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(I.A.E.G.)

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"THE USE OF UNSOUND BASALT AS CONCRETE AGGREGATE"

Eng. Francisco Rodrigues Andriolo
THEMAG ENGENHARIA LTDA.
Eng. Bento Carlos Sgarboza
CESP - COMPANHIA ENERGÉTICA DE SÃO PAULO
Eng. Miguel Normando Abdala Saad
CESP - COMPANHIA ENERGÉTICA DE SÃO PAULO
Brazil.

SUMMARY

In certain regions in Brazil, the occurence of basaltic rock flows is verified. Among these flows, the presence of unsound basaltic rocks has been observed, when exposed to weather cycles.

The Paranã river valley, stands in a region where the afore mentioned flows occure.

Since the Paranã river basin offers a high hydroelectric power potential, involving the construction of great a number of dams, each dam with concrete volume higher than $1{,}4 \times 10^6$ m^3 there was a certain interests to evaluate, in details, the behaviour and conditions for the use of this type of unsound rock as concrete aggregate.

Special studies were carried out with concrete specimens using this type of aggregate, simulating various different weather cycle conditions.

General data concerning these studies will be put forward in the present paper.

The comments regarding the conditions of use of this type of rock as concrete aggregates, will be based upon the informations registered during the above mentioned studies.

ASSOCIATION INTERNATIONALE DE GEOLOGIE DE L'INGENIEUR

(A.I.G.I.)

SYMPOSIUM INTERNATIONAL SUR LES GRANULATS

NICE (FRANCE) - MAI - 1984

" UTILISATION DE BASALTES DÉSAGREGÉABLES COMME AGRÉGATS POUR LE BÉTON "

Engº Francisco Rodrigues Andriolo
THEMAG ENGENHARIA LTDA.

Engº Bento Carlos Sgarboza
CESP - COMPANHIA ENERGÉTICA DE SÃO PAULO

Engº Miguel Normando Abdala Saad
CESP - COMPANHIA ENERGÉTICA DE SÃO PAULO
BRÉSIL.

RÉSUMÉ

Les regions centre et sud du Brésil, presentent des coulées basaltiques, d'age, Mesozoïque, couvrant une superficie d'un million de kilomètres carrés. Parmi ces coulées on peut observer la présence de roches basaltiques qui se désagregent quand elles sont exposées à des cyclages naturalles dues aux variations climatiques.

La valée du fleuve Paraná est la plus importante de ces régions etant donné le grand potentiel hidroélectrique de ce bassin - ce qui a conduit à la construction de nombreux grands barrages, présentant des consommations de béton supérieures a $1,4 \times 10^6$ m^3 par ouvrage - il y en a eu besoin d'évaluer en détail le comportement et le conditions d'utilization de ce matériel.

Le présent travail résume les résultats des essais de caractérisation et de bonne tenue de ce genre de roche quand soumise aux conditions mentionnées ci-dessus. On présente egalement un recueil d'informations concernant son comportement quand employées comme agrégats pour le béton, ainsi que les données relatives aux études spéciales effectuées sur ces bétons.

A partir des informations obtenues, sont commentées les conditions d'utilisation de ce matériel.

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INTERNATIONAL SYMPOSIUM ON AGGREGATES
NICE (FRANCE)-MAY-1984

"USO DE BASALTOS DESAGREGÁVEIS COMO AGREGADOS PARA CONCRETO"

- Engº Francisco Rodrigues Andriolo
  THEMAG Engenharia Ltda.
- Engº Bento Carlos Sgarboza
  CESP - Companhia Energética de São Paulo
- Engº Miguel Normando Abdala Saad
  CESP - Companhia Energética de São Paulo

Brasil.

R E S U M O

Em determinadas regiões do Brasil ocorrem derrames de rochas basálticas. Dentre esses derrames tem-se observado a presença de rochas basálticas desagregáveis quando expostas à ciclagens e intemperismos.

O vale do rio Paraná se encontra em região onde se destaca a ocorrência desses derrames.

Tendo em vista o grande potencial hidrelétrico da Bacia do Rio Paraná, implicando em construção de um número elevado de grandes barragens, com volumes de concreto superiores a $1,4 \times 10^6$ m^3 para cada obra, houve interesse de se avaliar em detalhes o comportamento e condições de uso desse tipo de rocha desagregável.

O trabalho apresenta resultados de ensaios de caracterização e de sanidade desse tipo de rocha, bem como informações de seu comportamento como agregado para concreto.

São apresentados dados de estudos especiais efetuados em concreto composto por agregados desse tipo de rocha, simulando diversas condições de ciclagem e intemperismos.

A partir das informações obtidas são comentadas as condições de uso desse material.

1 - INTRODUCTION

A great number of hydroeletric projects has been built by CESP - Companhia Energética de São Paulo, in the Paraná River Basin.

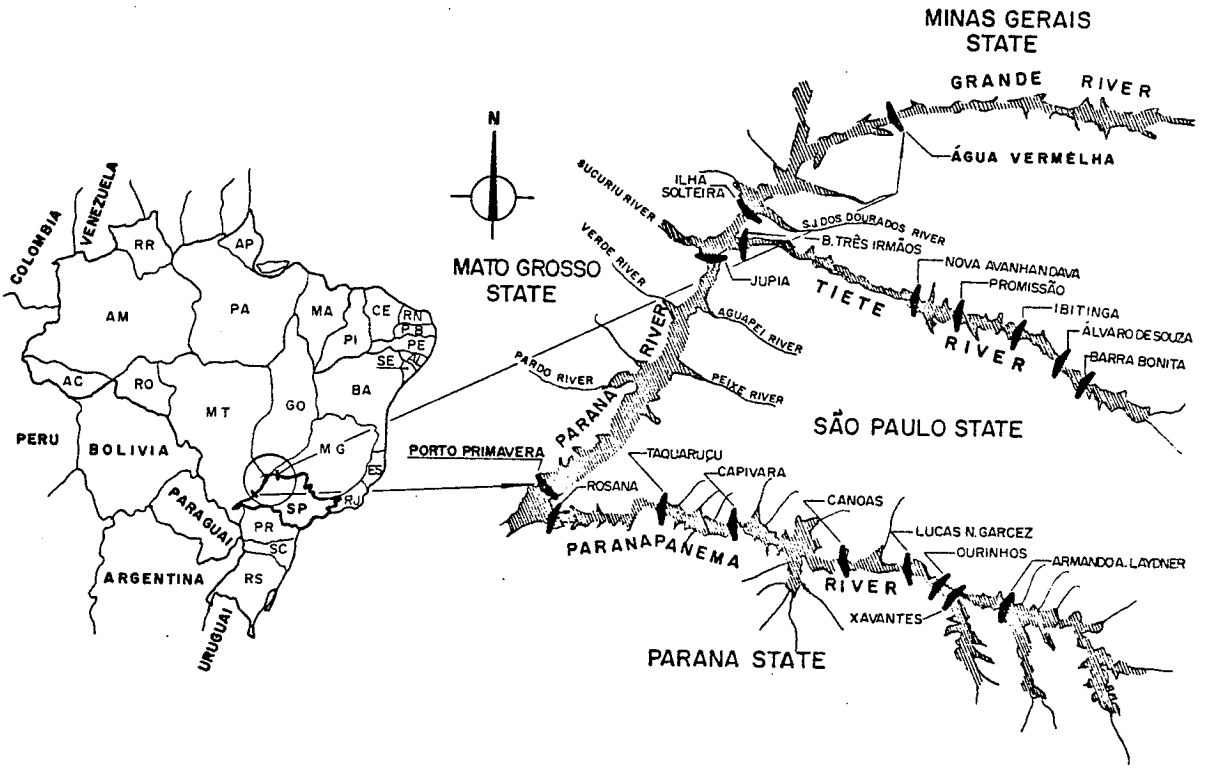

FIGURE 1 - HYDROELETRIC PROJECTS BUILT BY CESP

It was noted during the material studies for one of these projects the presence of Basalt rocks that were attacked by weathering and totally desintegrated after few days of exposure.

It was adopted that this material would not be used as concrete aggregate. However, the evolution of concrete technology and the need of less expensive solutions have induced the engineers to search the performance of this material as concrete aggregate.

Consequently, CESP has studied soundness of this material for new projects and in this paper results and suggestions regarding the use of this basalt for Porto Primavera project, are presented.

The climate of this region presents a minimum medium temperature in the colder month of 12°C, maximum medium temperature in the warmer month of 32°C, annual rain precipitaion of 1250 mm, relative humidity of 75% and no snow.

2 - MATERIAL

The unsound Basalt may be described (ASTM-C-295) as follows:

Color: Gray
Structure: Compact
Texture: Intergranulation, medium granulation
Composition: Plagioclase (Labradorite) - 40%
Pyroxene (Augite) - 40%
Clay mineral (Smectite) and devitrified glass - 20%

Some results of tests carried ou in samples of this basalt are shown below.

- Specific Gravity (ASTM-C-127) - 2,76 g/cm^3
- Absorption (ASTM-C-127) - 2,6%
- Compressive Strength (ASTM-D2938) - 770 kgf/cm^2
- Modulus of Elasticity - 300.000 kgf/cm^2
- Los Angeles Abrasion - Loss (ASTM-C535) - 49%
- Soaking in Ethylene Glycol - Corps of Engineers - CRD-C-148 - Total Desagregation after 5 days.
- Cycles of wetting and oven drying - A sample of basalt with 50 particles was submitted to alternated cycles of immersion in water and oven drying. Each cycle lasted 12 hours. Table 1 shows the results of this test.
- Exposure to weathering - 50 particles were exposed to ambient conditions and the observations are resumed in table 2.

NUMBER OF CYCLES	WEIGHT LOSS IN 19 mm SIEVE % ACCUMULATIVE	NUMBER OF AFFECTED PARTICLES		
		TYPE OF ATTACK		
		DESINTEGRATION	FRAGMENTATION	NO ATTACK
0	0	-	-	50
12	37.8	16	14	20
24	69.0	30	11	9
36	84.0	40	10	0
48	92.3	45	5	0
60	96.4	47	3	0

TABLE 1 - RESULTS OF WETTING AND OVEN DRYING TEST.

NUMBER OF DAYS	WEIGHT LOSS IN 19 mm SIEVE % ACCUMULATIVE	NUMBER OF AFFECTED PARTICLES		
		TYPE OF ATTACK		
		DESINTEGRATION	FRAGMENTATION	NO ATTACK
0	0	-	-	50
30	38.3	16	15	19
60	58.0	28	11	11
90	74.5	35	10	5
120	78.3	37	11	2
150	80.3	38	12	0
180	86.6	41	9	0

TABLE 2 - EXPOSURE TO WEATHERING OF 50 PARTICLES.

The characterization of the material was completed by observations of 5 m^3 of crushed stones of maximum size of 38 mm exposed to 3 conditions: Weathering; ambient exposure with daily wetting and covered to prevent weathering action.

The superficial stones exposed to weathering and to ambient exposure with daily wetting desintegrated in a few days but the ones protected showed no significative deterioration.

3 - STUDIES IN CONCRETE

With the aim of obtaining data of the concrete performance by using this unsound basalt as concrete aggregate, various tests had been made comparing concrete containing unsound basalt of Porto Primavera site with concrete containing a sound basalt that had been used in the construction of Agua Vermelha Dam.

A summary of the studies is showed as follows.

3.1 - DETERMINATION OF CONCRETE PROPERTIES

Four mixtures for each type of basalt, were tested varying maximum size of the aggregate, the water/cement ratio and the amount of pozzolan.

Cylindrical specimens of 15 x 30 cm and 45 x 90 cm, according to the maximum size aggregate (38 mm or 152 mm), were casted.

Table 3 shows the mixture composition and the results of compressive strength, modulus of elasticity (ASTM-C469) and splitting tensile strength (ASTM-C496).

3.2 - EXPOSURE OF CONCRETE BLOCKS TO VARIOUS CONDITIONS

In this test, concrete blocks were exposed to 3 conditions: immersed in water, cycles of wetting and drying and weathering.

Concrete blocks were casted, some of them containing unsound and others sound basalt to allow a comparison of perfomance of both materials.

Table 4 presents a summary of these tests.

Photo of figure 2 shows a block exposed to weathering.

MIXTURE		1	2	3	4	5	6	7	8
TYPE OF BASALT		SOUND	UNSOUND	SOUND	UNSOUND	SOUND	UNSOUND	SOUND	UNSOUND
MAXIMUM SIZE AGGREGATE (mm)		38	38	152	152	152	152	152	152
WATER / CEMENT		0.50	0.50	0.55	0.55	0.85	0.85	0.85	0.85
COMPOSITION (Kg/m³)	CEMENT	249	268	116	122	110	115	78	80
	POZZOLAN	49	53	40	42	-	-	27	27
	WATER	156	168	91	96	93	98	95	98
	SAND	728	702	526	478	565	487	560	487
	CRUSHED STONE 19 mm	662	542	237	229	237	234	237	234
	" " 38 mm	662	693	365	301	365	307	365	307
	" " 76 mm	-	-	529	440	529	451	529	451
	" " 152 mm	-	-	693	794	693	810	693	810
SLUMP (cm)		6.0	5,2	4.5	3.7	4.0	4.0	4.5	4.0
AIR ENTRAINED %		1.3	1.6	5.5	5.7	6.1	5.5	5.6	6.1
COMPRESSIVE STRENGTH (Kgf/cm²)	7 DAYS	235	163	116	96	81	57	41	36
	28 DAYS	354	275	200	171	115	87	84	68
	90 DAYS	399	312	272	225	135	88	121	95
	365 DAYS	478	337	310	263	133	88	140	115
MODULUS OF ELASTICITY (Kgf/cm²)	7 DAYS	387.000	165.000	230.000	141.000	254.000	116.000	170.000	106.000
	28 DAYS	502.000	240.000	346.000	203.000	306.000	154.000	242.000	151.000
	90 DAYS	512.000	262.000	375.000	237.000	310.000	220.000	293.000	175.000
	365 DAYS	572.000	365.000	461.000	322.000	-	-	340.000	255.000
SPLITTING TENSILE STRENGTH (Kgf/cm²)	7 DAYS	23.5	18.0	14.3	11.7	9.3	7.0	5.5	4.7
	28 DAYS	31.1	25.8	25.0	20.7	13.8	11.1	11.3	10.6
	90 DAYS	31.3	29.6	26.1	22.0	20.2	12.7	13.9	13.0
	365 DAYS	42.2	30.8	32.9	24.3	-	-	18.4	14.0

TABLE 3 - COMPOSITION, STRENGTH AND MODULUS OF ELASTICITY OF CONCRETE MIXTURES

TYPE OF EXPOSURE	SPECIMENS	NUMBER OF SPECIMENS	MIXTURES	INITIAL CURING	DURATION OF CYCLE	OBSERVATIONS / TESTS
WEATHERING	BLOCK 40 x 40 x 100 x 140 cm FIGURE 2	8	TABLE 3 1 TO 8	21 DAYS	—	VISUAL
	CYLINDRICAL SPECIMENS 15 x 30 cm	48	TABLE 3 1 TO 8	21 DAYS	—	COMPRESSIVE STRENGTH AT 1,2 AND 3 YEARS
WETTING AND DRYING	BLOCK 40 x 40 x 100 x 140 cm FIGURE 2	8	TABLE 3 1 TO 8	21 DAYS	48 HOURS	VISUAL
	CYLINDRICAL SPECIMENS 15 x 30 cm	48	TABLE 3 1 TO 8	21 DAYS	48 HOURS	COMPRESSIVE STRENGTH AT 1,2 AND 3 YEARS
IMMERSED IN WATER	BLOCK 40 x 40 x 100 x 140 cm FIGURE 2	8	TABLE 3 1 TO 8	21 DAYS	—	VISUAL
	CYLINDRICAL SPECIMENS 15 x 30 cm	48	TABLE 3 1 TO 8	21 DAYS	—	COMPRESSIVE STRENGTH AT 1,2 AND 3 YEARS

TABLE 4 – EXPOSURE CONDITIONS OF CONCRETE SPECIMENS AND BLOCKS

MIXTURE	AGE (YEARS)	COMPRESSIVE STRENGTH (Kgf/cm^2)					
		WEATHERING		WETTING AND DRYING		IMMERSED IN WATER	
		SOUND BASALT	UNSOUND BASALT	SOUND BASALT	UNSOUND BASALT	SOUND BASALT	UNSOUND BASALT
1 AND 2	1	440	368	388	318	392	269
	2	484	289	384	333	396	312
	3	413	299	452	358	414	355
3 AND 4	1	185	117	175	116	164	108
	2	175	83	174	148	163	155
	3	188	81	201	171	192	160
5 AND 6	1	118	97	151	136	155	131
	2	128	59	151	143	156	149
	3	129	56	188	154	161	153
7 AND 8	1	257	197	304	259	301	242
	2	277	192	276	272	313	277
	3	260	220	321	281	325	286

TABLE 5 – COMPRESSIVE STRENGTH OF SPECIMENS RELATED TO TABLE 4

FIGURE 2 - CONCRETE BLOCKS EXPOSED TO WEATHERING

Some comments regarding the observations of the blocks are showed on item 4.

The results of compressive strength related to table 4 are plotted on table 5.

3.3 - COMPLEMENTARY STUDIES

According to suggestions of Profs. Roy Carlson and Milos Polivka from the University of California at Berkeley, complementary studies with concrete containing this material had been made.

This type of basalt desintegrates quickly when subject to changes in Temperature and Moisture, but the desintegration would be much slower with the stones incorporated in the concrete, where they are protected by the surrouding mortar. So, it was assumed that a concrete deterioration should be preceded by significative expansion. Considering this assumption, tests in concrete specimens subject to various exposures conditions, were made.

The specimens were subjected to four different conditions:

- Temperature change only

- Moisture change only
- No changes of Temperature and Moisture, or rather, immersed in water with constant temperature
- Changes of Temperatura and Moisture.

Besides the unsound basalt of Porto Primavera, it was used a sound basalt in order to compare the values obtained for both materials.

The specimens were cylindrical 15x30 cm and 25x50 cm, respectively, for maximum size aggregates of 38 mm and 76 mm. Each specimen had embedded Carlson strain meter to provide sensitive measurements.

The specimens subjected to temperature changes only were sealed to prevent moisture change and stayed alternatedly during 24 hours at temperature of 2^{o} C and 38^{o} C, with strain readings after each 24 hours.

The specimens subjected to moisture change only were immersed in a water tank during 24 hours and stayed out also during 24 hours, with a temperature of 23 ± 2^{o} C.

The specimens with no temperature and moisture changes were immersed in the same water tank. The specimens subjected to temperature and moisture changes were exposed to weathering.

Figure 3 shows the results of these tests.

4 - ANALYSIS OF RESULTS

4.1 - MATERIAL

According to the results showed in item 2, it is noted that the basalt desintegrates quickly when exposed to weathering, but the deterioration can be prevented if a good protection is provided in the stockpile.

4.2 - CONCRETE

Concretes made with unsound basalt showed lower compressive strength, splitting tensile strength and modulus of elasticity than concretes made with sound basalt. Besides that, there is a compressive strength decrease at ages higher than

one year according to table 5. It is believed that this strength decrease is due to cracks in specimens exposed to weathering, mainly the ones made with concrete of high water--cement ratio. The specimens subjected to wetting and drying cycles and immersed in water presented no compressive strength decrease.

Figure 3 showed no significative strain differences in concretes made with sound and unsound basalts when compared in the same exposure condition.

It was noted that the strain variations were higher for the cycles of temperature and moisture changes (more than 100×10^{-6}) than for the other ones (10×10^{-6}). These results confirm values obtained for compressive strength.

5 - CONCLUSION

Considering these results, the authors believe that this type of unsound basalt could be used as coarse aggregate for mass concrete since a protective layer of concrete made with sound aggregate is used at exposed faces. It is suggested that the face concrete made with sound aggregate should be 1,5 to 2,0 meters thick.

The unsound basalt, however, must be used immediately after manufacturing or must be protected in the stockpile.

6 - REFERENCES

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7 - ACKNOWLEDGEMENTS

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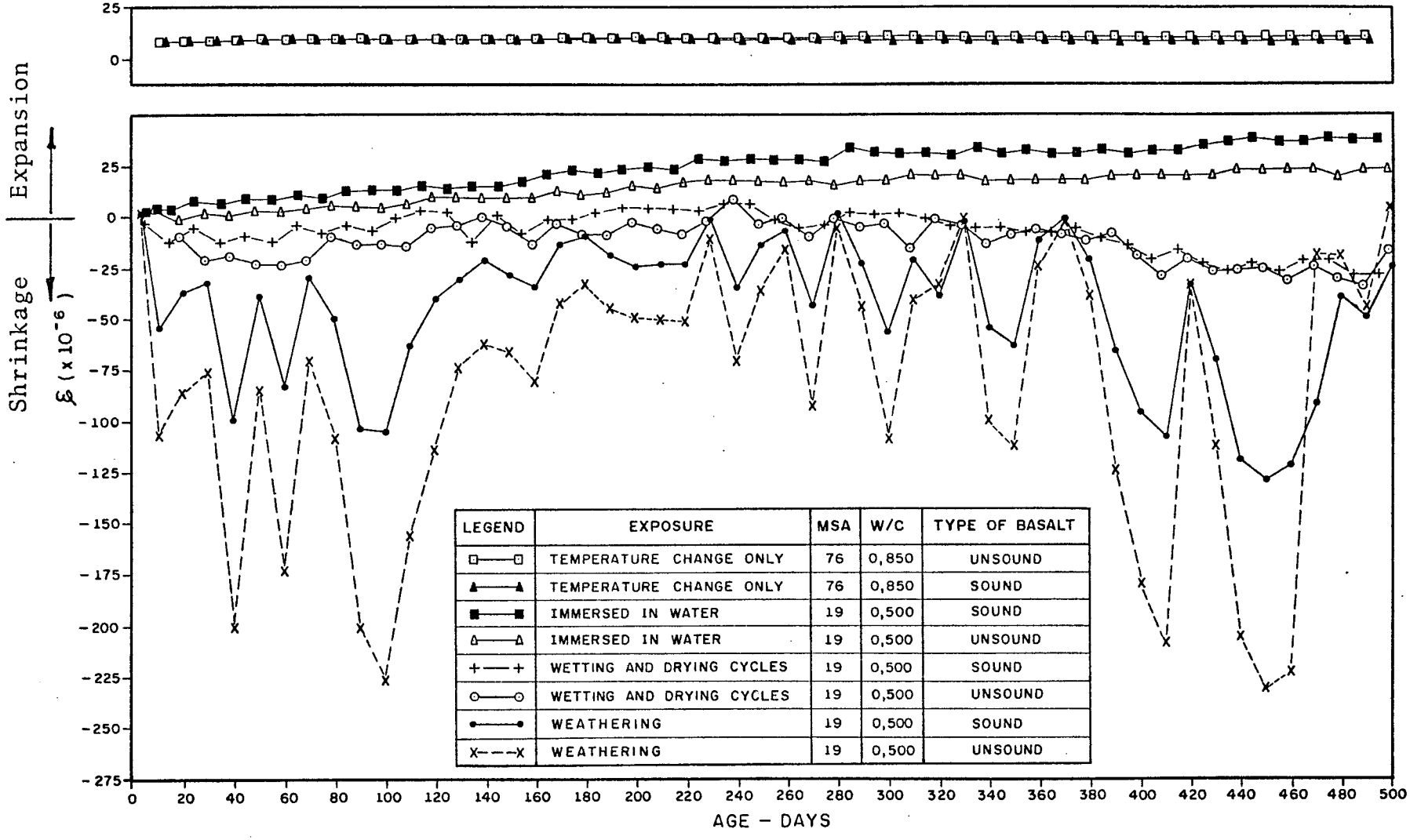

FIGURE 3 – RESULTS OF COMPLEMENTARY STUDIES

Paulo in furnishing the data presented as weel as Profs. Roy Carlson and Milos Polivka for suggestions received during the studies and analysis of results.