Research Journal of Engineering Sciences ______________________________________ ISSN 2278 – 9472
Vol. **9(2),** 13-18, May **(2020)** *Res. J. Engineering Sci.*

Slowing down the degradation of concrete by urea: use of glass powder

Conand Honoré KOUAKOU*, Koffi Clément KOUADIO, Maméry SERIFOU and Edjikeme EMERUWA
Laboratoire de Géomatériaux, Unité de formation et de Recherche des Science de la Terre, Université Félix Houphouët Boigny 22 BP 582 Abidjan
honore_kouakou2@yahoo.fr

Available online at: www.isca.in, www.isca.me
Received 31st January 2020, revised 28th April 2020, accepted 20th May 2020

Abstract

Some concrete structures can be subjected to aggressive environmental conditions and degrade early. To cancel or reduce this degradation, physical and chemical solutions are proposed. This work is a contribution to limiting the degradation of concrete by using waste such as used bottles. Its objective is to slow the progression of concrete deterioration by adding glass powder obtained by grinding used bottles. A finely ground glass powder was added to concrete in varying proportions and then specimens were made. After maturing for 28 days in water, these specimens were immersed in urea solution for four weeks. Each week, some specimens are removed and subjected to various tests (sclerometric index, ultrasonic test, compression test, mass loss and density). Analysis of the results indicates that adding glass powder to concrete increases surface hardness, reduces the amount of vacuum and increases compressive strength. All these improvements are due to secondary CSH training. Comparison of digestion rates from glass-free concrete to glass-powdered concrete shows that the latter is resistant to urea degradation. The addition of powder to concrete is therefore a way of improving the durability of structures in the face of certain chemical degradation agents.

Keywords: Glass powder, secondary CSH, urea, degradation, used bottles.

Introduction

Concrete is susceptible to attack by different types of aggressive chemical agents including urea. Concrete is a cementitious matrix material. It consists mainly of gravel, sand and ordinary portland cement. This cement ensures the connection between the various elements and gives the concrete most of these properties. Chemically it is composed mainly of Ca_2O, SiO_2, Al_2O_3 and Fe_2O_3. There is currently a diversity of concretes which are generally used in the construction of structures and particularly warehouses[1-4]. These allow the storage of agricultural production and the conservation of stocks of products such as urea.

The urea-concrete contact leads to early degradation of the concrete structure. In fact, urea is a nitrogen fertilizer of mineral origin that has a granulation that makes it easy to store, transport and also to spread at crop level. Its chemical formula is $CO(NH_2)_2$. This compound causes the concrete to dissolve or swell because ammonium salts mainly dissolve $Ca(OH)_2$ from the cured cement paste, resulting in ammonia.

In the literature, some authors have focused on the attack of acid and/or alkaline compounds on concrete. For example, the behaviour of concretes in the presence of all kinds of chemical compounds has be treated[5]. This research shows that acid attack on concrete involves a set of complex processes that lead to a reduction in the structural properties of the material. The speed of the attack is influenced by different factors: factors related to the acid solution (pH, type of acid, solubility of the calcium salt of the acid) factors related to the cement-based material (type of cement, permeability of the concrete, concrete quality) factors related to the attack conditions. Similarly, some authors studied the chemical attack of farm concrete by acids from animal feed (lactic and acetic acids) and their cleaning products[6-8]. It appears that the addition of fly ash and even more silica fume to the concrete contributes to increasing its resistance to attack from aggressive and very aggressive environments. In addition, Dyer investigated the influence of cement composition on the resistance to acid attack from organic acids selected for their ability to form complexes with metal ions present in the cementitious material and/or their potential to precipitate cement expansion products[9]. He notes that the extent to which different cements resist acidic chemical attack is low. Thus the design of concrete to resist acidic chemical attack goes beyond the type of cement but depends more on the low water/cement ratio. In addition, acidolysis is the main mechanism of cement degradation.

This work shows that it is possible to improve the resistance of concretes to aggressive environments by using mineral compounds. However, it does not specify the most appropriate process. Indeed, fly ash and silica fume can be added to concrete and it is also possible to add them to cement to give different types of cement that are used to make the same concrete. These two types of concrete obtained by different methods have different resistance to acidic chemical attack. Also, this work aims to explore a new product for limiting concrete degradation by chemical compounds. It is based on the use of the mineral addition method to concrete.

More specifically, it is to be verified that the addition of glass powder obtained from used bottles is a means of controlling the chemical attack of concrete by urea.

Methodology

Specimen development method: The raw material used in the production of concrete is composed of sand, cement, granite crushed granite, glass powder and water.

The cement is produced by SCA (Société de Cimenteried'Abidjan), a CUIRASSE CEM I type and 32.5 MPa class company.

The sand is extracted from the lagoon. It is a sand of average grain size, modulus of fineness and sand equivalent 2.15 and 97.5% respectively. It consists mainly of quartz grains (SiO_2).

Granite crushed granite is of granular class 5/15 and is supplied by CADERAC

The water comes from the drinking water distribution network. It is provided by the Société de Distribution d'Eau en Côte d'Ivoire (SODECI).

Glass powder is obtained by grinding used glass bottles. This is the 500 µm sieve passer-by.

For the production of our concretes, the volumetric dosage was used. Two (2) volumes of granite crushed material are first dry mixed with a volume of sand and a volume of cement. Then, the glass powder is added in the mass proportions of 0; 5; 10; 10; 15; 20%. Finally, the water is added while keeping a fixed Water-Cement ratio of 0.45. This set is mixed for three (3mn) to five (5mn) minutes and then the mixture obtained is introduced into the cylindrical moulds with a diameter of 10mm and a height of 20mm. After 24 hours the specimens are removed from the mould and stored in a room for 6 months at a humidity of 70%.

Characterization test: After six (6) months of age, part of the test pieces (three for each batch) are placed in contact with urea and the rest as a control is soaked in distilled water. Three weeks later, three specimens per batch are subjected to non-destructive (sclerometer and ultrasound) and destructive (simple compression) mechanical tests.

Sclerometer test: The sclerometer test is used to measure the surface hardness of the specimens. Its principle is based on the fact that the height of the rebound of a steel ball depends on the surface hardness of the test specimen. In practice, to determine this surface hardness, the sclerometric index is obtained using a sclerometer and then a correlation is established between the sclerometric index and compressive strength. For this purpose, different measuring points are identified along the specimen in three lines (depending on height) located at equal distances from the circumference of the cylinder. The difference between two consecutive measuring points along the same line is 3cm.

In this work, the standard sclerometer with aluminium housing type NR is used. The formula used to calculate the resistance is given by the standard NF EN 13791/CN.

Ultrasonic test: The ultrasonic test makes it possible to assess the internal strength of the specimens from the propagation rate of the ultrasound and to calculate the dynamic elastic modulus. This ultrasonic test was performed with the 58-E4900 sonic auscultation device from CONTROLS. During the test, the transmitter and receiver are placed in opposition (direct method) on either side of the sample. The device displays the time it takes for the wave to pass through the material from the transmitter to the receiver. In addition, the dimensions (length, width and thickness) of the sample are measured with a 0.02 mm precision caliper. The transmission time of the ultrasound (T) and the size of the sample (L) collected are first used to calculate the propagation rate (V) of the sound in the sample using the formula.

Direct Compression Test: The direct compression test is used to determine the ultimate crushing strength of the specimens. It was measured using a hydraulic press of the brand CONTROLAB with a capacity of 1500kN. The value of the compressive strength is given by the formula: $Rc=F/S$. Compressive strength is determined on specimens immersed in water and in contact with urea for three weeks.

Results and discussion

Surface hardness of concretes: Figure-1 shows the variation in the sclerometric index of the different specimens as a function of powder content. For the same duration of exposure to urea, the sclerometric index decreases to a content of 10% powder. However, above 10% a slight improvement is noted. This variation is due to the addition of glass powder to the concrete. Indeed, the quantity of granite crushed and sand added to the concrete being fixed, the addition of glass powder increases the volume of the matrix. Thus the quantity of sand, glass powder and cement, matrix, around the granite crushes increases with the powder content. As this matrix is softer than granite crushes, the surface hardness of the specimens will drop. However, its significant improvement is explained by the pouzolanic reaction between portlandite from cement and glass powder, which reaches its optimum between 10 and 15% glass powder.

Over time, the difference between the sclerometric indices increases for specimens without glass powder while for specimens containing powder it decreases for powder contents below 10% (Figure-2). Beyond that, the differences between the sclerometric indices are very small or even practically zero. This decrease in the gaps until its cancellation shows that the surface attacked with the duration of exposure becomes less resistant and therefore porous and can be removed by brushing.

However, the presence of glass powder reduces the degradation of this surface. This confirms that the urea in contact with the concrete destroys it. According to authors concretes with ordinary portland cement that have a high portlandite content and a high CaO/SiO_2 ratio in cement hydration products are more vulnerable to acid attack[10-12]. Concrete with blast furnace slag, on the other hand, because of its low portlandite content and the low CaO/SiO_2 ratio in cement hydration products is less sensitive to acid attack. Thus, the significant degradation of powder-free concrete is explained by the high portlandite content and CaO/SiO_2 ratio of cement hydration products compared to glass powder concrete which contain cement hydration products with portlandite content and low CaO/SiO_2 ratio. The presence of glass powder slows down the rate of degradation of the surface hardness of concrete.

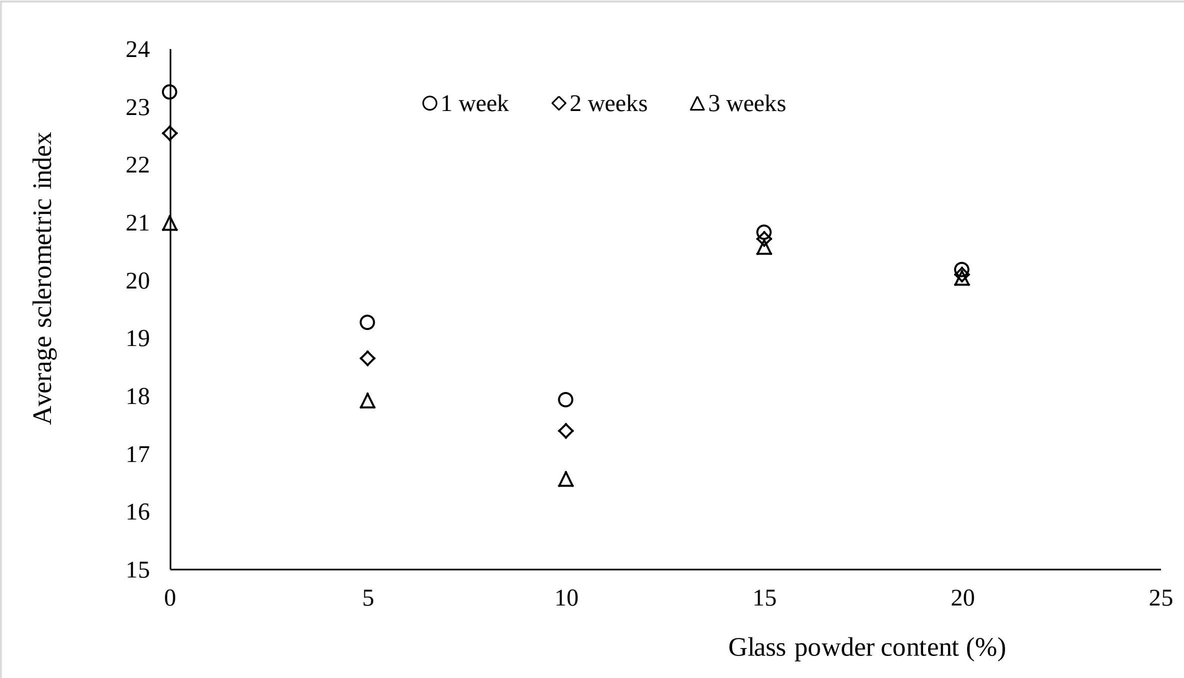

Figure-1: Variation of surface hardness with glass powder content.

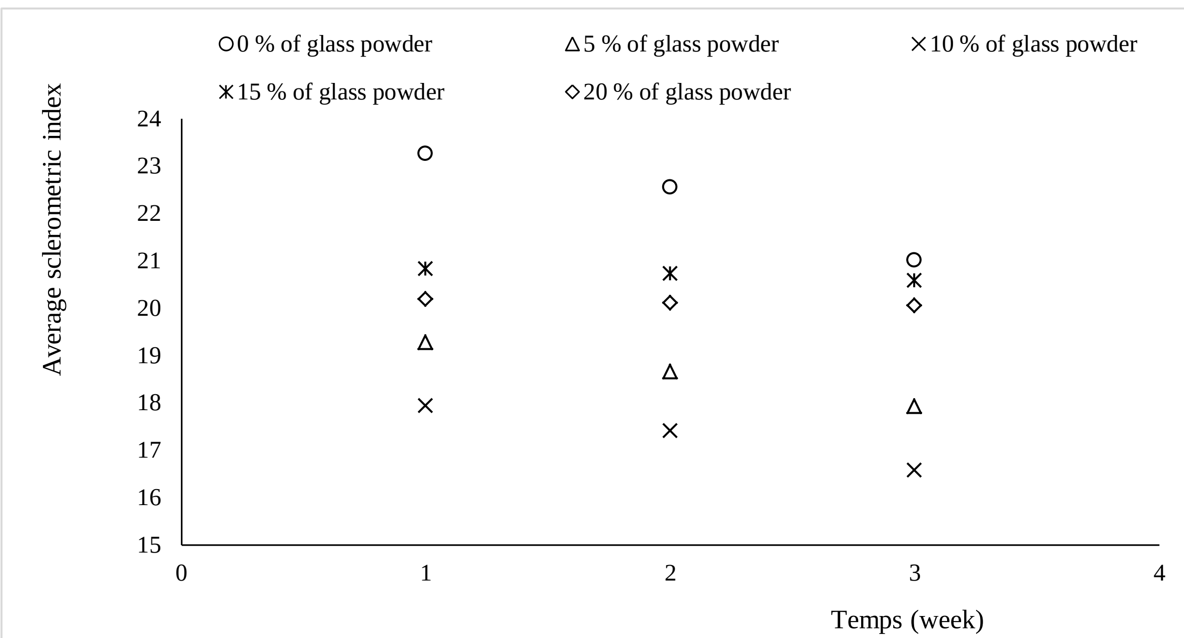

Figure-2: Surface hardness variation with urea exposure time.

Progression of urea in test pieces: The velocity of propagation of ultrasound in a material depends on its degree of damage. The more damage is caused (cracks, pores), the faster the ultrasound propagation rate becomes.

Figure-3 shows that in the presence of glass powder for the same duration of exposure to urea, the velocity of sound propagation decreases to a content of 10% powder and then appears to become constant above 10%. This variation is due to the addition of glass powder in the concrete. Indeed, according to authors, organic acids leach Ca^{2+} ions and the high strength of concretes containing blast-furnace slag is mainly due to the low CaO content and the high SiO_2 content[13]. Therefore, urea reacts with calcium from portlandite gold in the presence of glass powder, the pouzolanic reaction occurs between the latter and portlandite to form secondary CSHs. This reaction consumes calcium. Thus the amount of calcium that can react with urea decreases. Glass powder limits the effects of urea degradation on concrete properties.

The harmful actions of urea in contact with concrete are not limited only to the surface, they progress towards the inside of the concrete over time (Figure-4). At 0% glass powder, the speed differences between the different measuring moments increase, while in the presence of glass powder they decrease with the powder content until they become zero above 10%. Glass powder slows the progression of the urea's action towards the inside of the concrete. On concretes containing blast furnace slags from chemical analysis authors showed that the penetration depth of organic acids increases with exposure time but decreases when the proportion of blast furnace slag increases[13].

Compressive strength of concrete exposed to urea: Figure-5 shows the variation in the compressive strength of the specimens as a function of the glass powder content. Overall, it indicates that the strength drops with the addition of glass powder to the concrete. This is due to the fact that on the one hand the quantity of mixing water has remained constant while the proportion of fine has increased (addition of glass powder) and on the other hand, the volume of the sand-cement-powder matrix has increased.

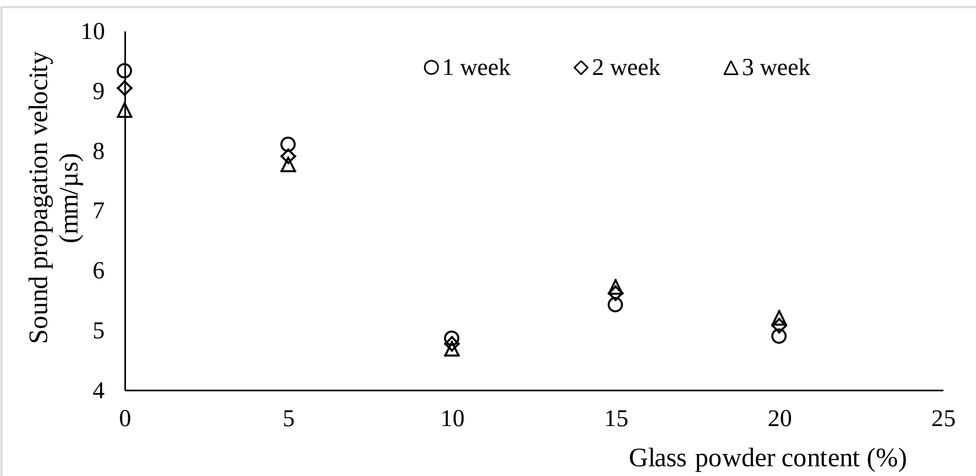

Figure-3: Variation of the sound propagation velocity as a function of the glass powder content.

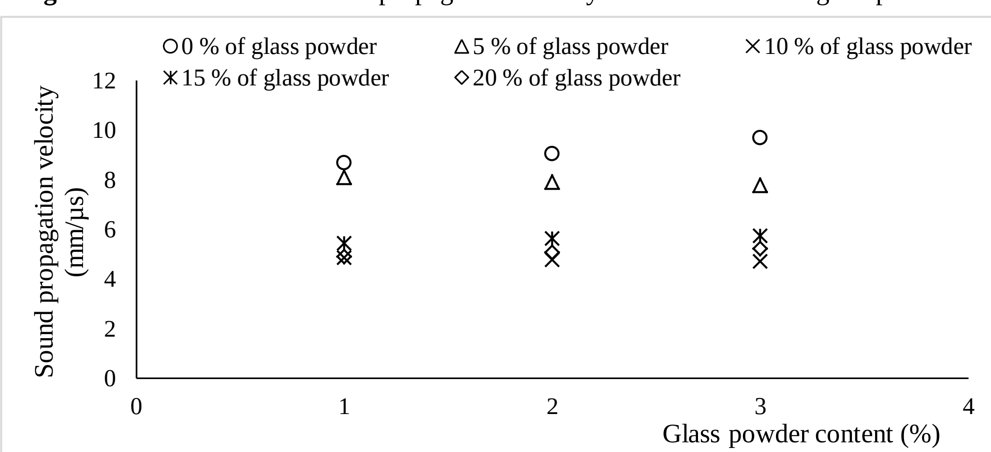

Figure-4: Variation of ultrasound propagation velocity as a function of time.

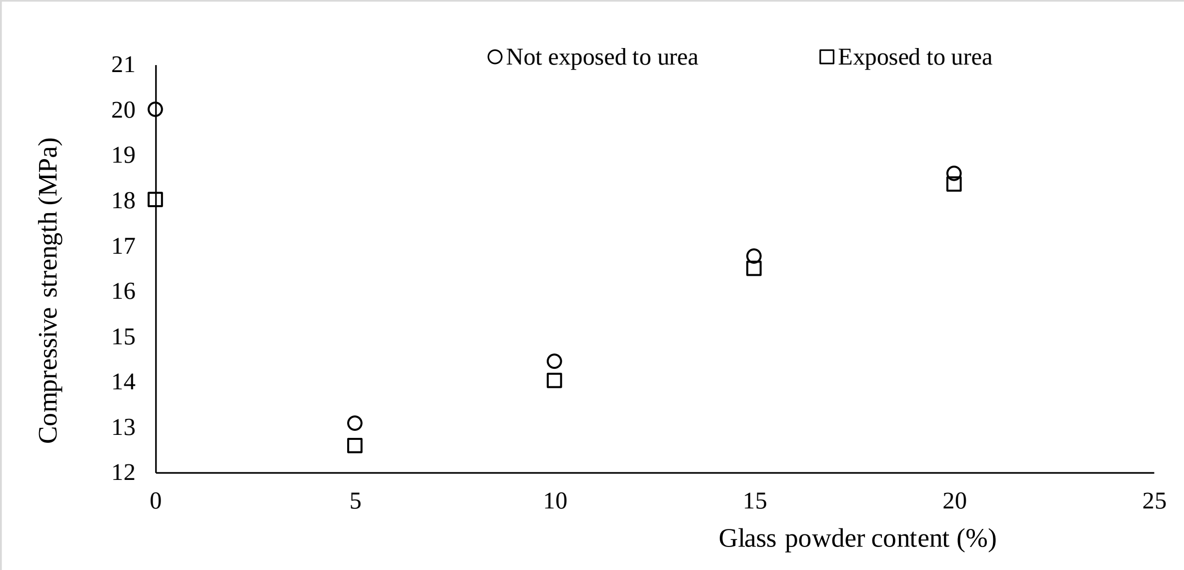

Figure-5: Variation in compressive strength of concrete exposed or not to urea as a function of glass powder content.

This figure also shows that for the same powder content, the compressive strength of concretes exposed to urea is lower than that of unexposed concretes. Urea degrades, including the mechanical properties of concrete. However, when concretes contain glass powder, the difference in strength between exposed concretes and not urea becomes small as the glass powder content increases.

Conclusion

Exposing concrete containing different proportions of glass powder to a urea solution allows the following remarks to be made: i. Contacting concrete without glass powder and urea causes a drop in surface hardness and compressive strength. Urea reacts with the calcium in the cement and causes deterioration of the properties of the concrete. This urea action progresses from the outside to the inside of the concrete. ii. Glass powder slows down the degradation of surface hardness and limits the drop in concrete strength. The pouzolanic reaction between portlandite and glass powder leads to the formation of secondary CSHs. The formation of the latter consumes calcium and slows the rate of degradation of concrete properties. The limit content of glass powder above which the effects of urea on concrete are practically nil is above 10%.

Glass powder can be added to cementitious matrix materials to slow the degradation of their properties when they are contacted with urea.

References

1. Assié, S. (2004). Durabilité des bétons auto-plaçants. Doctoral dissertation, Toulouse, INSA.
2. El Barrak, M. (2003). Contribution à l'étude de l'aptitude à l'écoulement des Bétons Auto-Plaçants (BAP) à l'état frais. *Revue Française de Génie Civil*, 7(1), 115-115.
3. Gramont F. (1998). Bétons Hautes performances: Contribution à l'élaboration de règles de formulation. Thèse de doctorat, Toulouse INSA (France)
4. Garros M. (2007). Composites cimentaires incorporant des granulats caoutchouc issu du broyage de pneus usagés: optimisation de la composition et caractérisation. PhD, Paul Sabattier,Université Toulouse (France)
5. Kurt H. (1995). Chemical Substances Affecting Concrete. *Cement Bulletin*, 63, 3-11
6. Bretron A., Escadeillas G. Duchesne J G. (2004). Cement pastes alteration by liquid manure organic acids: chemical and mineralogical characterization. *Cement and Concrete Research*, 34(10), 1823-1835
7. Bretron A., Duchesne J., Escadeillas G. (2005). Attack of cement pastes exposed to organic acids in manure. *Cement and Concrete Composites*, 27(9-10), 898-909.
8. De Belie N., De Coster V., Van Nieuwenburgt D. (1997). Use of ash or silica fume to increase the resistance of concrete to feed acids. 49(181), 337-344 https://doi.org/10.1680/macr.1997.49.181.337
9. Dyer T. (2017). Influence of cement type on resistance to organic acids. *Magazinz of concrete Research*, 69(4), 175-200. https://doi.org/10.1680/jmacr.16.00271
10. Gruyaert E., Van den Heede P., Maes M. De Belie N. (2012). Investigation of the influence of blast-furnace slag on the resistance of concrete against organic acid or sulphate attack by means of accelerated degradation tests. *Cement Concrete research*, 42, 173-185
11. Chen W. and Brouwers H. J. H. (2007). The hydration of slag: Part2. Reaction models for blended cement. *Journal of Material Sciences*, 42 (2) 444-464.

12. Richardson, I. G. (2000). The nature of the hydration products in hardened cement pastes. *Cement and Concrete Composites*, 22(2), 97-113.

13. Gruyaert E., Maes N., De Belie N., (2013). Performance of BFS concrete: k-value concept versus equivalent performance concept. Construction and Building Materials 47, 441-455 http://dx.doi.org/10.1016/j.conbuildmat.2013.05.006.