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Test Method

Long-term behaviour of GFRP pipes: Reducing the prediction test duration

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ABSTRACT

The certification of glass-fibre reinforced plastic (GFRP) piping systems is regulated by normative standards in which test series of 10,000 h are required to estimate the residual properties at the end of the expected life (normally, 50 years). In this paper, the possibility to reduce the test duration, whilst maintaining an equivalent prediction of long-term properties, is discussed. Experimental results from standard test procedures conducted on GFRP pipes of four different types and respective data analysis support this possibility. The estimation error when using only data from shorter tests is consistently less than 10% if compared to the standard methods.

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1. Introduction

Glass-fibre reinforced plastic (GFRP) pipes have been increasingly introduced into piping systems. They find attractive applications in chemical industry, ducts, offshore, water supply and sewage systems. However, the lack of fully understanding the failure mechanisms and long-term materials performance necessarily leads to over-design, in-service prototype evaluations and, furthermore, inhibits greater utilization. Moreover, the existence of different types of GFRP pipes construction, namely filament wound, centrifugal cast and hybrid ones, makes this task even more difficult. Thus, the mechanical behaviour of GFRP pipes under ring deflection and/or internal pressure is assessed in experimental procedures.

Two typical in-service load conditions are internal pressure and ring deflection. For these, empirical test methods have been developed and are described in the European Standards EN1447 [1] (based on ISO10471-2) and EN1227 [2] (based on ISO7509), respectively. The very long testing periods stated in these standards, in addition to the factors mentioned above, strongly discourage the industrial improvement and innovation of the products and also prevent the end users from performing confirmation tests. Shorter but reliable tests and/or better predictive models, capable of being standardized, are required by the GFRP piping industry.

The few research works conducted specifically on long-term properties of GFRP pipes between 1970 and 2000 gave relevant information but the conclusions could only be applied to classical filament wound GFRP pipes since all the experiments have been only performed on these [3–7]. More recently, several alternative short-term test methods for the various loading conditions and different GFRP pipes construction types have been studied in a co-normative European research project [8]. Ultimate elastic wall stress (UEWS) and strain at failure tests have been studied as alternative methods for estimation of long-term pressure and dynamic loading, UEWS and relaxation for the case of long-term ring deflection. In some of these procedures, a period of preconditioning under water before the tests was additionally considered. In fact, the slowness of the liquid diffusion at room temperature is a major aspect that is not taken into account in the

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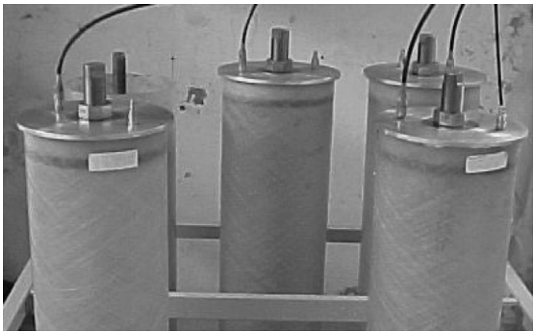

Fig. 1. Apparatus used in the EN1447 test procedures.

existing standard test methods. This phenomenon has been recently investigated [9,10]. Other limitations of the existing standard methods are the implicit assumption that the mechanisms responsible for the long-term failure are the same at different levels of load and the non-inclusion of material variability parameters that would damp the scatter typically observed in these tests. Although these problems are not explicitly considered in the standards, the experimental evidence of the whole failure phenomenon and the lack of adequate information was the main reason to extend the testing periods over 10,000 h. In a logarithmic time scale, this period is only 1.5 decades distant from 50 years and this makes the existing test and prediction methods seem reasonable. Any eventual phenomena occurring after 10,000 h contributing to unpredictable decrease in properties are, however, ignored in the actual standard analyses.

Polymeric materials exhibit a time dependent behaviour whose degree of linearity or nonlinearity is, often, not clearly determined and several modelling approaches have been presented through the years [11–15]. In most of these predictive models, the governing laws include parameters to be taken from experimental data. However, there are no established methods to predict long-term properties of GFRP pipes based on experimental data from short-term tests.

The European Standard EN705 [16], which is based on ISO/TC138/SC6/WG1/N197, ISO10928, describes procedures for the regression analysis of test data, normally with respect to time. These extrapolation techniques are used to extend the trend from data gathered over a period of approximately 10,000 h to a prediction of the property at 50 years. The method used in this analysis is transcribed in Appendix A. This work follows methods described in standards EN1447, EN1227 and EN705 to predict the long-term pressure and ring load/deflection properties from the tests data.

In the next sections, tests results from two groups of standard experimental test series according to EN1447 and EN1227 on GFRP pipes specimens of four different types are presented. Test procedures are briefly described, and the resulting data and their regression analyses are summarized. Conclusions are derived from the study.

2. Test procedures and results

Both test procedures specified in EN1447 and EN1227 relate to creep behaviour of GFRP pipes and state constant loading conditions to be imposed at different levels and during different periods of time to each specimen, from a few minutes up to 10,000 h. The determination of the long-term resistance to internal pressure (EN1447) is done by imposing hydrostatic internal pressure to the specimens using axial constraint-free end sealing devices. Failure must occur within a determined failure zone (in the middle of the specimen) for the test to be valid. Time to failure is registered. In Fig. 1, the testing apparatus used in the experimental tests for internal pressure property analysis is depicted.

For the analysis of the ring deflection creeping behaviour (EN1227) the pipe specimens are subjected to a constant ring load and the evolving ring deflection is measured during the test. The complete setup is immersed in water at room temperature. Time to failure is registered. In Fig. 2, one can see two different setups used in the experimental tests for ring deflection property analysis. The

Fig. 2. Apparatus for EN1227 test procedures.

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