International Journal of Natural Sciences Research
2016 Vol. 4, No. 4, pp. 75-82
ISSN(e): 2311-4746
ISSN(p): 2311-7435
DOI: 10.18488/journal.63/2016.4.4/63.4.75.82

EFFICIENCY OF PLASTIC FIBRES WASTE ON THE PHYSICO-MECHANICAL PROPERTIES OF MORTARS IN HOT-DRY CONDITIONS

Khadra Bendjillali[1]† --- Mohamed Chemrouk[2]
[1]*Civil Engineering Department, Faculty of Technology, University Amar Telidji, Laghouat, Algeria*
[2]*Faculty of Civil Engineering, University of Sciences and Technology Houari Boumediene, Algiers, Algeria*

ABSTRACT

This experimental study was aimed at evaluating the effect of plastic fibres waste on the physical and mechanical performances of mortars prepared and conserved under hot-dry conditions. The used fibres are recycled polypropylene fibres coming from industrial waste. Two dosages of fibres are used 0.5 and 1 % by weight. The results showed that the exposition of mortars to hot-dry conditions reduces their long-term mechanical strength and increases their shrinkage. Under hot-dry conditions, the reinforcement of mortars by plastic fibres waste has a positive effect on their flexural and compressive strength. The shrinkage of mortars conserved under these conditions is reduced by the addition of plastic fibres waste.

Keywords: Mortars, Plastic fibres waste, Hot-dry conditions, Mechanical strength, Shrinkage.

Received: 27 September 2016/ **Revised:** 27 October 2016/ **Accepted:** 2 November 2016/ **Published:** 8 November 2016

Contribution/ Originality

This study contributes to enrich the fibres mortars researches. For technico-economical and environmental interests, we used local materials coming from natural and industrial waste, such as the sand and fibres. It is one of very few studies which have investigated the effect of hot-dry conditions on the properties of mortars.

1. INTRODUCTION

Cementitious materials were influenced by several factors, such as the climate conditions. The hot-dry climate which covers the south of Algeria is characterized by a high temperature, a low humidity, a dry wind and intense solar radiations, especially in summer. In these conditions, the mechanical strength obtained at 28 days does not necessarily reflect the final strength of the concrete which should be taken into account in design calculations. Engineering offices always concentrate on compressive strengths at 28 days that will satisfy the control services and neglected the strength after this age, which leads to strength's overestimation and thus to an underestimate of materials, the concrete and the steel. Generally after 28 days of age, the strength tends to decrease under the effect of hot and dry environment and it stabilizes only after 91 days and even more. The decrease of the strength is due to the water evaporation at early ages that leads to the stop of the reaction of hydration and causes shrinkage cracks. The curing of concrete applied as soon as it is fabricated is an efficiency solution to limit the water evaporation and thus allowed to the concrete's strength to continue its evolution. Under hot weather conditions, some authors [1] recommend continuous wet-curing by water spaying for 14 days followed by wet-burlap curing for another 7 days. Cracks constitute easy entry for aggressive agents, resulting in the reduction of the durability of the structure at longer-term. Adding fibres to cementitious materials improve their tensile strengths and prevent their cracking [2-4]. The capacity of fibres to reduce shrinkage cracking depends on their properties, such as the

† Corresponding author

length, the stiffness, the surface texture and the dosage [5]. Depending on their type, fibres can reduce the crack area by between 40 and 85 % compared to plain concrete [6]. Polypropylene fibres waste was used in this experimental study as reinforcement for mortar. The use of recycled fibres represents an economic gain in the field of civil engineering. Polypropylene fibres are economical, have a low weight and high deformation and do not absorb water or react chemically with cement, disperse easily in the concrete and they are effective in controlling cracks of plastic shrinkage [7]. In this work, we study the effect of the hot-dry climate (T = 45 °C, HR = 30 %) of the city of Laghouat on the shrinkage and the mechanical behaviour of mortars reinforced by polypropylene fibres waste. Laghouat is situated in the south of Algeria, at 400 km from the capital and characterized by a dry and desert climate with an intense solar radiations and a sirocco wind.

2. EXPERIMENTAL PROGRAM

For the realisation of this work, we have used a limestone crushed sand 0/2 mm with a fineness modulus of 1.8 and a sand equivalent of 63, a Portland cement CEM II/A 42.5, a superplastizer, type SIKA VISCOCRETE TEMPO12 and polypropylene fibres waste (Figure 1) with a specific gravity of 0.99, a length of 20 mm a diameter between 0.38 and 0.51 mm, a tensile strength between 210 and 250 N/mm^2 and an elasticity modulus between 4 and 5 GPa. The fibres waste coming from plastic sweeps production was recycled and used as reinforcement for mortars. We have prepared mortar's samples with 400 g of cement, 1200 g of sand, 220 g of water and 11.5 g of superplastizer. We have used two weight dosages of fibres 0.5 and 1 %. We noted M0, the mortar without fibres, M0.5 and M1, the mortars reinforced respectively by 0.5 and 1 % of polypropylene fibres waste. We have prepared prismatic samples (40x40x160) mm^3, which were conserved after demoulded in water for 14 days and then under hot-dry conditions (T = 45 °C, HR = 30 %) or under laboratory conditions (T = 20 ± 2 °C, HR = 50 ± 5 %) until testing. After 7, 14, 28, 56 and 91 days of conservation in the two environments, we have measured the three-point flexural strength and the compressive strength of different samples, according to the French Standard EN 196-1. Specimens tested after two weeks of moist curing were considered as reference samples. The measure of the mortar's shrinkage in each environment was started from the first to 78 days of age.

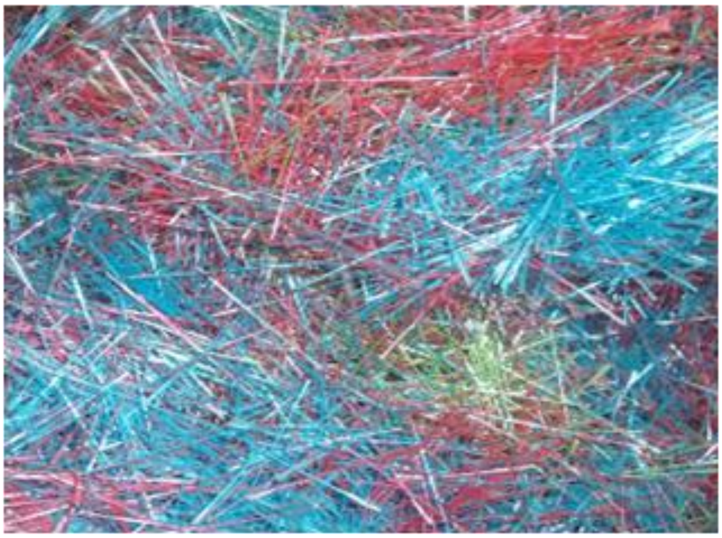

Figure-1. Polypropylene fibres waste

3. EXPERIMENTAL RESULTS

3.1. Flexural Strength

From the results of flexural strengths (Figures 2, 3), it is evident that an enhancement in strength compared to reference mortar occurred with the curing duration in all mixes conserved under both hot-dry and controlled conditions. All mortars reached their highest flexural strength in hot-dry conservation after only the first two weeks of curing, and then the strengths decrease considerably. After 14 days curing in this environment, the increase of the flexural strength for mortars M0 (mortar without fibres), M0.5 (mortar reinforced by 0.5 % of fibres) and M1 (mortar reinforced by 1 % of fibres) was about 116, 86 and 101 % respectively compared to reference strengths. On the contrary, a long-term progressive increase in the strength is achieved for the mortars conserved in the controlled environment, when the increase obtained after two weeks curing is about 60, 36 and 30 % respectively. This behaviour can be explained by the positive effect of the standards conditions of temperature and relative humidity of the laboratory conditions (T = 20 ± 2 °C, HR = 50 ± 5 %) for the strength evolution of cement materials. Under these relatively ideal conditions, the hydration reaction continues progressively producing more hydrates with a high quality and hence gaining more strength up to a maximum strength after 56 days curing. After three months curing in hot-dry environment, the variation of the strength decreased from the high values reached at 14 days curing to values around 19, 20 and 22 % of the reference strength for mortars M0, M0.5 and M1 respectively. Under laboratory conditions, these variations of the strength were around 67, 46 and 42 % of the reference strength, respectively and hence were higher than those obtained under hot-dry conditions. The relatively small increase of the strength values obtained after 91 days curing in hot-dry environment can be explained by the fact that as the high temperatures accelerate the setting of cement at the beginning, and also accelerate the hardening of the materials, which leads to a rapid evolution of their mechanical strengths at short and middle-term. The final strengths reached at longer-term decrease since high temperatures accompanied with low relative humidity lead to the water evaporation, which contributes to stop the hydration reaction and to weaken the already formed hydrates and thus to reduce the mechanical strengths.

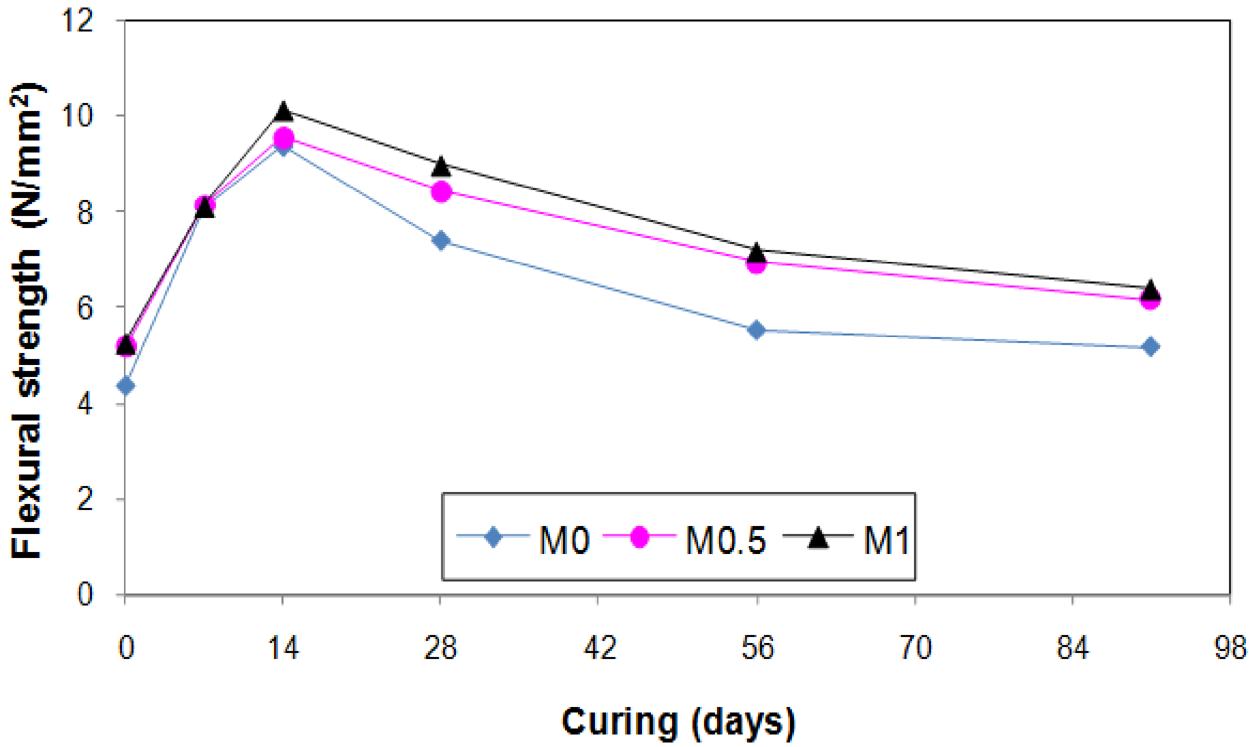

Figure-2. Flexural strength evolution of mortars under hot-dry conditions

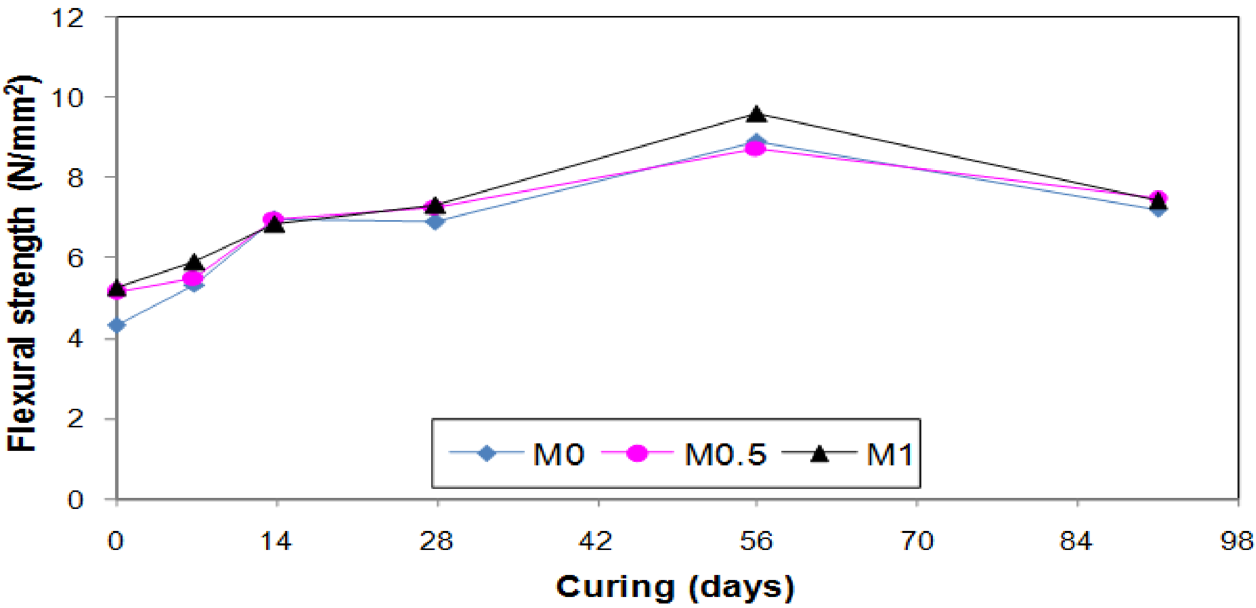

Figure-3. Flexural strength evolution of mortars under laboratory conditions

Compared to mortar without fibres, mortars reinforced by fibres have higher flexural strength, in hot-dry environment, particularly after 14 days curing. In effect, after three months curing in this environment, the increase of the flexural strength varies between 19 % in M0.5 and 24 % in M1 compared to the strength of M0. The polypropylene fibres seem to reduce the decrease after 28 days and stabilise the strength. Under hot-dry conditions, the polypropylene fibres have insured a higher bond with the cement matrix. This is important for the long-term performances and durability of the material fabricated in hot-dry climate. However, under laboratory conditions, the efficiency of polypropylene fibres does not seem to be significant, because under these standards conditions, the mortar does not need any fibrous strengthening to prevent the premature evaporation of water.

3.2. Compressive Strength

Figures 4 and 5 show that the compressive strength also increases with the curing time in the two environments compared to reference strengths. Nevertheless, the laboratory conditions have the best effect on the compressive strength, particularly at long-term curing. This is because these conditions constitute a favourable environment for the continuity of the chemical activity of the hydration. The consequence of this activity will be the increase of the long-term mechanical performances of the material. After a week curing of mortars in hot-dry environment, the increase of the compressive strength is much important and is comparable to that reached after a long curing period in laboratory conditions. This increase varies between 76, 63 and 49 % in mortars M0, M0.5 and M1 respectively compared to the reference strengths; in laboratory conditions, this increase does not exceed 20 %. This behaviour can be explained by the fact that high temperature amplifies the hydration at the early ages, which in turn increases further the temperature around the material and hence end up by causing the remaining uncombined water to evaporate. This explains the increase of the compressive strength with the curing until 28 curing in hot-dry environment, and then decreases slightly after complete evaporation of the remaining water and the possible weakening of some of the hydrates to stabilise at a later age. The presence of polypropylene fibres in mortars seems to improve efficiency their compressive strength at the longer-term after two weeks curing by comparison to the mortar without fibres. In the laboratory conditions, the compressive strength continues to increase with the curing. Afterwards, the presence of fibres seems to maintain the strength reached by comparison to the specimens no reinforced with fibres. After two weeks curing under hot-dry conditions, the increase of the compressive strength varies between 59 % in mortar M0 and 68 % in both M0.5 and M1 compared to the reference strengths. Under laboratory conditions, these percentages are around 40, 42 and 31 % in mortars M0, M0.5 and M1 respectively. After three months curing in hot-dry environment, the compressive strength increases by 49 % in M0.5 and by 47 % in M1, compared to the reference strengths. The compressive strength of the mortar M0 is relatively much less than that of the reinforced mortars. At 91 days curing in laboratory conditions, this increase's strength reaches 86, 71 and 55 % in mortars M0, M0.5 and M1, compared to the reference strengths. Under both conditions, the highest compressive strengths were reached when polypropylene fibres were added to reinforce the mortars.

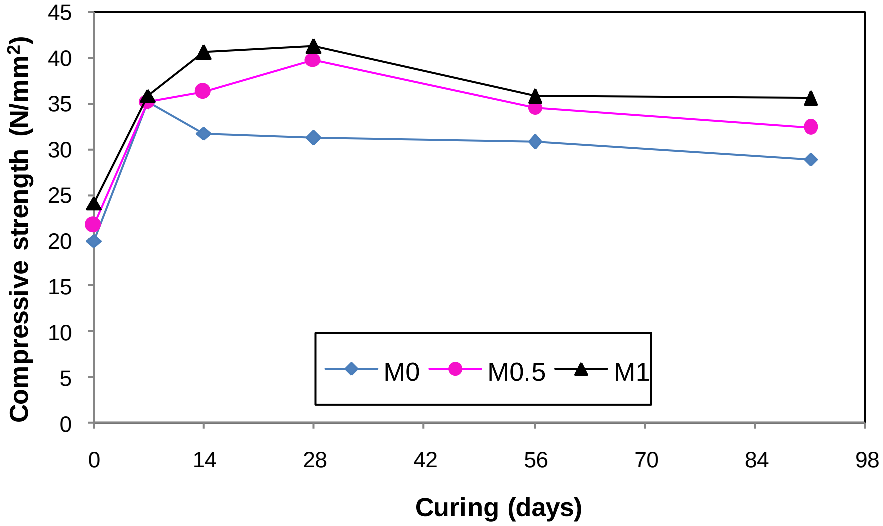

Figure-4. Compressive strength evolution of mortars under hot-dry conditions

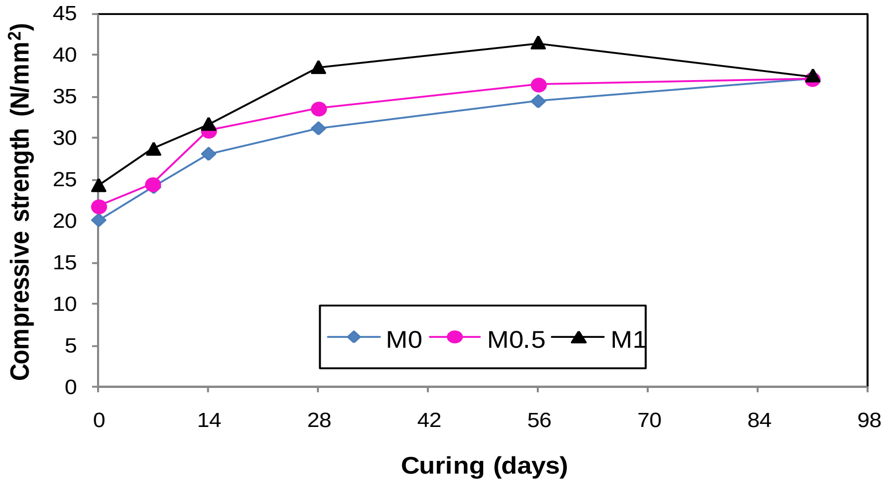

Figure-5. Compressive strength evolution of mortars under laboratory conditions

After two weeks curing in hot-dry environment, the gain of the compressive strength varies between 14 % in mortar M0.5 and 28 % in M1, compared to the mortar without fibres, but in the laboratory, it is about 10 and 13 % respectively. After three months curing under hot-dry conditions, the increase of the compressive strength in mortars M0.5 and M1 is about 12 and 23 % respectively, compared to M0, but in laboratory, no positive effect is observed. The majority of the studies realized on the fibres concretes published in the literature have reported that fibres had no or little improvement of the compressive strength [8, 9].

3.3. Shrinkage

As figures 6 and 7 show, the curing conditions have a high influence on the development of shrinkage. All mortars cured under hot-dry conditions reached the highest shrinkage, which rapidly evolves and stabilizes earlier; due to the rapid loss of mixing water caused by the hot and dry conditions of conservation, which leads to an increase of the risk of the shrinkage. Under these conditions, the hydration heat was higher, what accelerates more the water departure. Some authors have reported that the curing temperature has a significant effect on the both the rate and the magnitude of the total shrinkage [10]. The reinforcement of the mortar by polypropylene fibres considerably reduces the shrinkage, particularly in hot-dry environment; an introduction of 1 % of polypropylene fibres in the mortar reduces the shrinkage by more than half. The reinforcement of the cement materials by fibres constitutes an obstacle to any shrinking movement which occurs mainly within the cement paste. In general, the results found in this study are in agreement with those obtained in other works [11-16].

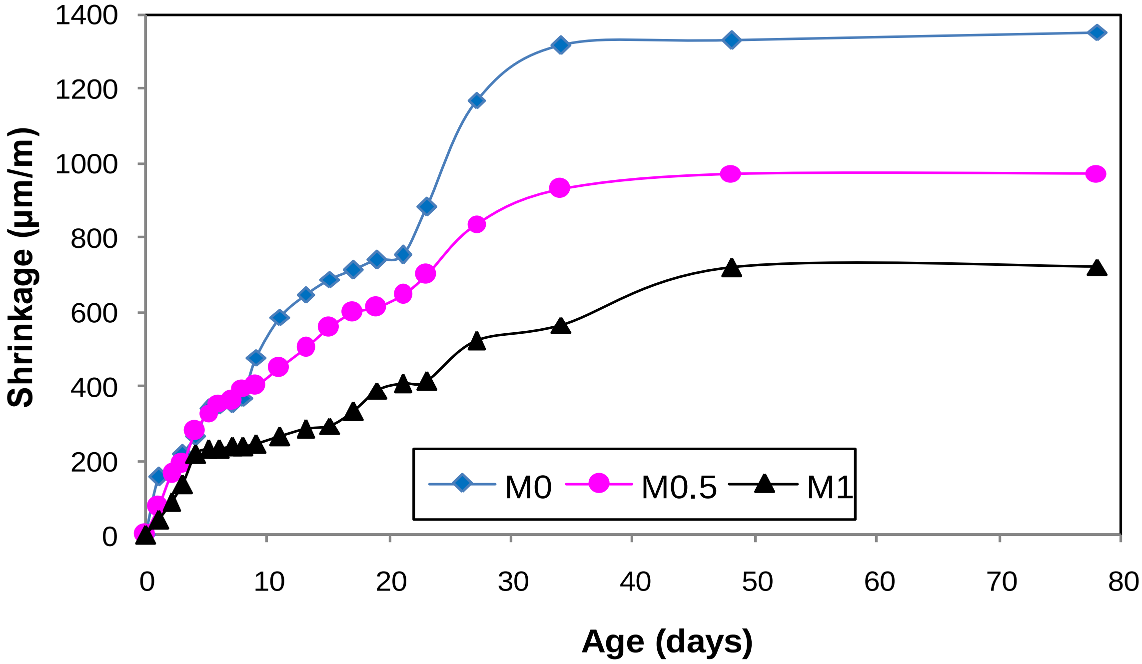

Figure-6. Shrinkage of mortars cured under hot-dry conditions

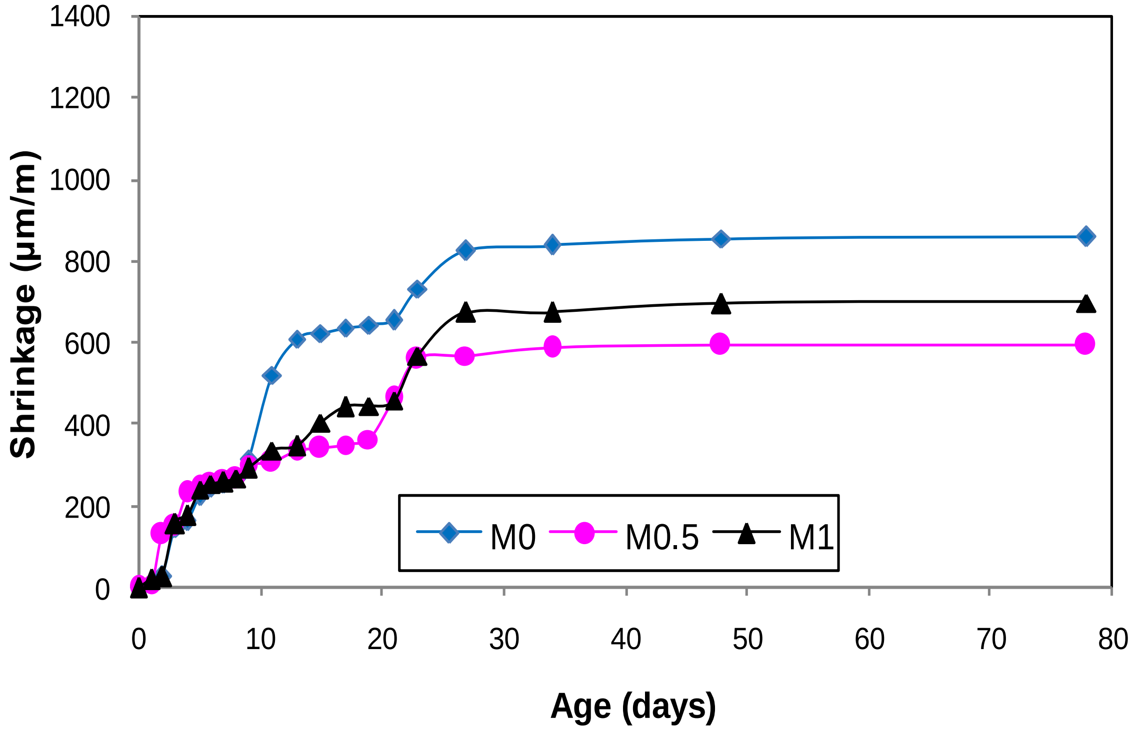

Figure-7. Shrinkage of mortars cured under laboratory conditions

4. CONCLUSIONS

From this experimental work, the following conclusions can be drawn:

During the first 28 days curing, the evolution of the mechanical behaviour of all mortars is more important under hot-dry conditions, by comparison to laboratory.

The flexural behaviour of mortars conserved under hot-dry conditions is enhanced by their reinforcement with polypropylene fibres waste. After three months curing under these conditions, the percentage enhancement of the flexural strength of mortar M1 is about 24 % as compared with that of M0. The recycled polypropylene fibres have not ensured any significant effect on the flexural behaviour of mortars conserved under the conditions of laboratory.

The reinforcement of mortars by polypropylene fibres waste enhances their compressive behaviour in both conservation conditions. A reinforcement of 1 % of recycled polypropylene fibres increases the compressive strength obtained after three months curing under hot-dry conditions by 23 % as compared with the strength of M0. Whereas under laboratory conditions, no positive effect of the polypropylene fibres waste is observed in the compressive behaviour of the mortars after 91 days curing.

Under hot-dry conditions, the mortars reach the most important shrinkage by comparison with the laboratory conditions. The recycled polypropylene fibres have presented a high efficiency to reduce the amount of the shrinkage of mortars conserved under hot-dry conditions and to delay its evolution since young age. The shrinkage in the mortar M1 presents only the half of the shrinkage of the mortar M0.

Funding: This study received no specific financial support.

Competing Interests: The authors declare that they have no competing interests.

Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study.

REFERENCES

[1] O. S. B. Al-Moudi, M. Maslehuddin, M. Shameem, and M. Ibrahim, "Shrinkage of plain and silica fume cement concrete under hot weather," *Cement & Concrete Composites Journal*, vol. 29, pp. 690-699, 2007.

[2] V. Langlois, B. Fiorio, A. L. Beaucour, R. Cabrillac, and D. Gouvenot, "Experimental study of the mechanical behavior of continuous glass and carbon yarn-reinforced mortars," *Construction & Building Materials Journal*, vol. 21, pp. 198-210, 2007.

[3] Y. Ma, B. Zhu, and M. Tan, "Properties of ceramic fiber reinforced cement composites," *Cement & Concrete Research Journal*, vol. 35, pp. 296-300, 2005.

[4] L. A. Pereira de Oliveira and J. P. Castro-Gomes, "Physical and mechanical behaviour of recycled PET fibre reinforced mortar," *Construction & Building Materials Journal*, vol. 25, pp. 1712-1717, 2011.

[5] C. Qi, J. Weiss, and J. Olek, "Characterization of plastic shrinkage cracking in fiber reinforced concrete using image analysis and a modified Weibull function," *Materials & Structures Journal*, vol. 36, pp. 386-395, 2003.

[6] J. Branch, A. Rawling, D. J. Hannant, and M. Mulheron, "The effect of fibers on the plastic shrinkage cracking of high strength concrete," *Materials & Structures Journal*, vol. 35, pp. 189-194, 2002.

[7] N. Banthia and R. Gupta, "Influence of polypropylene fiber geometry on plastic shrinkage cracking in concrete," *Cement & Concrete Research Journal*, vol. 36, pp. 1263-1267, 2006.

[8] B. Barr, S. B. Hoseinian, and M. A. Beygi, "Shrinkage of concrete stored in natural environments," *Cement & Concrete Composites Journal*, vol. 25, pp. 19-29, 2003.

[9] A. García-Santo, J. M. Rincón, M. Romero, and R. Talero, "Characterization of a polypropylene fibered cement composite using ESEM, FESEM and mechanical testing," *Construction & Building Materials Journal*, vol. 19, pp. 396-403, 2005.

[10] F. Bouziadi, B. Boulekbache, and M. Hamrat, "The effects of fibres on the shrinkage of high-strength concrete under various curing temperatures," *Construction & Building Materials Journal*, vol. 114, pp. 40-48, 2016.

[11] Y. Ma, B. Zhu, M. Tan, and K. Wu, "Effect of Y type polypropylene fiber on plastic shrinkage craching of cement mortar," *Materials & Structures Journal*, vol. 37, pp. 92-95, 2004.

[12] P. S. Song, S. Hwang, and B. C. Sheu, "Strength properties of nylon- and polypropylene-fiber-reinforced concretes," *Cement & Concrete Research Journal*, vol. 35, pp. 1546-1550, 2005.

[13] M. Hsie, C. Tu, and P. S. Song, "Mechanical properties of polypropylene hybrid fiber reinforced concrete," *Materials Science & Engineering A Journal*, vol. 494, pp. 153-157, 2008.

[14] T. Aly, J. G. Sanjayan, and F. Collins, "Effect of polypropylene fibers on shrinkage and cracking of concretes," *Materials & Structures Journal* vol. 41, pp. 1741-1753, 2008.

[15] Z. Sun and Q. Xu, "Microscopic, physical and mechanical analysis of polypropylene fiber reinforced concrete," *Materials Science & Engineering A Journal*, vol. 527, pp. 198-204, 2009.

[16] W. Boshoff and R. Combrinck, "Modelling the severity of plastic shrinkage cracking in concrete," *Cement & Concrete Research Journal*, vol. 48, pp. 34-39, 2013.