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HIGH PERFORMANCE CONCRETE IN AREAS SEISMICALLY ACTIVE OF THE ARGENTINEAN REPUBLIC

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SUMMARY

In this work the evaluation of different additions minerals is presented you activate existent in the region center west of the República Argentina and its application in the elaboration and mechanical characterization of Concretes of High Performance (HPC). It is sought to evaluate the aptitude of use of the HPC, associated to new approaches of design of structures sismorresistentes that are developed in the IMS.

It is known that the mechanical properties of the HPC are controlled mainly by the materials used in the elaboration of the concrete and for their possible combinations, what transforms it into a susceptible material of varying from a place to another. For this reason, remarkable divergences usually present in the normative one international and in some approaches of security when it is sought to use HPC in structures sismorresistentes.

This work is part of an investigation program dedicated to develop, to characterize mechanically and to generate necessary design limits for the use of HPC in structures located areas of moderate and high seismic risk. The structural analysis will be carried out in a case following approaches of design traditional sismorresistente, using different types of special concretes rationally and in another case it will be made on designed structures using HPC in combination with systems of energy dissipation.

This program is of excellent interest for the area center west of the República Argentina.

In this work the first part of this program is presented that it consisted on the characterization of natural puzolanas and other regional materials. The followed treatment to facilitate their use. The design of mixtures of HPC and the characterization of fundamental mechanical parameters of the concrete. It was reached with success the acceptable economic technical development of HPC with resistances of 50 Mpa up to 85 Mpa, on those that it was determined Modules from Yung to different ages, Cohesion and Angles of internal friction and it compares it to him with traditional concrete. In the work it is also presented the work plan that is continued to identify the way of dominant flaw of the HPC low states multiaxiales of tension and to compare it with that of the traditional Concrete.

INTRODUCTION

Active mineral additions, as components of concrete, make possible the enhancement of the mechanical resistance of the concrete. Besides, it allows preparing concrete with better durability properties, i.e. resistance against aggressive agents and lower development of hydration heat. Anyway, it is possible to get significant energy savings and design purpose made mixtures for specific structures located in special areas. This preparation of mixtures is what we call in this work HPC.

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A lot of research works exist in relation to the use of active mineral additives (micro-silex, fly ashes, metha-kaolin, etc.) in the elaboration of HPC. Physic-chemistry properties of these additions are variable and the action mechanism is controlled by the pozzolan reaction. The mechanical properties of the HPC, also depend on the characteristic of the granular materials used. There are considerable differences on the mechanical behaviour of HPC, inclusive with the same resistance, depending on these variables and on where they are been manufactured. Research on the characterisation of natural pozzolan of volcanic origin and diatomaceous ground extracted from local quarries, with the purpose of being employed, as active mineral additives, is shown in this work. Preliminary geologic surveys, specimen collection and tests for physical chemical characterisation were also carried out. The most interesting samples were selected to investigate the effect of fineness and granulometry on the pozzolanic activity. In addition, some concrete samples were made to evaluate traction and compression mechanical properties and their evolution in time. The work presented in this paper is part of a greater research project which aim is the evaluation of the technical and economical possibilities for using this HPC, made with local materials, in building structures of the Argentinian West Central area. This area is, on the other hand, the zone of maximum seismic risk in this country.

MINERAL ADDITIONS OF THE REGION

The HPC referred in this work is made from raw materials extracted from volcanic rocs and ashes located in the area of the Andes mountain range (San Juan and Mendoza provinces) in the region of “Cuyo”. This region of Cuyo is located in the Argentinian West Central area.

2.1 The volcanic materials of Cuyo

The different materials of volcanic origin, i.e. granulated pumice, volcanic ashes and pozzolan, which age is nearly always from the post-Tertiary, of the region mention above, are included in this denomination. This area is where the main production is registered.

San Juan

The main outcrops of volcanic rocs and ashes, in the San Juan province, are located in the eastern edge of the Andes pre-mountain range, in the north of the *Blanco* hill of *Ullum* and in the first counterforts of the *Dehesa* mountain (about 30 km. from San Juan city -SJC-). Important deposits of ashes and tufa exist also in the edge of the Andes, especially in different areas of the *Albarracín* pass. The main deposit in the pass is located in its western edges (about 36 km from SJC). A second county with these kind of volcanic materials exists in the western edge of the Andes pre-mountain. One, nearly *Sorocayense-Barreal* at the end of the *Rincón Blanco* pass (about 170 km. from SJC) and the other in the *Iglesia* Valley (about 220 km. from SJC).

At last, other important volcanic ash areas exist in two mountain formations belonging to the Frontal Andes mountain range. One of this, called by Grosser, the Formation of tufaes, breaches and conglomerates, belongs to the under-Jurassic period and is located in the *Cura* valley, *Colangüil*, *Vacas Heladas, Los Bañitos, La Brea,* etc. The other is from a modern period, with facies of the Tertiary and the Quaternary, with a lot of volcanic episodes and in a lot of cases with interesting cupro-auriferous. The data of diatomaceous ground from *Iglesias* county is also presented.

Mendoza

The development of volcanic materials to be used in civil constructions and some industrial activities (isolations) has been done in this province since years ago. These main deposits are situated in the central area of the province: *Campos de Yaucha* (*San Carlos* county). Nevertheless, other less important deposits are located in the surrounding area of *Chihuido* hill, the *Escorial*, the *Reyunos*, *Loma del Medio* and *Agua de la Chilena*. All of them are in the southern counties and they are not so much exploited. The area of *Yaucha* is located in the eastern edges of the Frontal Andes mountain range, 20 km. along the sides of the *Yaucha* stream. The greater formations lay like long hills over the plain area.

2.2. Characterisation of the local pozzolan.

Natural Pozzolan from San Juan and Mendoza provinces was selected for this work. Details about the chemical composition of that Pozzolan can be found in table 1. Figs. 1 to 3 show x-ray diffraction patterns from the Pareditas, Diatomaceae and Kaolin samples.

Table 1 Chemical composition of local natural pozzolane

Samples	*SiO2*	*Al2O3*	*Fe2O3*	*CaO*	*MgO*	*Álcalis*	*P. 105 °C*	*P.P.C.*
Diatomacea - San Juan	61,38	17,36	4,52	3,83	2,22	6,20	2,38	5,86
Tufa 1 - San Juan	62,00	19,00	3,45	4,48	1,32	4,10	1,00	3.50
Tufa 2 - San Juan	54.18	18.49	5.27	6.20	1.95	3,67	1,54	3,50
Kaolin - San Juan	72,80	16,61	0,32	2,62	0,13	2,00	1,62	2,35
Tufa Pareditas - Mendoza	59,20	19,47	3,54	3,20	2,15	7,05	1,73	6,24

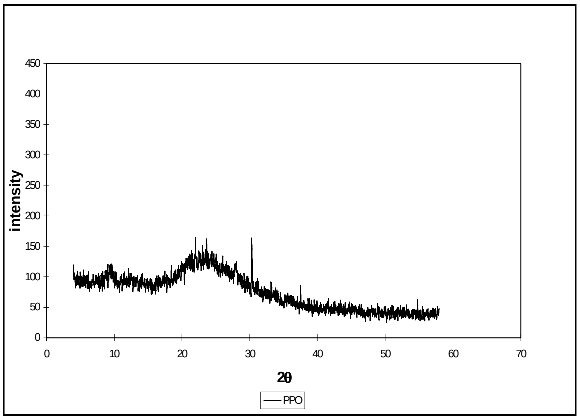


Fig. 1 DRX - Pareditas

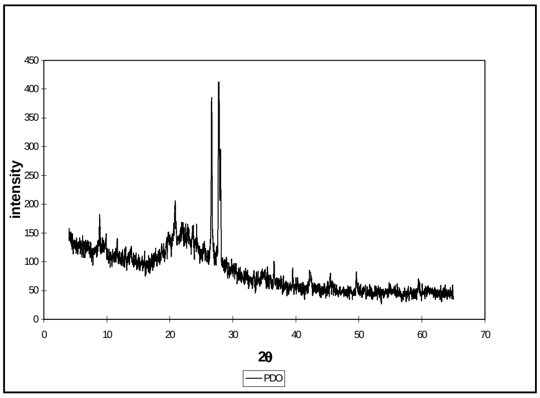


Fig. 2 DRX - Diatomaceae

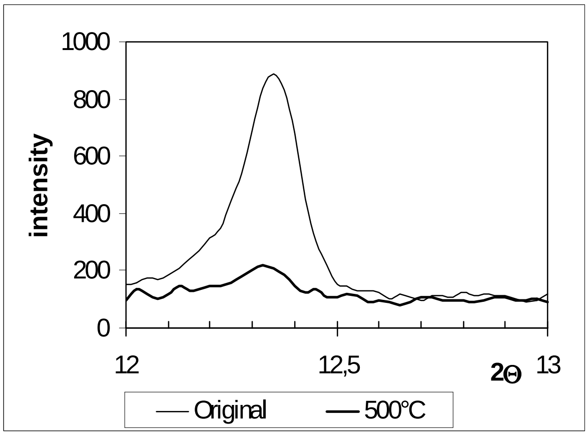


Fig. 3 DRX – Thermal-treated Kaolin

To evaluate the pozzolanic activity and its dependence from grinding degree (particle size distribution) several Pareditas samples were ground, in the laboratory mills, to obtain finer powders. The particle size distributions obtained are shown in fig. 4.

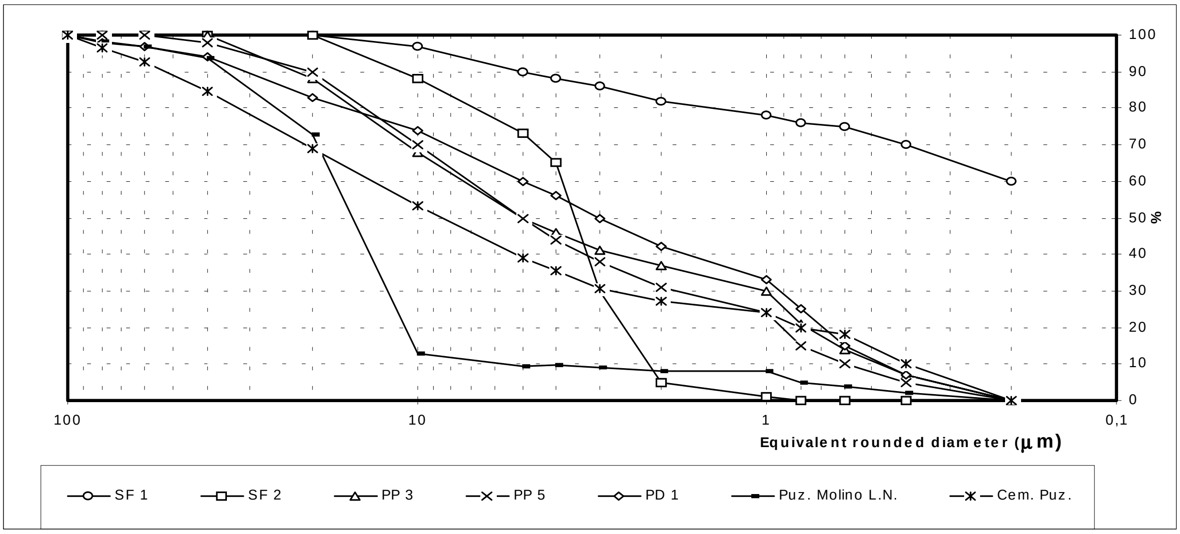


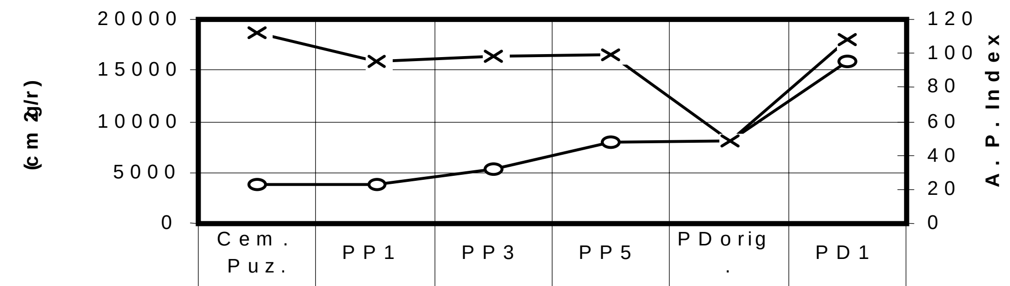
Fig N° 4 Granulometry of natural pozzolan

Samples where the 25% of the cement was replaced by Pozzolan and in the same conditions other control mortar sample containing only cement were prepared. Both sets of samples were tested after 28 days to bending and compression. The results of these tests are summarised in table 2. It can be seen, on one hand, that the diatomaceae, with a high degree of grinding, are the most actives and, on the other hand, that the tufaes, with lower degree of grinding have similar efficiency.

Table 2 Pozzolanic activity. Fitness and granulometry

	Bending Kg.	Bending Kg/cm^2	Comp. Kg.	Comp. Kg/cm^2	Ip %	S.Esp. cm^2/gr	Fluidity %
CONTROL MORTAR	236	53	4270	257	**---**	**3160**	**291**
	224		3900				
	224		4170				
Pozzolanic Cement	295	70	4560	288	**112**	**3860**	**168**
	310		4530				
	293		4740				
PP5	350	79	4135	256	**99**	**7959**	**268**
	318		4080				
	342		4050				
PP1	300	73	4180	245	**95**	**3730**	**273**
	330		3800				
	302		3800				
PP3	312	74	4060	251	**98**	**5247**	**316**
	315		3950				
	325		4040				
Original PD	155	36	2010	125	**49**	**8051**	**186**
	147		2000				
	160		2000				
PD1	307	76	4400	279	**108**	**15824**	**136**
	317		4520				
	347		4460				

In Fig. 5 it can be observed that the granulometric distribution of the active fine-grained material has a great influence in the last properties of the mortar. The sample of pozzolanic cement tested includes two well-defined modal forms about its granulometric distribution. But, for a very low fineness the values of the activity are equivalent.



	Cem. Puz.	PP1	PP3	PP5	PDorig.	PD1
Blaine (cm 2/gr)	3860	3730	5247	7959	8051	15824
IP (%)	112	95	98	99	49	108

Fig. 5 Activity and efficiency Vs fitness and granulometric distribution.

To check the pozzolanic reaction X-ray diffraction analysis and scanning electron microscopy (SEM) pictures were performed. Fig. 6 shows the diffraction pattern of the control mortar, without mineral addition. It can be seen clearly calcium hydroxide from the cement hydration. In fig. 7 the diffraction pattern of mortar with paredita´s pozzolan (25% proportioning) can be seen. In this case there is no calcium hydroxide because it reacts with the pozzolan. The SEM analyses point to the same observation and conclusions.

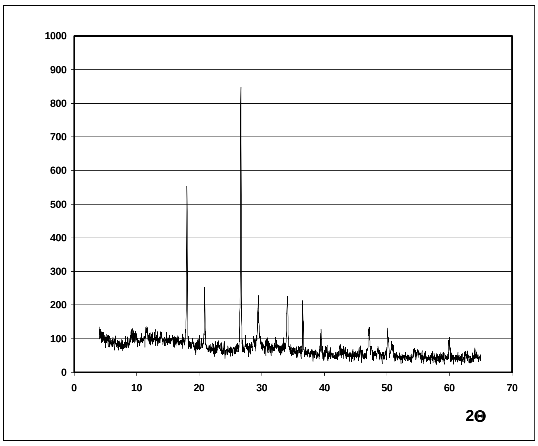


Fig. 6 XRD Control mortar – 90 days

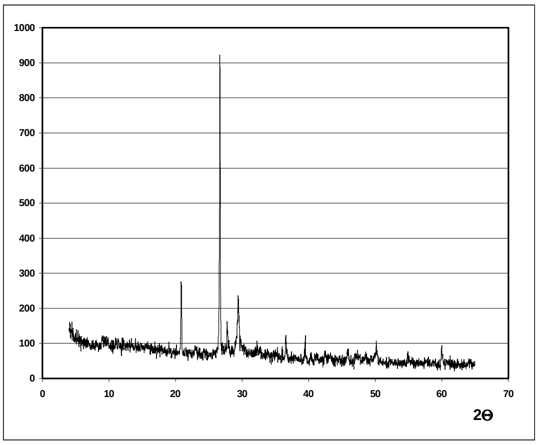


Fig. 7 XRD 25 % Diatomaceae - 90 days

HIGH PERFORMANCE CONCRETE

To evaluate the properties of the pozzolan used in the preparation of HPC and to ascertain their behaviour in both fresh and hardened conditions, further essays were carried out. The material has to be adequate not only from the technical point of view. It has to be competitive in terms of final cost after the industrial process. The criteria for the selection and the mixture design were the local availability of the raw materials.

Hence, for the manufacture of these materials, standard cement from local factories (of 50 Mpa.) with high content of C_3S and low content of C_3A was employed. The aggregates used are rolling stones from San Juan river. They are of good quality, uniform dimensions, resistant, clean and without soft mineral particles. The rocks exhibit high resistance to compression (in average 120 Mpa.). Also an additive, from a well-known manufacturer, to reduce the water/cement ratio was used. Table 3 summarises the mixtures prepared and Table 4 shows the results of the essays carried out on hardened concrete.

Table 3 Mixtures of the samples

COMPONENT	Unit	P1	P2	P3
Cement	Kg/ m^3	500	500	500
Pozzolan	Kg/ m^3	100	125	125
Water	Lt / m^3	150	175	175
Gravel (19 – 9,5)	Kg/ m^3	807	760	762
Gravel (9,5 – 4,75)	Kg/ m^3	200	190	190
Sand (4,75 – 0,6)	Kg/ m^3	440	415	635
Sand (0,6 - 0)	Kg/ m^3	235	225	
Super-fluidity	Lt/ m^3	14	12.2	8
Consistence	cm.	18	15	12

Table 4. Test results of hardened concrete. C°: Compression, T°: Traction, C : Cohesion and ϕ : Internal friction angle

	P1					P2					P3				
Age Days	C° (Mpa)	T° (Mpa)	C [Mpa]	ϕ	E (Mpa)	C° (Mpa)	T° (Mpa)	C [Mpa]	ϕ	E (Mpa)	C° (Mpa)	T° (Mpa)	C [Mpa]	ϕ	E (Mpa)
7	58,5	----	----	----	----	69,5	----			----	---	---			
28	76	----	----	----	36500	73	----			36000	46	---			41000
90	76	5,35	11,35	56	48000	----	4,8			----	62	4,3	9,17	57	----
365	95	7,10	14,74	55	54000	88	5,3	11,93	59	51000	70	4,8	10,28	57	

CONCLUSIONS

Nevertheless, it is necessary to investigate further in the optimisation and study of structural elements under different load patterns, in order to use this HPC in the Cuyo region. As we mention before this is a high seismic region. The following conclusions of the first results can be pointed out:

The pozzolanic activity of the samples studied has been tested and proved.

The addition of active raw materials from the geographic area can be considered to be apt to elaborate concrete of especial properties. For instance, durability, i.e. sulphate attack resistance, and to control the hydration heat dissipation.

Despite of having a lower efficiency than concrete prepared with microsilex, still it is possible to use the Pozzolan to make HPC.

The cost of the quarry is around $2 per ton. From the economic point of view is very interesting and can be considered to be apt.

The fresh concrete has a slightly higher viscosity compared with the ones without pozzolan, but nevertheless is apt to be placed through difficult access places.

Hardened shows increasing resistance up to one year, with a higher increase in the beginning due to the type of cement used.

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