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da Silva Bezerra, Augusto Cesar; Paulino Aguilar, Maria Teresa; Cetlin, Paulo Roberto
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The influence of specimen capping on the results of compression strength tests of cementitious composites

Influência do capeamento nos resultados do ensaio de resistência à compressão em compósitos cimentícios

Augusto Cesar da Silva Bezerra
Coordenação de Edificações, Campus IV,
Federal Center for Technological Education of Minas Gerais.
augustobezerra@araxa.cefetmg.br

Maria Teresa Paulino Aguilar
Department of Materials and Construction Engineering, Engineering School,
Federal University of Minas Gerais.
teresa@demc.ufmg.br

Paulo Roberto Cetlin
Department of Mechanic Engineering,
Engineering School,
Federal University of Minas Gerais.
pcetlin@demet.ufmg.br

Resumo

Os compósitos cimentícios, comumente, são avaliados em função de sua trabalhabilidade, do teor de ar incorporado, do seu módulo de elasticidade e de resistência à compressão. Essa resistência é determinada através de ensaios de compressão axial de corpos-de-prova moldados especialmente para essa finalidade. Na execução do ensaio de compressão, é necessário que as superfícies, onde se aplicam as cargas, sejam planas, paralelas e lisas, de modo que o carregamento seja uniformemente distribuído. Para isso são utilizadas diversas técnicas e materiais, como capeamentos aderentes, não aderentes, sistemas de desgaste mecânico ou moldes especiais. Atualmente, os capeamentos mais utilizados são os que utilizam argamassas de enxofre ou almofadas de neoprene. O presente trabalho avalia, experimentalmente, a interferência de diferentes tipos de regularização das bases dos corpos-de-prova para compósitos cimentícios de diferentes classes de resistência.

Palavra-chave: Compósitos cimentícios, ensaio de compressão, capeamento, dispersão de resultados.

Abstract

Cementitious composites are commonly evaluated considering their workability, level of incorporated air, elasticity modulus and compression strength. Data from compression testing commonly present a high dispersion, which has been attributed to effects of the specimen geometry, dimensions and of the degree of material compaction, as well as to problems in the specimen end-faces, such as their parallelism, orthogonality in relation to the compression axis and surface regularity. Specimen end-face regularization has been achieved through various techniques, such as adhering or non-adhering capping with various materials, mechanical grinding and systems involving special moulds. The regularization methods utilized more frequently employ sulfur mortar capping, neoprene cushions and surface grinding. The present work covers the experimental compression tests of cementitious composites of different classes of strength employing sulfur mortar capping and neoprene cushions. It was concluded that there is a strong influence of the chosen regularization technique on the measured compression strengths.

Keywords: *Cementitious composites, capping, testing for compression strength.*

1. Introduction

From the macroscopic point of view, cementitious composite is a multiphase, heterogeneous material, displaying a complex microstructure. The various phases present in this material are distributed heterogeneously, and even the phases themselves may be inhomogeneous and of difficult determination. The analysis of the structure - properties relationship of cementitious composites is thus still under development, and it is of paramount importance the adequate understanding of the variables affecting the available testing techniques of this material, so that one can eventually isolate only the structural effects on the material properties. Compression testing is an important test utilized for the evaluation of cementitious composites properties, and one must understand clearly the effect of the testing variables on its results. Compression strength is one of the main parameters in the classification, quality evaluation and design of structural cementitious composites components. On the other hand, literature reports indicate that the results of these tests present a high dispersion (Scandiuzzi & Andriolo, 1986; Patnaik & Patnaikuni, 2002; Lima & Barbosa, 2002; Marco et al., 2003), which has been attributed to effects of the specimen geometry, dimensions and of the degree of compaction, as well as to problems of specimen end-faces such as their parallelism, orthogonality in relation to the compression axis and surface regularity. The situation concerning the effect of the specimen end-faces surface regularization, however, is much more complex. This regularization has been achieved through various techniques, such as adhering or non-adhering capping with various materials, mechanical grinding and systems involving special moulds. The regularization methods utilized more frequently employ sulfur mortar capping, neoprene cushions and surface grinding.

2. The effect of specimen end-faces on compression testing results of cementitious composites

The surfaces of the compression testing specimens where the external load is applied should be flat, parallel to each other, orthogonal do the loading direction and smooth, so that uniform loading is achieved (Scandiuzzi & Andriolo, 1986). Slight surface irregularities seem to be sufficient to induce heterogeneous loading, which leads to a lowering of the measured specimen strength (ABNT, 1994; ASTM, 2003; Coutinho & Gonçalvez, 1994; ABNT, 1996; Bucher & Rodrigues Filho, 1983). It is easier to satisfy the above specimen surface characteristics when cubic specimens are utilized, since one has 3 parallel sets of faces where loads can be applied, and there is thus a greater chance of finding adequate loading surfaces. This is not true in cylindrical specimens, where only one set of 2 specimen surfaces are available for testing.

Adhering capping systems involve the utilization of a material forming a regular layer adhering, physically or chemically, to the end-faces of compression cementitious composites specimens, and displaying the following characteristics: good adherence to the specimen end-faces, chemical compatibility with cementitious composites, low viscosity upon its application, smooth and flat finish after hardening and compression strength compatible with those typical of cementitious composites.

Non-adhering capping systems involve the use of a material (confine do not) as a cushion between the testing machine plates and the specimen end-faces. The cushion materials initially employed were cardboard, lead or rubber, but the low strength of these materials allowed their flow during the test, introducing transversal tensile tests in the cementitious composites close to the cushion-specimen interface, leading to specimen failures associated with the combined compressive and tensile stresses, causing a pronounced lowering of the measured material compressive strength (Marco et al., 2003).

3. Materials and methods

The experiments covered the laboratory preparation, curing, capping and testing of cementitious composites compression specimens. The cementitious composites components and content are described in Table 2. Three different types of cementitious composites were made with the materials describe in this table (Table 1).

For cementitious composites of groups 1 and 2, 24 cylindrical testing specimens were prepared, each one with a diameter of 100mm and a height of 200mm., whereas for group 3, 12 cylindrical specimens were prepared. The specimens were kept in their molds for 24h, and then extracted and kept in water for curing up to the day before the specimen compression testing. Before the tests the specimens were capped.

The compression strength tests were

Materials	Description	Specific mass (Kg/dm³)	Unit mass (Kg/dm³)	Fineness modulus
Agglomerates	Portland Cement III – 40 RS	2.950	1.000	-
	Duracem Cement AD300	2.950	1.000	-
Fine Aggregates	Natural Sand	2.667	1.420	2.760
	Stone dust	2.717	1.684	3.377
Large Aggregates	Gravel 0	2.660	1.000	6.051
	Gravel 1	2.682	1.000	6.949
Water	-	-	-	-
Additives	EXPA 925	-	-	-
	Maste4rmix 460 N	-	-	-
	Glenium 3200 HE	-	-	-

Table 1
Components and their content in the cementitious composites.

Table 2
Weigh of materials used
in the cementitious composites.

Materials	Group 1 (weight)	Group 2 (weight)	Group 3 (weight)
Portland Cement III – 40 RS	1.000	1.000	-
Duracem Cement AD300	-	-	1.000
Natural Sand	2.246	1.423	1.564
Stone dust	0.761	0.480	0.529
Gravel 0	-	-	0.393
Gravel 1	3.477	2.490	2.252
Water	0.650	0.450	0.338
	(Volume)		
EXPA 925	0.004	0.004	-
Maste4rmix 460 N	-	-	0.009
Glenium 3200 HE	-	-	0.010

carried out with two different types of capping: with a double-ventilated sulfur powder and with neoprene cushions with 68, 78 and 82 Shore A hardness. Sulfur capping was molten with a tabletop gas flame and then poured in the bottom of a metallic mold; the specimen was slid vertically into the mold and on the molten sulfur, ensuring the alignment of the capping and the specimen. The solidification of the capping occurred very quickly. For the neoprene cushion capping, it was necessary to employ metallic rings for confining and restricting the radial expansion of the neoprene cushions (Figure 1), following the conditions indicated in Table 3.

The literature often cites the importance of utilizing a capping material stronger than the material to be tested (CMN, 1996; ASTM, 1998). The present sulfur compression strength was determined for two compression cylindrical samples with a 55mm diameter and 100mm high., displaying a strength of 34.73 and 35.15MPa each. The strength of neoprene is indirectly controlled through their hardness. For the first neoprene sample, the average measured values coincided with the manufacturer's specifications. For the second and fourth groups had different hardness than commercially specified.

Table 4 shows the capping material used for each group. Experimental problems limited the use of all different capping materials for the three kinds of cementitious composites.

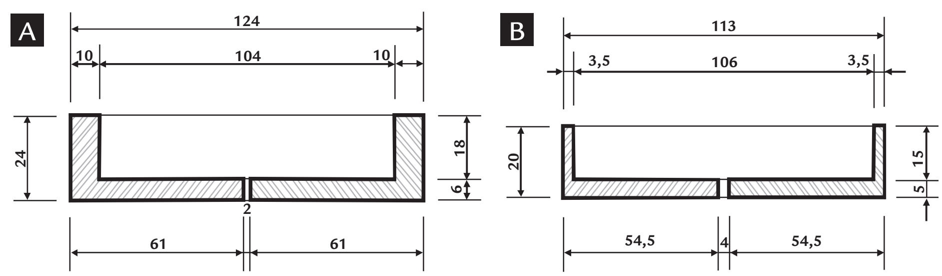

Figure 1
Elastomeric capping ring.
A) Capping ring 1.
B) Capping ring 2.

Tabela 3
Capping rings and elastomeric
cushions in the elastomeric cappings.

Material	Hardness (Shore A)	Hardness Obtained (Shore A)	Size (mm)	Diameter (mm)	Metallic qwring
Neoprene	70 ± 5	68	10	104	1
	70 ± 5	78	10	106	2
	70 ± 5	82	5	106	2
	70 ± 5		3	106	2

Table 4
Distribution of the test blocks
in the compression strength test.

Type of capping	Width (mm)	Number of sample blocks		
		Group 1	Group 2	Group 3
Pure súlfur	≈ 2	3	3	3
Neoprene 68 shore a confined	10	3	3	3
Neoprene 68 shore a confined (Reuse)	10	-	-	3
Neoprene 78 shore a confined	10	3	3	3
Neoprene 82 shore a confined	5	3	3	-
Neoprene 82 shore a confined	3	3	3	-
Neoprene 68 shore a non- confined	10	3	3	-
Neoprene 82 shore a non- confined	5	3	3	-
Neoprene 82 shore a non- confined	3	3	3	-
Total		24	24	12

4. Results and discussion

Figure 2 shows the experimental strength of the cementitious composites for group 1, utilizing the various capping materials.

Considering the results obtained with sulfur as a reference, the only adequate capping system was the neoprene capping with Shore A hardness of 68 and 78, 10 mm thick, independent of the dimensions of the ring. In addition, the thickness of the neoprene appears to be more relevant than its hardness in the case of elastomer capping.

Figure 3 displays the compression strength test results can for the various capping systems in group 2.

The results are similar to those obtained for group 1: Neoprene 68 or 78 utilizing bases of different widths lead to results similar to those obtained for sulfur capping. For group 2, Capper 2 and 10mm thick Neoprene 78 led to the highest strength and lowest standard dispersion).

Figure 4 shows results for the compression strength tests with various capping systems for group 3. The results once more reinforce the adequacy of using 10 mm thick Neoprene 68 or 72 for measuring the highest cementitious composites strength, which was reached with capper 1.

For group 3, capper 2 was expected to have the best performance since it had the best performance in group 2 (a group with greater strength than group 1). However, due to the elevated strength of group 3, capper 2 (which is narrower than capper 1), underwent plastic deformation and the neoprene cushion exceeded the restrictions of the metal reinforcement. This deformation of the restriction ring influenced the result, lowering the compression strength a little and slightly increasing the standard deviation.

Sulfur capped specimens presented a conical failure, whereas testing with elastomeric capping displayed conical, sheared or columnar failures, all of

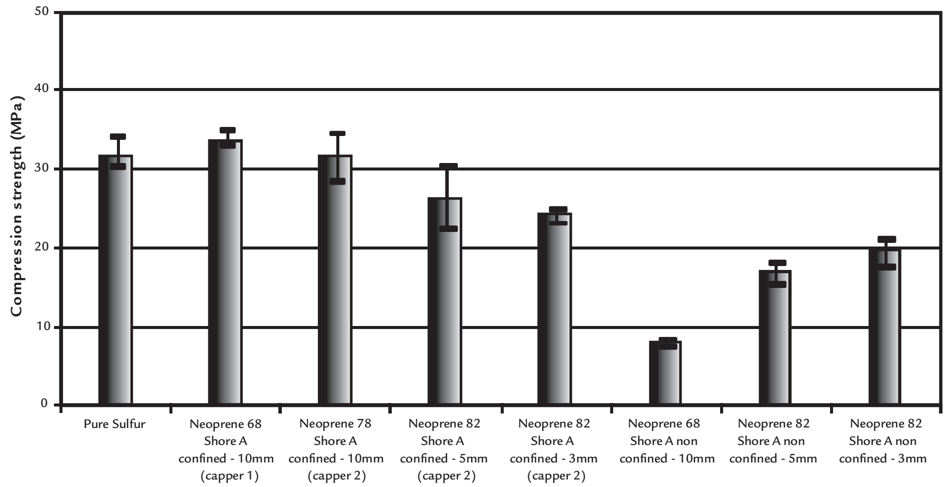

Figure 2
Compression strength of the cementitious composites utilizing various capping procedures.

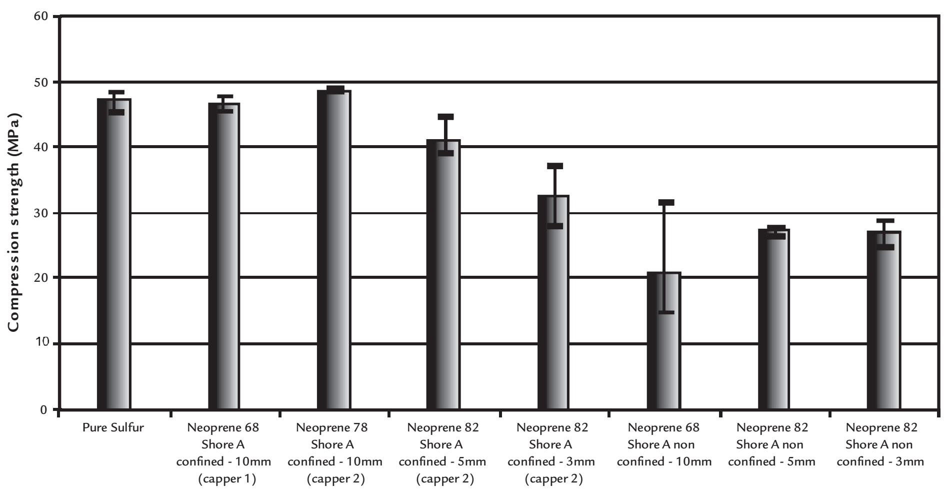

Figure 3
Compression resistance test results with various cappings for group 2.

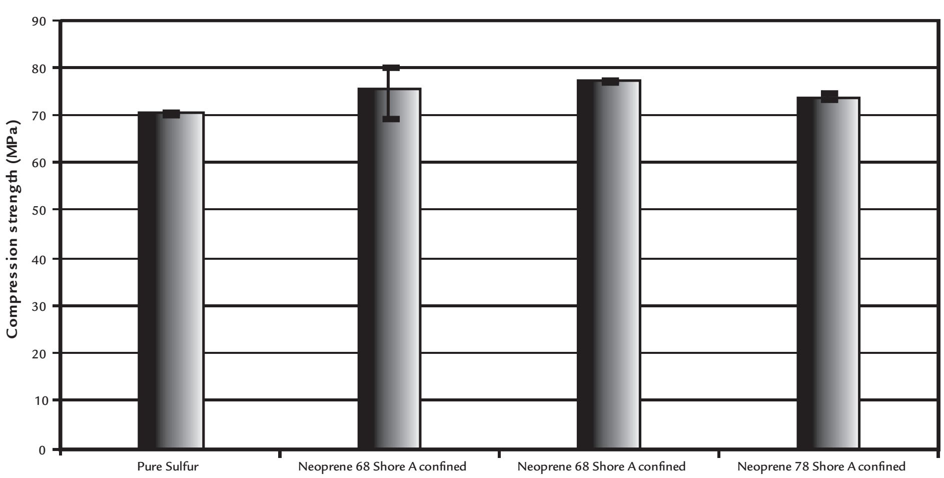

Figure 4
Compression resistance test results with various capping systems for group 3.

which are in accordance with those accepted in the Brazilian ABNT (1994) standard NBR 5739. Baykov & Sigalov (1996) showed that the shape of the failure in specimens tested under compression depends on the friction between the compression platens and the specimens. The difference in the above reported failure modes for the two capping methods would thus be associated with the different specimen/capping/platen for sulfur or neoprene.

5. Conclusion

The present experiments indicate that the following testing aspects can affect the measured compression strength of cementitious composites:

a) The performance of the confining ring of elastomeric cappings.
b) The thickness and presence of confinement in the use of neoprene.
c) The type and material of the capping are especially important.
d) Sulfur and confined neoprene cappings lead to similar results for cementitious composites with strength in the range of 30 to 45MPa. On the other hand, sulfur cappings led to lower strengths than neoprene cappings, for cementitious composites with a 60MPa strength.

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