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CHARACTERIZATION OF CEMENT PASTE AS ENGINEERED BARRIER OF BOREHOLE REPOSITORY

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ABSTRACT

Results of axial rupture by compression of cylindrical cement paste samples are presented. This is part of a research on cement paste behavior aiming at investigating the durability of cementitious materials in the environment of repositories for radioactive waste. Portland cement paste is intended to be used as a backfill in a deep borehole for disposal of sealed radiation sources which concept is under development. The service life of the engineered barrier materials plays an important role in the long term safety of such facilities. Accelerated tests in laboratory are being used to evaluate the performance of cement paste under the temperature expected at some hundred meters below grade, under exposure to the radiation emitted by the sources, and under the attack of aggressive chemicals dissolved in the groundwater, during the millennia necessary for the decay of the most active and long-lived radionuclides present in the waste. The large variability in results of mechanical strength as measured by axial compression of cylindrical samples is the subject of this short communication.

1. INTRODUCTION

Studies on the performance of cement materials as immobilization matrices and as engineered barriers in repositories for radioactive waste dates back to the beginning of the nuclear industry. Surprisingly, this issue is still the object of research and publication of technical papers. An ongoing Coordinated Research Program (CRP) organized and sponsored by the International Atomic Energy Agency on the behavior of cementitious materials is one example. The complexity of the chemistry of Portland cement and the variability of repository conditions may be an explanation for the continuing question of how cementitious materials behave in the long term [1].

The Radioactive Waste Management Laboratory (RWML) of the Institute of Energy and Nuclear Research (IENR) is participating in that CRP as part of its program on development of the concept of a borehole repository for disused sealed radioactive sources in which cement paste is used as backfill [2].

Concrete is par excellence the structural material of cement and cement paste is seldom used as structural material. One exception is oil or water wells construction, where the annular space between the well casing and the geological formation is backfilled with cement slurry to settle and harden in place. In the RWML's concept of repository for sealed sources, hardened cement paste will function as an additional barrier against water inflow, water movement between different strata of the geological setting crossed by the borehole, and against the migration of the disposed radionuclides out of the facility.

The aim of the research project reported here is to evaluate the durability of cement paste under the conditions that are deemed to prevail in the environment of that kind of repository. Preliminary studies were done to establish the sizes of the samples for testing, their geometries, reproducibility of the test conditions and so on.

Previous results from RWML's cement laboratory showed too large variability in the mechanical resistance of cement paste samples. Differences in mechanical resistance of samples of the same lot were large enough to make the test procedures useless to detect the expected changes in performance induced by the exposure of the cement paste to aggressive environment.

Possible causes of variation in results could be: mistakes in the preparation of the samples, bad quality cement, inadequate setting conditions, improper plastic moulds, and failure of testing instruments.

To identify the cause of the great variability of the results, a series of tests was performed and results are presented in this article. The results of durability tests are presented in another paper in this meeting.

2. MATERIALS AND METHODS

To check the quality of equipment and procedures of RWML's laboratory, results were compared with results from a reference cement laboratory – the Laboratory of Civil Construction Materials of the São Paulo State's Institute of Technological Research (ITR).
Standard size reusable metallic cylindrical moulds 100 mm high x 50 mm diameter were compared with disposable plastic moulds standard size and non-standard half scale (50 mm x 25mm) size to validate test procedures with smaller samples. Samples were tested in relation to the mechanical resistance by axial compression [3]. The smaller sample sizes, cast with plastic moulds will be required to standardize the tests in the irradiation trials.

Cement paste was prepared with Portland cement Type V of ABNT [4], equivalent to HES cement of ASTM [5]. One cement bag was purchased from a retailer and one bag was supplied by the Brazilian Association of Portland Cement (ABCP) through the ITR.

The following factors were considered in a complete multifactorial experiment to detect the cause of the large variability observed:

a) The molding laboratory – RWML or ITR;
b) Source of the cement – purchased from retailer or a sample bag provided by ABCP;
c) Setting conditions – sample sealed in the mould or kept in a moist atmosphere chamber;
d) Testing equipment – ITR's compression tester or RWML's equipment;
e) Moulds – standard metallic moulds or plastic moulds.

Sample lots were prepared according to the scheme shown in Table 1, with six samples per lot. Samples were put to set in a moist chamber according to ABNT standards at ITR laboratory or were kept in the sealed plastic moulds at RWML laboratory. The size and geometry of plastic moulds are the same of the metallic standard moulds but plastic moulds are disposable because they must be broken to allow cast samples to be removed.

Table 1. Distribution of sample lots according to the factors under investigation.

Lot ID	Moulding Laboratory	Cement Origen	Setting conditions	Test Laboratory	Mould type
A	ITR	ITR	ITR	ITR	Plastic
B	ITR	ITR	ITR	ITR	Standard
C	ITR	ITR	ITR	RWML	Plastic
D	ITR	ITR	ITR	RWML	Standard
E	ITR	RWML	ITR	ITR	Plastic
F	ITR	RWML	ITR	ITR	Standard
G	ITR	RWML	ITR	RWML	Plastic
H	ITR	RWML	ITR	RWML	Standard
I	RWML	RWML	RWML	ITR	Plastic
J	RWML	RWML	RWML	ITR	Standard
K	RWML	RWML	RWML	RWML	Plastic
L	RWML	RWML	RWML	RWML	Standard

3. RESULTS AND DISCUSSION

Samples of each lot were tested after the curing period of seven days. Results are presented in Table 2 and in Figure 1.

Table 2. Pressure of rupture of cement paste samples, seven days old

	Testing lots				Pressure of rupture (MPa)		
Cement origin	Mould type	Casting Lab	Testing Lab	Lot ID	Maximum	Minimum	Median
RWML	Plastic	ITR	ITR	E	36	15	25
			RWML	G	31	22	25
		RWML	ITR	I	37	14	35
			RWML	K	37	27	34
	Standard	ITR	ITR	F	53	24	40
			RWML	H	44	38	43
		RWML	ITR	J	41	13	37
			RWML	L	42	25	40
ITR	Plastic	ITR	ITR	A	33	20	26
			RWML	C	39	13	34
	Standard	ITR	ITR	B	47	24	43
			RWML	D	43	36	41

These results show that even the sample sets with the closest maximum and minimum values to the median, the variability is larger than expected. ABNT Standard accepts a coefficient of variation, that is, the percent of the standard deviation to the mean, in rupture pressure of mortar samples, of 6% [6]. As there is no standard for cement paste, a value of about 10% was expected and set as test acceptance limit.

Analyses of that data resulted in no identification of a factor (cement origin, casting or testing lab, and mould type) that could explain the large variation coefficients observed. Figure 2 shows the results separated by each factor, noting that IENR stands for RWML laboratory.

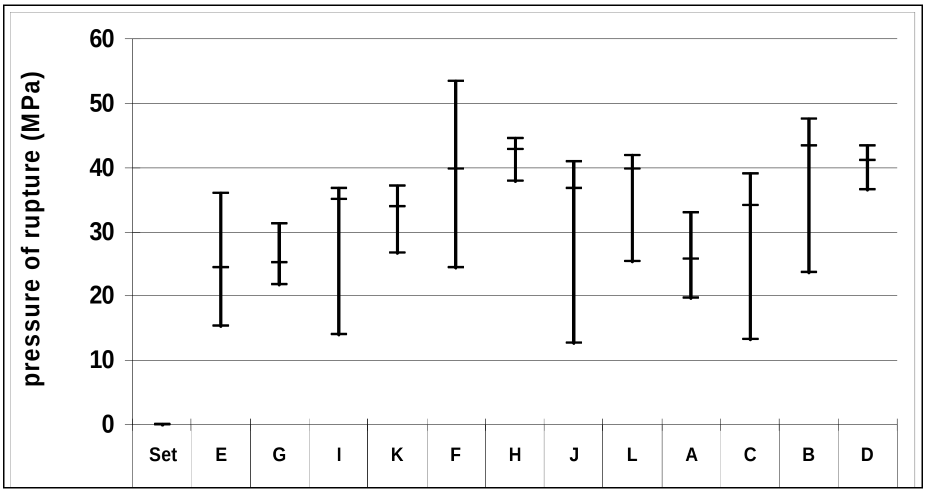

Figure 1. Pressure of Rupture: Low, High and Median values of all sample sets.

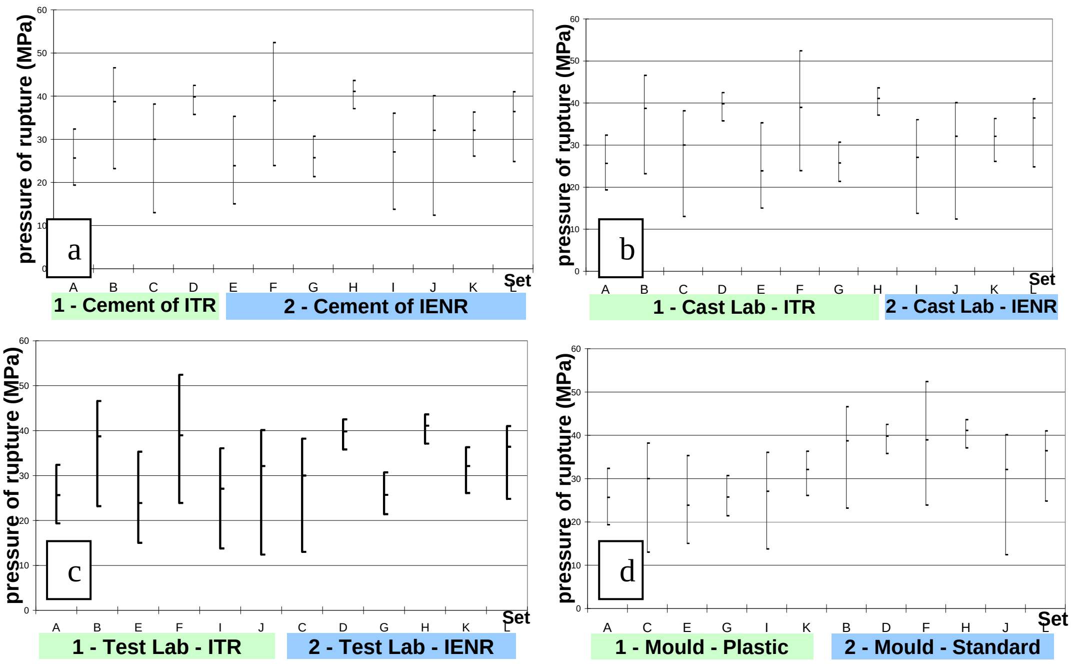

Figure 2. High, low, and median rupture pressure results, grouped by factor.

The grouping of test results seems to indicate that no factor individually or a combination of factors seem to point a reason for the large variability observed, except, perhaps, the testing laboratory (Figure 2c, above) because most sample sets, except one, tested at the RWML's equipment showed lower variability. However, that was a fortuitous output. Careful casting, curing, and testing of samples did not avoid large variability of results. One possible explanation is that this behavior is an intrinsic property of cement paste. However, a literature survey resulted in no hint on this matter. This suggests that more research is needed.

4. CONCLUSIONS

The large variability in results of mechanical strength of cement paste samples could be thought as an intrinsic property of cement paste. A very careful testing of 12 sets of six samples each resulted in rupture pressure varying in as much as about 50% variation coefficient around the mean. However, a literature survey indicates that no such large variation is reported, although no specific discussion about the mechanical resistance of cement paste was found. Furthermore, large variations in the properties of this material were unexpected based on the knowledge of the properties of cement paste as a constituent of mortar and concrete. So, another explanation must be searched for. Preliminary trials with cubic 2 cm x 2 cm x 2 cm cement paste samples exhibited results within five to ten percent around the mean, indicating that the idea of large variability as a property belonging to the very nature of cement paste is unsustainable. These results will be presented in a future communication.

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REFERENCES

1. Mehta, P;KJ.; MONTEIRO, P.J.M., *Concrete: structure, properties and materials*, 2nd ed., New Jersey (USA), Prentice Hall (1993)

2. Philipose, K.E., "500 year concrete for a radioactive waste repository.", '88 Waste Management Conference. Tucson Arizona, Feb. 28 – Mar. 3 (1988)

3. ABNT. Concreto – Procedimento para moldagem e cura de corpos-de-prova, NBR 5738 Dez., (2003)

4. ABNT. Cimento Portland de alta resistência inicial, NBR 5733, Jul (1991)

5. ASTM C150-07. Standard Specification for Portland Cement

6. ABNT. Concreto – Cimento Portland – Determinação da resistência a compressão., NBR 7215 Dez., (1996)