Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Building and Environment 41 (2006) 262–267
BUILDING AND ENVIRONMENT
www.elsevier.com/locate/buildenv

The effects of atmospheric exposure on the fracture properties of polymer concrete

J.M.L. Reis[a,*], A.J.M. Ferreira[b]

[a]*Laboratório de Mecânica Teórica e Aplicada, Universidade Federal Fluminense, Programa de Pós-Graduação em Engenharia Mecânica, UFF, Rua Passo da Pátria, 156, Bloco. E, sala 216, 24210-260, Niterói, Rio de Janeiro, Brasil*
[b]*DEMEGI—Departamento de Engenharia Mecânica e Gestão Industrial, Faculdade de Engenharia da Universidade do Porto, FEUP, Rua Dr. Roberto Frias 4200-465, Porto, Portugal*

Received 11 November 2004; received in revised form 7 December 2004; accepted 9 December 2004

Abstract

In this experiment the effect of atmospheric exposure of epoxy and fiber-reinforced epoxy polymer concrete was investigated to evaluate its fracture properties, such as stress intensity factor, K_{Ic}, and fracture energy, G_f. The deterioration and structural performance of polymer concrete were investigated in a real situation of exposure during a year period and compared the same formulation in laboratory conditions. The relationship between year period, exposure time and load-bearing capacity of deteriorated polymer concrete is studied and fracture mechanics of the specimens are discussed. From the tests results and discussion it is clear that the material studied, polymer concrete, suffers a high deterioration when subjected to aggressive environments.

Keywords: Polymer concrete; Environmental exposure; Fracture mechanics

1. Introduction

The deterioration of a material depends on how and to what extent it interacts with its surroundings. The outdoor environment if considered in terms of sunshine, temperature, rainfall and wind, varies widely in duration, intensity and sequence. As far as the durability of materials is concerned, weight should be given to severe climatic conditions and depends on the confidence level required in the performance of the material, but in general it is the time-averaged climatic factors which should be considered. It is thought the prevalence of certain elemental features for prolonged periods has to be the basis of the concept of climate involved. Various climatic classifications have been developed to meet particular human requirements: in agriculture to define vegetation and crop distribution, in transport to make safer travel by land, sea and air and in medicine to relate man's physical well-being and social development to his environment. There is as yet no accepted classification of climates for the deterioration of man-made materials are in its infancy. However, examples such as the hydrolic reversion of polyurethanes, the ozone-induced stress cracking of rubbers, the decoloration of polymers by sunlight and the dimensional variability demonstrate the interaction between the environment and polymers. The main components of weather which cause degradation are sunlight, temperature, moisture, wind, dust and pollutants.

Because of their impact on man's social economic welfare, features of the weather have been measured for many years and detailed records go back to more than a hundred years in certain regions. Today, meteorological data are collected at numerous sites throughout the world through a network of global stations, but concentration of this varies widely over regions.

*Corresponding author. Tel.: +55 216295588; fax: +55 216295585.
E-mail address: jreis@mec.uff.br (J.M.L. Reis).

0360-1323/$ - see front matter
doi:10.1016/j.buildenv.2004.12.017

The durability of any material is related to the environment that it is exposed to UV radiation, temperature, rain and wind represent large variations in durability and it is related to the characteristics that are intended to be obtained from the material that is being used.

There is no climatic classification in terms of material degradation, although the principal clime components which cause degradation are solar radiation, rain, humidity, temperature, wind, dust and contamination [1].

The high level of temperature, humidity and radiation combined make the places hot and wet (tropical) the hardest clime for composite materials.

There are several countries which have their atmosphere data recorded for several years, in our case the reference that is going to be used is a meteorological tower that Aveiro University has nearby the place where tests were performed.

In this paper, the fracture properties of epoxy polymer concrete and fiber-reinforced polymer concrete were tested by three-point bending tests after exposure to different weather conditions. Polymer concrete consists, in essence of an aggregate blend mixed with a polymer resin in convenient proportions which were studied previously by authors [2,3] and are used in repairing or in constructing layers or sections in reinforced concrete structures with high ductility [4].

To perform these tests, the TPFM is used to evaluate two independent-sized fracture parameters, the stress intensity factor, K_{Ic}, and critical crack tip opening displacement $CTOD_C$ according to RILEM recommendations [5,6]. Another fracture parameter calculated from these tests was the fracture energy G_f. The fracture energy also is calculated following RILEM recommendations [7].

2. Experimental program

2.1. Environmental condition

The meteorological tower from Aveiro University, Portugal, was used to collect the temperature and humidity from Aveiro city, which is an excellent indication of the local weather condition during the year.

There is another significant issue of these tests: the weather condition in Aveiro is overall similar temperature and humidity every combined season, registering the lowest temperatures in January, in winter, and the hottest in the beginning of September, summer. According to the meteorological tower the lowest registered temperature was 5.9 °C in January and the highest was 20.3 °C in early September. The air humidity on these precise days was 77% and 66%, respectively. The air humidity during the year varied from 43% to 103% [8].

2.2. Test samples

Polymer concrete formulations were prepared by mixing an epoxy resin with siliceous sand with rather uniform granulometry.

The aggregate used in this study was foundry sand which consists in siliceous sand, designed by SP55, from SIBELCO used in the foundry industry, with uniform granulometry, and an average diameter of 245 μm in 80% of mass. The epoxy resin system used was EPOSIL 551, from SILICEM based on a diglycidyl ether bisphenol A and an aliphatic amine hardener it was processed with a maximum mix ratio of hardener of 2:1, in 20% of mass.

The reinforcement used in this research was 1%, in mass, of E-glass fiber provided from by PPG with no sizing. The fibers were emerged in a solution of 2% of Silane A174 for adhesion treatment. Carbon fiber provided by TENAX, which is a PAN HTA 5131 fiber, with epoxy sizing was added in the percentage of 2%, in mass. All fibers have an average length of 6 mm. The fiber percentage was also investigated by the authors in their previous works [9,10], in order to obtain higher reinforcement performance.

Both reinforced and plain polymer concrete, with these binder formulations and mix proportions were mixed and moulded to specimens of size 30 mm × 60 mm × 280 mm, and then notched with 20 mm depth using a 2 mm diamond saw according to RILEM standard TC113/PC2 [11]. All specimens were allowed to cure for 7 days at room temperature and then post-cured at 80 °C for 3 h.

2.3. Experimental procedure

The specimens were placed in the roof of a house near "Aveiro", 60 km away from "Porto", near the ocean. The samples faced Southwest with the notch free from touching any surface, for the fracture properties that were studied to express a real situation. The material deterioration and structural performance were investigated in a real situation of exposure for a year period. The relationship between year period, exposure time and load-bearing capacity of deteriorated Polymer concrete is studied and fracture mechanics of the specimens are discussed.

After the environmental exposure the samples were tested in laboratory conditions to determine their fracture properties. The tests setup apparatus is displayed in Fig. 1. A decomposition of CMOD is done due to nonlinear effect.

The critical opening displacement of the original precrack tip, $CTOD_C$, is calculated from the maximum