Realization of FRC interior and exterior furniture

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Abstract. This article deals with the implementation of fibre reinforced concrete for interior and exterior furniture. The use of fibre reinforced concrete for non-traditional and small structures brings some specifics in design and realization. These are, in particular, the design of a suitable mixture, the choice of the shape of the structure in relation to the technological possibilities of realization, the static effects and finally the actual production of the element.

1. Introduction

It is well known that concrete is no longer just a load-bearing material hidden under cover of the final surface. Concrete is becoming a design complement of nowadays households, both interior and exterior. This trend emerged after spreading of fibre reinforced concrete and high-strength concrete, due to the properties of the composite formed by filler, binder and fibres, which are able to transfer tensile stresses in the structure. This enhancement enabled fundamental reduction in weight of the resulting product, creating subtle elements and complete omission of the classic reinforcement.

It should be mentioned that it is not only furniture, what is made from concrete, but also jewellery and house equipment such as bowls, lamps (Figure 1), etc. Many practical applications of fibre reinforced concrete can be found in [1].

Figure 1. PP fibre reinforced HPC lamp
2. Production process

The production of FRC tables, chairs, pots, lamps and other similar equipment brings specific requirements. We always require sufficient load-bearing capacity combined with the minimum thickness of the structure aiming to ease a manipulation with the product. Colour and surface quality requirements such as completely bubble-free surface or surface without visible cracks are common in this area of production. Fulfilling these requirements is essential for using concrete as design material because the product is observed by a user from far shorter distance than typical concrete surfaces are. Different scale of these structures compared to traditional concrete structures requires different approaches to most steps of the production process (e.g. load bearing test – Figure 2). This paper is discussing the specificity of mixture design, dyeing, formwork choice and casting relevant for small fibre reinforced concrete structures.

![Figure 2. Load test of Nuselsky bridge (left, archive of DPP) and load test of FRC lamp (right)](image)

2.1. Mixture design

For the mixture which is used for the furniture and house equipment smoothing of the grain curve, (especially the very small fractions of the aggregate) is very important, due to small size and visual requirements. As result very high cement content is needed.

Both meta-kaolin and micro silica fume were tested in the mixture. Better strength characteristics were achieved using meta-kaolin. Experimentally optimised mixture design is displayed in Table 1.

| Component       | Amount (kg.m⁻³) |
|-----------------|-----------------|
| Cement CEM I 42.5 | 700.0           |
| Meta-kaolin     | 140.0           |
| Water           | 168.0           |
| Aggregate       | 1350.0          |
| Plastificator   | 7.0             |
| Stabilizator    | 3.5             |
| PP fibres       | 4.0             |

Not only the mixture design, but also additional parameters of the homogenization procedure (e.g. type of the mixer, mixing speed, air pressure in the mixer, sequence of addition of the compounds, mixing times or temperature), are specific to fibre reinforced concrete. Many of these parameters are discussed in detail in [2-4].

2.2. Dyeing of concrete

Dyeing of concrete products is a very complex discipline. The fact, that concrete is alkaline, limits the usage of pigments only to inorganic dyes. Dyes are commonly available on the market in the form of a
powder or a liquid. Manufacturers also supply colour samplers along with their dyes, but they are only informative because the resulting colour depends on many factors.

The main factor that affects colouring is especially the dose of pigment. Percentage of dosing refers typically to the amount of cement in kilograms. (When dispensing with a liquid suspension, the amount of water in the suspension has to be considered.) For pigment dose of more than 10% is necessary to verify the properties of the resulting concrete (compressive strength etc.). However, the authors of this paper have concluded experimentally that control samples should be rather casted for any amount of pigment dose, as the samplers from suppliers are very often inaccurate. Experimentally prepared control samples of grey-scale toning polypropylene fibre reinforced concrete flower pots are displayed in Figure 3.

Additional experimental observations relate to the amount, type and composition of cement used - it turned out that dark black colour of the product is only possible to make with white cement used in the mixture rather than with usual grey cement. Furthermore, it was observed that using the same type of cement from two different cement plants can lead to a different shade of the resulting product.

Additionally, several other factors impact the final colour, e.g. the amount of water in the mixture, the colour of the aggregate and the length of time the product is moulded and cured.

2.3. Formwork
With such small structures as furniture, there are highly different requirements for the precision of production than for the load-bearing structures of buildings. Dimensional tolerances are routinely in the order of one millimetre, larger deviations are already visible. Many works about influence formwork on concrete surfaces were publicised, for example [5-7].

For classical plywood formwork, 15 high quality turnarounds were achieved for FRC flower pots. The first 4 pieces were of perfect quality and their surface did not have to be additionally grinded. The formwork must be thoroughly cleaned with formwork-oil. The cleaning highly affects the final surface of the concrete, especially amount of bubbles created.

Silicone formworks are used industrially for casting surfaces looking similar to a natural stone in tiles. When casting three-dimensional furniture parts, we encounter the problem of silicone shrinkage and loss of dimensional accuracy. Therefore, we recommend to test the shrinkage properties of the used silicone (properties are not same for all silicones) first, then adjust the shape to the expected deformation or change the silicone supplier. It is also recommended in FRC furniture production not to use the cheapest available silicones on the market due to their far worse properties. Properties also affects the surface quality of the final product.
2.4. Casting Furniture
Concrete mixture with scattered reinforcement was poured into the formwork and vibrated. The piece was removed from formwork after about 15 hours and put into the heat chamber where the increase in strength was accelerated. The resulting product had higher strength due to heating in the heat chamber and had higher suitability for potential grinding. When double taped a piece after removing from the heat chamber a ringing sound similar to the sound in clinker bricks was clearly hearable. With hydration acceleration, we were able to achieve a nominal pressure of up to 150 MPa and a tensile strength of 20 MPa in in the order of dozens of hours.

When jewellery was produced in small quantities (Figure 4), the mixing water was pumped through the syringe in order to achieve millilitre precision.

![Figure 4. FRC necklace (left), FRC earing (right)](image)

3. Conclusion
Fibre reinforced concrete home accessories will probably soon be widely spread, especially thanks to the ability to produce subtle elements with very high strength parameters. The industry of concrete furniture and jewellery is not likely to be the privilege of only large specialized companies, but it will be a chance for even small companies.

Authors of this paper studied the specificity of mixture design, dyeing, formwork choice and casting relevant for small fibre reinforced concrete structures. The findings provide useful guidance for manufactures and researchers of small FRC castings, in particular experimentally verified mixture design, approach to dyeing of products, formwork choice and design and casting process.

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References
[1] Vodička J, Veselý V, Kolář K, Krátký J 2007 Practical Application of Fibre Concrete, In: Fibre Concrete 2007. Praha: Vydavatelství ČVUT, pp. 181-184.
[2] Dils J, De Schutter G, Boel V 2012 Influence of mixing procedure and mixer type on fresh and hardened properties of concrete: a review Materials and Structures 45 pp 1673-1683.
[3] Mazanec O, Lowke D, Schiessl P 2009 Mixing of high performance concrete: effect of concrete composition and mixing intensity on mixing time. Materials and Structures 43 pp 357-365.
[4] Topçu I B, Uğurlu A 2003 Effect of the use of mineral filler on the properties of concrete. Cement and Concrete Research 33 pp 1071-1075.
[5] Courard L, Goffinet C, Migeotte N, Martin M, Pierard J and Polet V 2012 Influence of the reuse of OSB and marine plywood formworks on concrete surface aesthetics *Materials and Structures* 45 pp 1331–1343.

[6] Almusallam A A, Khan F M, Dulaijan S U, Al-Amoudi O S B 2003 Effectiveness of surface coatings in improving concrete durability *Cement and Concrete Composites* 25 pp 473–481.

[7] Goldammer K R 2012 DBV-guide to good practice for concrete cosmetics on exposed concrete surfaces *Beton- Stahlbetonbau* 107 490–494.