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REACTIVE POWDERS CONCRETE

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Abstract: *This paper features the author's theoretical studies and experimental research regarding a relatively new concrete, called reactive powders concrete, characterized by special performance. Reactive powders concretes have, besides the very high compression resistance (200-800 N/mm^2), other performance characteristics, such as: high impermeability, usage without passive reinforcement, resistance to agressive chemical agents, frost resistance. Presented are: the obtaining principles and technology, the constitutive materials and the composition, some properties and domains of usage.*
Key words: *powders, silica fume, superplasticizer, elasticity*

1. INTRODUCTION

Since 1990, in France (Richard, 1995), there is being studied a concrete with special performance called reactive powders concrete (RPC), characterized by an ultra-high resistance to compression, tightness to water and gases, placement without passive reinforcement, and other.
Reactive powders concretes (RPC) are obtained from powders: fine sand, cement, ground quartz, ultrafine silica, having grains which do not exceed 0.6 mm.
They are prepared in conditions similar to those used for the usual concrete, but with a very small quantity of water.
The RPC special performance is obtained by applying four principles:
- the improvement of the material homogeneity by eliminating large aggregates;
- the increase of compactness through granular mixture optimization and, if possible, through pressing before and during setting;
- the improvement of the microstructure through thermal treatment;
- the increase of ductility through steel wire fibres adding.

There have been identified two types of reactive powders concretes:
- RPC 200, which are obtained through thermal treatment at 90 ^oC;
- RPC 800, which are obtained through pressing and a thermal treatment at 250 ^oC applied after setting.

2. THE EXPERIMENTAL PROGRAMME

The experimental programme has been carried out in France, at The Superior Normal School from Cachan, in The Building Materials Laboratory, led by associate professor Gérard Bernier, Ph.D.
The programme included the obtaining and testing of two concretes made up of reactive powders concretes, without and with steel wire fibres, of RPC 200 type.
Each concrete type has been used to obtain cylindrical specimens of 70 mm diameter and 140 mm height, and prismatic specimens of 40x40x160 mm.
On the hardened specimens, there have been established the following: the apparent density, the compression strength (on cylinders), stretching strength from bending (on prisms), the $\sigma - \varepsilon$ diagram at compression, the elasticity module at compression (on cylinders).

3. TECHNICAL ASPECTS OF THE SPECIAL INDUSTRIAL CONCRETE

3.1 The materials and compositions used for this concrete manufacture

Reactive powders concrete has been obtained in L'ENS Cachan Laboratory (France), having in its composition the following foreign materials:
Cement: of CPA 55 HTS type, with high content of silicates;
Sand: siliceous of 0.25 mm grains dimension;
Silica fume: produced by SEPR firm (*** 1996);
Superplasticizer: of MAPEFLUID X 404 type (*** 1996);
Steel wire fibres: produced by BEKAERT firm (*** 1997), having the following characteristics: - carbon content: 0.69-0.76%; - minimum stretching strength: 2000 N/mm^2; - length/dimeter ratio: 13/0.16=81; - source: dead-drawn steel wire. The compositions of the tested reactive powders concretes have been established on the basis of the data that exist in the literature (Dugat et al. 1995), and they are presented in table 1.

3.2 Concretes obtaining

The RPC have been manufactured by using the standard paddle mixer for the establishing of the cement class, the paddle being modified in case of steel wire fibres RPC to prevent fibres aglomeration.
The sequence of the mixing operations at RPC without fibres has been as follows:
- the manual mixing of the materials in the wet mixer tank granulation (cement, sand, SUF);
- wet mixer operation and low speed mixing of the granular materials for 10 seconds, at the same time with the introduction of water in which there has been previously

Component materials	RPC 200 (without fibres)	RPC 200 (with fibres)
Cement CPA 55 HTS, kg/m^3	950	950
Silica fume (SUF), kg/m^3	237 (25% of the cement mass)	237 (25% of the cement mass)
Siliceous sand with d_{med} = 0,25 mm, kg/m^3	997	997
Steel wire fibres with d = 0,16 mm şi l = 13 mm, kg/m^3	-	146 (1,86% in volume)
Superplasticizer MAPEFLUID X 404 (dry substance), kg/m^3	17 (1,43% din cement+SUF)	17 (1,43% din cement+SUF)
Water, kg/m^3	180	180
W/(C + SUF)	0,15	0,15

Tab. 1. Reactive powders concretes compoziton

Preser-ving condi-tions	In moulds covered with polyethyle ne foils	In water up to 20 °C	In water and in drying chamber at 90 °C and 80% relative humidity	In drying chamber at 90 °C and 50% relative humidity
Durata	2 days	7 days	4 days	2 days

Tab. 2. The RPC hardening conditions

Con-crete type	Appa-rent density, kg/m^3	Compression strength f_c, N/mm^2	Stretching strength from bending f_t, N/mm^2	f_c/f_t
RPC without fibres	2227	158,20	17,27	9,16
RPC with fibres	2366	186,12	35,67	5,22

Tab. 3. The RPC characteristics in hardened state

mixed the superplasticizer solution;
- the mixing is continued with middle speed for 10 seconds, and then with high speed for 30 seconds.

For the RPC with steel wire fibres, there has been prepared first the RPC without fibres by observing the sequence of the mixing operations presented above, and then there have been manually introduced the fibres by means of a screen, followed by low speed mixing for 15 seconds, middle speed mixing for 15 seconds, and high speed mixing for 30 seconds.
The concretes hardening conditions (thermal treatment) are presented in table 2.

3.3 The apparent density, the compression strength, the stretching strength from bending

The apparent density, the compression strength, and the stretching strength from bending have been carried out according to the standards in force.
The average values of the characteristics that have been obtained for the hardened RPC are given in table 3 and table 4.
The analysis of the results from table 3 shows that, for reactive powders concrete with steel wire fibres, there have been obtained the following results: for compression strength 186.12 N/mm^2, for stretching strength from bending 35.67 N/mm^2, and an apparent density of 2366 kg/m^3. The strengths thus obtained comply with the values highlighted by the literature for the RPC 200 type, which are of 170 - 230 N/mm^2 for the compression strength, and of 30 - 60 N/mm^2 for the stretching strength. The steel wire fibres have led to the increase of the compression strength with 17.65% and of the stretching strength from bending with 106.50%.

3.4 The σ – ε diagram and the elasticity module at centric compression

The σ-ε diagrams on the cylindrical samples tested at compression have been established by using an automatic logging. The σ-ε curve for the RPC without steel wire fibres is presented in fig. 1, and that for the RPC with steel wire fibres is presented in fig.2.

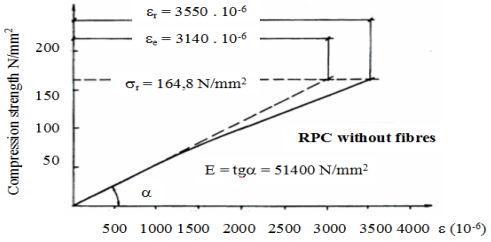

Fig. 1. The σ – ε diagram for the RPC without steel fibres

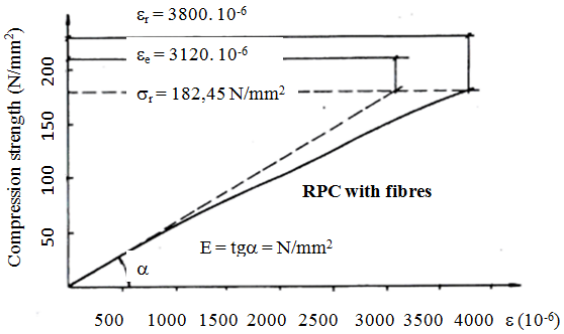

Fig. 2. The σ – ε diagram for the RPC with steel fibres

Concrete type	Compression strength, N/mm^2	The elasticity module, N/mm^2
RPC without fibres	158,20	51 400
RPC with fibres	186,12	55 610

Tab. 4. The elasticity modules for RPC

Comparing these curves with those obtained by other researchers (Dugat et al. 1995), there can be observed a good agreement regarding both quality and quantity. The use of steel wire fibres has contributed to the increase of the breaking stress and ultimate strain. The σ-ε diagrams have enabled the calculation of the elasticity modules. Their average values are given in table 4.

4. CONCLUSION

The analysis of the results obtained for the reactive powders concrete that has been achieved leads to the following conclusions:

1. the strengths, at the compression of 186.12 N/mm^2 and at the stretching of 35.67 N/mm^2, comply with the values highlighted by the literature, which for the BPR 200 type are as follows: 170 - 230 N/mm^2 for the compression strength, and 30 - 60 N/mm^2 for the stretching strength;
2. the comparison of the obtained σ - ε curves with those reported by other researchers indicates a good agreement regarding both quality and quantity;
3. the values for the elasticity modules are near to those from the literature;
4. the reactive powders concretes with steel wire fibres are adequate for structures without passive reinforcements, bent elements, lattice structures, and by their use at precompressed elements there can be obtained much more lighter structures than those achieved from the usual concrete.

5. REFERENCES

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