991, the Building Decree has now been changed 31 times, often minor changes and two mayor revisions as described above.
The Building Decree does not cover the whole spectrum of regulations relevant to building. For specific buildings and safety and healthy rules, the specialized Ministries published their own technical regulations.
Besides these, the EU regulations for construction products were introduced, due to the required free movement of goods and reduction of use of energy.
In order to reduce the burden of too many regulations and organizational fragmentation the Dutch government recently decided to implement three important measures:

a) one ‘environmental counter’ for dealing with ‘environmental’ related permits (the General Physical Environmental Rights Act), but at the start of the Government Rutte I in 2010 a more rigid law reconstruction in the Environmental area is foreseen;
b) bundle all knowledge at the enforcement level by combining the responsible local services at regional level, implementing the advice of the Mans Committee (VROM 2008);
c) organize the fire departments regionally (Act on Safety Regions).

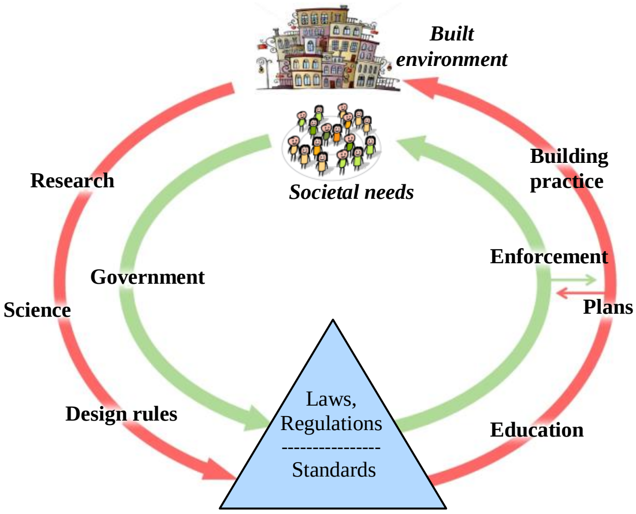
A necessary review of the system

The three recent measures are administrative and organizational answers to problems that are rooted deeper. Both, the public legislation and the privately developed system of Building Standards form a part of a knowledge system that is necessary to realize and manage safe, healthy and sustainable buildings. That system should function properly, which is not the case at present. The regulation is more effective, when it is developed in line with this knowledge system. Everybody involved in buildings, construction and its management, must be able to properly understand, interpret and apply the regulations.

This knowledge system should also facilitate possible adaptations and the development of new regulations. Of course, these regulations should comply with the practice of design, construction and use. The lessons learned from practice should in turn lead to research and improved regulation. Attention must be paid to the transfer of knowledge as well as to the restructuring of the regulations.

The cycle of knowledge

The skills of designing and constructing good and reliable buildings are rooted in building science. This has largely developed empirically and is continually developing further. With a view to practical applications, scientific knowledge has been incorporated in design regulations, governmental rules and regulations and standards. We may assume that buildings are sufficiently safe, healthy and sustainable when architects adhere to these regulations. Naturally, the same counts for owners and users when managing and running their real estate. Should they not do so, we ought to change the regulations or stimulate people's adherence to the regulations. Occasionally, or in case of technological innovations, people should be able to deviate from the details in the regulations without necessarily endangering safety, health or sustainability. We have depicted the process outlined here as a circle of knowledge (see Figure 1):



The *public* learning track (green): public requirements are translated into rules and regulations through legislation, enforced according to public law by means of a licensing system, general terms and conditions, or sanctions recorded in the Housing Act, Municipalities Act and the Provisions of administrative law; The *private* learning track (red) runs from research and science, through technical specifications and known solutions which are transferred in training programs, leading to professional practice. Some of these specifications and agreements have been laid down in the Standards and assessment guidelines.

Figure 1. Knowledge circle (Scholten, et al. 2010)

Building regulations combine the two tracks to become crossroads. Knowledge of the Standards and their background is also essential for enforcement, and knowledge of rules and regulations is just as important for education and training programs.

On the basis of the ideal model we are able to clearly illustrate the practice related hitches. Figure 2 charts these hitches.

The first general problem is that the various actors in the private-law circle of learning work totally independently from each other. Universities, research institutes, schools for professional training, commissioning clients, designers, engineering consultants, building contractors, fitters, suppliers and consumer representatives, they all adhere to their own policies, focusing specifically on their direct self-interests, and without much coherence.

The next problem is caused by both a highly fragmented sector and the fact that not a single party individually obtains a competitive advantage from investing in the development of communication systems and therefore chooses not do so, however these systems are necessary to structure and improve mutual understanding in the sector. Centralized communication systems are no–one's priority, and no 'central market superintendent' exists who could organize this. And then there are other factors. We refer to the characters in the black dots of Figure 2, described in (Scholten, et al. 2010). We summarize the importing ones. In order to make public-law rules and regulations and private- law agreements match, the two learning tracks on the left-hand side should be linked up with each other. At present there is no interaction whatsoever.

Standardization must be based on research. The performance requirements must be based on measurement, determination or calculation methods. At present, unfortunately, many terms and conditions, and standards are insufficiently based on science. Due to the lack of proper financing, universities have little interest in the methodology and modeling necessary to formulate rules and regulations. The technological institutions such as TNO (Netherlands Organization for Applied Scientific Research) largely depend on occasional commissions from the government and industries.

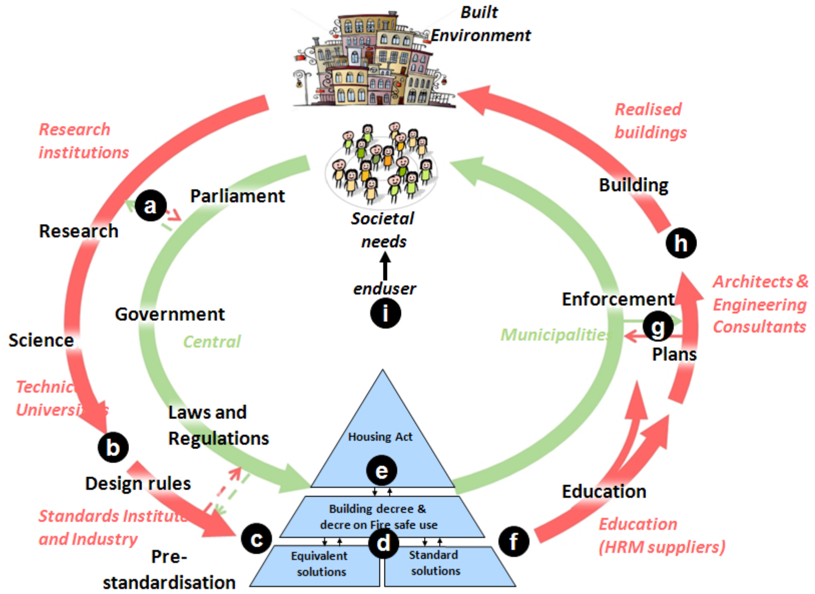


Figure 2. Hitches in the knowledge circle (Scholten, et al. 2010)

This is the reason why they miss the long-term stamina necessary for the development of scientifically sound rules and regulations or standards.

The knowledge on which the development of regulations and standards is based has been insufficiently recorded and managed in the present system. After the successful completion of a regulatory project, everybody should be able to easily find the relevant background information with a view to clear objectives and an unambiguous interpretation, and support of the equivalence of possible, fresh solutions. Now, this knowledge seems to ebb away to such an extent that even the responsible bodies themselves do not always understand their regulations.

Individual private-law regulations, such as standards, have been drawn up based on different disciplinary backgrounds, for instance: by constructors, experts in fire safety, and those in building physics or materials specialists; also the European standards use other words than the Dutch regulator; so these regulations do not match nicely. One result is a differing and inconsistent use of language. As the Building Decree (2012) refers to such regulations, unavoidable inconsistencies develop in legislation. The legislator's use of language is not that of the standardization committees, while neither speaks the language of the man on the building site, the performance approach requires a level of abstract thinking which is not used on the shop floor; specialists with secondary education only understand problems by way of practical solutions. Would regulation be consistent and translated in shop floor language, the correct application of regulations would improve greatly.

The scope of application of building regulations should probably be extended. According to the original Housing Act, building rules and regulations were meant for the safety and health of the users of a building. Later, as an effect of these, regulations were added with a view to its usability and energy efficiency, later followed by accessibility and sustainability and by April 2012 also by fire safe use, demolition, safe maintenance and sustainability. Up to now, economic and cultural aspects and the prevention of criminality have been included only to a small degree. However, the regulations which have to promote the well-being of construction and aid-workers, such as firemen, have been laid down in the Law on Conditions at the Workplace; one can only find them implicitly in building regulations. Although, the construction industry is one of the most dangerous, unhealthy and energy-consuming economic sectors. Surely, a building application or process should not only meet the building regulations, but also satisfy the Commodities Act: elevators and appliances), the Environmental Management Act, the Nuclear Power Act: ionization alarm, Police Act, Records Act and the Law on Conditions at the Workplace. With such complexity it is not surprising that people experience regulations related stress.

Rules and regulations only form a minor part of the curricula in secondary and tertiary professional education and universities. This creates an important gap in knowledge both within industries and within law enforcement organizations of the government. It seems as if people no longer see how closely the administrative and building laws as well as technical regulations are connected.

Preventive assessment to meet the public law is done only in the design stage of a building. So, one cannot be sure that buildings realized actually comply with the relevant regulations.

In today's building processes the end user, often the owner (to be) of a building, hardly plays a role. As the end users often are parties differing from the commissioners of buildings (the developers and investors), their specific interests will generally be insufficiently represented in the design and construction stages. Therefore, they will have to rely on the public rules and regulations to protect their interests. Many commissioners completely ignore many kinds of aspects that, for a society, are desirable and beneficial in the long run – think of the accessibility of buildings for persons with functional limitations, or the adaptability to various other uses of a building. If these requirements have been carefully dealt with in their design and construction, the layout of buildings might have to convert less often, the risk of vacancy might be lower, and early demolition due to their being unfit for purpose might be scarcer. The only way in which to realize this societal goal is for the government to list minimum regulations and enforce them.

PROPOSALS FOR SYSTEM INNOVATION

The starting point is the enforcement of regulations the societal usefulness of which has been proven. To diminish the burden of overregulation we can for each aspect present the rules on three different assessment levels. That is needed for three areas of application: the newly built buildings (construction works); the renovation/-refurbishment/transformation and the existing stock. For each of these areas an own set of objectives and rules might be necessary and logical.

The starting point should be for all sub aspects that the objectives of regulation are quite clear and are discussed between all parties concerned, not in the least with the end-users, and are formulated clear and concise. This is functionally a governmental task and should be taken up before anything else.

The translation of the objectives into regulation for constructions and buildings is clearly a task of the professional market parties.

A first assessment level is meant for easy elaboration of 'standard solutions'. We assume that possibly 80% of the building plans or the existing buildings are or consist predominantly of 'standard solutions'. The middle level more or less resembles or would be an improved Building Decree 2012 that focuses on performance. The proposed third level concerns building works in which unconventional and innovative solutions are to be implemented, using a probabilistic approach in assessment.

Should an applicant differ in opinion on whether a proposal meets the level of the standard solutions or the level of the ordinary assessment according to the performance requirements of the Building Decree, the third level would then provide the possibility of assessment according to the objectives regarding safety, health, usefulness, energy efficiency and sustainability. In that way discussions with regard to technical content need not end in judicial disputes.

For many people the introduction of these two new levels will substantially diminish the burden of overregulation. By standard solutions one could implement the greatly simplified regulations instead of those of the Building Decree 2012. While, at the third level, one can judge innovations against the formulated objectives. outside the known territory of solutions and construction rules.

It is in no-one's interest to enforce a regulation that is not well understood. The three level structure will improve the practical use of the regulation and will promote the legislators real objectives: the enforcement of safety, health, usefulness, energy efficiency and sustainability. That is how the regulation is linked with objectives.

Because of the lack of knowledge the development of the objectives and structure of three levels and three areas of application should be prepared by a "Knowledge Institution", financed by the Government and the market parties together (PPP). In this institution the few experts there are at the moment will join forces to organize and prepare the outline of the objectives and to oversee the development and elaboration of the structure of regulation. Within the Knowledge Institution all data behind the regulations will be concentrated and stored, accessible for all parties concerned, for now and in the future.

ERB proposes also to improve the safeguarding of the regulation related knowledge. Together with all those involved in the building process - from science, knowledge institutes, education, architects and engineering consultants, to the actual builders and the real estate sector - we must try and form a secure chain of knowledge with properly linked up sub processes. Only with a properly functioning knowledge system can we rely on the building sector to meet the objectives which we may expect from it. The foreseen Knowledge Institution will form the focal point.

Procedural innovations are required. We need to attune the three assessment levels. The accepted standard solutions will be assessed according to the performance requirements as laid down in the second category and the question whether the performance requirements themselves meet the objectives set, is answered by means of the risk approach which we will apply in the third category.

The elements which the three levels share at a generic level: objectives, risk models, user models,

functional models and performance requirements, prepared by the Knowledge Institution and discussed with all parties concerned.
The general structure of rules and regulations as presented below, in Figure 3, has been depicted in the form of the grey triangle. This part of the structure ensures that the system remains consistent, also when objectives change or new objectives, rules or constructions are introduced. The parts relevant to applicants and assessors are represented in blue.

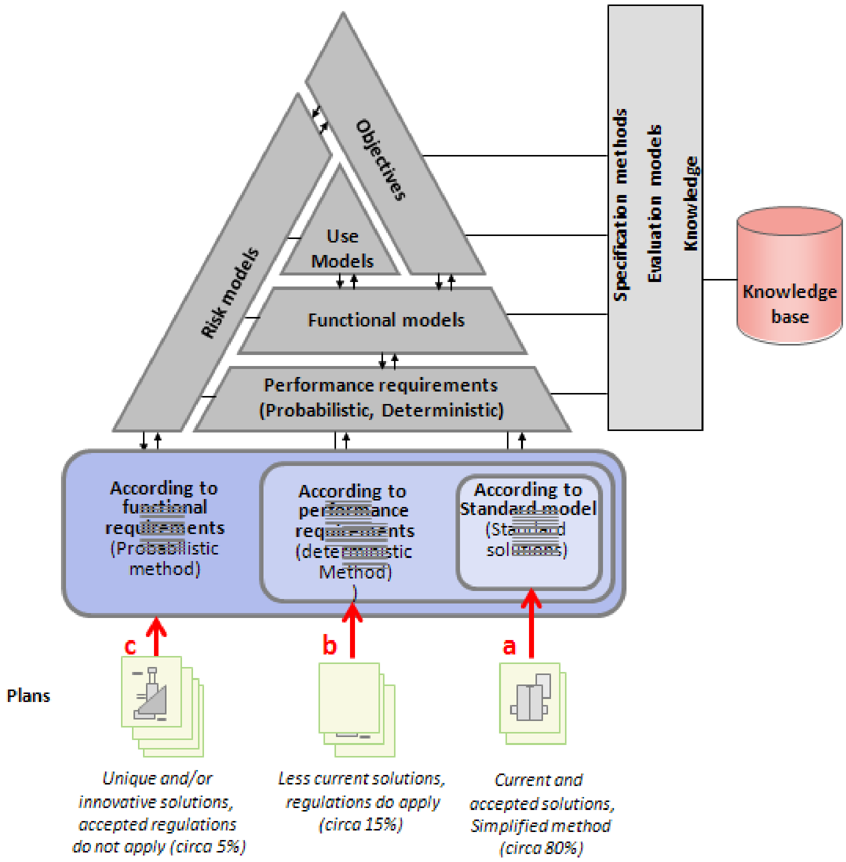


Figure 3. Presentation of the firm structure of development of building regulations (Scholten, et al. 2010)

Explanation of captions used in Figure 3

Objectives. Regulation must be the outcome of a single coherent system of objectives. These objectives are the foundation of the regulatory system and should be well defined and written down.
Risk models. Absolute guaranties for safety, health and sustainability cannot be given. Objectives always deal with *possibilities* and *risks*. They deal with the possibility of collapse, the risk of permanent physical injury or death, and the possibility of environmental damage. The present regulation often provides strictly limited values for these possibilities and risks. Does it mean that exceeding these limit values immediately results in unsafe and unhealthy situations or limited sustainability? Depending on varying circumstances or the use expected, a building may still, in an acceptable way, meet the objectives laid down.
That is why we will again have to standardize the whole system of regulations, standards and limit values according to the objectives using risk models and the theory of probability. These models must become an integral part of the regulatory system. This too would greatly simplify regulation.
User models. We can only translate objectives into specifications for buildings if we also know how these are going to be used and who their end users will be. Models are necessary because of the variation of use in practice. That is why there is a need for realistic rules and regulation based on *user models*. By projecting these user models on the model of a building, in terms of floors, working spaces and partitioning elements, we then can list functional and performance requirements.
Functional and performance requirements. Functional requirements describe the requirements of a building in a functional sense.
The performance requirements for a building and its parts depend on their function and use.
Modifiability. Naturally, the rule and regulation system reacts to ever changing opinions in the society. In the past decade, for instance, terrorism,

climate change and sustainability moved to top positions in agenda. Undoubtedly, new requirements and objectives will be added in the coming decades which cannot be foreseen for the moment. We should be able to change the rules and regulations as easily as possible, with minimum economic effects for users and real estate managers, while retaining previously acquired rights.

Knowledge. Many rules are clear-cut. But it is not always clear why certain rules exist or why others *do not*, or why specific terms are used. Often, the persons involved have stored this background knowledge in their minds, but it is not at all or hardly available to third parties. That is why this knowledge has to be publicly recorded and everybody will be able to properly interpret and apply this.

The government wishes to withdraw from markets that might just as well be left to trade and industry, as underlined in the report of the Dekker Committee *'P*rivate whenever possible, public whenever required'.

Differing from most of the other industrial sectors, the knowledge process in the building sector is highly dispersed, as has been shown earlier and depicted in Figure 2. Most of the parties only take responsibility for their own part in the process; nobody feels any overall responsibility. The chain of responsibilities is poorly organized in the building sector and the process is highly fragmented. This might be different in other countries, but it is the case in the Netherlands. We are highly dependent on the smooth cooperation of all parties. This has its advantages but also many disadvantages.

The system of regulations and standards forms an essential link in the knowledge process, so we should continue to invest in it for future development and maintenance. However, that does not happen sufficiently. In Figure 4 we have indicated several points of necessary improvements in the knowledge cycle.

The present public system of assessment against the building regulations is aimed at the granting of an "Environmental" permit in case of a construction or renovation project. But the authority will never be responsible and will never guarantee that the building fulfills the regulation. The authority does not have the duty or the capacity to check the whole building process. Many people have the false hope that the authorities will guarantee that the performances of the building will be in line with the regulations and the market wishes. Reality is that most of the buildings do not fulfill the regulations, a lot of mistakes are made and that contractors do not feel the responsibility and liability. They say „we have a permit and it is accepted by the authorities".

The owner of real estate is responsible that the building will be in line with the regulation. The authorities should issue penalties in case of non compliance. But the authorities do not have the manpower and the knowledge to do so. In reality we do not know whether buildings comply or not. The owner does not know what the performance of his real estate is, nor the requirements. When transferring to a new owner or tenant no one knows what quality is sold or rented.

To break through this false chain we propose the following:

1) Technical assessment of the construction project will no longer be necessary beforehand, but just before occupation of a building it should be clearly stated and documented by a recognized, independent body, that it meets the regulation; if not, the use of the building will be forbidden; in the environmental permit this clause will be standard implemented. How much documentation is necessary depends on the level of regulation that is applicable (simplified solutions, performance based clauses or probabilistic methods).
2) The regulation for the existing buildings will be based on the Civil Law so that liabilities are clear and people can submit objections and complaints at the Civil Court Chamber; experts of the Knowledge Institution can advise the Court on the technical content.
3) When transferring real estate (sale or rental; conveyance) a guaranteed documentation of actual performance will be handed over for which the seller or landlord is liable;
4) All parties involved, also the normal man in the street, can complain at a new Body in case of unsafe or unhealthy building in the neighborhood.

By changing the system in this way and by changing the content of the building regulations and the process to develop and maintain the regulations as mentioned before, self regulation of the marked will become possible and a knowledge push will take place. All parties concerned will probably take insurance so they can bear their responsibilities and liability. Not the law dictates the duty to insure, but the market system will realize that by itself. That also will strengthen the quality chain. This innovated system will give an upward impulse to realize real performances to the level that the market expects. This system will only function when the knowledge chain is closed.

The implementation will create new functions. Acknowledgement should be organized for independent technical-legal arbitration, so that for parties that have a conflict on technical points, the dispute can quickly be settled on technical-legal arguments. The formal road of objection and appeal according to the General Administrative Law is much too cumbersome for this and can be evaded.

Furthermore, knowledge should be easier accessible and actively promoted through training, publication, the Internet and knowledge systems, thus transferred to professionals in the building chain as well as to the law enforcement organizations.

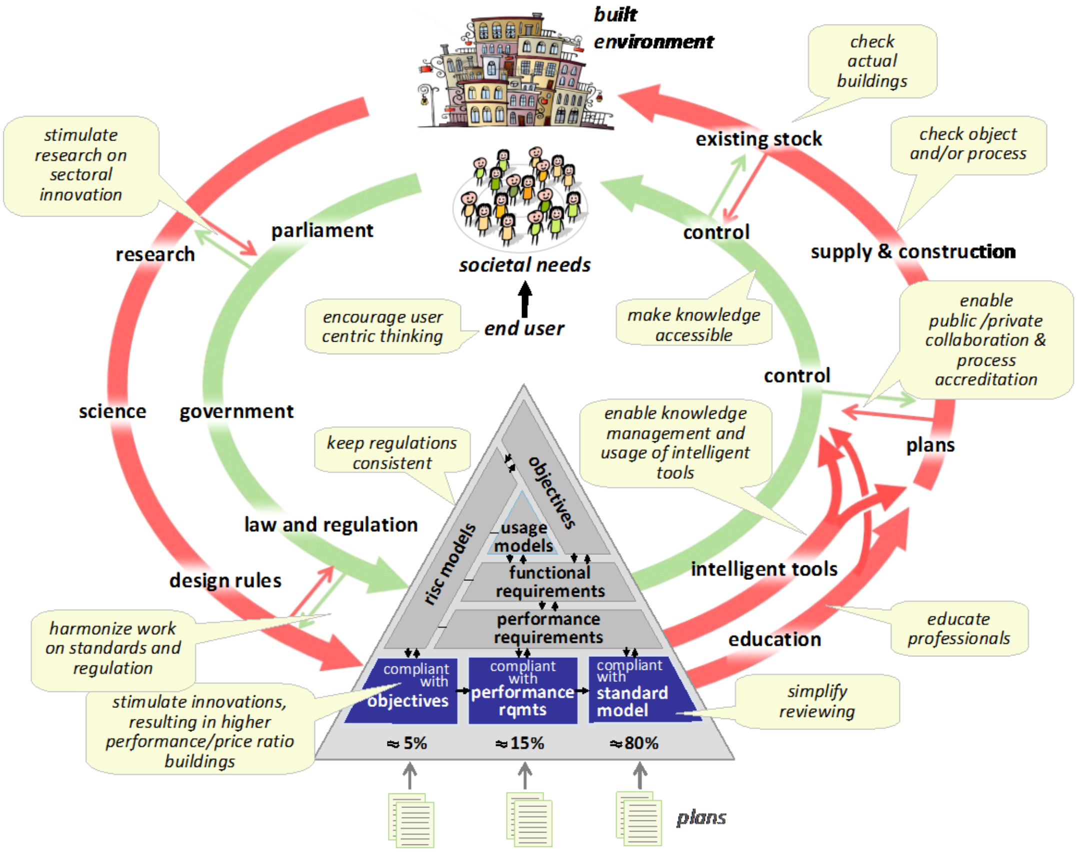


Figure 4. Vision on future development of building regulations in closed and linked public and private law chains of knowledge (Scholten, et al. 2010)

Moreover, emphasis could shift from design to process assessment, and possibly to process certification. That is to cover the complete process from design to the building process, including quality management and guarantee after acceptance/completion. This quality related thinking (ISO 9001) has been accepted in many sectors of industry, but what would this mean for the structurally so fragmented building sector? The ultimate test in quality related thinking is customer satisfaction, but as already stated, the actual customer, the end user, generally, takes no part in the Dutch building process, except the scarce homebuilding principal. Besides, designers, contractors, suppliers, and authorities have shared responsibilities: nobody feels accountable for the whole process. Although, integrated contracts are becoming more popular - partly as a consequence of the need of integral accountability - they still only constitute a small part of the present market of construction and refurbishment.

With a coherent approach also methodical improvements can be implemented and monitored leading to a more consistent practice that, by means of reference, can become a part of the same chain of knowledge.

ECONOMIC AND SOCIETAL RELEVANCE

Structured regulation has a key role in translation of the essential needs regarding the built environment. As we are all regular users of that built environment, whether it be living, working, recreating or travelling, that regulation is essential for our society.

However, everything has its price. When we look specifically at the development, learning, applying, enforcing and implementation of the rules and regulations – which we have symbolically represented with the two knowledge circles in Figures 2 and 4 – then this refers to a process which involves thousands of specialists on a daily basis. There are no exact figures on this commitment of people and costs.

The construction, management and maintenance of real estate involve substantial amounts of money. Some expenses directly contribute to the quality of the built environment; other expenses are needed solely to apply regulations, so at the best they contribute indirectly to the safety, health and sustainability of buildings. The latter expenses ERB estimates for a big part unnecessary.

Moreover, costs arise when a design or existing work does not meet the regulation, because the applicant simply knows them insufficiently and the regulation is not enforced. At present, enforcement takes place mainly by means of random checks based building plans on paper. Enforcement should take place much more on the basis of buildings actually constructed, specifically with a view to the real risks for which this regulation has been written.

In the ERB study report it is demonstrated in a conservative estimation that by implementing the proposals every year more than € 1 billion can be saved on a turnover of € 20 billion. Other benefits will be:

5) Better and more understandable building regulations;
6) A very simplified process to get the environmental permit;
7) Better environmental performance ;
8) Less disputes;
9) More satisfied people in relation to the quality of buildings.

THE STEPS TO TAKE

The ERB report 'After Dekker' describes actions to be taken to innovate the building regulations and the building assessment system. First of all the parties concerned have to sign a covenant that outlines their intentions, their duties and their rights. The government has to provide the starting capital to finance the creation of the independent Knowledge Institution and the first steps of the renewal of the system of building regulations (stating the objectives). Also the government has to decide the necessary changes in the laws and the moment that the environmental permit system will no longer need the technical assessment of a building plan, but instead the owner and contractor will have to declare the performance at the occupation moment.

When those decisions will be taken, all other improvements will follow as the logical outcome of the new structure. All parties involved can finance yearly the Institution from their savings every year, estimated at least the € 1 billion predicted efficiency improvement.

At the moment the Parliament is in discussion with the Ministry about the future of the building regulations and the innovation that is needed. The reports of Actal, EIB and ERB are therefore the starting point. The need is higher because of the political discussion about the limited quality of the Building Decree 2012.

ACTAL AND EIB-STUDIES

The Actal study is complete in line with the ideas of the ERB-study. The differences are that the ERB-study is comprehensive, both in regulation steps as well as in process steps, with an activity plan, time schedule and cost reduction estimation. The Actal study only gives suggestions without further motivations and conclusions.

The predominantly monetary EIB study calculates costs and benefits of rules and regulations. They focus on rules and regulations that they define as unnecessary, because they are not cost effective. The study sees balconies and sheds as unnecessary: houses are cheaper without. The same applies to high standards for energy saving. The calculation of the savings of money is too high: it is not related to the effects in reality (e.g, 10% less balconies, because the majority of houses still get them) but takes the costs of all balconies because they are not longer an obligation. For other aspects they argue that the rules are not effective and thus unnecessary (the measurements of staircases). We think this is an argument for better regulation, not doing without. In total the study counts to 0,5 billion cheaper construction without these rules, which is only theoretical and highly overstated.

INTERNATIONAL EXPERIENCES

In a lot of countries discussions are ongoing about the system of building regulations, deregulation, and the position of the parties in the building process, and to attain building of adequate quality faced by the end users.

In Sweden the system of only private certification to the building regulation is deserted. Sweden had bad experiences regarding the quality that was built. And as a result of that the Swedish Parliament changed the Planning and Building Act in May 2011 (Stig, 2012). The major changes are about the construction process with reinforced inspection and construction supervision.

The new construction process involves the introduction of both - new elements and rules that are extended and clarified. New stages of the process are the start permit, site visits and final consultation and the use permit for the building to be used. The content in the technical consultation and the inspection plan requirements are clarified.

Building regulatory systems in Iceland are enacted to protect the interest of the general public and are run by the government – central, provincial, state or municipal, depending on the structure of a country government and the authority of particular levels of the government. In Iceland, there are only two levels of government; central and municipal. The central government makes policy decisions and is in charge of developing the legislation and building regulations and the municipalities, through their building officials, enforce, to a great extent, the building regulations. A new law on construction was developed, introducing mayor change. The new law was finally passed by the Parliament in 2010 and a

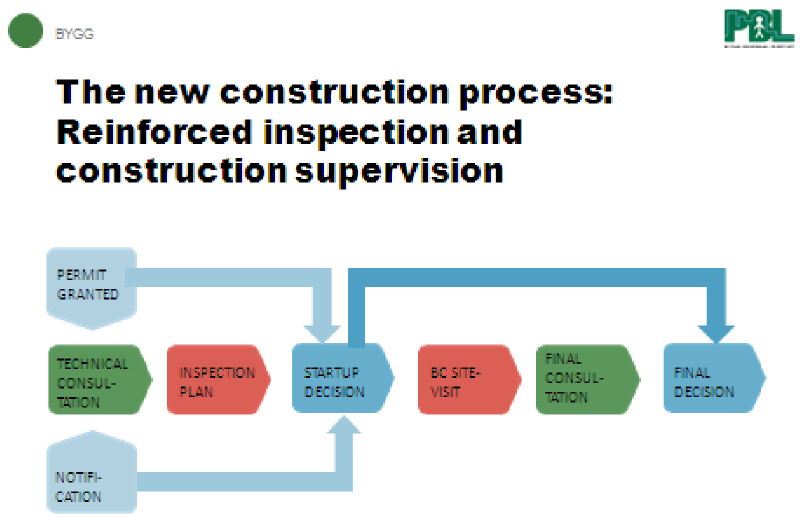


Figure 5. The new construction process involves reinforced control and construction supervision

new government body, the Iceland Construction Authority (ICA) was formed. The ICA is responsible for overseeing laws, regulations and rules in regard to building regulations, fire safety and electrical safety. (Karlsson and Tomasson, 2012)

According to the new Law on Construction, all designers, construction managers and master builders must be certified and have a quality assurance system as from the year 2015. The ICA is also to produce Inspection Manuals and all official control of building plans and construction works that are to be inspected according to these. The manuals must be developed in a wide range of building regulatory fields, such as stability, fire safety, energy efficiency, universal access, health and noise, to name some fields. By the year 2018 all inspectors must be certified and inspections must be carried out by accredited inspection firms or an accredited municipal building authority.

This regulatory method has been quite successfully implemented in a number of fields, such as automobile safety, ship safety and electrical safety, to name a few inspection regimes overseen by the authorities. However, it must be seen as a considerable challenge to attempt such an implementation in the area of construction, since buildings are usually not mass produced and each building is a unique production.

In Australia problems arise with private building control and innovative techniques (Chateau, 20012). Fire Safety Engineering and Science continues to evolve and afford benefits to society, however, given ambiguity of performance based approval processes and a competitive market, the regulatory framework and its operational structure must be robust and sufficient to mitigate the risks associated with the failure in full or part of both reform initiatives. Knowledge problems rose because privatized certifiers do not have the skill to judge fire safety engineering solutions.

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PROBABILISM, THE WAY OUT FOR PERFORMANCE BASED BUILDING REGULATIONS

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ABSTRACT

Performance based regulations emerge increasingly. The actual situation in the Netherlands is described. We observe from our consultancy experience permanent obstruction of innovation and prescription of well known solutions because of a lack of understanding by local authorities. Bureaucracy and disasters force opponents and politicians to blame the complicated and scientific nature of modern democratic performance regulations. Political emphasis on reduction of the body of (technical) regulations however is counterproductive. Expert opinion is that a decrease of regulatory-burden is possible by improving regulatory methodology. Meanwhile, probabilistic thinking is developing. We cannot live nor build without the risk of failure. The acceptance level of risk should be a political decision. Knowledge and understanding of building regulations should increase and be fostered by improving education. Eurocodes show quite some advance; "tight rope" calculations can be made. Application of probabilistic methods in other areas than structural design is still in its infancy or research stage. New regulations of emissions to ground, air and water have to be developed by reason of a sustainable world, but may not hinder re-use of building products. The content of a building product is not important, but the risk that dangerous emissions will damage the environment. By applying performance based principles, using probabilistic methods adequately, we could really advance. Management by incident by issuing new regulations based on one accident is unholy. When disaster strikes, politicians and the regulators usually create a new host of rules to prevent recurrence. Acceptance of effects based probabilistic judgement should be the issue. Poor regulations, conflicts in practice, huge administrative burden and quite some destruction of capital are observed in building practise. Based on our experience we see blockades for the application of innovative technical and organisational solutions, and the use of unsatisfactory solutions that only can be put to level only at great cost. Owner/user orientation ensures acceptance and proper application. Research and education should aim at tools to manage probabilistics in the building industry and assessment procedures.

Keywords: probabilism, performance, regulations

DUTCH SITUATION

The building industry, which provides 9-12 % of the GNP of the Netherlands, does not have any self-guiding capacity. The market is split into a large number of sub-markets, each with its own role and dependent of the other. The building sector has no driving force capable of providing private guidance to ensure that the public is served with a built environment that is safe, healthy, useful, energy efficient and durable. The customer has almost no voice in this: the building owner or user has no choice and few possibilities to influence the quality of the product he is provided with. Mainly because there is a scarcity of buildings, particularly houses, lack of money and only limited possibilities to lend money because of the crises so that the customer is forced to accept what is offered. Architects and builders are unable to match their offer to the demand and certainly not to future demand. In such a situation building regulations play a vital role. Ensuring that publicly required, Figure 1 shows schematically the interfaces that building regulations have in the process of safeguarding the public interest. The inner circle describes the public world. The outer circle - the private market from the research in building owners. Building regulations is a part of this world. The satisfaction of the built environment and the public interest should be the driving factors of the whole system. It should be born in mind that in Holland the owner is responsible for fulfilling the regulations. After 1995 fundamental research[1] on building regulations stopped[2]. Technical building regulations have not been part of university and vocational training curricula for more than 20 years. In October 1992 new building legislation in the Netherlands was introduced in the form of the revised Housing Act (Woningwet), the Building Decree (Bouwbesluit) and related technical documents.

1 Research about scientific content en way of expression of regulations, standards e.g.

2 In the PhD-study "De juridische en technische grondslagen van de bouwregelgeving – Woningwet en Bouwbesluit", May 2001, TUD, N.P.M. Scholten, Msc a complete overview of all studies is given.

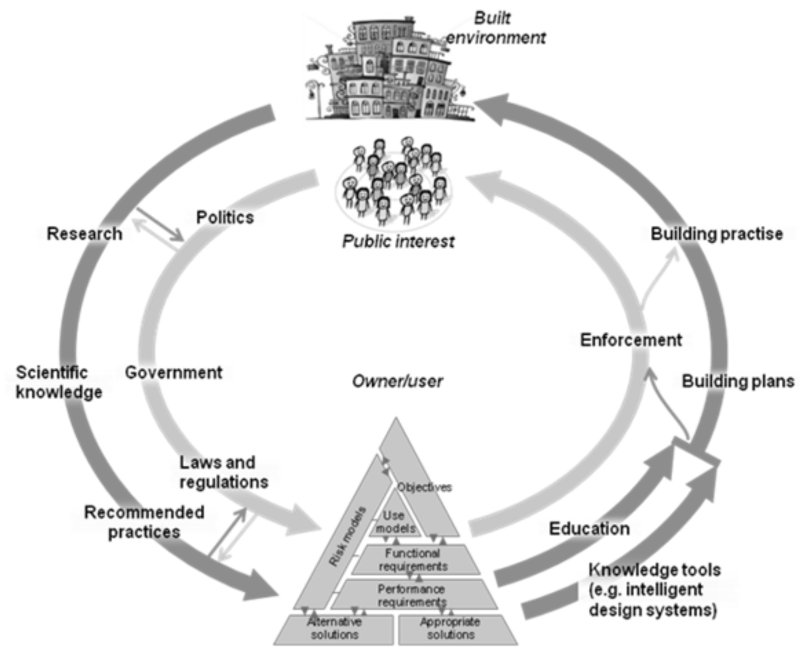

Figure 1. Building regulations and the public interest

Figure 2 shows the relation between the documents under the new legislation. Next to complying with these technical requirements local authority by-laws must also be satisfied. However, these are not technical. From November 2008 the requirements on fire safe use of buildings have been transferred to national level in the new legislation in the Decree on fire safe use of structures (Gebruiksbesluit).

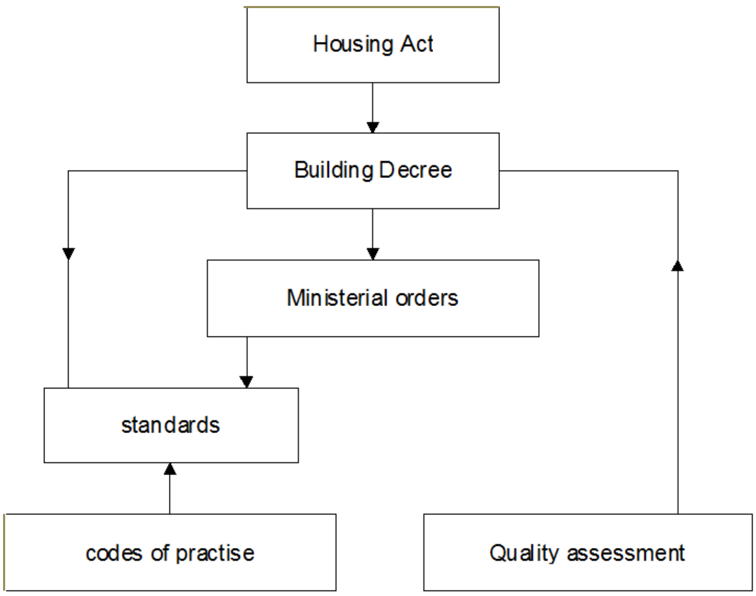

Figure 2. Relations between the documents

In April 2012 a following huge deregulation operation was implemented, the Building Decree 2012. A mixture of the Building Decree 2003, the Decree on fire safe use of buildings, the Decree of building tunnels, all requirements of building bylaws and implementation of European directives. But deregulation caused 25% of the requirements to be skipped instead of diminishing administrative burden as wished by the public. For renovation the level of requirements was lowered drastically, mostly to the level that by not fulfilling a non-compliance penalty follows immediately.
The Building Decree, the general body of administrative regulations based on the Housing Act,

is expressed in performance requirements. The performance requirement is based on a functional statement. The statement is thought to express the intention of the performance requirement. The performance requirement consists of a limit value and a determination method. The limit value is the minimum level of performance that has to be attained. The determination method is usually a Dutch Standards Institute standard, so that (elements of) these standards are also part of the Decree.

This means that the standards in the Decree must meet specific criteria and follow the same conceptual model as used in the Decree. The standards have to be performance based and have objectives that are in line with the Decree. The standard terms and definitions have to be the same as those in the Housing Act and the Building Decree. The boundary conditions in the standards should be clear and the standards should not be in conflict with the government policy. In 1985 policy paper the conditions to be fulfilled were laid down explicitly (MVROM, 1984).

A number of large research and standardisation projects have been carried out in the Netherlands to align the standards with the Building Decree. In the period 1985-1992 the "Action plan Building Decree and standards" reformulated more than 80 standards. Between 1992 and 1995 standards were produced to be used in assessing the existing building works. In 1996 and 1997 the standards were reformulated again to get complete uniformity between the standards and the Decree. Later on Ministerial orders included only few technical clauses requiring standards. The 2012 Building Decree brought about a change in terminology and modelling and required all standards to be revised in 2001 and 2002. The standards have to be in line with the administrative Decree before a Decree can be published. The references to standards have to be correct; otherwise regulations cannot be used in practise. So, research on reformulating standards starts on a pre-Decree version.

Based on the Building Decree quality assessments (technical approvals, certificates) are thought to be an efficient way to verify that buildings and construction materials comply with the performance-based requirements. The Building Decree provides that formal quality assessments issued by accredited bodies, which are recognised by the Minister of Housing, are acceptable as sufficient proof of compliance with the requirements.

Performance requirements give building contractors and suppliers the freedom to make choices to achieve compliance. Nevertheless, there is a need for practical instructions on how to achieve compliance through using current solutions. This need is met by NPR's (Dutch Codes of Practice, Nederlandse praktijkrichtlijnen), which describe the calculated or measured performances of using current solutions. The Building Decree does not refer to these NPR's, but they have been prepared on the basis of the standards referred to in the Decree. Only a few NPR's have been prepared.

In the period from 1992 until the end January 2012 the Building Decree has changed 31 times. Ministerial orders (in 1992 there were 5 Ministerial Orders and from 2012 only 1) have changed 38 times. A ministerial order is a document, referred to in the Building Decree that can change qua content in time.

REALITY

Introduction

The dissertation (Scholten, 2001) proposes a model to determine if the existing or still-to-be-developed regulations serve their purpose.

In practice the background to the regulatory requirements and their objectives is poorly documented in the explanatory text of the Building Decree. Documentation can be found in the Expertcentre Regulations in the Building library. This is a private initiative. Also the terminology and modelling of the building structure in the 2012 Building Decree does not align with the building industry customs. Moreover, the 2012 Building Decree is written in legal language that is barely understood[3] by professionals and normal people. Regrettably, the standards of the Dutch Standards Institute show the same shortcomings.

The determination methods described in the standards need to be target oriented and consequently they are written in scientific language. Furthermore, they must be aligned with the underlying principles of the 2012 Building Decree. For example, they must be able to accommodate flexible building plans and the principle of equal rights. In practice few people understand and correctly apply the 2012 Building Decree, Ministerial orders and associated standards. That is the experience of all teachers of courses given about parts of the regulations. Also the members of standardisation committees are not competent to formulate the content of their technical expertise in the juridical form of the regulations.

Not all the regulations are yet performance based. The Building decree still contains numerous regulations formulated in functional terms, handling those situations that are either too complex, or where insufficient knowledge exists, to specify quantifiable performance criteria. A building permit requestor or a building owner has to demonstrate that the regulations will be met and the local authority has to agree or disagree. The Court adjudicates in cases of dispute. In practice much discussion and dispute arises due to lack of clarity and precision of the Decree and limited knowledge about the content. Even where parties are in

[3] From post graduate education experience it is clear that the students do not understand the language of the regulations.

agreement, misinterpretation means that it is uncertain whether their agreement meets the regulations. The reviewing authority can have set the demands too high or has given its agreement wrongly.

Equivalent performance

The administrative burden can increase enormously if tried and tested solutions are passed over in favour of innovative new ones. The 2012 Building Decree and the Decree on fire safe use of structures allow this if proof of equivalent performance is provided. Only if this possibility is driven by common sense, unnecessary costs will be avoided. (Needless discussions in obtaining approvals, unnecessary extra work in building modifications, avoidable costs in (re)constructing buildings for which permission was incorrectly given).
The following are examples from our consultancy:

1. Is a computer controlled ventilation system acceptable that takes into account the number of people in a room at any given time but in which the ventilation levels averaged out over daily and yearly cycles are less than legislated requirements? Is this system acceptable in assessing the energy performance coefficient (epc) of a building? Can a TNO developed computer model be used for this assessment that takes into account the outside climate and the activities of the occupants (Phaff, 1992)?
2. Can the developments in high efficiency boiler technology be taken into account, by which lower exhaust temperatures are emitted when determining the risk of fire starting in a chimney exhaust pipe? How do we ensure that an incorrect boiler is not actually installed thus creating a fire hazard (ERB, 2008; ERB, 2009)?
3. Can “Tritium-Light” emergency exit signs be used instead of the approved traditional ones with their specific colours? Are the standards unknowingly and unjustifiably protecting the manufacturers of traditional signs from competition (Varkevisser, 2009)?
4. What in fact are the criteria for determining adequate emergency routes? What are the criteria for safe operations by the fire brigade? In which cases will it be necessary that the fire brigade comes into action? Can CFD calculations help in demonstrating the circumstances of safe escape or safe extinguishing? Are these calculations comparable to much simpler models such as one and two zone models? We refer then to restricted visibility length due to smoke, temperature and heat radiation, toxicity, etc. (Tonkelaar, 2009).
5. How should a structure fire resistance limits be determined, beyond which it collapses, if instead of using the standard fire curve the natural fire safety concept is used? How does the positive contribution of a sprinkler system or fire alarm affect the outcome? What are the implications for the safety which is the objective of the currently accepted performance requirements (Herpen et al., 2009)?
6. When evaluating historic buildings, can a risk-based method be used instead of simpler models based on performance requirements (Vandevelde, 2005)?
7. What to do with the existing block of flats with only one entrance and escape route exceeding 1500 m² floor area for living? Rebuilt them totally or do we accept by FSE simple techniques to improve the fire-safety?

If probabilism were the highest level of regulations this question could be solved. The condition is however that we have the skills to use this way of thinking on both sides of the table (the market and the competent authorities).

Exemptions

A source of discussion was the competence that local authorities have in cases of complete or partial reconstruction or modification of the existing buildings, to approve lower performances than required for new buildings. The Building Decree 2012, clause 1.11, regulates local authorities’ competence and ability to do this. In the 2012 Building Decree the competence is in practise reduced to zero, but the necessary performance level to get a permit gives unsafe and unhealthy buildings. The Government expects that - market driven – always higher levels should be realised, but at a time that money is very expensive that is hope against better knowledge.
Taking into account the intentions of the regulations this is only logical when buildings are built for a very short lifetime. Standards are subject to economic constraints: for a building with a short life-span, disinvestments should be avoided. Similarly, what is the benefit of a 2.3 m high door in a new extension of an existing building if all the other doors in the building are only 2.1 m high? But buildings should be used also after renovation for many years and have to fulfil the wishes of the end-user. It is waste of money and gives negative environmental performances when buildings short after renovation have to be broken down because they do not fit the market demands. The content of the Building Decree 2012 is so poor that there is full of menace to conclude that for the whole Real Estate we will have big problems in the near future.

Education

Building regulations are not a part of the technical education curricula and this creates practical problems. The regulations should be a lot better understood at all levels in the building industry. Owners and users, architects, consultants, builders, fitters, suppliers, authorising bodies and assessors are struggling to apply the regulations correctly what is the overall experience of the leading experts in the field of building regulations leading to unnecessary discussions, unnecessary revised superfluous plans and unnecessary rejections, the cost of which is all born by the end-user.

Certifying bodies and those involved in standards meet the same problems.

The limited extra-curricular and post-doc education on the subject adversely affects also further development in the regulations.

Normally all goes well in straightforward cases. But in more complicated cases, when equivalent performance plays a role or a complex determination method is involved, or worse, when the regulations are not quantified, then everybody gets off track.

The most distressing example is the revision of the regulations in the 29th November 2009 Official Journal on safety requirements for renovations of structures that are not buildings (bridges, tunnels, etc.) (Vrouwenvelder, 2009). The safety requirements that applied to the existing buildings were considered acceptable to apply after renovation. There was no appreciation of the risks that were thereby considered acceptable. Following the advice of the Expertcentre Regulations in Building an urgent revision to the regulations was made and published (MJUS, 2010). But by the 2012 Building Decree the donkey had bumped for the second time, but now for all renovations and for all subjects.

Court cases

The situation does not improve when the legal system is used to decide disputes. The General Administrative Law Act (MJUS, 1992) seldom leads to a judgement satisfactory based on purely technical considerations. The judge reviews the procedures that have been followed. Has the local authority decision been arrived at reasonably? In few cases does technical expertise enter the discussion to allow a more substantial consideration of the issues. Frequently understanding of the background to the regulations is needed to judge if unacceptable risks are involved.

The following are examples:

1. Should the fire brigade in a three story artificially ventilated parking garage with a sprinkler installation at any time be able to search the garage and rescue victims close to the fire? An extra investment of € 70.000 for a sectional fire alarm system depends on the answer to this question. If the chance of victims and of a successful search by the fire brigade is sufficiently small then the extra investment may be considered disproportionate. Probabilistic is a tool that can help decide in such cases (Verdict Arnhem Court, 2009).
2. What should be done in the case of an empty industrial building of 12.000 m² that four squat watchers occupy from 9.00 to 17.00 (an artist using 40 m², an office of 40 m² with a computer table and chair, storage of 50 m² for 100 chairs and a furniture maker with 50 m²)? Should the four squat watchers be forced to vacate the building within 24 hours because there is a danger of fire spreading to an office building 5 m distant? In this case a risk-based approach can help find an answer. The administrator should also set this off against the risk of squatters occupying the building and of fire then breaking out (Verdict The Hague Court, 2010).
3. What is the chance of the first floor of 66 m² collapsing in a restaurant that can accommodate 75 people in a former hayloft? The floor can withstand 3,5 kN/m² while the building regulations require 5 kN/m² - but this is based on a worst-case scenario of a group of dancers in a discotheque. Here also a risk-analysis can end the discussion (Verdict Zwolle-Lelystad Court, 2009).
4. Should a care hotel located close to a gas pipeline be equipped with a 60-minute fire resistant shield if the probability of a fire occurring with a radiation impact of 22 kW/m² on the end wall is 1.10^{-6} per year? What is an acceptable level of probability at which we stop investment in further safety measures? Must we be able to withstand all the dangers that could possibly face us, whatever the cost?
5. How should various forms of panic exit devices in a large discotheque be assessed?
6. Should the doors be locked which serve under certain circumstances as emergency exits and under other circumstances as security barriers? For example when a building can be used as well partly (only one or a few rooms) or as a whole (Verdict Zutphen Court, 2009).
7. What to do with a smoke exhaust system with elements from outside Europe, so the system cannot be certified and the Local Authority does not have enough knowledge. Should in that case the premise be closed?

Only when the parties to a dispute (local authorities, fire brigades and building owners) consider their differences in terms of risks and probabilities the number of disputes will drastically reduce. This ability is present at only a few experts and they are not working for local authorities where the decisions are made.

Disasters

Incidents and accidents serve to shape regulations and determine how buildings are appraised and how the regulations are enforced. If probabilistics play a role then “management by accident” will occur much less and regulations can be far less detailed.

In the past 10 years a number of large accidents and disasters have occurred. Volendam (café fire causing 14 deaths and 180 injured), Schiphol (prison fire causing 11 deaths), near collapse of a market square above a parking garage and inadequate structural load capacity in one of the nearby apartment buildings, partial collapse of a parking garage, collapse of a series of balconies (Fig. 3), complete burn-down of the Architectural Faculty building at Delft (Fig. 4), death of three firemen in a boatyard, collapse of a theatre during construction, health complaints in a new residential district due to a faulty ventilation system.

Figure 3. Collapse of balconies in Maastrich

Figure 4. Burn-down of a faculty building in Delft

Recently the roof of the soccer stadium in Enschede and of a multi-storey building in erection in Rotterdam collapsed.

In retrospect we can ask ourselves: how could this happen and how can it be avoided? Are the regulations comprehensive enough? Is it due to inadequate education? Are lessons and experiences from the past coming across to newcomers in the building industry? The lessons we have learnt from the past are not being fed into the improved regulations. A limited number of studies are being undertaken to try to learn from the collapsed buildings and fires (Herwijnen, 2009). Until now too little has been documented, which means that the basis for a probabilistic approach to building issues is still very small.

GOVERNMENT VIEW

General

The government understands that revision of the building regulations is needed**.** Political circumstances hinder development aimed at the optimum solution**.** The government is involved only to a limited extent with the technical content of its regulations. This is a result of “lean government” and the loss of expertise in the Ministries. It is also the result of the way in which communication takes place between the government and the industry (The formal advisory body receives in practise one week before the advice is due in the crucial documents). Feedback from the industry to the government is almost non-existent. The government is mainly concerned with a number of specific political issues: how to reduce the administrative burden for the public? De-regulation is fashionable. This has led to the new Wabo (Law of generic clauses related to regulations having an impact on the environment (Wet algemene bepalingen omgevingsrecht) (MINJUS, 2008) in which all building related permits have been combined (i.e., 25 separate legal statutes from national, provincial and local government). It is now possible to present one single permit request for all permits together, which the local authority has to quickly decide upon.

However, the technical regulations on the background are unchanged and remain as unconnected to each other as they were before. As a consequence the preparations for a building project become more risky because all the preparatory work needs to be done before the submission of the request for a building permit. This can be considered as a disadvantage. The risk of a large number of legal proceedings stopping the project is however reduced. In the mind of the government and Parliament deregulation means fewer regulations. This may have undesirable consequences for the public in an industry that needs regulations to ensure that minimum levels of safety, health, usability, energy efficiency and durability and sustainability are met. Competitive market forces do not exist and therefore cannot provide what the public needs, also with regard to the future.

Government regulators could have learned more from the lessons of 2003: subsequent to the deregulation of balconies and external storage space in housing, apartments have been built without them. This has produced disadvantaged neighbourhoods where people do not want to live but have to, due to the lack of free choice. Parliamentary pressure has resulted in reintroduction of these regulations. Nevertheless, the government intends still to discard 25% of the existing regulations to diminish the volume. No research has and will be done in the consequences for the built environment and people welfare.

The objective of the course should be a reduction of *regulatory burden*. This is not the same as simply scrapping regulations. Formulating the regulations more understandable and making them less complex can achieve effectively a 25% reduction in regulatory burden.

The outcome of the current politically dominated process in the government is the following – only partly addressing the above mentioned problems:

- combining the legislation on permit requests (Wabo);
- regional pooling of knowledge for local authorities to call on as they wish; in the juridical world the Courts will believe that the regional pool advices stand for material knowledge, but without education the lack of knowledge is not solved. In reality people discuss with each other without the background knowledge of the regulations and that will give bad advice;
- regionalising the fire brigade with the same effects;
- integrating the 2003 Building Decree, local building by-laws, Decree on fire safe use of structures and technical requirements for tunnels and at the same time discarding 25% of the regulations.

The readability and complexity are not addressed, nor the education issue. The regulations will still not be tailored to the needs of their users. The knowledge and misunderstandings of the regulations are not addressed. The end-users are not centralised in the whole renovation of the content and system of the building regulations, although they pay the bill for all the unnecessary discussions that take place and all non-conformities against the regulations that happen in practise.

European influence

The Netherlands is a member of the EU and responsibilities are attached to that. National regulations should not hinder free trade and this means that the Dutch regulations should be aligned with the European standards and quality assessment systems. Multinational companies that pay little attention to legislative principles largely influence the content of these standards. This can lead to market disruption by formulating unnecessary high performances that are not in line with the goals of public regulation. The ERB equivalent performance declaration about Tritium Lights escape signs demonstrates this related to NEN-EN 1838 (ERB, 2009). The need to introduce The European Regulation for construction products (Council Directive, 1988 and 2003) forms an illustration of the disruption caused by the CPD and in the future the CPR (Regulation, 2011).

Introduction of the Eurocodes in the Netherlands will not help reduce the regulatory burden. On the contrary, it will increase because the Eurocodes are ambiguous and a mix of technical, legal and administrative provisions. Consultation needs and discussion with the competent authorities will increase and the cost of all this will be for the owner/consumer. These negative local effects for the Dutch national market are accepted because of the possibility to freely operate in the whole EU in the advisory practise. That was the outcome of the discussion between the responsible Minister and the Parliament and can be read in the Parliament documentation and the documentation of the mirror standardisation committee 351 001 “TGB-Plenair” and the working group “Implementation Eurocodes”, 351 001 00 01.

Europe is also working on standards for durability and sustainability as part of implementation of the CPD (Council Directive, 1988 and 2003) and CPR (Regulation, 2011). Environmental regulations are aimed at pollution of air, water and ground. Regulations based on the content of materials frustrate material recycling and so cause unnecessary environmental pollution. Influential European member states do not seem to understand this. Instead of putting society interests up front fear of the unknown is creating excessive environmental demands; if something is not included in a product it cannot cause any harm. This way of thinking kills innovation and consequently also the environment. Where do we put all our building rubbish if we cannot recycle it? In the documentation of CEN TC 351 'Sustainability of construction works” documentation about the tough discussions can be found.

THREE RECOMMENDATIONS

Three important Dutch publications have been made concerning rethinking building regulations:

1. The Dekker committee report (Dekker Committee, 2008).
2. The Mans committee report on improving enforcement (Mans Committee, 2008).
3. The report of the Expertcentre Regulations in Building (ERB, 2009).

The Dekker report makes a number of recommendations of which the Minister of MIA is not convinced. In particular, the recommendation to privatise a part of the enforcement process (for example, discontinuing preventive checks on building structures) which would lead to informed solutions. The Dekker committee assumes a beneficial working of market forces that up to now has not proven to be the case. For decades the responsibilities for those in the industry have been clear, but the government supervision is still required to ensure that the public interest is safeguarded. This report will not suddenly change this. A situation where new buildings would have to be closed immediately, because a repressive enforcement system revealed that the building regulations had not been followed, will not be acceptable and will raise political problems. That would be a waste far exceeding the cost of the present system. Authorities will not have the courage to enforce break down completely recent works.

The Mans committee concludes that most local authorities are too small to upkeep their knowledge adequate and up-to-date. Yet, we have to accept local authority autonomy. Pooling knowledge is now actively being pursued, but for the local authorities still voluntary to consult. This is a desirable objective also in the field of building regulations.

The Expertcentre report puts the user centre stage. Regulations should be tailored to the users' needs, because the user/owner is in the end responsible for fulfilling the Law. This requires a quite radical and comprehensive re-write of the regulations. Knowledge expansion and integration of regulations in technical education curricula is indispensible. The most urgent priority is to document why the regulations exist and what their objectives are. Also the permit system should be changed radically. No permit for an administrative building plan at the start of a project, but an independent demonstration to the local authority by full documentation of the whole building process that all governmental requirements are fulfilled just before the moment the (renovated) building will be used. The permit to use will be blocked when the documentation is unconvincing. The full responsibility lies by the owner, who will deposit the liability full to the contractor. The documentation should be topical at every moment in the lifetime of a building, also in the case by selling or renting a building. By that system the involved parties cannot hide themselves and a quality push will take place to the benefit of the end-user.

THE WAY OUT IS PROBABILISM

To solve the various dilemmas as sketched above, the actual regulations should, according to the opinion of the ERB-experts, be developed in three levels once the objectives are properly stated. Objectives that satisfy the just needs of the owners and users. Detailed into use and risk models the regulatory provisions should be divided in probabilistic, deterministic and deemed to satisfy sets.

The top of Figure 5 is thus representing the objectives in un-quantified terms. These can be translated in functional requirements to be fulfilled.

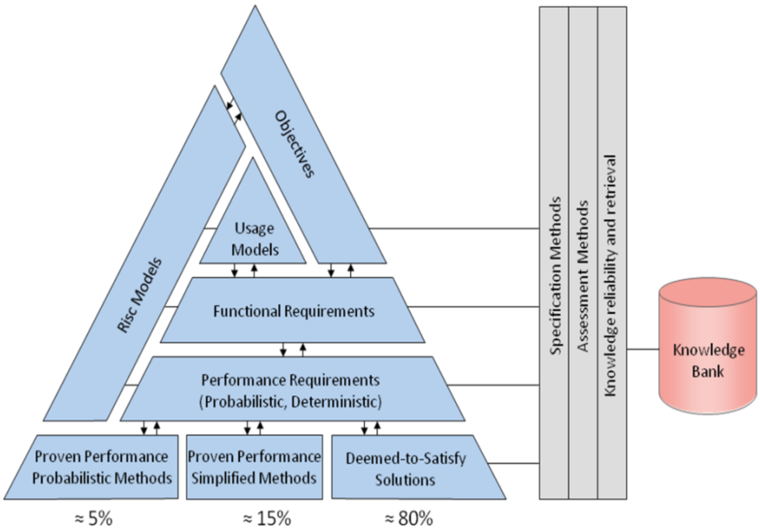

Figure 5. Structure of the future building regulations

The highest level of performances should be given in a probabilistic way by formulating the acceptable risk level in the clauses of the regulation.

Structural safety is already covered in that way by the standard NEN-EN 1990 (NEN-EN, 1990) by reliability-indices. Acceptable models already exist covering a number of other subjects (see summaries of the research of TNO for different products and publications of ERB (Scholten, 2009; ERB, 2009). For others research is necessary to develop appropriate models, the basis for which is the risk = probability * effect. The regulations have to specify the acceptable risk of not achieving the objective. The details will depend heavily on statistics. One expects that at approximately 5% of the building projects or 5% of the disputes about the existing buildings will involve this kind of regulation. For 80% of the building projects and the existing stock we have to document how plans or existing works can be reviewed in the most straightforward way (deemed to satisfy) in deciding whether or not they meet the regulations. For the remaining 15% of the building projects and the remaining part of the existing stock, regulations will need to be simplified performance based (the middle between probabilistic and deemed to satisfy). Regulatory solutions are not readily available. So, an opportunity must be created and resources made available.

RESEARCH PROGRAMME

Referring to Figure 1, the ideal regulatory framework needs the feedback loop to be closed and a body of knowledge to be built up. The backlog in documenting the background must be quickly resolved into a memory data bank or else too much experience and knowledge will be lost, since the existing regulators are dying out. A new dedicated research programme is needed for this, providing the cradle for future oriented knowledge as well as for breeding of a new generation of regulators.

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EUROCODES AND STRUCTURAL SAFETY OF THE EXISTING BUILDINGS – CONSIDERING THE PUBLICATION OF THE DUTCH NEN 8700

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ABSTRACT

Since 1992 there have been a number of proposals to renew calculation methods available to assess the structural safety of the existing buildings. But without operational results.
Upon publication of the Eurocodes NL decided to renew and to include them in the Dutch building regulations. The question was how.
It was decided to develop a new Dutch national standard: NEN 8700. That shows how, in conjunction with the 58 Eurocodes, an expert opinion can be assessed on the structural safety of an existing building.
The Building Decree 2012 refers to this standard for load actions that have to be taken into account, the response of the structure and the required strength of structure, and references to the Eurocodes. The set up of the new standard is explained.
A building is classified as an existing building after it has been completed.
So the standard applies to all building stock, but the owner primarily must ensure that during the design working lifespan the legally required performance for newly built buildings remains satisfied except accidents.
The safety assessment of an existing building differs from that of a new one in ways that are elaborated:

- *cost in relation to safety;*
- *safety in relation to the reference period;*
- *availability of the actual status data versus the design data.*

Unlike the regulations that apply to new buildings the new standard includes for the judgement of the lower limit of safety of the existing structures (the moment that the use immediately has to cease):

- *probability theory;*
- *harmonisation of the Eurocodes with safety of the existing building constructions on an arbitrary moment;*
- *acknowledgement of durable safety requirements other than a 1 year period;*
- *exclusion of requirements pertaining to the uncertainties that may arise during the theoretical design life;*
- *amendment of determination methods for the properties of the structural materials used;*
- *ability to review at any time the actual constructed situation.*

The new standard also establishes the lowest limits of safety levels in the renovation, alteration or enlargement of an existing building.
Reliability and load factors are summarized extracted from the underlying TNO report.

Keywords: safety assessment, regulation, existing building, renovation, standard, Eurocodes, NEN 8700

INTRODUCTION

On October 1, 1992 the Building Decree came into force together with some 6 Ministerial Orders. As from that moment quantifiable calculation methods became available to assess the structural safety of the existing buildings as laid down in the Building Decree and later the Building Decree of 2003 and the Building Decree 2012.
These calculation methods were based on the well-known Dutch TGB standards series together with the more detailed regulations in the Ministerial Order on structural and user safety. This Order has been legally and administratively simplified a number of times but the content is unchanged till April 1, 2012. This Order was originally based on the TNO Building Research report B-91-832. After April 1, 2012 reference is made to the Eurocodes.
There have been a number of standardisation proposals since to publish a separate TGB series to deal with the existing buildings, but this has not come to anything.
The above-mentioned TNO report was issued in 2004 and published as TNO B&O report 2004-CI-R0159.
After the publication of the Eurocodes and the decision to include them in the Dutch building regulations (following the introduction of the third

issue of the Building Decree in 2003) the question arose of what to do about the regulations concerning the structural safety of the existing buildings. The choice was not difficult because making 58 standards to cover the existing buildings or alternatively making 58 sets of follow-up regulations to cover the existing buildings in the 58 Eurocodes was not an option. The choice was made to develop a new Dutch standard: NEN 8700. This standard shows how, in conjunction with the 58 Eurocodes, an opinion can be arrived at on the structural safety of an existing building.
The following research questions are solved for the Dutch situation:

1. What are the differences between the public requirements for structural safety between newly built buildings and existing buildings?
2. What are the backgrounds of the safety philosophy to motivate these differences and how can the assessment of the safety of the existing buildings be used in practice?
3. What are the logical structural safety requirements by renovation of the structure of the existing buildings?

In a national or international perspective the research can be placed as following:
New Eurocodes for the assessment of newly built buildings are introduced in the European Union. In the Dutch building regulations also requirements are given for the minimum performance of the existing buildings. So the existing regulations have to be changed to bring them in line with the 58 Eurocodes parts. In 2010 the Eurocodes will be compulsory. At that moment also the requirements for existing buildings and renovation should be available.
Within the EU discussion is opened to develop also Eurocodes for the existing buildings. The Dutch NEN 8700 and background report can be a good starting point.
The main conclusions and recommendations of the project are:

a) The safety philosophy of newly built buildings can also be used for existing buildings and renovation.
b) The reliability-index can be decreased for the assessment of the existing buildings and for buildings in renovation, because economical aspects have to be dealt with in another way than by newly built buildings. Because of another reference period the actions can be decreased. Also durability aspects are not the same. The way safety figures of the structure itself may be used gives also a different assessment.
c) The study and standards provide a direction how to judge in a practical way whether the minimum safety requirements are fulfilled.

THE STRUCTURE

The intention is that the Building Decree 2003 will refer to NEN 8700 for load actions that have to be taken in account, the response of the structure and the required strength of the structure. The new standard will make reference to the Eurocodes.
Purpose of the standard
The standard applies to all existing buildings, regardless of their age. A building is classified as an existing building after it has been completed.
The owner of the building must ensure that during the reference period the legally required standards are or remain satisfied other than caused by an accident. The legally required standards are the safety standards required by legislation at the time of construction, unless a building permit as defined in the article 40 of the Housing Act has expressly permitted a lower standard (for example, in the case of renovation) or if knowingly or unknowingly an incorrect building construction is approved. The legal regulations that determine new structural safety standards apply to the entire reference period, which is defined as the design working life of the building.
If the legally required safety level at the moment of erection is not met, then the article 13 of the Housing Act may on request of the Authority require the building owner to modify the building construction. Whether this is invoked depends amongst others like on the timing of the infringement in relation to the remaining service life of the building. The Municipal authorities have the discretion to accept a certain degree of deviation from the regulations.
A separate issue is the private relationship between contractual parties. If a contractual agreement has not been met then the disadvantaged party has the right to a civil law process and the other party is liable for not fulfilling the contractual obligations.

MAIN CONTENTS

The safety assessment of an existing building differs from that of a new one in a number of essential ways:

- Firstly, increased safety levels usually involve more costs for an existing building than for buildings that are still in the design phase. The safety provisions embodied in safety standards have to be set off against the cost of providing them, and on this basis these costs are more difficult to justify for the existing buildings. For this reason in certain circumstances a lower safety level is acceptable.
- Secondly, the remaining lifetime of an existing building is often different than the standard reference period of 50 years or 15 years that applies to new buildings. This aspect plays an important role in determining if the building construction is still adequately safe.

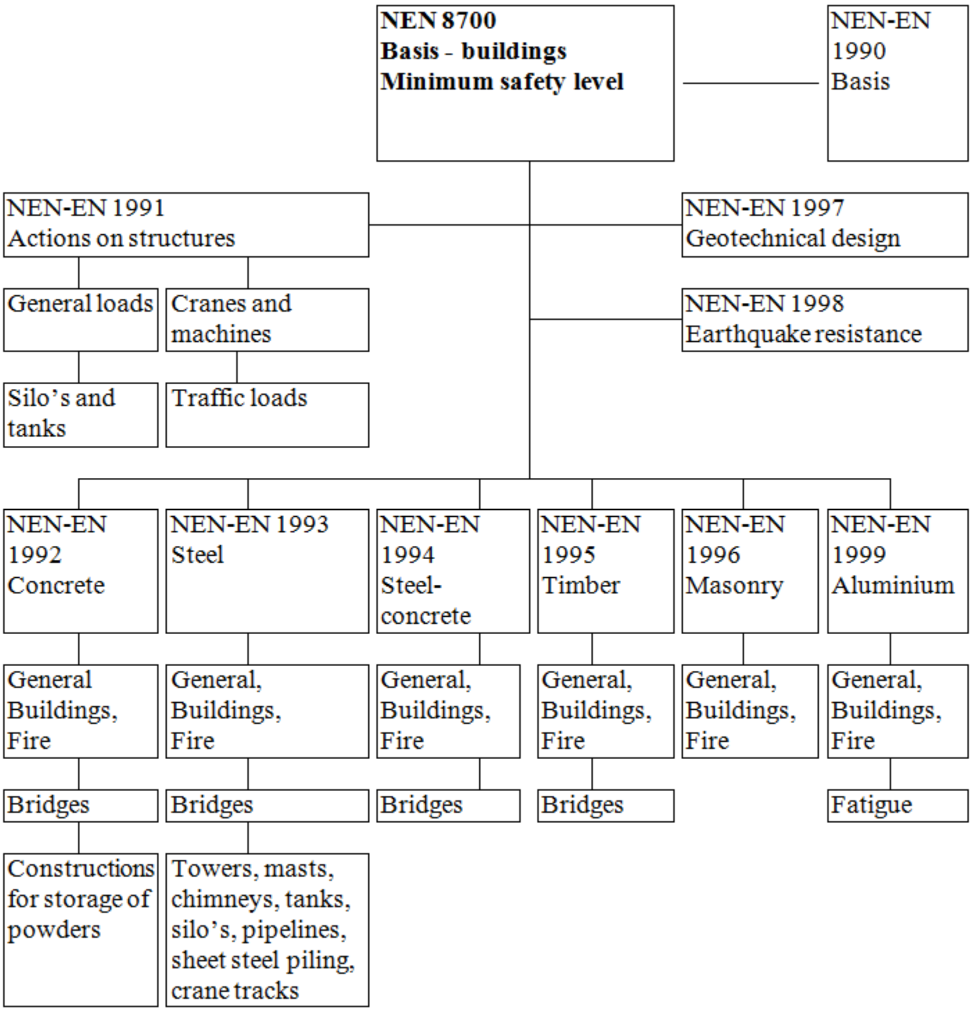


Figure 1. Overview of the standard structure

Table 1

Minimum values for the reliability index β with a minimum reference period (extreme limit) of 15 years for CC1B

Consequence class	Minimum Reference period for existing building	New construction[c] β_n		Repare[d] β_r		Summon[e] β_b	
		wn	wd	wn	wd	wn	wd
1A[b]	1 year	3.3	2,3	2,8	1.8	1.8	0.8
1B[b]	15 years	3.3	2,3	2,8	1.8[a]	1.8[a]	1.1[a]
2	15 years	3.8	2.8	3.3	2,5[a]	2,5[a]	2.5[a]
3	15 years	4.3	3.8	3.8	3.3[a]	3.3[a]	3.3[a]

wn: wind not dominant
wd: wind dominant
[a] In this case the minimum limit for personal safety is normative.
[b] In this case a distinction is made between class 1A (loss of life unacceptable) and 1B (danger of loss of life is small).
[c] For reference period and service life NEN-EN 1990 applies.
[d] For reference period and service life local authority discretion (≥ 15 years) applies
[e] With a remaining lifetime of 1 year.

- Thirdly, in an existing building actual measurement can be made in order to gather the facts.

More information on these aspects and their influence in determining the reliability levels chosen in the standard is contained in a report produced by TNO and the Expertcenter Regulations in Building: TNO-Report 2008-D-R0015/B.

Unlike the regulations that apply to new buildings the requirements of the new standard include:

- The regulations in NEN-EN 1990 which concern probability theory. This pays no attention to individual structural materials but is dependent on the purposes for which the building is used and pays attention to the probability of load stresses occurring over a short reference period. Herewith account is taken of known actions on the building taken place in the past and the probable properties of the building itself and not the structural properties of the building products as products in the market from which the building is made.
- Taking the opportunity to harmonise the Eurocodes with the basic principles on the safety of the existing building constructions on an arbitrary moment. The safety assessment assumes a remaining lifetime of 1 year. Reference periods in determining the size of the load factors are 1 year for buildings in class CC1A and 15 years for buildings in class CC1B, CC2 and CC3. This is therefore a different assumption to the durable safety requirements of a newly built construction.[4] These have in the case of permanent buildings a design lifetime and a reference period of 15 or 50/100 years dependent on the class of the building. For this reason the reliability index β and the load factor γ can be lower than those for a new construction.
- Formal acknowledgement that guarantees on the durable safety requirements need other than to cover a remaining lifetime period of 1 year.
- Excluding requirements that relate to the uncertainties that may arise during the theoretical, paper design of the building.
- Amendment of the methods to determine the properties of the structural materials used in the building; and
- The ability to review at any time the actual constructed situation (a review based on the original design may be sufficient where there are no indications that the actual situation is worse).

Because the introduction of the Eurocode standards NEN-EN 1990 up to NEN-EN 1999 represents a breakthrough in the traditional assessment methods, there is justification for further transforming the old ways of working to the way that has been adopted with the Eurocodes as described above. NEN 6720 assesses concrete on its cube compressive strength, whilst NEN-EN 1992 assesses concrete on its cylinder compressive strength. Timber has now introduced strength classes, whilst for years visual control was the method used despite the need for an objective strength assessment. These are just a few examples.

In the development of the new standard we have tried not to change the confidence levels by which building structures were declared unsafe and were upheld by legal bodies up to the time of publication of the new standard.

In the transition from the TGB 1990 standards to the Eurocodes (NEN-EN 1990 to NEN-EN 1999) the safety classes recognised in NEN 6700 have been transformed to consequence classes. This classifies buildings differently than in NEN 6700. To avoid this having unintended effects for the existing buildings the consequence class CC1 has been split into class CC1A and CC1B. Class CC1A includes buildings that according to NEN 6700 fall in safety class 1 and according to the Building Decree 2003 may be assessed using a reference period of 1 year until the time of the introduction of the new standard. In Class 1A human safety will be subsidiary.

RENOVATION

The new standard also establishes the lowest limits of safety levels in the renovation, alteration or enlargement of an existing building. These limits differ from those which apply to newly constructed buildings and which are laid down in NEN-EN 1990. Note that granting exemptions to a level of the standard that may be below an already legally sanctioned level is not the intention. By doing so the authorities would be accepting a lower standard than they had originally sanctioned. However, the authorities could well take account of the remaining lifespan of the building when granting a permit for renovation, alteration or enlargement. The remaining lifespan can be different from that of an entirely new building. Exceptional circumstances also may occur whereby exemption could be granted, for example, after the occurrence of an accident.

The standard does not contain specific rules relating to minimum safety levels for renovation, alteration or enlargement of a building whereby the remaining lifespan and therefore the reference period of the building to be renovated are taken into account. The

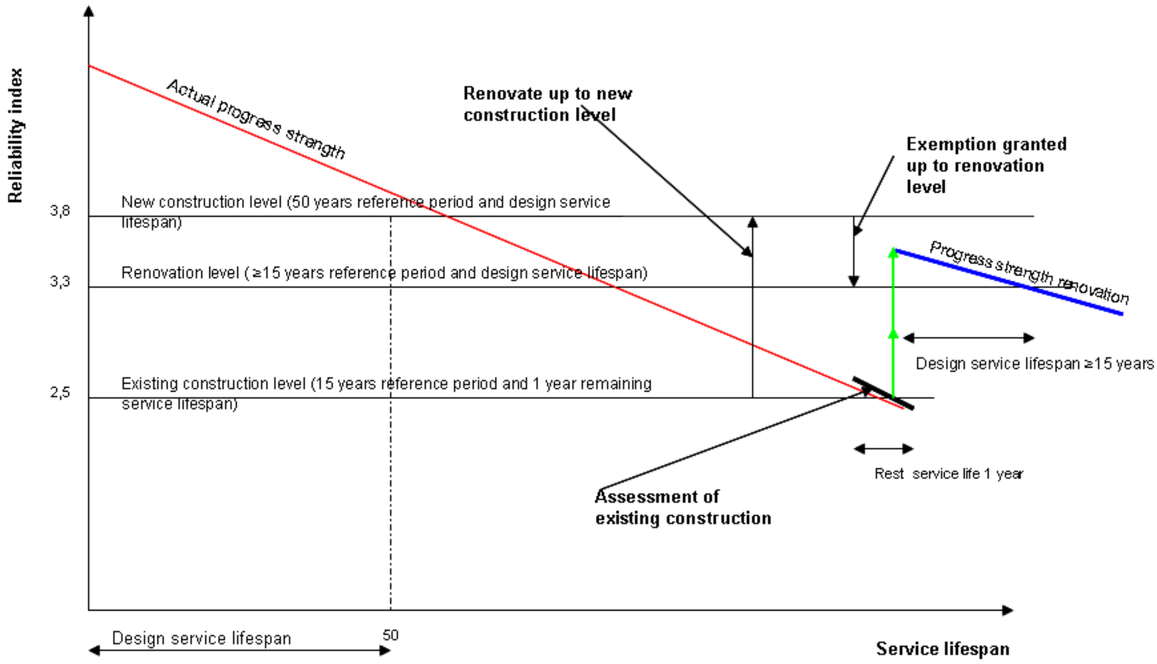
[4] The NEN 8700 and the Eurocodes make a difference between the reference period which expresses the size of the loads to be taken as basis for the calculations and the service life or remaining lifetime. The remaining lifetime is the indicator for the safety of the structure when loads are applied.

TNO report 2008-D-R0015/B does include recommendations for this.

SUMMARY ON RELIABILITY AND LOAD FACTORS

Extracted from the TNO report and applied to the different situations the reliability indices are shown in Table 1.

Figure 2 illustrates how the regulations are intended to work based on an example in consequence class 2 (with a service life of 50 years for a new construction and 15 years for renovation and in both cases the wind is not taken into account). Table 2 shows the conversion to load factors.



Strictly speaking the reliability indices relating to various lengths of service life and remaining lifetime cannot be captured in a single graph because to do this the β's should be calculated on the basis of 1 year. This has not been done.

Figure 2. Effect of the regulations on structural safety shown in terms of the required reliability of the building against time

Table 2

Overview of load factors

	NEW CONSTRUCTION					RENOVATION					EXISTING BUILDING				
	Load factors ULS, New construction (STR/GEO and extreme)					**Load factors ULS – Renovation (repair)**					**Load factors: ULS – Existing buildings**				
	Reference period is 15/50/100 years; service life is 15/50/100 years					**Reference period: dependent on the situation (≥ 15 years; service life: dependent on the situation (≥ 15 years)**					**Reference period 1 year with CC1A 1 year and with CC1B and 2 and 3 ≥ 15 years; remaining lifetime 1 year)**				
Load combination	Permanent load		Dominant variable load	Other variable load	Extreme load	Permanent load		Variable load	Wind force	Fire	Permanent load		Variable load	Wind force	Fire
	Un-favourable	Favourable				Un-favourable	Favourable				Un-favourable	Favourable			
STR/GEO (6.10a)															
Consequence class 1	1,2	0,9	1,35Ψo	1,35 Ψo	-	1,1	0,9	1.10Ψo	1,10Ψo	-	1,1	0,9	1.00Ψo	1,10Ψo	-
Consequence class 2	1,35	0,9	1,50Ψo	1,50 Ψo	-	1,3	0,9	1.30Ψo	1,30Ψo	-	1,2	0,9	1.15Ψo	1,30Ψo	-
Consequence class 3	1,5	0,9	1,65Ψo	1,65 Ψo	-	1,4	0,9	1,50Ψo	1,50Ψo	-	1,3	0,9	1,30Ψo	1,50Ψo	-
STR/GEO (6.10b)															
Consequence class 1	1,1	0,9	1,35	1,35 Ψo	-	1,1	0,9	1.10*	1,10*	-	1	0,9	1.00*	1,10*	-
Consequence class 2	1,2	0,9	1,5	1,50 Ψo	-	1,2	0,9	1.30*	1,30*	-	1,1	0,9	1.15*	1,30*	-
Consequence class 3	1,3	0,9	1,65	1,65 Ψo	-	1,3	0,9	1,50*	1,50*	-	1,2	0,9	1,30*	1,50*	-
Extreme (6.11)															
All classes	1	1	1		1	1	1	1		1	1	1	1		1

dominant" multiply by Ψo

Dependent on the reference period the following applies for variable loads: If NEN-EN 1991 has no directive, as with floor loads, then the following may apply:

$$F_t = F_{t_0}\{1+\frac{1-\psi_1}{9}\ln(\frac{t}{t_0})\}$$

Where:
is the adjusted extreme value of the variable equally spread load for the remaining lifetime;
is the extreme value of the variable equally spread load for a service life of 50 years;
is the ψ-factor value from table A1.1 in the standard;
is the service life or the remaining lifetime;
t_0 is the service life of 50 years.

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LANDSCAPE ARCHITECTURE

THE BENEFITS OF GREEN ROOFING FOR LATVIAN BUILDING ENVIRONMENT

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ABSTRACT

Green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife and helping to lower urban air temperatures and mitigate the heat island effect. The modern trend started when green roofs were developed in Germany in the 1960s, and has since spread to many countries. Today, it is estimated that about 10% of all German roofs have been "greened". Green roofs are also becoming increasingly popular in the United States, although they are not as common as in Europe; however, one sees more and more architects opting for green roofs as an alternative to large flat roofs. A green or vegetated roof is not such a traditional roof type for the Latvian building environment. Mainly because of a lot of the ideas that it harms the whole structure, problems with leaking, problems with hydro isolation, too large a weight and a lot of additional maintenance work and costs. And the greatest idea is that this roof type is totally unsuitable for local weather conditions when historically green roofs are widely used in Norway and also in Great Britain where weather conditions are much more harmful for greenery. These ideas mainly are coming from the fear to get into a situation with high risk to maintain a building with a green roof and if it is cost effective. In the present research, review is given on green roofing worldwide and Latvia, different roof systems and describes the benefits of green roof implementation.

Key words: Green roofs, extensive and intensive roofs.

INTRODUCTION

There has never been so much interest in the ecological impact of buildings as there is today. The difficulty is that green is so fashionable that everyone is jumping on the bandwagon, claiming astonishing sustainability or remarkably low-energy consumption (Jodidio, 2009). Buildings are one of the heaviest consumers of natural resources and account for a significant portion of the greenhouse gas emissions that affect climate change. One very old method to improve sustainability is to bury architecture, or to cover it with vegetation. A layer of earth serves as insulation (permits 6° reduction in internal temperatures in summer) and ultimately allows nature to return to its rightful place on a given site. The thermal benefits that green roofs provide may also have indirect benefits for people living or working within the buildings. This has not been researched, but anecdotal evidence from Germany in the late 1990s is of interest. In a survey of staff absence due to sickness at the Bundepost offices in Stuttgart, it was shown that staff in one building demonstrated significantly lower absences than those in others. The only change in the 4-year period that could be identified was that one of the buildings was given a green roof; this building supported lower staff sickness levels. It is possible that the green roof reduced the fluctuation of daily mean temperatures within the upper levels of the building, and/or the vegetation helped cool and moisturize in-going air near ventilation ducts (Fig.1.) (Livingroofs.org). Nowadays, Stuttgart is one of the "greenest" cities.

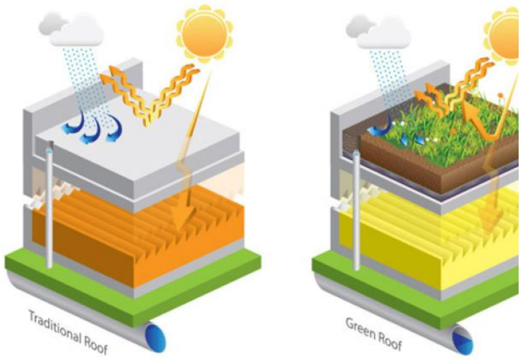

Figure. 1 Green roof versus convention roof comparison (Source: www.greenroofguidelines.co.uk)

Bringing nature into a city center provides relief from an otherwise artificial environment (Jodidio, 2009). Modern humans have a bad habit of replacing naturally occurring water-absorbent soil and plant systems with impervious surfaces as roads, parking lots and roofs (Snell, 2009).

Considering the roof space is generally underused and ugly in most cities, covering it with vegetation is good solution as from the aesthetical point of view and as from an ecological one too. Green roof technology provides an exciting and virtually endless palette of design opportunities for innovators, who can play a key role in the reinvention of miles of wasted roof space on our buildings (Cantor, 2008). Roof gardens and green roofs both belong to a type of roof that supports vegetation, which have numerous social, economic and environmental benefits and can contribute positively to issues surrounding climate change, flooding, biodiversity and declining green space in urban areas (www.thegreenroofcentre.co.uk). Green roofs cost a fraction of a roof garden and are lightweight with thin soil profiles and require minimal maintenance in comparison to roof gardens. Green roofs descended from the vernacular architecture of various centuries in all parts of the globe, whereas roof gardens are known as luxury items of the affluent since the famous hanging gardens of Babylon in ancient Mesopotamia (between 6th and 7th century B.C) (Werthmann, 2007). The Hanging Gardens have been identified as one of the seven ancient wonders of the world. They are described in written records and have been confirmed by archaeological evidence. One record states that the Hanging Gardens: consisted of vaulted terraces raised one above another, and resting upon cube-shaped pillars. These are hollow and filled with earth to allow trees of the largest size to be planted. The pillars, the vaults, and terraces are constructed of baked brick and asphalt (Design Considerations, 2009). Modern green roofs, which are made of a system of manufactured layers deliberately placed over roofs to support growing medium and vegetation, are a relatively new phenomenon. However, green roofs or sod roofs in Northern Scandinavia, Iceland, Great Britain and Canada have been around for centuries for insulation from extreme cold. For example, traditionally, such earth structures were used for partially submerged food, wine/beer cellars and bomb shelters (Ferguson, 2012). In Scandinavia, roofs were covered with sod that was stripped from surrounding grassy meadows. This was done to insulate homes. Underneath the sod are structurally heavy timber beams interspaced with birch bark to act as a waterproofing layer. Eventually, cheaper, lighter, more effective and mass-market based systems were developed to replace sod roofs (The history of green roof technology). Therefore, green roofs are not a new thing, they are an old thing that we have rediscovered. Until 1970, green roofs were regarded as luxurious home amenities. In the same year, Professor Hans Luz, a German Landscape Architect, proposed the use of green roofs as a means of improving the quality of the urban environment (The history of green roof technology). In the beginning of the twentieth century, green roofs experienced a renaissance through the modernist movement. The invention of the flat wood-cement roof was the first key point of the advancement of green roofs to inhabit a new healthy outdoor space by all levels of society (Werthmann, 2007). At the beginning wood-cement roofs in Berlin were covered with a layer of gravel and clay. Through wind seeding grass began to grow spontaneously. Roof gardens became popular on multi-storey buildings in Berlin in the late nineteenth century and continued to be constructed on large city-centre structures throughout the twentieth century (Green roof guidelines). The modern trend started when green roofs were developed in Germany in the 1960s, and has since spread to many countries. In the 19th century, in Germany Forschungsgesellschaft Landschaftsent-wicklung Landschaftsbau e.V or The Landscaping and Landscape Development Research Society E.V (FLL) were established. And in 1982 by FLL the first Guidelines were published for Green roofs, where there was included for the first time, information about effective design and planning of green roofs that included soil deepness, grading composition of soil in use, waterproofing and drainage that nowadays serve as a handbook for the correct implementation that is also adopted by other countries. Since that moment, green roof technology covered areas started growing in geometrically progression, not only in Germany, but also all over the world – in Europe, Asia (firstly in Beijing) and the USA. Green roofs are becoming increasingly popular in the United States, although they were not as common as in Europe, except in the last few years, when green roof technology was imported to the USA. Germany supposedly has the highest implementation rate of green roofs in the world, but it took thirty years of research and twenty years of proactive green roof policies to reach the current market rate of about seven percent. At the end the twentieth century, the green roof gained renewed relevance through environmentalism when its varied benefits were recognized as useful for alleviating problems of heavily urbanized areas (Werthmann, 2007). Green roof experts in the German-speaking countries already identified and labeled it as a "simple intensive roof-greening" in the 1970s. In England, the combination is called a "semi-extensive or semi-intensive green roof" (Werthmann, 2007). The terms "extensive" and "intensive" describe the grade of maintenance needed for a specific cultivation system and its degree of sustainability. Green roofs are considered extensive because they should require only a little maintenance and be self-regenerating. There are two types of green roofs defined – extensive and intensive, but in a few of the definitions as well, semi intensive – roof type between intensive and extensive can be found, and a brown roof type that excludes the preprocessing of vegetation installation (Greenroofs.com). Extensive roofs serve as an ecological covering that provides society with environmental benefits and the building owner with life cycle cost benefits. A description based on the depth of the growing medium on the green roof is: Extensive green roofs typically have a growing medium at a depth of 4 to 6 inches, which may be retrofitted onto an existing building or planned as part of a new construction (Dictionary of terms). A lightweight (0.7 – 2.4 kN/m^2), low-maintenance roof system, with limited choice of plants (often sedum because of their stability on windy, frosty and heat impacted environment, also sedum or stonecrop, comes in many varieties and colors, has very shallow roots and can absorb up to 50% of its weight in rainwater, thereby alleviating drainage problems typically associated with flat roofs) planted into a shallow substrate that is low in nutrients, with less energy efficiency and storm water retention benefits, and also unattractive to some, especially in winter (Werthmann, 2007). Intensive green roofs typically have minimal depth of growing of 15 cm. Intensive green roofs more closely resemble ground level gardens and must be engineered to support the highest level of loading (1.8 - 6.0 kN/m^2) on a building because of it thickness. Generally, the maximum depth of growing cannot be determined because of a wide diversity of applicable plants. Therefore, intensive roofs have a greater diversity of plants and habitats, can be made very attractive visually, have good insulation properties, more energy efficiency and storm water retention capability and longer membrane life. Other disadvantages besides great weight loading on the roof can be mentioned: a need for irrigation and drainage systems requiring energy, water, materials; higher capital and maintenance costs; more complex systems and expertise.

Technical shortcomings like leakage problems of the early roof gardens created an aura of suspicion and avoidance – prejudices that persist up to today.

Methods of exchanging the gravel of ballast roofs for a thin coat (three to five inches) of growing medium were tested. The low weight of the soil made structural reinforcement of the existing roofs unnecessary, thus substantially reducing cost and this minimal type of a “roof greening” provided similar environmental benefits as traditional roof gardens. The thin coating retained and cleaned rain water, cooled and humidified the surrounding air, filtered dust, reduced noise levels, insulated against heat, helping lower urban air temperatures and migrated the heat island effect, provided a habitat for flora and fauna, and prolonged the life expectancy of the roof. The lifetime of a conventional roof is about 20 years, whereas a green roof should last 40 years or longer (Getter, 2006). The technology was widely implemented as a remedy against many problems of urban density, such as frequent flooding, water and air pollution, high energy consumption and non dependence on climate issues as one might assume. For several years, until German intensive green roofing implementation, the roof-top remained a privilege of the wealthy living in historic districts, the democratic promise of the modern movement to build roof gardens for everybody has obviously failed. For example, the Rockefeller Center, built in 1937 had the concept of the Hanging Gardens, which was to give the building occupants a pleasant view of the surrounding greenery (The history of green roof technology). Since the biggest factor was the considerable additional expense of a roof garden compared to a regular roof and the reinforcement of the whole structure that has to hold the weight of the garden.

At the current moment there are 3 different types of green roof systems in use – complete systems, modular systems and precultivated vegetated blankets. Variations between them are generally found in the manner in which the growing medium and drainage layers are treated. The main difference between those types can be defined in how the growing medium and drainage layers are treated. Only several companies offer ready complete systems, but there are only a few companies around the world that work on production of high quality vegetated blankets. There are many construction companies and manufacturers established and ready with predefined technical solutions for the most commonly applicable and the most problematic nodes in green roofs. Those systems and connections are presented together as one full system. In spite of the lack of special standards, green roofs now are designed according to structural regulations. Mainly in Europe, all structural designs are in accordance with the Euro Code, starting with fire resistance, wind and snow loads and finally according to construction structural designs. The most popular guidelines are developed by Fachvereinigung Bauwerksbergrpünung e. V. (FBB) – Germany, Landscape Research, Development and Construction Society (FLL) – Germany, Green roof organization (GRO)) – UK, U.S. Green Building Council (organization that mainly works on LEED) - USA and City of Toronto Building division – USA. Those are main guidelines are widely accepted. Besides, there are a lot of different local guidelines and they are adjusted for local conditions, but mainly they have the same basis.

MATERIALS AND METHODS

Green roofs are not so popular at the moment in Latvia but within the last decade several objects had been built. like, for example, Eastern Latvian creative service centre – Zeimuls or Caran d’Ache located in Rezekne, which was built in 2012 (Fig.2) and the Shopping center Olympia (Fig.3) located in Riga, which has been open for clients since December 2002.

Figure 2. Zeimuls in Rezekne
(Source:http://www.tirailatvijai.lv/raksts/1384)

Figure 3. Green roof of the shopping centre Olympia
(Source: www.bptam.com)

Figure 4. Photo map of Kipsala, Riga in the year 2001
(Source: Rigas pilsetas dome)

Figure 5. Satellite map of Kipsala, Riga in the year 2012
(Source: www.maps.google.com)

An interesting fact is that many architectural bureaus design constructional objects with green roofs but during the construction process the project is modified and green roofs when finished don't

Figure 6. Green roof of shopping centre Olympia
(Source: photo by the authors, 2012)

appear (www.vilnitis.lv). The shopping center was built in Kipsala in a place where a little forest used to be and the green roof was a target to compensate the lack of a green cut landscape which had disappeared (Fig. 4 and 5). The concept of the project belonged to the Norwegian architects. The initial idea was to green the building where grass, flowers and trees are along the inclined driveway up till the roof; cafes and a children's playground are among the grass, flowers and trees which are situated on the top of the roof (Smilge, 2002). A nice concept taking into account that Kipsala is located in the UNESCO historical centre and the importance of the building design in this area is rather high. Later artist Andris Breze will say that the Shopping centre in Kipsala is strategic mistake; its scale is rather big for this place, which should keep its intimate character (Smilge, 2002). When the project was confirmed to be built, there was an idea that a roof with a green area will be available for access but after 10 years of existence it is not open for walking and has a warning sign for pedestrians. Passing by this building sometimes a question arises, concerning structural problems with the building itself, or the green roof is not properly designed. Nowadays, the roof has only grass on the eastern part of the roof (Fig.3) and no trees, no flowers, no cafes and children's playgrounds on the roof as it was supposed to be.

Taking into account that the Shopping center Olympia was built 10 years ago with such rare roof type for the Latvian building environment and the present condition of the roof was somewhat interesting for observation, the roof itself was easy to access for a visual survey, study for diploma work (Pastars, 2013) has been carried out and the results are shown in present paper.

RESULTS AND DISCUSSION

The eastern side of the roof (Fig.3) is greened and the roof can be classified as an intensive green roof (Fig.6). The assumption was made based on the observation about vegetation on roof (grass) and additionally a test was made to check the depth of the growing media. A test was made using a marked wooden stick with an average depth of 20 cm. Geotextile was used to hold all the vegetation in place where it should be (Fig.7.). All borderlines and junctions were separated from the growing media with a gravel strip, which protects the membrane from root impact in the places where there is the most danger of leaking if not correctly made. The gravel sides also function as drainage system which removes all excessive water to drainage system output. During the roof survey a few possible damages and incorrectly installed system were found.

Figure 7. Geotextile sticking out from gravel (Source: photo by the authors, 2012)

Figure 8. Waterproof membrane with no connection to structural element (Source: photo by the authors, 2012)

The first thing that can be seen, is the inappropriate installation of the waterproof membrane (Fig. 8), which is not glued or connected with another connection type to the structural elements (at least on exposed areas). Also in some places the waterproof membrane is lower than the vegetation or side border gravel. Another exposed thing that may not be the best solution is separation between the growing media and gravel, where for this function a wooden plank is used, that in 10 years time would be rotten and in time it would not be able to normally perform the function it was made for (Fig.9).

After a visual survey it was concluded that a green roof performs certain functions and it also is aesthetically attractive, but expensive too. But if we leave the construction as it is now and vary only

Figure 9. Wooden separation plank (Source: photo by the authors, 2012)

with roof covering materials, then the roof cover should be visually attractive, because it is exposed and you can see it also really close. It should be difficult to resist a situation if someone decides to climb up as it starts directly from ground level. It should be added that roofing material should be appropriate - it should not heat up to high temperatures. The possibility that anyone can burn any parts of body and also reduce heat coming directly from cover to the pedestrians should be excluded. Nowadays, the most popular roof type is metallic because it is cheap, lightweight, easy to install and has long life. There are many types of metallic roofing materials for different type of use for residential buildings and also for public buildings with double coating or with more layer coating. Different profiles and forms are available. But for this particular situation those materials are not good enough because of thickness and not so high scratch resistance. Another option is the usage of expensive metals, which are also thicker. For that application suitable materials are copper and stainless steel. But they are more expensive and also a little bit heavier (in that case this factor can be ignored because an intensive green roof is a few times heavier than metal sheeting roofs). But still it cannot be ignored that this covering in sunny days warms reaching high temperatures and causes discomfort for persons walking near by the roof. The same situation is in the case of usage of insulated sandwich panels. An additional value in comparison with simple roof sheeting is strength and resistance to external forces. In the category of soft roofing materials are all materials, which consist of bitumen or rubber elastic materials. Those are usually used for flat roofs to avoid flowing down on impact of the slope and heat. That covering is always used for non-accessible roofs because usually it is installed directly on insulation layer. Of course, in some cases it also may be installed on pre-made base material (OSB, LVL or other plate materials). Access usually is allowed only for service staff. The most problematic for this particular situation that roof starts on one level with ground and it means that there is a need for protective hedge and usage of this material would not be accepted by local landscape architects because of aesthetical aspects. Next roof types could be all wooden materials. Usually wood chips, thin boards or shingles treated with special materials or untreated are used as materials. This is really attractive solution and looks nice. But those materials usually are not suitable for public buildings especially with accessible roofs. Usually wooden chips, boards and shingles are used for residential buildings. The main reason for that is high price slow roofing process and usually with not so long warranty time. Now it is the main problem, because everyone would like to build as cheap as possible without any additional repair work. And as one side of this roof is at the same level with the ground this time also will be decreased and it is additional risk for owners and investors. Ceramic or concrete tiles and cement plates can be combined in one another group as an option for roofing and also for shopping center Olympia. Actually this group might be the most appropriate one. The assumption is based on the fact that those are massive materials which in the end form one solid structure with good resistance to external forces and influence of outside conditions. But still it cannot be used for accessible roof because of fragility and bad resistance to momentum impact forces due to which cracks appear, and it means that functionality is lost. Again the problem is that it starts at the same level with the ground and it is difficult to control access. Other non-traditional roofs would not be taken into account, because they are absolutely not suitable for a shopping center. Green roof installed on this particular shopping center is fully acceptable in spite of high price. But by paying this price investors and owners of this building reduced maintenance cost and service time.

CONCLUSIONS

Nowadays green roofs can be found all over the world from the cold North regions and to the hot equatorial regions. Since "green thinking" became more popular, green roofs have become more advanced and also more popular. But there is a lack of scientific data due to insufficient record-keeping and performance monitoring which prevents the costs and benefits of green roofs from being quantified and green roof technology from being adopted. In several cities green roofs are designed due to environmental benefits whereas in some other cities just due to aesthetical aspects. Lack of scientific data can be resolved through design and construction cost tracking, life cycle cost analysis, cost benefit analysis, performance monitoring and research. Lack of market acceptance of green roofs is different and people are typically resistant to changes. Green roofing is not so popular at the moment in Latvia but individual projects mentioned in present paper could encourage developers, architects and engineers to consider green roof in their new design. In summary one main problem for green roofs can be defined – high price that includes not only the cost of the project itself, but maintenance cost as well. On the other hand, there might be a few situations when the construction of green roof is the only and the best possible solution. It always depends on the situation and also on the construction solution. According to the research it definitely can be told that the system may harm the whole structure, there could be problems with leaking, problems with hydro isolation, too large weight and a lot of additional maintenance work and costs have no substantiation. If the roof construction is made at high professional level, green roof can be defined as more immune from the defined problems. All regulations pertaining to qualitative construction are also important and must be taken in account for green roofs. Another greatest fear still is that this roof type is totally unsuitable for local weather conditions. The answer to this problem is really simple. The only thing that should be taken into account is the choice of roof type and greenery that suit the preferred type and clients wishes for maintenance and visual view. Green roofs correspond to all weather conditions and areas. Technically there are only small differences between regular and well known construction, all solutions are made to provide total safety of property owners from possible problems. The companies specializing in the construction of green roofs provide all technical solutions and if the construction is made according to them, the problems of leaking, waterproofing and the like can be successfully avoided. Moreover, green roofs bring along many advantages like absorbing rainwater, providing insulation, creating a habitat for wildlife, helping lower urban air temperatures, mitigating the heat island effect, and ensuring longer service life.

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LANDSCAPING OF SIBERIAN CITIES

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ABSRACT

One of the land management tasks is an improvement of natural landscape. It is often performed by means of decorating urban areas with flowerbeds. As a rule, flowerbeds decorate squares, access roads, objects of landscaping (gardens, parks, boulevards and woodland parks). They help to regulate transport and pedestrian movement, and from ecological point of view they improve city environment. The aim of the research was to identify the most widespread and original types of flowerbeds in Siberia and to specify the most suitable flower species.

Key words: landscaping, Siberia, city, flower garden.

INTRODUCTION

Traditionally, flowerbeds are created in landscape or regular style (Downing, 2010). Landscape style flowerbeds include groups, blocks, mixed borders, solitaires (single plants), flowering lawns, alpine gardens. They are created out of perennial plants of different forms and sizes. Regular style flowerbeds include geometrical parterres, ridges, borders (Nehring, 2002). A special group is represented by modular flowerbeds which are created by using minor architectural forms and vases, containers or baskets for plants (Container Gardening). Nearly all types of flowerbeds are used in Siberian cities landscaping. As a rule, the central part of the city, where administrative buildings are situated, is decorated with parterres that comprise an assembly of flowerbeds, ridges or borders. Usually, annual plants are used, such as salvia divinorum, China aster, Begonia, Iresine, Cineraria, different forms of Sedum to be used as a background (Pasko, 2012).

MATERIALS AND METHODS

Experiments were conducted in an experimental area of the Siberian Botanical Garden of Tomsk State University. It is located in the fifth agroclimatic region of Tomsk Oblast, refers to the subtaiga (southern) part of the region and is characterized as moderately warm and moderately humid (Evseeva, Romashova, 2011). Winter is long with an absolute minimum temperature of down to -58°C. The length of the frost-free period is about 105—125 days. The sum of temperatures above 10° is 1700°C, the amount of precipitation during the same period is about 180-240 mm, 350—520 mm during a year (Agroclimatic resources..., 1975).

According to the Agrometeorological Bulletin from the Hydrometeocenter of Tomsk Oblast, the average annual air temperature in the area of the experiments is 0.6°C. The number of days per year with temperatures above 5°C is equal to 153, above 10°C - 113, and the sum of temperatures above 10°C reaches 1750°C. The vegetation period is determined by a stable transition of a daily average temperature through +5°C, in Tomsk May begins early. The duration of the warm period with an average daily temperature >0°C is 185 days, frost-free period - 95 days (86 - 148 days). The danger of frost exists until mid-June and increases again from mid-August. Fluctuations in multiyear average temperatures in Tomsk region during the summer months are within 3°C. Autumn and spring on the contrary are characterized by large amplitude fluctuations (up to 20—30°C).

The amount of precipitation falling in summer is relatively significant. The maximum falls in the summer. The average monthly distribution of rainfall is as follows: May — 44, June — 70, July — 75, August — 71 and September — 46 mm. In early periods of development plants often suffer from the lack of moisture but in the end – from over-moistening.

The experimental area of the Siberian Botanical Garden, where the observation took place, is located on gray forest medium loamy soils with the content of humus of about 3-4%, and mobile forms of phosphorus and potassium about 10.5 mg/100 g of soil. The soils are characterized by low water and air permeability and the propensity to crust formation. The reaction of the soil solution is slightly acid (5.9-6.0).

The soil was dug, enriched with organic fertilizers and mulched with sifted peat before sowing the seeds or planting the flowering plants in the ground. The first thinning was performed after germination, the second – after the unfolding of true leaves. Further care of the plants consisted of timely weeding, hoeing, and tying up of climbing plants.

At the end of the experiment, the pericarps were carefully cut and wrapped in paper bags. Ripening was carried out in a dry warm room for a month. The plants were threshed. Seeds were cleaned and put in paper bags, which were stored at a temperature of 22-24°C. Then the germination was determined.

The objects of study were 45 species of annuals related to five families (Vorontsov, 2011). They were characterized by a great diversity of habitual signs, decorative qualities and rates of development: Summer Pheasant's-eye — Adonis aestivalis L. (Ranunculaceae), Love-Lies-Bleeding — Amaranthus caudatus L. (Amaranthaceae), Chinese Aster— Callistephus chinensis Nees. (Asteraceae), Spreading Marigold— Tagetes patula L. (Asteraceae), Viola Wittrock — Viola wittrockiana Gams. (Violaceae), Treasure Flower — Gazania splendens hort. (Asteraceae), Strawflower — Helychrisum bracteatum (Vent) Willd. (Asteraceae), Annual Baby's-breath — Gypsophila elegans Bieb. (Caryophylaceae), Sweet Pea — Lathyrus odoratus L. (Fabaceae), Rocket Larkspur — Delphinium Ajacis L. (Ranunculaceae), Tall Morning Glory — Ipomoea purpurea (L.) Roth. (Convolvulaceae), Slipper Flower — Calceolaria hybrida L. (Scrophulariaceae), Elegant Clarkia — Clarkia elegans Dougl. (Onagraceae), Golden Tickseed — Coreopsis tinctoria Nutt. (Asteraceae), Flowering Flax — Linum grandiflorum Desf. (Linaceae), Garden Nasturtium — Tropaeolum majus L. (Tropaeolaceae), Scarlet Sage — Salvia splendens Sello ex Nees (Labiatae), Drummond's Phlox — Phlox Drummondii Hook. (Polemoniaceae), Common Zinnia — Zinnia elegans Jacq. (Asteraceae), California Poppy — Eschscholzia californica L. (Papaveraceae).

Some species used in the experiment were represented by the following kinds: Chinese Aster 'Blauer Turm' kind; Spreading Marigold 'Frills' kind; Sweet Pea 'Spenser' group, 'Ambition' kind; Garden Nasturtium 'Feuerball' kind; Scarlet Sage 'Scharlach' kind; Drummond's Phlox 'Atropurpurea' kind; California Poppy 'Mandarin' kind.

Most plants were planted by the non-seedling method of cultivation. Seedling cultivation was used for Chinese Aster, Viola Wittrock, Treasure Flower, Strawflower, Scarlet Sage, and Drummond's Phlox.

Determination of timing of the onset of phenological phases and duration of periods of plant growth and development was carried out according to traditional methods (Beideman, 1974; Voroshilov, 1960). In addition, the sum of effective temperatures (in °C) required for the onset of budding, flowering, fruiting and seed maturation phenophases was calculated (Pasko, 1995).

Experiments were carried out in quadruple repetition in plots of an area of about 10 m2. A random selection of not less than 20 model plants from different points of the plot was used to obtain reliable results. The processing of biometric data was performed by a standard method (Dospekhov, 1985).

RESULTS AND DISCUSSION

Special attention should be paid to flowerbeds compositions in the city of Kemerovo (see Figure 2). They combine tricky geometrical forms made from different color flowers and leaf plants (Sedum, Iresine, Lobelia, China aster, one year Kochia).

Green sculptures of animals, traditionally created in Krasnoyarsk and Barnaul can be of great interest. In Barnaul the streets are decorated with models of a sitting bear, Ivonna horse, peculiar Russian fairy tale character Chudo-Yudo-ryba-kit, etc. The sculptures have steel or wire mesh support frames filled with soil substrate, where the seeds are planted. Germinating crop seeds cover the sculpture surface with a lawn that imitates animal fur. Not far from the building of the Regional Administration on a hill, there is a flowerbed clock which looks like a clock-face, the background and marks are made of flowers and the moving hands are made of golden painted metal.

Krasnoyarsk masters are also noted for their original works. The brand sculptures of the city are big scale realistic models of elephants, bears and giraffes, created on bases of stiff support frames filled with soil substrate and covered with ground covering plants like bluish Sedum (which imitate fur and skin) and purple Iresine (eyes, nose, mouth). Everyone who has visited Krasnoyarsk recollects containers with big palm trees which decorate central alleys of the city – those are the presents from one of the former citizens who moved to Krasnodar. Tomsk special features are cachepots with begonias fixed on lamp posts and rectangular vases on the handrails of street barriers. Lately, in several places of the city flower “fountains” have been installed – steel constructions coming out of the center of the composition and having round cachepots with flowering plants on ends.

In Tyumen and Tobolsk flowerbed compositions are diverse. The main accent is made on trimmed lawns and landscape style flowerbeds, which harmonize naturally with old churches. In modern parts of these cities we can point out flower pyramids 2.5-3.0 m high. They look like square containers with soil substrate put into one another and covered with exuberant begonias.

Traditionally, a wide variety of flowerbeds can be found in Omsk. Among them there are large scale flowerbeds in parks and small flower compositions in Japanese, Scandinavian and Russian styles that attract cafes customers.

The analysis of species and variety diversity of flowers allows one to conclude that mainly annual flowers are used for the city landscaping. Perennial flowers like peonies, roses, irises, tulips, narcissus bloom impressively in Siberia but for a very short time. That is why the emphasis is laid on annual flowers which decorate the environment with bright colors and diverse forms, create a feeling of an open air celebration and make the area very attractive.

According to our data the period of annual flowers vegetation in open air is limited by 5 months, the period of flowering – by 2 months (see the figure 3).

The obtained data allowed us to define the most suitable species for efficient landscaping of Siberian cities and to widen their range to at least 50 species.

Thus, the current research allowed the authors to find out species suitable for the creation of compositions for continuous flowering, species suitable for field-seed growing, as well as to consider the most widespread and original types of flowerbeds in Siberia.

a b

c d

Figure 2. Examples of annual flower plants in landscaping - Siberian cities.
a, b - Krasnoyarsk, c - Tomsk, d - Barnaul (Source: Photo by the author, 2009-2012)

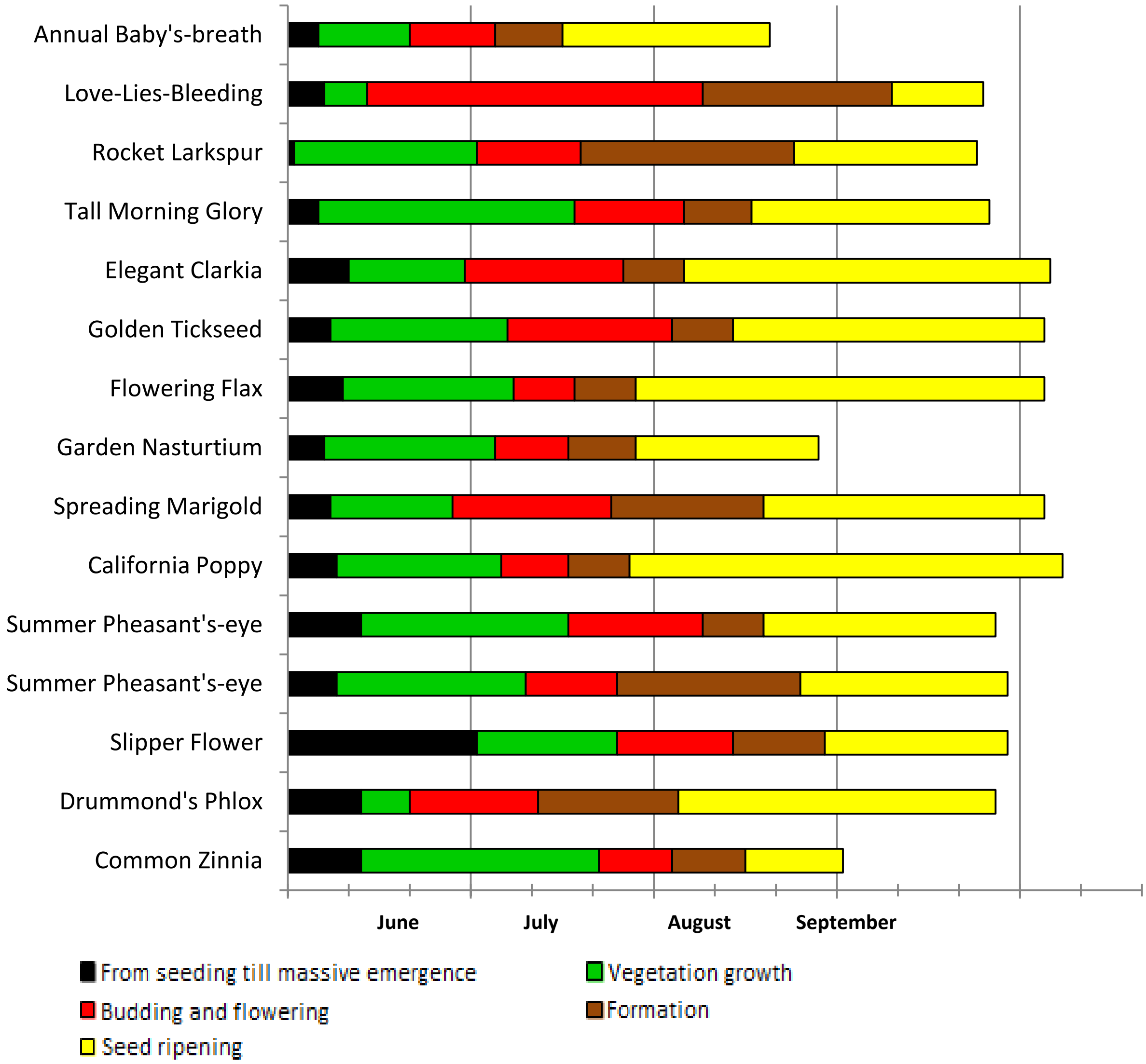

Figure 3. Phenological spectrum of one year flowers development in Tomsk
(as of five years of research by the author)

CONCLUSIONS

The decorative effect of plants is not only restricted to the non-seedling method. In spite of significant difference in duration of the initial phases, 46% of the species are characterized by simultaneous mass flowering and 38% of them – by almost simultaneous flowering. The remaining introducents with a long period of vegetative growth (Treasure Flower, Giant Blue-Eyed Mary) differ significantly in terms of flowering. The difference reaches 50 days. It is natural that they can achieve the phase of mass flowering only with the seedling cultivation method.

The maximum percentage of annuals with rapid development was observed in Novosibirsk, the minimum — in Yakutsk and Tomsk. In Tomsk plants , which unvaryingly give mature seeds, but do not complete the life cycle are primarily used for landscaping. In Irkutsk their use is insignificant. The difference in species sets of annuals of the third and fourth groups in the above mentioned geographic areas is insignificant.

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ENVIRONMENT AND ENVIRONMENTAL EFFECTS

HIGH STRENGTH WASTEWATER TREATMENT PROCESS SIMULATION

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ABSTRACT

Researchers and engineers are continuously striving to enable quicker and more individualized wastewater treatment processes control solutions for the development of process models, which is a long procedure with calibration and validation, and online data supply as they are dynamic systems introducing another level of sophistication (Sen and Randall, 2008). The existing mathematical wastewater treatment models give a forecast for treatment results under various flow and pollutant circumstances, but results still are dissatisfactory due to the changeable dynamics of pollutants, which affects the treatment systems directly. The investigation was done for an existing pharmaceutical factory wastewater treatment plant with a moving bed biofilm reactor(MBBR) process, which offers the specific advantages of the biofilm system in the treatment of high strength wastewater. The basic research was undertaken to verify a model and investigate the biodegradable and slowly biodegradable COD fraction variations influence on the model's results.

Key words: Wastewater treatment, process simulation and control, biofilm, fungi.

INTRODUCTION

The objectives of this research were to simulate the existing pharmaceutical factory (JSC "Grindeks") wastewater treatment process using *BioWin ASM 2D* model, where important process scenarios are possible to investigate.
The simulation period was 1 year for all the given scenarios, but the feasibility of the scenarios was investigated through the impact of high strength organic loading rates, COD fraction component conversation and maximum specific substrate removal rate at temperatures ranging from 28 to 32 °C and flow rates ranging from 10 to 30 m^3/h, which correspond to existing WWTP performances.
Many of the waste streams resulting from the pharmaceutical factory have high pollutant strengths and thus are of concern to the environmental pollution issue. However, this research concentrated on the wastewater from the process line (buffer tank) and treated wastewater effluent to the existing Riga town sewer system, where they must apply the limits given from local municipality. The wastewater from the factory is of particular concern because it contains BOD_5 ranging from 1000 to 4 500 mg/l, COD concentration from 1000 to 10 000 mg/l, and in the effluent they must reach the 600 mg/l for COD and 500 mg/l for suspended solids, also a limitation for total nitrogen, phosphorus and another pollutants exist as well, which time by time create difficulties for the process stability resulting in the pollutant concentration limit exceeding in the effluent.

MATERIALS AND METHODS

WWT plant description

The wastewater treatment process consists of the following main components: buffer tank, five in series moving bed biofilm reactors (MBBR) with plastic suspended carriers and finally a flocculation and flotation unit for suspended solid removal. In a MBBR process, the biofilm grows on small carrier elements suspended throughout the liquid in the reactor.
At the end of the 1980's MBBR biofilm technology was developed at the Norwegian University of Science and Technology in Trondheim by professor Odegaard and coworkers (Odegaard, 2006).
Biofilm carrier elements type K3^{TM} (*AnoxKaldnes*) made of polyethylene, which has a density slightly less than water and size of 12×25 mm, with a surface area of 500 m^2/m^3. The wastewater from the factory process line is moved to a buffer tank with a wet volume of 200 m^3. The wastewater is pumped with frequency controlled pumps to the first biological reactor. The wet volume of each reactor is also 200 m^3 and all five biological reactors contain 50% carrier material K3^{TM}. The flow rates, temperature, pH and oxygen concentration are monitored in each reactor separately. The air flow rate in the reactors can be between 250 – 1000

Nm^3/h. In the first reactor MBBR1 most of the easily degradable organic content will be removed. In reactor MBBR2 the reduction of larger molecules and in the third reactor MBBR3 more organic biological degradation takes place. In the fourth reactor MBBR4 the nitrification process takes place, but in the fifth reactor MBBR5 the denitrification process takes place. The reactor MBBR5 is equipped with both an aeration system and a gentle mixer for mixing the suspended carriers. In the case when the MBBR5 is used as nitrification stage, the reactor is aerated (Lind et al., 2009).

BioWin 3.0 simulator model ASM 2D

BioWin is a Microsoft Windows-based wastewater treatment process simulator used world-wide in the analysis and design of wastewater treatment plants.
Fig. 1 shows a pharmaceutical factory wastewater treatment plant system configuration set up in *BioWin* accordingly to the existing WWTP (Lind et al., 2009; Gujer et al., 1995).

Substrate transformation and utilization in the biofilm processes is more complex than in activated sludge, therefore a more complex *ASM 2D* model was used for the modeling of the MBBR process (Gujer et al., 1995; Gjunsburgs et al., 2006). This is principally because of the introduction of diffusion within the biofilm and also a parallel suspended growth bacterial activity is taking place (Sen and Randall, 2008).
To perform the comparative analysis, the model was mainly aimed at the biological step, where organic matter and nitrogen removal were incorporated. Using the *BioWin 3.0* simulator model *ASM 2D*, the model step in various scenarios, and COD for high and low load range are presented in the article. Simulations were performed using the data from the existing WWTP from the year 2011, and influent data are presented in Figures 2-3, effluent data are presented in Fig. 4.

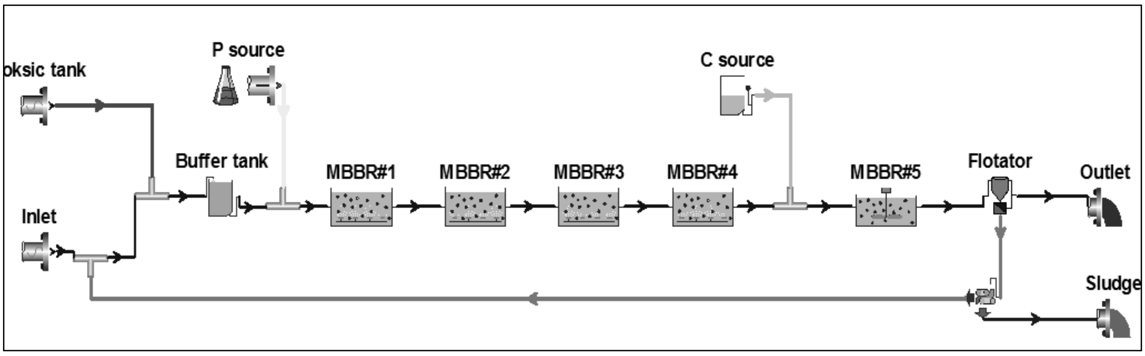

Figure 1. BioWin model WWTP layout

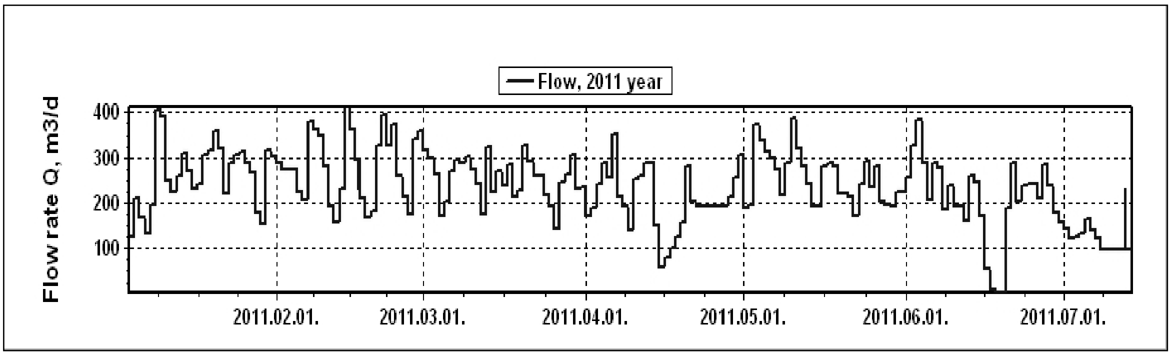

Figure 2. The incoming wastewater flow rate for year 2011 (7 month period)

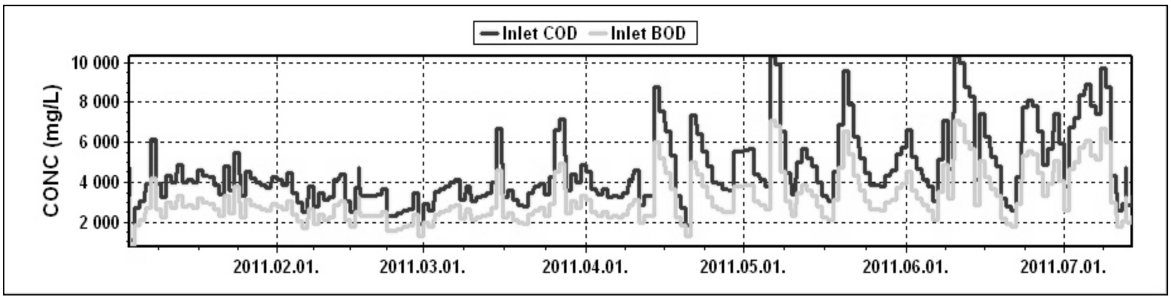

Figure 3. The inlet wastewater COD and BOD_5 for year 2011 (7 month period)

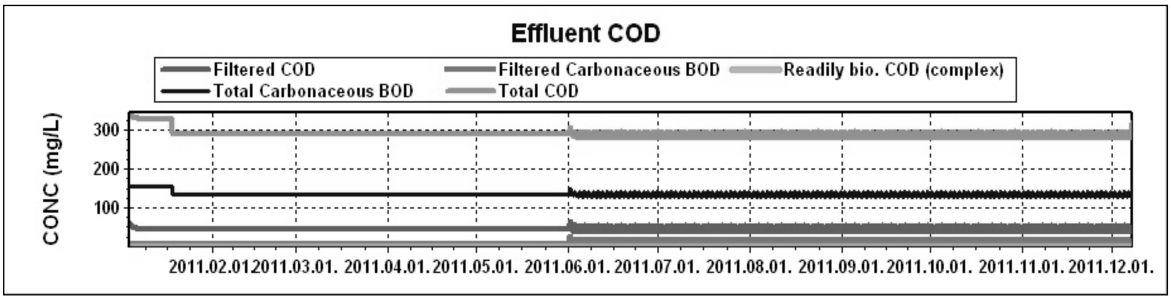

Figure 4. The effluent COD and BOD for year 2011

Calibration

In order to evaluate the quality of the BioWin ASM 2D model under the dynamic conditions, it was proposed to check, if the simulated value of an output variable was included in the confidence interval estimated for its measured value of the effluent (Jeppsson, 1996). The simulation was successful because there was no significant statistical difference between the simulated and measured values of the investigated variable COD, see Fig. 6. The calibration of the COD fractions were investigated using the existing wastewater COD components, such as - readily biodegradable, un-biodegradable, slowly biodegradable soluble and particulate. Table 1 shows the incoming wastewater fractions from buffer tank. The total COD is assumed to be composed of different particulate and soluble components and represented by relative fractions. As a start up input value of the COD soluble fraction was 3604 mg/l. The total soluble COD fraction is about 90% from the total COD.

Each of the simulated variables was included in the confidence interval and according to the Table 1 data and the inlet wastewater COD fraction was estimated for the respective measured variable and is given in Fig. 5.

Table 1

Wastewater COD fractions from buffer tank

Parameter	Description	23.03.2012. Value, mg/l (± 5%)	23.03.2012. Percentage from total COD (± 5%)	Measurement methods
COD	Total COD	3976	100	The standard COD measurement
S	Total soluble COD	3604	91	Determine for example pH>9 and coagulation $ZnSO_4$, filtration 0.45 μm
S_S	COD readily biodegradable	~ 80	2	BOD measurement after 2 h
S_I	COD un-biodegradable soluble	321	8	The difference between soluble COD and BOD
X	COD particulate	372	9	$X = COD_{total} - S$
X_S	COD slowly biodegradable	3433.6	86	$X_S = BSP_{total} - S_S$
X_I	COD un-biodegradable particulate	28.6	0.7	The difference between COD and soluble fractions of COD and BOD

The comparison between measured and model obtained data for COD and BOD_5 values is given in Fig. 6. The kinetic parameters and biofilm diffusivity coefficients of the soluble components, for the first stage of investigation were taken from references (Gjunsburgs et al., 2006; Lapara, 1998; Sen and Randall, 2008) for the *ASM 2D* model and used for the process simulation in the MBBR for the existing wastewater treatment plant. The calibration and validation of the current *BioWin* model must be based upon laboratory scale experiments for the coming investigation stages, but for the start of investigation, the model behavior has been verified with available resources from literature (Tchobanoglous and Burton, 1991; Guisasola et al., 2003).

Biodegradation with Fungi

The slowly biodegradable COD fraction consists of different ingredients, where phenol components are present. The phenol from the biodegradability point of view can be classified as a slowly biodegradable fraction of COD (Guisasola et al., 2003; Kekisheva et al., 2007). Biodegradation of the particular fraction was also investigated in this model. The laboratory investigations were performed with the aim to replace bacteria in one of the MBBR with fungi.

The slowly biodegradable colloidal and particulate variation profile is given in Fig. 7.

For determination of treatment efficiency of slowly degradable substance with fungi (Rancano et al., 2003; Wesenberg et al., 2003; Majeau et al., 2010), batch tests of degradation of phenol containing wastewater was elaborated. Initially 4 fungi stock cultures were tested, from which Trametes Versicolor showed most degradation pattern. Batch tests were performed in a culture medium by adding phenol wastewater, with a final concentration of 400 mg/l, and stock culture (T.versicolor). Experiments were done in 250 ml flasks containing 100 ml culture medium, 50 ml citric – phosphate buffer for maintaining a pH of 5.0, 7.5 ml phenol wastewater and 10 ml (OD=0.700 Abs) stock culture. The stock culture was inoculated from a liquid medium. Flasks were placed in an incubator with an orbital shaker at 30 ^{o}C temperature and 150 rpm rotation and the pH (5.0) was controlled manually. Experiments were done in sterile conditions by autoclaving all cultures.

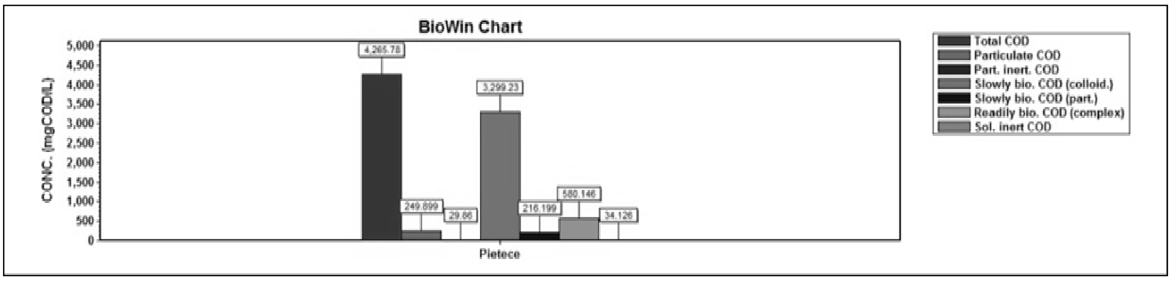

Figure 5. The incoming wastewater fractions for BioWin model

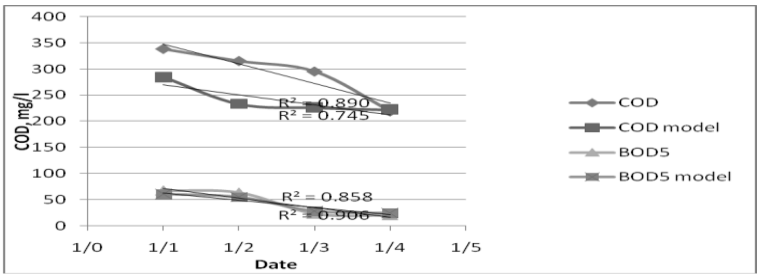

Figure 6. The effluent COD and BOD_5 value comparison for model and measured data

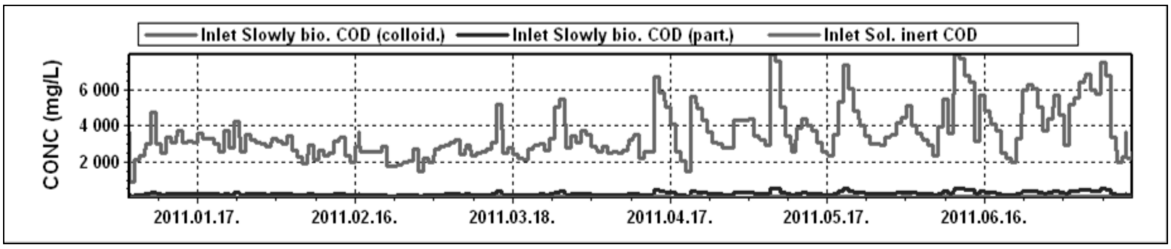

Figure 7. The slowly biodegradable COD fraction profile for average load scenarios

medium, buffers, and flasks prior to adding the stock culture. Flasks were covered with cotton corks for aerobic conditions. The duration of the experiment was 7 days, where samples were taken on days 0, 1, 2, 3, 5 and 7. All experiments were performed in 3 repetitions. The culture medium in experiment, per 100 ml contained: 0.08g KH_2PO_4, 0.02g K_2HPO_4, 0.05g $MgSO_4$, 0.50g yeast extract and 0.03g NH_4NO_3. Before the experiment, a stock culture was inoculated from an agar plate in a growing liquid medium for 7 days. On the final day all media with formed fungi were homogenized and added to the experiment flasks. The phenol concentration was determined with a spectrophotometer.

RESULTS AND DISCUSSION

Biodegradation with Bacteria

The *BioWin* model was prepared for twelve wastewater treatment scenarios, and the simulation was performed for the following hydraulic load variations from an average of 10 - 16 m^3/h up to extremely high 21 - 30 m^3/h, also the scenarios for COD load variation was perform for average from 3000 - 6000 mg/l up to extremely high over 9000 mg/l and also for low load range < 1000 mg/l. The temperature for all simulations was in average range from 28 to 32 °C, but also the additional scenarios for extremely high temperature range till 45 °C was investigated. In this article due to the limits only the hydraulic flow rate, COD and the biodegradable and slowly biodegradable COD fraction variation simulations are presented. For the scenarios with hydraulic loads increases, there was no significant influence to the variations on treated wastewater effluent for COD and BOD values. In this scenario the temperature was 30 °C and MBBRs process was capable of producing stable COD removal, still the oxygen supply rate was in the design range till 1000 Nm^3/h, see Figs. 8 and 9.

The decreasing stability was recognized for temperature 45 °C possible due to high oxygen uptake rate imposed by high COD consumption rate, see Figs. 10 and 11.

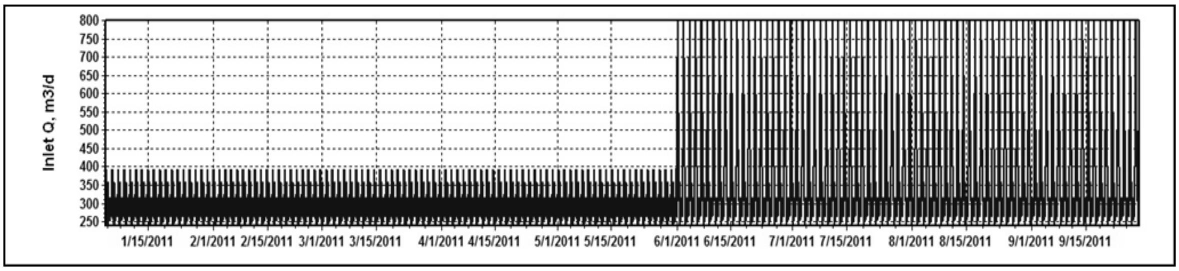

Figure 8. The Inlet hydraulic flow profile with sharp flow rate increase

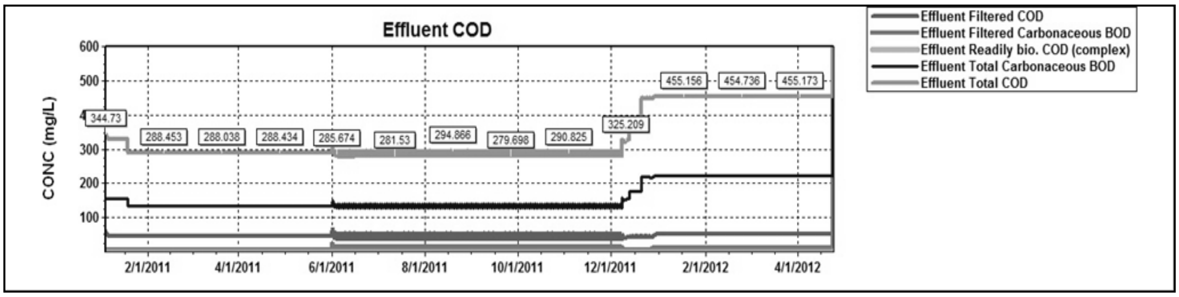

Figure 9. The effluent COD variation profile for the scenarios with flowrate increase, for temperature 30 °C

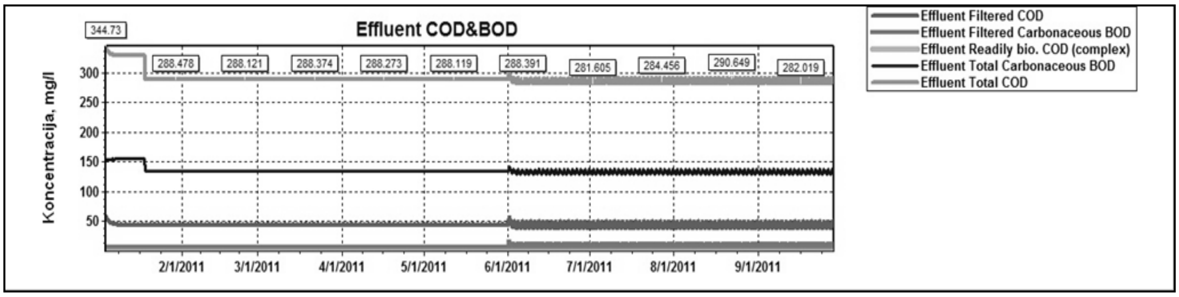

Figure 10. The effluent COD and BOD variation profile for scenarios with flow rate increase, temperature of 45 °C

The effect of varying COD and BOD on the MBBR performance was simulated by changing the values between 1000 mg/l and 10 000 mg/l for temperature 30 °C and also under the different flow rates from low to high, which corresponded to the simulation scenarios. The MBBRs process was also capable of producing stable COD removal for average and high load region, but COD in effluent exceeded the limits for extremely high load range (> 9000 mg/l), for these particular scenarios. The comparison between COD and BOD values of process parameters in influent and effluent per day within the year 2011 (7 month) period under the dynamic conditions are presented in Figures 12, 13, and 14.

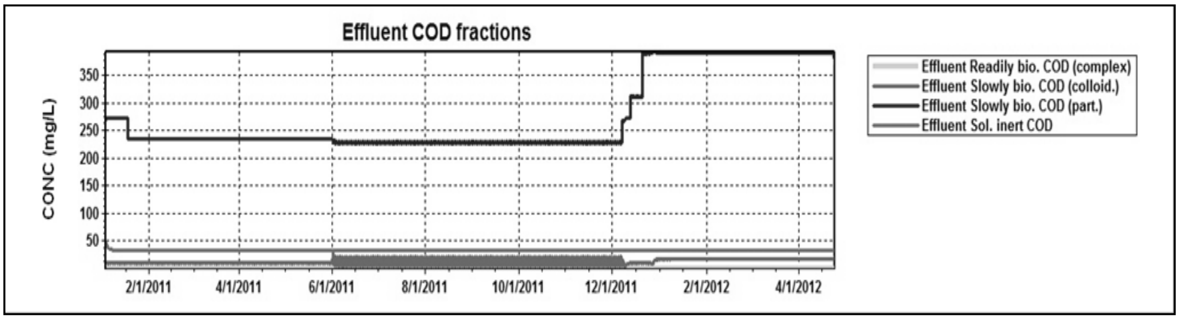

Figure 11. The effluent COD fraction variation profiles for scenarios with flow rate increase, at the temperature of 45 °C

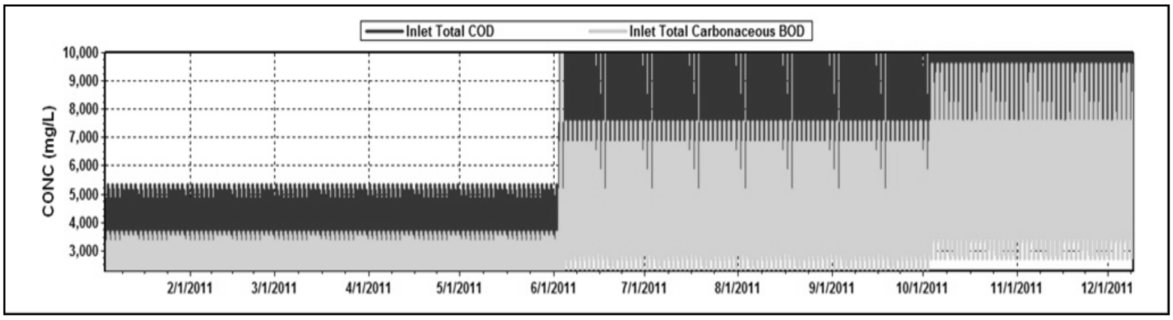

Figure 12. The COD and BOD inlet values for high load scenarios

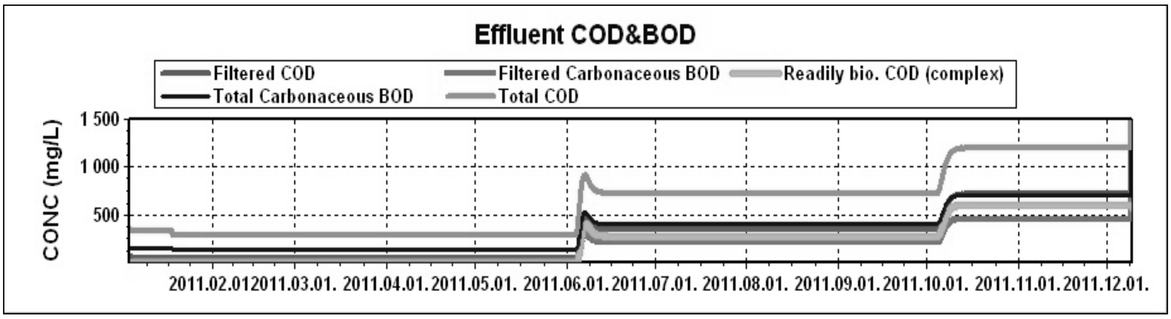

Figure 13. The effluent COD and BOD variation profile for high load scenarios

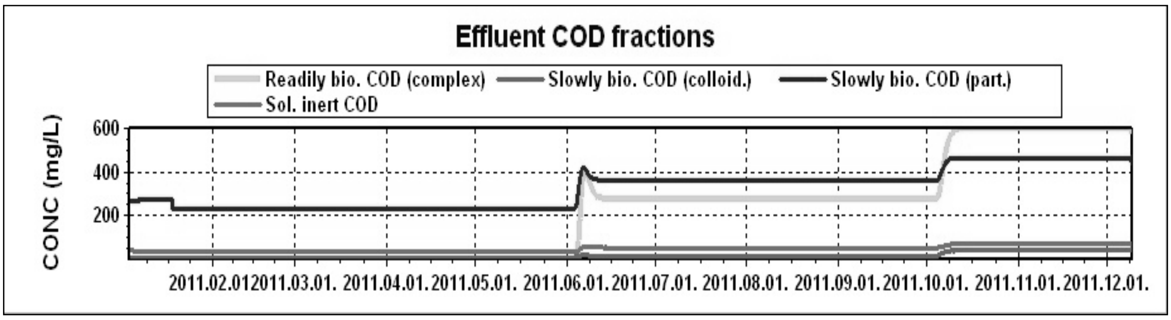

Figure 14. The effluent COD fraction composition for high load scenarios

The model also shows, that because of a higher biodegradable COD value the biofilm thickness in MBBR 1 and MBBR2 had a higher value of 0.87 mm and 1.1 mm comparing to 0.73 mm in MBBR3, MBBR4 and MBBR5. To compare with municipal wastewater where more difference between the biofilm thicknesses is recognized (Sen and Randall, 2008), see Fig. 15.

The effect of COD fraction influence on the model results was investigated by varying the COD biodegradable and slowly biodegradable components from 3976 mg/l to 1000 mg/l. The total COD values in the inlet was 6000 mg/l, the temperature was 30 °C which corresponds to the average values simulation scenarios. There the MBBR's process was capable of producing stable COD removal, but exceeds the limits when the biodegradable COD fraction has a sharp concentration drop and the slowly biodegradable fraction increases. This always was accompanied by the filtrated COD values increase in effluent, and also the model results show a sharp oxygen decreases till 0.97 mg/l in the last two MBBRs. The inlet COD and fractions profiles are given in Fig. 16 and the values of effluent are presented in Fig. 17.

Biodegradation with Fungi

The achieved degradation of phenol containing wastewater was 68% within 7 days, decreasing from 410 mg/l to 130 mg/l concentration of total phenol. It was found that the degradation process of phenol wastewater can be approximated to a linear line, with a rate of 40 mg/l/day, e.g. degradation of phenol mg per litre per day. While for various bacteria mixtures in literature, the degradation rate of phenol is reported between 120 – 300 mg/l/day for phenol concentration of 400 mg/l (Vasiliadou et al., 2008; Tziotzios et al., 2005). The phenol removal rate can be used for the wastewater

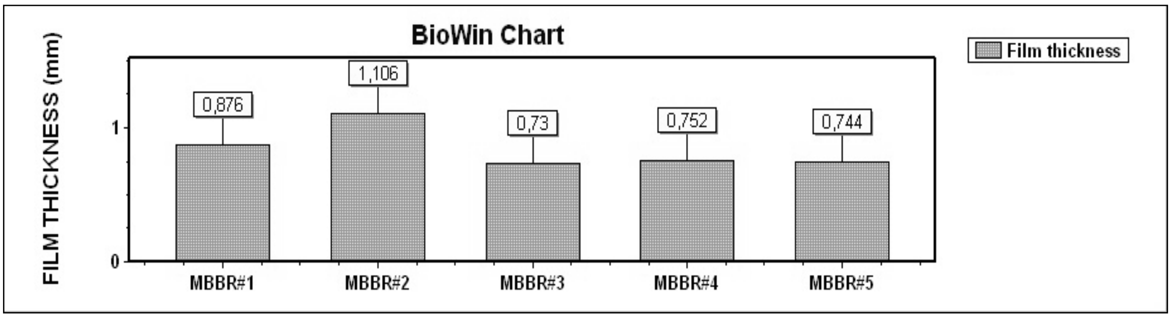

Figure 15. The biofilm thicknesses variation per each MBBR for high COD scenarios

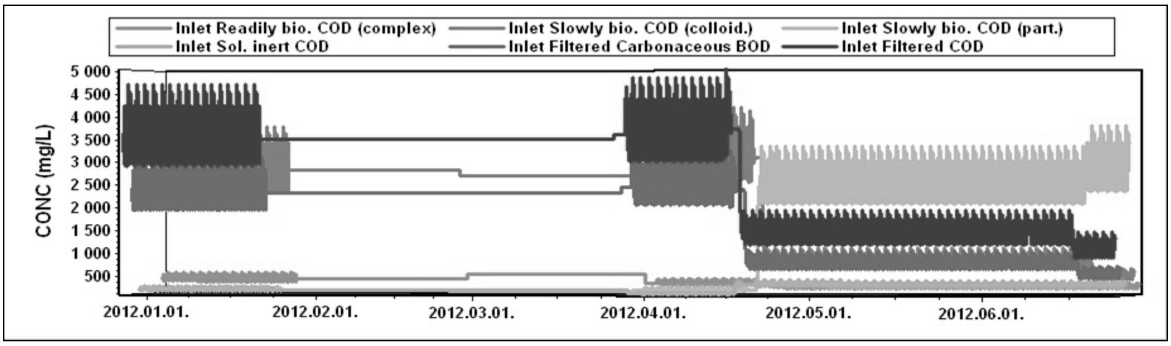

Figure 16. The inlet COD fraction variation profiles

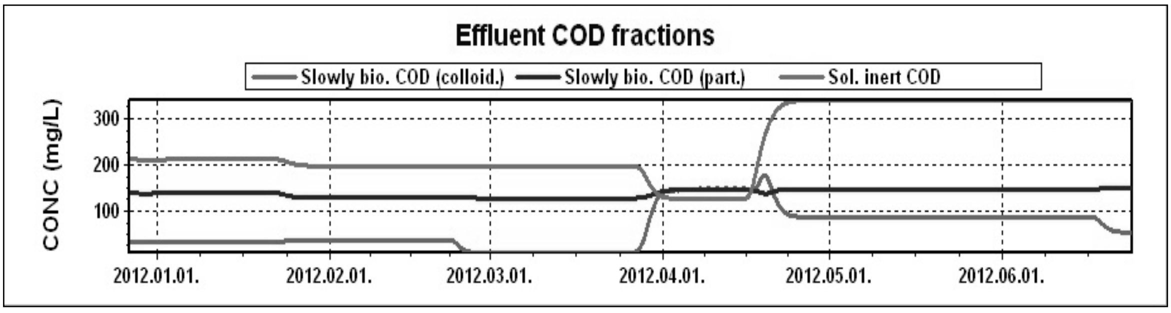

Figure 17. The effluent COD fraction variation profiles

treatment process modelling for bioreactors with fungi in suspension, at a fixed operational state of pH 5.0 and a temperature of 30 ^{o}C. However the synthetic medium impact on resulted rates should be noted, since the carbon and minerals source was not limited during the experiments.

CONCLUSIONS

This research focused on performance of the MBBR simulation for high strength wastewater treatment of a pharmaceutical factory, with different COD fractions, from biodegradable to slowly biodegradable. Evaluation of the treatment process simulation results and the author's difficulties encountered in performing the simulation are presented in this paper.

The *BioWin ASM 2D* model can be used to simulate the high strength wastewater treatment process, but proper calibration of the model's parameters can be a difficult task without involving respirometric procedures as experimental tools.

A respirometric batch tests must be conveniently used further in this study in order to estimate the main kinetic and stoichiometric model coefficients and they must be determined for aerobic and anaerobic conditions.

The simulation of the MBBR process showed that the technology is capable of producing a stable COD removal for average and high load (up to 9000 mg/l), and meets the limits in effluent for these particular scenarios with the exception when the biodegradable COD fraction has a sharp concentration drop and slow biodegradable fraction increases.

The difference in biofilm thickness must also be taken into consideration and further the diffusion mechanism into biofilm investigated, as well as the role of the activated sludge particles, which are in suspended form, must be taken into consideration.

ACKNOWLEDGEMENT

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PREPARATION OF COAL-WATER SLURRY USING A HIGH-SPEED MIXER-DISPERSER

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ABSTRACT

The present article describes a method of preparation coal-water slurry using a high speed mixer-disperser (HSMD).The method is based on the multiple impacts in a liquid media by dispersing elements in the appearance of cavitation effects. Considering the design features of a high-speed mixer-disperser it was found that the processing of coal-water slurry increases their stability due to particle size deceasing.

Key words: mixer-disperser, cavitation, water-coal slurry, water-coal fuel.

INTRODUCTION

Water-coal slurry (WCS) technology was developed during the worldwide oil crisis of the 1970’s to produce a novel and clean fluid fuel as a substitute for petroleum. The slurry is prepared as a mixture of 60–70% fine coal, 29–39% water, and about 1% additives (dispersants involved) determined specifically for each different type of coal (Yun et al., 2011),(Zhu et al., 2012). Creation of fine WCS during mixing is difficult because of bad distribution of coal particles in water. To solve this problem, special surfactants (Zhou et al., 2007),(Zhou et al., 2012), various mixers and disperser are used, for example, the propeller mixers, rotary pulsation devices, etc. (Sidenko, 1977). In works (Knapp et al., 1970), (Polyakov et al., 2008) it is found that with increasing the speed disperser elements can have simultaneously occurring effects as high-speed shock wave, ultrasonic vibration, cavitation process and as a result hydraulic impacts in a liquid medium.

The particular interest is in the cavitation process - generation in fluid cavitation bubbles (cavities) by local reduction of pressure in the fluid. In the initial phase of fluid cavitation small size bubbles are allocated. When cavities get to the area of high pressure, the steam bubbles collapse. Thus, there is a hydraulic shock (Knapp et al., 1970). Destruction of cavitation bubbles generates shock waves that destroy firm particles and mix them, forming thus a stable suspension.

Kinetic stability in dispersed systems, ability of a dispersed system to maintain an even distribution of particles throughout the entire volume of the dispersed phase, are characterized by the Stokes' law. The Stokes' law is derived by solving the Stokes’ flow limit for small Reynold numbers of the Navier–Stokes’ equations number (1) (Batchelor, 1967).

$$F_d = 6\pi\mu R v_s \qquad (1)$$

where:
F_d – frictional force – known as Stokes' drag – acting on the interface between the fluid and the particle (N),
μ – dynamic viscosity (N s/m^2),
R – radius of the spherical object (m)
v_s – particle settling velocity (m/s).

If the particles are falling in the viscous fluid by their own weight due to gravity, then a terminal velocity, also known as the settling velocity, is reached when this frictional force combined with the buoyant force exactly balances the gravitational force. The resulting settling velocity (or terminal velocity) is given by (Venkatalaxmi et al., 2004) equation number (2):

$$v_s = \frac{2}{9}\frac{(\rho_p - \rho_f)}{\mu} g R^2 \qquad (2)$$

where:
v_s – particle settling velocity (m/s) (vertically downwards if $\rho_p > \rho_f$, upwards if $\rho_p < \rho_f$),
g – gravitational acceleration (m/s^2),
ρ_p – mass density of the particles (kg/m^3), and
ρ_f – density of the fluid (kg/m^3).

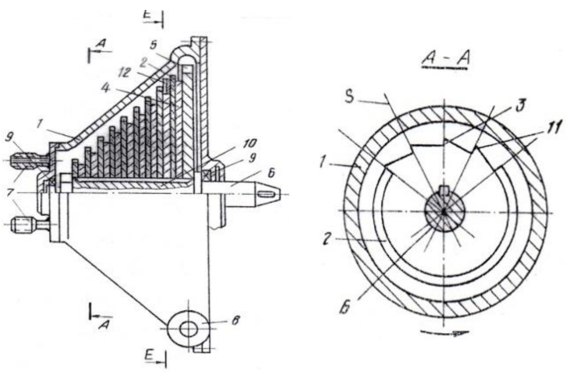
Based on equation number (2), the sedimentation rate is directly proportional to the square of the radius of the particles, and the difference in density between the solid and the liquid medium, and inversely proportional to the viscosity of media. Therefore, reducing the rate of sedimentation the sedimentation stability is increasing, the following methods can be used:

- To reduce the initial size of the particles;
- To pick up the dispersive environment with a density close to the substance density.

MATERIALS AND METHODS

Features of preparation of the high-speed mixer-disperser

For experimental studies we have proposed the construction of a high-speed multi-disc mixer-disperser (Polykov et al., 2008), (Polykov et al., 2007), which is presented in Fig 1. It comprises of the body 1, working disks 2 with teeth 3 and the intermediate washers 4, impeller 5, shaft 6. The shaft, working disks, washers and the impeller make up the rotor in the form of a truncated cone. The body 1 has two inlet mouths 7 and one outlet mouth 8. The rotor shaft rotates in bearings 9. The disks form a conical rotor 10. The working surface 11 of the teeth 3 is directed towards rotation and lies in the plane S, passing through the axis of a disk 2.



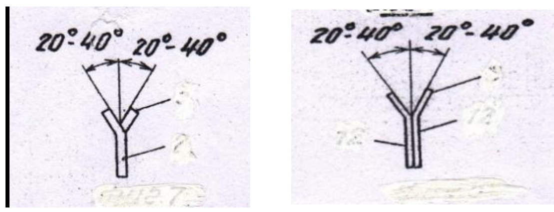
a) b)

Figure 1. Multi-disk unit mixer disperser,
a) longitudinal sections; b) transverse sections

With the motor the rotor shaft rotates at 9000 rpm. The travel speed of the work items is 70-80 m/s. In the zone of influence of the work item in the liquid medium at the same time there are several phenomena: impact, vibration and cavitation. The device operates as follows. Through connections to the mixer 7-dispersant serves subjected to mixing environment passing through the mixer mixed environments, including large broken up into small micron size.

With the motor the rotor shaft rotates at 3000 rpm. Thus, in the zone of influence of the working elements in the liquid medium there are some phenomena at the same time: impact, transonic fluctuations and cavitation. The device works as follows: through the inlet mouth 7 in the mixer environments are subject to mixture movement, passing through the mixer of the environment mix up, large inclusions are breaking in small to the micron size.

In the main scheme the disks are executed flat as it is presented in Fig.1. It is rather simple at production. However, overall performance of a mixer can be raised if the teeth of a disk are unbent from the plane of flange on 20° - 40° (Fig. 2). And each subsequent tooth should be unbent aside opposite the previous (Fig. 2a). The disks can be also executed from two plates, and their teeth are unbent to the opposite sides (Fig. 2b).



a) b)

Figure 2. Design of disperser disk with curved teeth

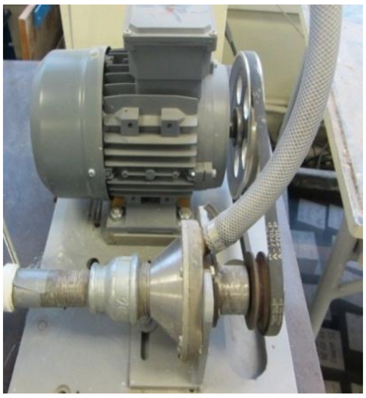
Experimental: water-coal slurry

It is known that WCS is used as fuel. Burning coal in coal-water slurry has a number of economic, environmental and operational advantages more than pulverized and especially fluid bed firing (Tillman et al., 2004), (Farag et al., 1989), (Kijo–Kleczkowska, 2011). This fuel has been on a substantial scale approved on a number of power objects. Works on burning mazut coal and water coal fuel were carried out by V. Kustov (Kustov, 1942). In a fire chamber coal particles have to burn down without ceding to speed combustion of fuel oil. The usual size of the particles of coal that used for coal fuel oil producing reaches 60-80 microns. It is established that it is expedient to apply a quantity of liquid non-flammable environment – water. However, coal-water slurry coal particles adhere to each other only when they are added stabilizers - surface active agents (SAA) – surfactants (Zhu et al., 2012), (Li et al., 2008). Water in such suspensions should not be more than 55%. The main way of mechanical dispersion of coal is wet milling in the rotating ball, rod or vibrating mills. Their drawback is inability to get fine suspension.

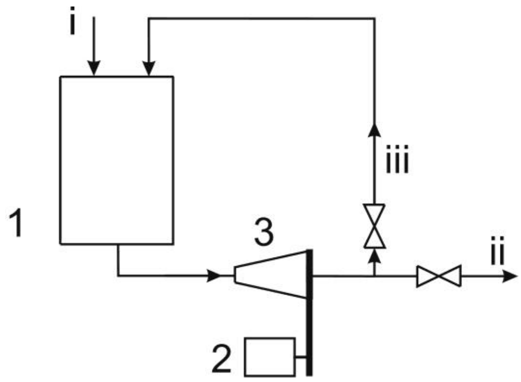
Preparation of water-coal slurry using a high-speed disperser

At the Riga Technical University (Latvia) a pilot plant based on the new high speed mixer-disperser for preparing water-coal and water-cement suspensions has been developed (Mironovs et al., 2011). The setup is shown in Fig. 5. It allows you to change the angular rotation speed from 0 to 9000 rpm continuously.

In conducting the studies long-flame grade coal D (volatile content - 39% or more, -76% carbon content, calorific value - 7500-8000 kcal/kg) was used. The maximum grain size is 200 μm. As the sample coal dust waste was used that produced during the production of coal briquettes (the company "EU Zeme", Riga, Latvia). Dust waste cannot be disposed of in its entirety for various reasons, and it accumulates, creating a significant environmental problem.



a)



b)

Figure 5. Experimental setup for water WCS obtaining. General view (a) and scheme (b).
1 - container for suspension, 2 - motor, 3 - mixer-disperser; i - supply components to be mixed; ii - suspension output; iii - recycle stream

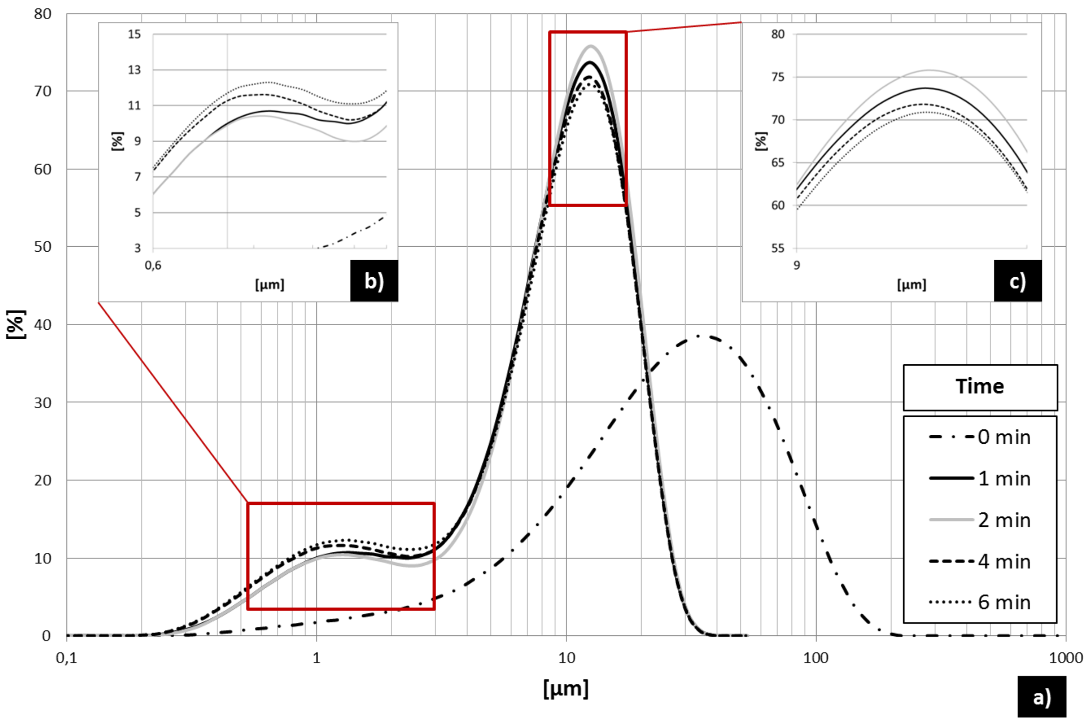


Figure 6. Particle size distribution of coal before and during treatment in HSMD

Dust-like coal waste is mixed with water and a surfactant in a ratio of: coal - 750.0 g, water - 1000.0 g, surfactant ((-)-Ethyl l-lactate by Fluka (now Sigma-Aldrich)) - 1.50 ml, till smooth. The received mass was poured into the container (1) for suspension of the high-speed mixer-disperser (3), given to rotation by the electric motor (2) Fig. 5(b). Treatment in high-speed mixer-disperser was carried out for 1 to 6 minutes at 9000 rpm of the rotor. During the process of dispersing (6 min), the temperature of the suspension increased from 17°C to 35°C.

Particle size distribution analysis

The size of the particles of coal after their processing in the disperser was defined by the method of granulometric laser diffraction on the device Analysette 22 Nano Tec (FRITSCH GmbH). The following parameters are used during the measurements.

Figure 7. High-speed mixer-disperser DRS10 (capacity -10 m^3/h, pressure - 0.2 MPa, motor power - 5,5 kW)

Measured media: distilled and deionized water (light refractive index: 1.3312). Optical properties: light reflection coefficient 1.8, the absorption coefficient 0.5 (both factors are taken due to that more exact values are not known), unless otherwise indicated. Ultrasound: is off. Water pump power: 30%. Direct laser beam hidden by 7 - 13%. The method of calculation: very broad. The measured particle size range: 0.1 to 50 μm.

RESULTS AND DISCUSSION

The resulting suspension remains stable for 4 days. During dispersing probes of WCS for particle size distribution are taken on 1-th, 2-d, 4-th, 6-th minutes. The results are presented in Fig. 6, which shows the curves of the particle size distribution: at baseline (0 minutes) and after treatment.

As seen in Fig. 6, after 1 min of treatment in HSMD the particle size decreases significantly: from one particle mode d_{50}=25 μm 2 modes d_{50}=13 μm and d_{50}=1.3 μm are formed. This fraction is almost absent in the source material. Apparently, this is the maximum possible range of grinding particles of coal, which provides the used mixer-disperser at the noted above conditions (rotation speed, water-coal rate, type of coal). The increase the dispersion time from 1 minute to 2 gives a small (from 73% to 76%) growth in the fraction d_{50}=13 μm. Due to increased processing time, the mode of d_{50}=13 μm reduced (Fig. 6 (b)), but the mode with d_{50}=1.3 μm increased, (Fig. 6 (c)). It can be concluded that long-term (more than 2 min) treatment is not practical because it does not contribute to the further significant refinement of the material.

The firm CORVUS Company (Latvia) started production of a high-speed mixer-disperser DRS10, which is shown in Fig. 7.

CONCLUSIONS

Using of the high-speed mixer-disperser stable water coal suspension with considerable fineness coal particles is prepared that will allow to increase the quality of burning water coal fuels in industrial boiler rooms and improve ecology in places of overload of coal.

Increasing processing time in HSMD more than for 2 min treatment is not practical, because it does not contribute to the further significant refinement of the material.

Coal dust short-time processing time for WCF obtaining is prospective for this technology in future implementation on commercial scale.

Increase a temperature of the environment during of preparation of water coal suspension evidences existence of the cavitation effect during the disperser work.

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