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Influences of water by cement ratio on mechanical properties of mortars submitted to drying

Ismail Yurtdas [a], He Peng [b], Nicolas Burlion [b,*], Frédéric Skoczylas [c]

[a] Laboratory of Mechanics, Materials and Structures, Université de Reims Champagne Ardenne, Rue des crayères, 51687 Reims Cedex
[b] Laboratory of Mechanics of Lille, UMR CNRS 8107, Polytech'Lille — USTL, Cité Scientifique, 59650 Villeneuve d'Ascq, France
[c] Laboratory of Mechanics of Lille, UMR CNRS 8107, Ecole Centrale de Lille, Cité Scientifique, 59650 Villeneuve d'Ascq, France

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Abstract

Concrete materials are submitted to drying when the relative humidity of their surrounding is decreasing. The main purpose of this study is to highlight the variation of multiaxial mechanical behaviour of mortars which depends on desiccation level and cement paste properties (quality). The behaviour under discussion includes uniaxial and triaxial strengths, elastic properties and volumetric strains due to hydrostatic loading. Multiaxial experiments, carried out on two mortars for which the only difference was the water by cement ratio (w/c=0.5 and 0.8), show a competitive effect between the increase in material rigidity due to capillary suction and saturation gradients, and the microcracking which comes from material heterogeneity and differential shrinkages of the sample. This effect mainly depends on cement paste properties and its porosity; therefore the capillary suction effect is preponderant for a high paste quality (i.e. lower porosity) while a low paste quality would be more sensitive to microcracking.

Keywords: Drying; Microcracking; Compressive strength; Mechanical properties; Mortars

1. Introduction

The mechanical behaviour of concrete will vary as drying induces local and structural modifications. The drying process brings about desiccation shrinkage whose origins are: an increase in capillary suction [1,2]; variations in disjoining pressure [3,4]; and in surface energy [4]. These effects occur at a microscopic scale. As regards the whole structure, saturation gradients [1–8] are created due to non uniform drying. The latter derives mainly from the low permeability of concrete, and the structure geometry. On the other hand, the kinetics of drying are faster near the surface than deeper in material. This leads to non homogeneous strains that induce tensile stresses and microcracking [1–5]. Microcracking may also occur close to the interface between cement paste and aggregates which is mainly due to their differential stiffness [5,9,10]. This effect, which is weak and relatively superficial for small aggregates, leads to an important diffuse microcracking for aggregates size greater than 6 mm [10]. As a result, dried concrete can be considered as damaged prior to any mechanical loading. This damage will change the elastic properties and strength limits of the material. To avoid such a phenomenon, specific laboratory conditions must be followed: either desaturation carried out with very small increments of relative humidity or the use of samples of very low thickness [4,11,12]. As drying induced microcracking weakens the material and increases its permeability [13], it will also play an important role in the durability of concrete structures.

Uniaxial compressive tests have been used to evaluate the variations due to drying [6–8,14–23], but few results obtained with conventional triaxial tests are reported on the role played by interstitial water [24]. A study of these data shows important scattering and uncertainty as regards the drying effects on strength and elastic modulus variations.

Results on strength variations, which are found in the literature, are ambiguous. It is often observed that uniaxial

* Corresponding author.
E-mail address: Nicolas.Burlion@polytech-lille.fr (N. Burlion).

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strength increases with drying [17–19,21,24–26]. Increases up to 60% have been reported for a mortar with w/c=0.75 [19]. Studies have shown progressive increases in uniaxial strength as relative humidity decreased, whether [21,22] or not [6,7,15,17] the sample drying was homogeneous. However, two phases are sometime present: a decrease in strength in the range 100% to 50% of relative humidity followed by an increase for lower humidity [8,19]. A decrease in strength, following an initial increase was obtained for concrete samples, dried under steady conditions of temperature and relative humidity [20,27]. The drying state of these samples was not homogeneous. The final strength was higher than that measured before drying. Two competitive effects may be at the origin of the observed differences:

1) there is an increase in capillary pressure (suction) as saturation decreases. This pressure acts in the material like an isotropic prestressing and leads to a stiffening effect [2,7]. This phenomenon is amplified by saturation gradients which result in a confining effect of the core of the sample, leading to higher strength [2,6–8].
2) microcracking occurs simultaneously if saturation is not homogeneous [4,7,8,11]. This global (*structural*) effect is enhanced by aggregates (*local effect*), which are more rigid than the cement paste. Hence, local microcracking takes place at the interface of cement paste and aggregates [9,10]. The drop in strength occurs as soon as this microcracking becomes preponderant, with respect to capillary suction. Cracking is highly dependent on the tensile strength which in turn is strongly linked to the w/c ratio.

The variation of Young's modulus with relation to saturation has been observed with uniaxial compressive tests [8,20–23]. The results obtained on a mortar by Okajima et al. [21] showed that the elastic modulus remains almost constant down to 40% relative humidity. There is then a 9% to 20% decrease as relative humidity decreases from 20 to 0%. Dantec and Terme [22] also observed that there was no significant variation down to 50% relative humidity. On the other hand, a 7% decrease was measured, by Brooks and Neville [20], for a concrete under 60% relative humidity. The compressive tests were performed on the same concrete either stored at 60% relative humidity for 28 days following a 28 days wet curing, or wet cured for 56 days. It is difficult to draw a conclusion as the higher modulus of the wet cured specimens may be due to further hydration. A 25% decrease was also observed by Burlion et al. for a concrete stored at 60% relative humidity [23]. Some results, reported by Torrenti [8], are somewhat different as a 15% decrease in modulus was observed from 100% to 50% relative humidity followed by a 10% increase down to 0% relative humidity. As for strength, Young's modulus evolutions are due to complex phenomena which depend on concrete composition and conservation conditions. The same and previously mentioned competitive effects can be also pointed out: the material stiffening due to an increase in capillary pressure and the induced microcracks due to drying (structural and local effects). Again, the w/c ratio will play a major role.

The main objective of this experimental study is to evaluate the change in multiaxial mechanical behaviour occurring with drying. The brief review of the literature, proposed here, shows that there is a large scattering of the data and results, particularly those concerning the drying effect on strength and elastic properties. Some important questions are still opened: what are the changes in concrete properties and what is the precise role of cement paste quality? To answer these questions, an experimental program has been undertaken, which forms the second part of this paper. This consisted of testing two mortars with different initial porosities. The first mortar is representative of a "good quality" cementitious material; the second one has a lower quality. The difference between these materials is their water–cement ratio (w/c), which is equal to 0.5 or 0.8. The final part is devoted to a discussion of the main results derived from 75 multiaxial mechanical tests [14]. This discussion will focus on elastic properties and strength variations. Finally, we will conclude by putting in light the competitive effect between capillary suction and microcracking during the desiccation process: the relative influence of the both phenomena is related to the cement paste quality, and would explain the scattering results found in literature.

2. Testing program

Both mortar mixes are detailed in Table 1. The first mortar (designated as mortar05) with a w/c of 0.5 can be regarded as a high quality material (50 MPa uniaxial strength). The second one (designated as mortar08) had a w/c of 0.8. This higher w/c was chosen to obtain a material with higher porosity (see Table 2) and permeability. Its mechanical properties are close to those of a typical concrete (25 MPa uniaxial strength). Water–cement ratios higher than 0.42 were chosen in order to minimize, during the early stages of drying, the possible effects of hydration and endogeneous shrinkage [12,28] on strength and elastic property measurements.

Each mortar was used to cast beams 1 m in length and with a cross section of 150×150 mm^2. Beams, which have been demoulded after 5 days, were stored for six months in water at 20 °C to obtain a high maturity [14]. This six month wet curing was chosen for two reasons: it is generally agreed that strength increase due to hydration becomes relatively small after 6 months [15,27,29] and, that endogeneous and thermal shrinkages can be neglected after a storage of six months in water [12,28,30].

At the end of this six month period, cylindrical samples of 74 mm length and 37 mm diameter were cored from the

Table 1
Mortars composition

Components	Mortar05	Mortar08
Normalized sand (EN 196-1) 0/2 mm	1350 kg	1350 kg
Cement CEM II/B-M 32.5 R (EN 197-1)	450 kg	450 kg
Water	225 kg	360 kg
w/c ratio	0.5	0.8

Table 2
Porosity values for the 2 mortars (for more details on porosity measurements, see [14])

w/c	Sample 1	Sample 2	Sample 3	Average [%]
0.5	17.7	18.7	–	18.2
0.8	25.4	26.6	26.5	26.2

beam, then rectified in order to have perfectly parallel surfaces. This diameter was chosen to allow the various parameters under discussion to be quite rapidly measured. After curing, the set of samples was divided into 3 different series:

i) Samples which were 100% saturated with water and preserved from drying with two adhesive aluminium sheets. The properties of such samples were taken as a reference in order to describe the drying effects. On the other hand, they can be used to verify the assumption about the absence of endogenous shrinkage.
ii) Samples allowed to dry, by storage at a 21±1 °C temperature and 45±5% relative humidity. Total shrinkage was measured with these samples.
iii) Samples dried in an oven at an imposed temperature of 60 °C and 10% measured relative humidity, until constant weight. These samples were prevented from re-saturation with adhesive aluminium sheets, and were regarded as having reached the (asymptotic) state of a complete drying.

Strain measurements were carried out by the use of four strain gauges, two longitudinal and two transversal. For each series of samples, mechanical tests consisted of three uniaxial compression tests and two conventional triaxial tests performed with a confining pressure of 15 MPa. Samples under drying were tested with respect to the time of drying, which corresponded to a given mass loss. More details on these procedures can be found in [14,31,32]. In addition, three cyclic compression tests were undertaken on dried and 100% saturated samples to obtain initial and final values of strength and elastic modulus. Young's modulus was measured in accordance with RILEM recommendations [33] — i.e. after three loading–unloading cycles up to a stress of 9 MPa. Poisson's ratio was calculated with the longitudinal and transversal strains measured after these three cycles. A similar method was used for elastic properties determined by triaxial tests [32].

3. Influence of drying on mechanical behaviour as a function of w/c ratio

3.1. Drying of mortars and desiccation shrinkage

Fig. 1 shows the relative weight loss of mortar05 (6 cylindrical samples ϕ37 mm, 120 mm height) and of mortar08 (5 cylindrical samples ϕ37 mm, 120 mm height) as a function of drying time. The relative weight loss (RWL) is the amount of water which has evaporated from the sample and is written with:

$$\mathrm{RWL}(t) = 100 \cdot \left(\frac{W(t) - W_0}{W_{\mathrm{dry}} - W_0} \right) \quad (1)$$

where W_0 is the initial sample weight, $W(t)$ is the weight at the time t and W_{dry} is the constant weight obtained after an oven drying at 60 °C. RWL=0% means the sample is totally saturated while RWL=100% is for a dried state — i.e. with no more free water. This parameter is used to compare the mechanical behaviour evolutions at comparable states of drying.

One of the main observations is that, for a fixed w/c ratio, the relative weight loss almost follows the same evolution (Fig. 1). As a result, it can be assumed a similar process of drying occurs for the whole set of samples of a given mortar. An increase in w/c leads to an increase of the capillary porosity (Table 2), one of the consequences of which is more rapid drying. Moreover, the higher w/c should mean that the capillary porosity of mortar08 remains continuous [34]. On the other hand, the nanoporosity of hydrated cement (in particular in the CSH) is little affected by w/c ratio [35]. Though the amount of water that can evaporate from mortar08 is higher than that of mortar05, the relative weight loss is of the same order, about 65% (Fig. 1).

As higher porosity generally leads to increase in permeability and compressibility, it is consistent to observe higher shrinkage rates for mortar08. The asymptotic shrinkage values were reached faster and were higher than those obtained for mortar05. The mean values (3 samples 40×40×160 mm^3 for each mortar) of desiccation shrinkage are shown in Fig. 2. The absence of endogeneous shrinkage was verified with the saturated samples (for more details, see [14]), as a consequence the desiccation shrinkage is equal to the total shrinkage (measured on 160 mm length prisms).

3.2. Multiaxial mechanical behaviour of the mortars

Typical results, derived from uniaxial compression and conventional triaxial tests, are shown in Figs. 3 and 4. To make

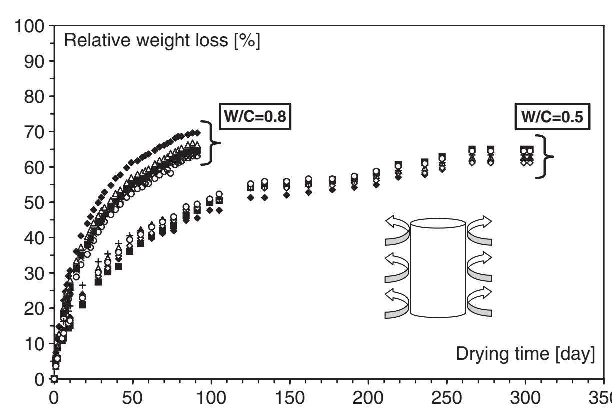

Fig. 1. Relative weight loss according to the drying time for the 2 mortars. All measured evolutions are presented for each mortar sample.

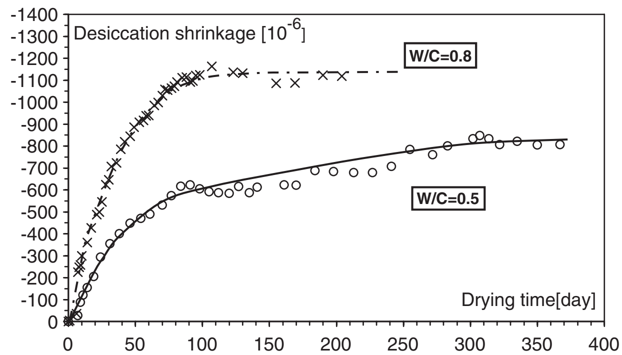

Fig. 2. Average desiccation shrinkage versus the drying time for the 2 mortars.

possible the observation of microcracking effects due to drying, a confining pressure fixed at 15 MPa was chosen after a preliminary study on mortar05 [14,32]. Both figures are representative of results obtained after the given periods of drying. Such results are then used to evaluate the drying effects of a complete drying phase, from a saturated to a dried state. As a result, the changes in mechanical properties can be observed and analysed in relation with time or relative weight loss. Even if not completely comparable, the results show that the mortar08 is of poor "quality" compared to the mortar05. Uniaxial strength of mortar05 is almost twice that of mortar08, and the same ratio is found for the deviatoric strength (Fig. 4).

This is a classical effect of an increase in w/c ratio, leading to an increase in porosity. A decrease in Young's modulus is also detected (see Fig. 3). The general behaviour can be considered as brittle with softening effect but, due to measurements problems (rupture of strain gauges), this softening part is not represented in the figures.

Material behaviour under hydrostatic loading is shown in Fig. 5 (obtained during the early part of the tests previously shown in Fig. 4). The hydrostatic loading was thus in the range 0–15 MPa. The response of the four strain gauges is shown in order to demonstrate material isotropy. Strain values (measured on a given mortar) are very similar, which suggests an almost isotropic behaviour, which would in turn suggest a homogeneous distribution of microcracking with no preferential

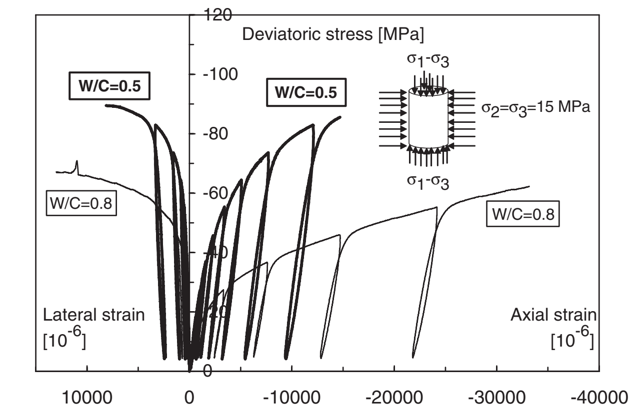

Fig. 4. Triaxial compression test on a mortar05's sample and a mortar08's sample respectively after 14 and 16 days of drying in controlled ambient air.

orientation. Recalling that saturation gradients are perpendicular to measurements or gauge directions, a global isotropy seems to be preserved after drying. Along with a decrease of bulk modulus, an increase in w/c ratio leads, for mortar08, to a loss of behaviour linearity from 10 MPa and over, that can be regarded as an elastic–plastic phase.

3.2.1. Effect of drying on uniaxial strength

3.2.1.1. Mortar05. A first series of mechanical tests were undertaken on the saturated material (or very close to complete saturation). These tests were performed at different time in order to verify that no unexpected effects, like further hydration, had occurred. These were carried out from one day to one year after the wet curing. The results, shown in Fig. 6 show that uniaxial strength remains almost constant with time, making valid the hypothesis of a material at complete maturity [31,32]. These results correspond to the range 0% to 5% RWL. For higher values of RWL, the strength increased by almost 21% from the saturated to the dried state. This 21% increase is reached at a RWL value of 30%, which occurred after about 30 days of drying. Further drying, beyond 30% RWL, does not lead to significant strength evolution.

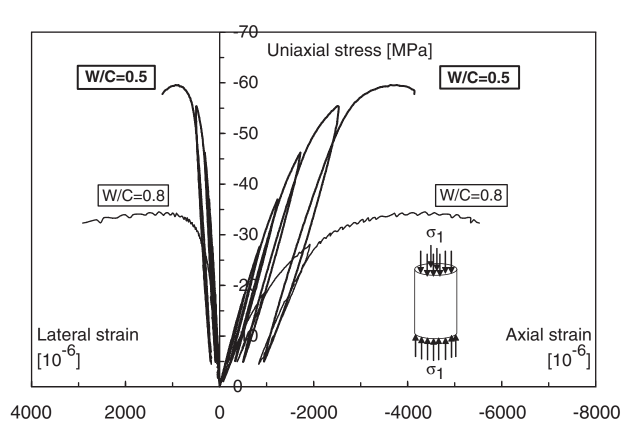

Fig. 3. Uniaxial compression test on a mortar05 sample and a mortar08 sample respectively after 9 and 15 days of drying in controlled ambient air.

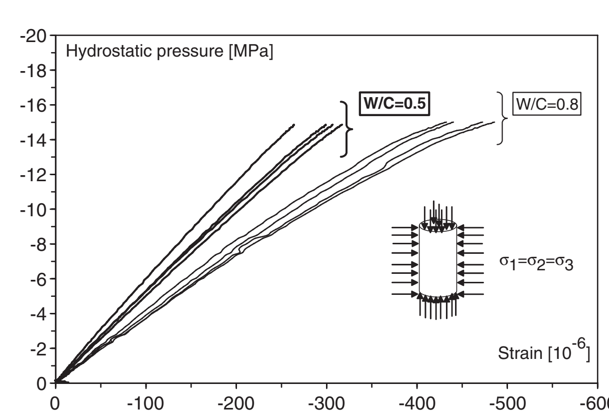

Fig. 5. Responses of 4 gauges for each mortar sample of Fig. 4 under hydrostatic compression.

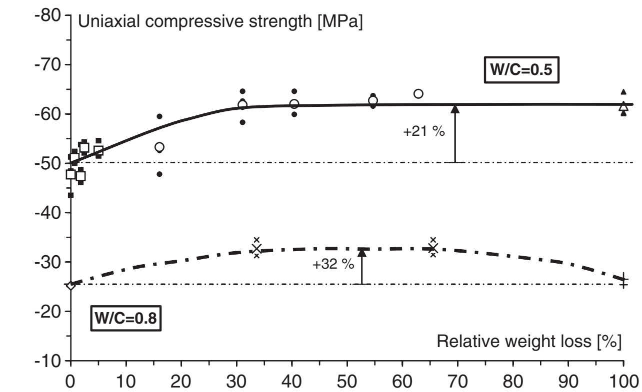

Fig. 6. Uniaxial compression strength versus relative weight loss for the 2 mortars: individual (■) and mean (□) values of saturated samples, individual (●) and mean (○) values of drying samples, individual (▲) and mean (△) values of dried samples for mortar05; individual (♦) and mean (◊) values of saturated samples, individual (×) and mean (**×**) values of drying samples, individual (+) and mean (**+**) values of dried samples for mortar08.

3.2.1.2. Mortar08. As the maturity of mortar08 is more rapidly achieved, it was supposed that after a period of 6 months of wet curing no more hydration effects occurred. Therefore, the value of saturated materials uniaxial strength was measured on three samples just after this wet curing. The mean value was derived from these three tests and taken as a reference data. This value is shown in Fig. 6 (for RWL = 0%). This mortar behaves differently when drying occurs. There is first a 32% increase of strength followed by a drop of the same amplitude. The maximum strength is obtained at 33% RWL, which occurred after 15 days of drying. The final decrease of strength may be due to microcracks which, at this stage, dominate the effects of capillary pressure.

3.2.1.3. Comments. The strength increase is attributed to two concomitant phenomena: first, a positive and isotropic effect of capillary pressure; second, a confining of the sample core induced by moisture gradients [6–8]. Both of these effects are present and dominant for the mortar05 and for the mortar08 during the first phase of drying (RWL ≤ 65%). The relative strength increase is higher for mortar08 than for mortar05 (32% against 21%) since the absolute strength increase is higher for mortar05. At this stage, it is quite difficult to draw definitive conclusions. The porous network of both materials had not been deeply investigated though it is intimately linked with capillary pressure levels i.e. pre-stressing effects. However, compared with uniaxial strength, triaxial strength increases are of the same level for both mortars (see Fig. 4) loaded by the same hydrostatic pressure. This may be evidence of a capillary effect which is lower for mortar08 than for mortar05. It can also be noticed that the presence of water results in a decrease of cohesive forces [17,25] and has a lubricating effect.

There is no measurable variation in strength, for the mortar05, between 30% and 100% of RWL. This means no measurable effect due to the microcracks that occurs with drying and its consequences (differential strains) since there is a noticeable effect for the mortar08. At a particular level of saturation, the influence of microcracking is no longer balanced by capillary pressure effects and becomes dominant. The lower tensile strength of the high w/c matrix is able to amplify this phenomenon. As a partial conclusion, it can be assessed that competitive phenomena (increase in capillary suction, micro-cracking) take place, that explain some disparities found in the literature about compression strength evolution with drying. If capillary suction is preponderant, increase in uniaxial strength is obtained [17–19,21,24–26]. If microcracking becomes important — i.e. the cement tensile strength is low, uniaxial compression strength decreases [8,19,20,27] during the desiccation process.

3.2.2. Effect of drying on triaxial strength

3.2.2.1. Mortar05. Variations of triaxial strength are shown in Fig. 7. The confining pressure, fixed at 15 MPa, leads to a classic increase in strength compared with uniaxial loading. This effect was present whatever the level of saturation. The effects of drying were similar to those observed with the uniaxial test — i.e. a progressive increase in strength up to a level of 29% for dried samples. However, some differences were apparent: while there was a plateau in the strength evolution measured by uniaxial testing, this was no longer the case for strength evolution measured by tests with confining pressure. This property increases continuously with drying.

3.2.2.2. Mortar08. Drying also induced a higher deviatoric strength for mortar08 (see Fig. 7). This increase reached a maximum (50%) at between 33% to 66% RWL. It was then followed by a slight decrease to finally reach 44% for dried samples. The same phenomena observed with the uniaxial test are presumably involved in the triaxial test. There is however a delayed effect of microcracking for the mortar08 when compared with the uniaxial case. This delay is attributed to the confining pressure. The microcracking effect is particularly visible for the mortar08 which differs from the mortar05 by its lower cement paste tensile strength and its higher porosity. As a

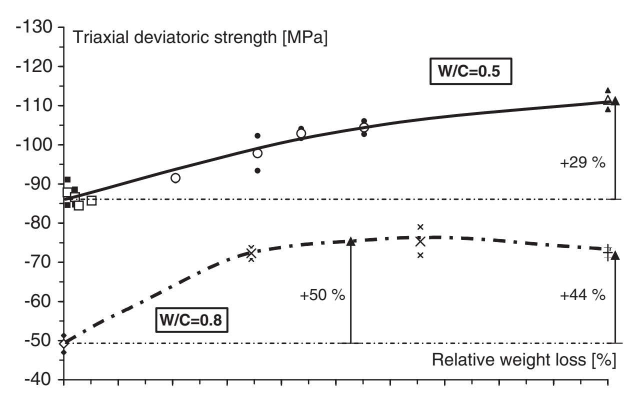

Fig. 7. Deviatoric strength versus relative weight loss for the 2 mortars: individual (■) and mean (□) values of saturated samples, individual (●) and mean (○) values of drying samples, individual (▲) and mean (△) values of dried samples for mortar05; individual (♦) and mean (◊) values of saturated samples, individual (×) and mean (**×**) values of drying samples, individual (+) and mean (**+**) values of dried samples for mortar08.

partial conclusion, there would be a preponderant capillary effect for mortar05 as it was already supposed for uniaxial results.

3.2.2.3. Comments. Compared with uniaxial loading, triaxial loading leads to two main differences: the difference in the level of increase in strength and the delayed microcracking effect, i.e. at higher RWL values. The deviatoric strength increase of mortar05 (29%) is higher than for the uniaxial strength (21%). The same tendency occurs for the mortar08 (50% against 32%). These differences are attributed to effects deriving from the initial sample saturation and the kind of test performed. At high level of saturation and since the test is effectively sealed, there is a global pore pressure increase in the sample [24]. This will induce faster growth of microcracks due to triaxial stress particularly in a saturated sample. As the saturation decreases this effect tends to vanish and the test is more like an unsealed test leading to relatively higher strength. In proportion, this effect will combine with capillary suction influence to result in a relative increase in strength which is higher than for the uniaxial case. The delay observed on the microcracking influence can be attributed to a classical confining pressure effect that leads to crack closure. In fact, it would be of interest to perform further triaxial tests at higher level of confining pressure. It can also be supposed that, due to the over pore pressure mentioned above, the saturating fluid fills the sample more homogeneously. Hence, the isotropic prestressing will act more efficiently than in the case of a uniaxial test, leading to a delay of the damaging and rupture processes. This is consistent with the observed increase in strength with w/c ratio. Such an increase was also reported in Pihlajavaara [19] for uniaxial tests.

3.2.3. Effect of drying upon elastic properties

3.2.3.1. Mortar05. The average values of Young's modulus versus RWL are shown in Fig. 8. These values, derived from uniaxial and triaxial tests, always vary between two limits: the upper limit is obtained with saturated samples while the lower one is measured with dried samples. Within these limits, the elastic properties remain almost constant in a first stage then decrease toward the lower limit. In the dried state, Young's modulus had dropped by 15%.

3.2.3.2. Mortar08. It can be seen in Fig. 8 that the behaviour of mortar08 exhibited a similar tendency as mortar05. Young's modulus has dropped by 18% in the completely dried state. The decrease in Young's modulus begins at a higher level for mortar08 (RWL=65%) than for mortar05 (RWL=45%).

3.2.3.3. Comments. The competitive effect between capillary suction (amplified by the confining effect due to moisture gradients) and microcracking can again be mentioned. As long as capillary suction effect is preponderant the elastic properties remain almost constant but beyond a particular value of RWL, the microcracking effect overrides the effects of capillary suction which results in a drop in elastic properties. It can also be noticed here that the measured properties are to be taken as

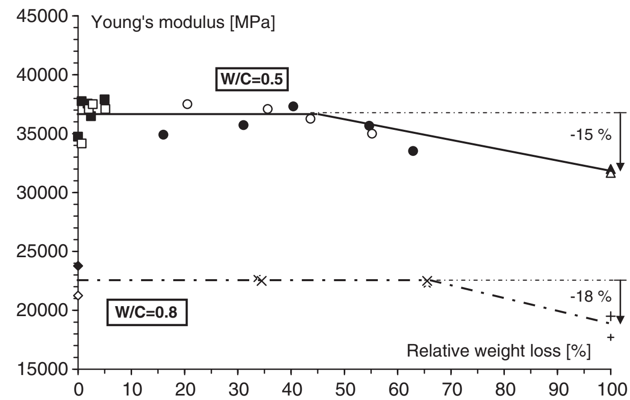

Fig. 8. Young's modulus versus relative weight loss for the 2 mortars: mean values of saturated samples obtained by uniaxial (■) and triaxial (□) compression, mean values of drying samples obtained by uniaxial (●) and triaxial (○) compression, mean values of dried samples obtained by uniaxial (▲) and triaxial (△) compression for mortar05; mean values of saturated samples obtained by uniaxial (♦) and triaxial (◊) compression, mean values of drying samples obtained by uniaxial (×) and triaxial (**×**) compression, mean values of dried samples obtained by uniaxial (+) and triaxial (**+**) compression for mortar08.

apparent as saturation and stress states are not homogeneous in the samples. Hence, due to non homogeneous state of water content, they rather behave like structures. Microcracks would decrease the actual elastic modulus of the material without any visible and measurable strain due to structural and capillary effects. The latter would increase the apparent stiffness of the sample by prestressing. The resulting competition between these 2 opposite effects may explain why the elastic modulus of the material does not vary before a certain loss of water. Beyond this level, more significant microcracking, coming from the higher amount of lost water, decreases the elastic modulus towards the elastic modulus of the dried samples.

The Young's modulus of mortar08 decreases by 18% (compared to 15% for mortar05); this is due to a more significant microcracking as the tensile strength of its paste is lower than that of mortar05. All these results under discussion are consistent with those reported in the literature for uniaxial test [20,21,23]. Moreover, none of re-saturation process undertaken on dried samples has allowed the initial Young's modulus to be recovered [21]. Drying leads to irreversible microcracks to be created.

Notice that no significant variation of Poisson's ratio was measured with mortar08; on the contrary, the Poisson's ratio of mortar05 decreases about 25% from saturated to dried conditions [31].

3.2.4. Effect of drying on volumetric strains up to 15 MPa confining pressure

Hydrostatic loading is an efficient tool to evaluate the microcracks porosity and is widely used for that purpose in rock mechanics. In the case under consideration, measured volumetric strains give useful information on cracks induced by drying. The results, based upon mean values, are shown in Fig. 9. There is a first phase where the volumetric strain obtained at 15 MPa confining pressure remains almost constant (as does Young's

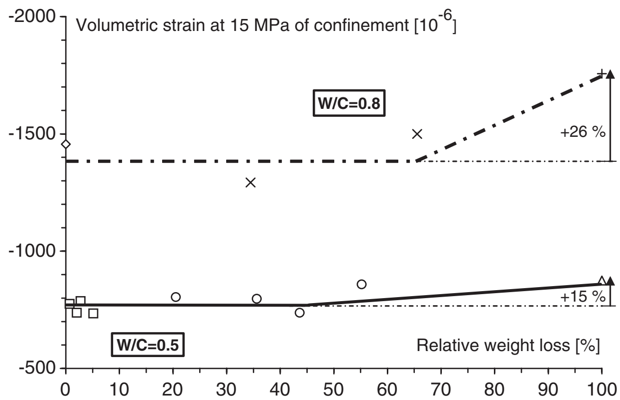

Fig. 9. Volumetric strains obtained after a 15 MPa hydrostatic pressure versus relative weight loss for the 2 mortars: (□) mean values of saturated samples, (○) mean values of drying samples and (△) mean values of dried samples for mortar05; (◊) mean values of saturated samples, (×) mean value of drying samples and (+) mean values of dried samples for mortar08.

modulus). At a certain level of RWL, respectively 45% and 65% for the mortar05 and mortar08, the volumetric strain increases up to 15% (mortar05) or 26% (mortar08). This phenomenon is to be observed in parallel with the Young's modulus decrease from RWL levels being of the same order. This is a confirmation of the preponderant role played by microcracks beyond a given value of RWL, as classical and macroscopic hydrostatic loadings make clearly microcracking visible. It is also of interest that the increase in volumetric strain is higher for mortar08 which is evidence of a lower quality paste — i.e. with a high density of microcracks.

4. Conclusions

For two mortars, which differed only in water–cement ratio, tests have shown the following effects of different levels of drying:

- There is an increase in uniaxial strength which is almost 21% for the mortar05 and 32% for the mortar08. For the latter, the strength decreases at the end of the drying.
- The increase in triaxial strength (at a fixed 15 MPa confining pressure) is respectively 29% and 50% for the mortar05 and mortar08. As for uniaxial strength there is a decrease, but less pronounced, for the mortar08 at the end of the drying.
- Young's moduli of the two mortars remain constant up to a certain level of drying then decrease by 15% (mortar05) and 18% (mortar08).

The previously mentioned effects find their origin in the competitive effects of capillary suctions and moisture gradients leading to a material strengthening in one hand and microcracking induced by the same moisture gradients and amplified by the presence of rigid inclusions (in the other hand, aggregates). Cement paste quality is critical, as the material damage will depend on its tensile strength. As a result, when the cement paste is of "good quality," capillary suction will remain dominant and multiaxial strength will increase under all drying conditions. However, if the cement paste quality decreases, microcracking dominates capillary suction leading to a strength decrease above a certain level of water loss. This competition is also involved in the variation of elastic properties which remain almost constant up to a given level of drying, and then decrease. A confirmation is found in the volumetric strain whose increase is a proof of growing and creation of microcracks beyond a certain level of drying.

The whole set of results brought about by this experimental study gives answers to some scattering of observations found in the literature whose origin may be mainly due to the cement paste nature used and its quality. Due to the competition between induced microcracking and prestressing effects, the composition of the tested concretes (found in literature) has then a major influence on the variation of mechanical properties during drying. Nevertheless, new investigations have to be performed on both materials to better understand the role of their porous network structure linked to their characteristic curves (i.e. capillary pressure versus saturation). This is among the objectives of further studies.

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