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ULTRA-HIGH PERFORMANCE CONCRETE FRESH COMPOSITION PROPERTIES

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Abstract: *The present investigation relates to an ultra–high strength concrete composition with and without steel fibres having a compressive strength of about 150 MPa and 170-180 MPa, respectively. The ultra-high strength concrete composition, which includes a binding material containing cement, fine sand powder, silica fume and water at a mixing ratio 15% to17%,is easy achievable in Romania and therefore its workability and strength are just as easy retained.*
The object of the present investigation is to provide an ultra-high strength composition which includes a binding material containing cement, fine sand powder, silica fume and anhydrite for a determined mixing ratio and a determined workability and to study its behaviour under different keeping conditions especially in view of the compressive strength.
Keywords: *ultra-high strength concrete, disperse reinforcement, hybrid concrete, quartic sand, flow*

1. INTRODUCTION

Recent research studies in the past decade have showed the potential of concrete with dispersed reinforcement especially for a durable development, [1].
Ultra-High Strength and Performance Concrete (UHSPC) has specific desired properties, both as fresh or hardened concrete, making it ideal for a large pallet of structural applications.

2. TECHNICAL REQUIREMENTS

The authors' study focused on two types of UHPSC:
- With and without fibres for a medium slump
- With and without fibres for high slump and flow

UHPSC owns its special properties to a high dosage of Portland cement, a small Water/Binder ratio achieved due to the usage in high dosage of the latest generation of super-plasticizers, a high reactivity puzzolanic material such as silica fume (most common) and the addition of steel fibres as disperse reinforcement. As aggregates, the most common used are quartic sands with a maximum diameter of 1 or 2 mm. The final mix has a constituency very similar to that of a mortar but it's still referred to as concrete.
In the authors' study, the Portland cement has been provided by Lafarge Romania, the super-plasticizer by BASF Romania and the steel fibres with a characteristic ratio of 0.4/25 (diameter/length in mm) with hooked ends by BAUM CAS FIBRES Romania.
The first step in the present study was to achieve an adequate granulometry curve for a maximum possible compaction, as presented in figure 1. The mixing was done with a DIEM concrete pan mixer machine with forced gearing and a maximum capacity of 139 litres, at previously set time intervals.
The principles followed to achieve UHSPC mixes are, [2]:
- An increase in homogeneity by eliminating gross aggregates
- An increase in the bulk density by optimisation of the granulometry curve of the mix
- A better microstructure by usage of a curing method
- A better ductility by addition of steel fibres
- An easy-to-follow procedure in practice

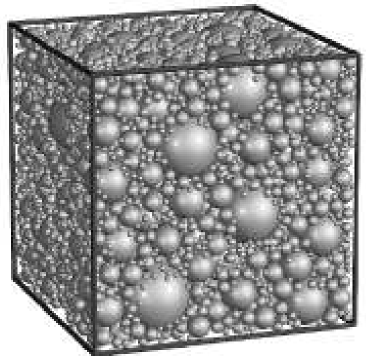


Figure 1: Maximum compaction

2.1. Concrete mixes without fibres or with long fibres

The characteristics for the mixes without fibres (ME 21 and ME 22) are presented in table 1, while figure 2 lists various aspects while mixing, such as workability or slump and flow classes conformity according to the national code provisions (CP 012 /2007).

Table 1: Characteristics for the mixes without fibres

Fresh properties	UHSPC without fibres	
	ME 21	ME 22
Water/Cement (W/C)	0.20	0.22
Water/Binder (W/B)	0.16	0.18
Slump [mm]	220	265
Flow [mm]	340	560
Viscosity [sec]	N/A	36
Temperature [°C]	28.0	26.7
Fresh Concrete Density [kg/mc]	2300	2273
Mix Calculated Density	2331	2288

ME 22 was the reference mix to show the best performance.

ME 21, $S_5 = 220$ mm, $F_1 = 340$ mm | ME 22, $S_5 = 265$ mm, $F_5 = 560$ mm

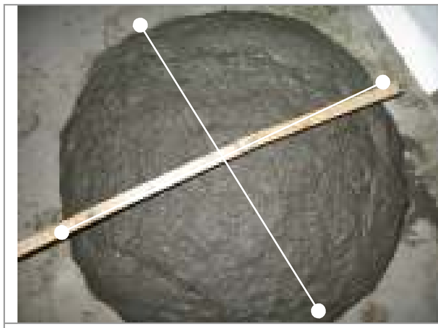
Figure 2: Class conformity for slump and flow tests without dispersed reinforcement

Table 2 shows the fresh properties for dispersed reinforced concrete (OE 20÷OE 24), while figure 3 presents aspects during mixing.

Table 2: Characteristics for the mixes with long fibres (ϕ 4/25 mm)

Fresh properties	UHSPC with long fibres			
	OE 20-6,5%	OE 22	OE 23	OE 24
Water/Cement (W/C)	0.24	0.20	0.22	0.23
Water/Binder (W/B)	0.16	0.16	0.18	0.18

Slump [mm]	230	120	247	240
Flow [mm]	430	47	428	440
Viscosity [sec]	29.3	27.7	29.5	28.8
Temperature [°C]	-	-	4.56	-
Fresh Concrete Density [kg/mc]	2392	2406	2395	2470
Mix Calculated Density	2414	2441	2419	2443

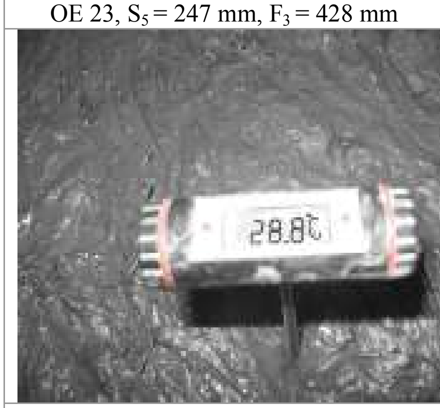


OE 20-6,5%, S_5 = 230 mm, F_3 = 430mm

OE 22 , S_3 = 120 mm,

OE 23, S_5 = 247 mm, F_3 = 428 mm

OE 24, S_5 = 240 mm, F_3 = 440 mm



Temperature measurement

Air content test

Figure 3: Fresh mix properties testing

2.2. Hardened properties for mixes without fibre addition

Table 3 lists the mixes' properties. The results for the compressive strength are determined as the medium value for six specimens (cubes with an edge of 70.1 mm).

Table 3: Keeping conditions impact on compressive strength development in time

UHSPC properties	UHSPC without fibres, with curing			UHSPC without fibres, in water		
	ME 20	ME 21	ME 22	ME 20	ME 21	ME 22

Water/Cement (W/C)	0.20	0.20	0.22	0.20	0.20	0.22
Water/Binder (W/B)	0.16	0.16	0.18	0.16	0.16	0.18
f_{cm} 1 [day]	-	74	65	-	74	65.
f_{cm} 6 [days]	148	152	131	53	78	85
f_{cm} 28 [days]	140	145	125	105	100	101

It is clear that the compressive strength for concrete under curing at 6 days is higher than for the concrete kept under water. At 28 days, the values slightly increase and in some cases they even decrease. For concrete under water to the age of 28 days, it can be seen a gradual increase in the compressive strength over time until testing.

2.3. Hardened properties for mixes with fibre addition

Table 4 lists the mixes' properties for long steel fibres (ϕ 4/25 mm).

Table 4: Keeping conditions impact on compressive strength development in time

UHSPC properties	UHSPC with fibres under curing at 90°C				UHSPC with fibres under water			
	OE 20-	OE 22	OE 23	OE 24	OE 20-	OE 22	OE 23	OE 24
Water/Cement (W/C)	0.24	0.20	0.22	0.23	0.24	0.20	0.22	0.23
Water/Binder (W/B)	0.16	0.16	0.18	0.18	0.16	0.16	0.18	0.18
f_{cm} 1 [day]	77	87	78	131	77	87	78	131
f_{cm} 6 [days]	167	199	172	168	108	115	105	120
f_{cm} 28 [days]	156	201	173	172	142	163	129	137

No matter the curing, it is clear the positive effect on the compressive strength of the addition of fibres. Differences between values in tables 2 to 4, are the result of different super-plasticizer dosage.

2.4. Comparison for concrete without fibres, with long fibres and hybrid

ME 22 mix is the reference for both long fibres and hybrid concrete.
The hybrid mix consists of even quantities of long (ϕ 4/25 mm) and short (ϕ 0.175/6mm) steel fibres.
Slump and flow for concrete without fibres and hybrid are very similar, while for the concrete with fibres, though smaller, do not impair its workability (a property with a high degree of dependence on the addition of fibres), [3].
The authors' study aimed at improving the workability and behaviour of UHSPC under complex loading, especially from the point of view of cracking.

Table 4: Fresh and hardened properties

UHSPC characteristics	UHSPC with fibres under curing		
	ME 22 without fibres	OE 23 with L type fibres	Hybrid OE 23
Water/Cement (W/C)	0.22	0.22	0.22
Water/Binder (W/B)	0.18	0.18	0.18
Slump	265 – T_5	247– T_5	260– T_5
Flow	560 – F_5	428– F_3	545– F_5
Temperature [°C]	26.7	29.5	30.5
Air content	4.60	4.56	4.40
Fresh Concrete Density [kg/mc]	2273	2395	2413
Mix Calculated density	2288	2419	2419
f_{cm} 1 [day]	65	78	84
f_{cm} 6 [days]	131	172	171.8
f_{cm} 28 [days]	139	173	174

An analysis of the above shows that the fresh properties of hybrid concrete (hybrid OE23) is about the same with the reference mix (ME22), but superior to the long fibre mix (OE23 with L fibres). Also, the compressive strength is very similar for all mixes with fibres addition. Figure 4 presents specimens after a compressive strength test.

Figure 4: Specimens after the 6th day test (cubes with the edge of 50 mm, 70.1 mm, 100 mm and 150 mm)

3. CONCLUSION

Achieving quality UHSPC using only local commercially available constituents is a remarkable result in the field of structural concrete.

In their study the authors have developed concrete with high early stage compressive strength of about 170-200 MPa with addition of steel fibres.

A warning is also given regarding curing conditions and the type of super-plasticizer used for achieving the desired properties.

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