Research on Mechanical Strength of Technological Fluid Storage Tank Made of Polyester Resin Reinforced with Fiberglass

ADRIANA TOKAR[1]*, ARINA NEGOITESCU[2], MARIUS ADAM[1], DANUT TOKAR[2]

[1]University Politehnica from Timisoara, Civil Engineering Faculty, Department of Civil Engineering and Installations, 2 Traian Lalescu Str., 300223, Timisoara, Romania

[2] University Politehnica from Timisoara, Faculty of Mechanical Engineering, Department of Mechanical Machinery, Equipment and Transport, 1 Mihai Viteazu Blv., 300222, Timisoara, Romania

One of composite materials used in plumbing is the resin reinforced fiberglass or carbon. The most common applications in the field, refers to fluid storage tanks, piping, tubing, and given that storage tanks used in water supply systems are used to the action of the natural environment, the work deals with issues related to the influence of the external environment on behaviour in time of the composite material of a water storage tank. There are comparatively analyzed two sets of samples with 25-30% of reinforcement, made of 601 general used polyester resin reinforced with fiberglass, CSM 225, CSM 450 and Tesutino 300. The first set of samples was taken from a tank made in 2002 and exposed to the action of the external environment for 10 years. The second sets of samples was taken from a manufactured material in 2014. The research consists in determination of tensile strength after exposure period. By evaluating the tensile strength of the two sets of samples, there is comparatively analyzed the influence of the external environment on the material resistance degradation to the cumulative action of the following factors: UV, snow, rain, dust, wind. The study provides data on setting life of use of the stationary storage tanks, in safe conditions.

Keywords: composite materials, tensile strength, stress, strain, storage tank

The literature provides numerous data on composite materials, although there are still many concerns regarding their behaviour in time [1-7]. As a result of the research conducted over a period of three years, in 2002, Strongwell Corporation, presented a report on the sustainability and cost – effectiveness for composites, thus encouraging the development and their utilization [7].

Due to the favorable relation between strength and weight, composite materials are used to manufacture products in construction fields, plant construction, automotive, aviation, rail, food, mechanical, etc. [6, 8-13]. In installations, composite materials are used to manufacture a variety of products: objects and accessories, cold water storage tanks and fluid technology, sedimentation and scrubbers, manholes for water wells, manholes, pipes and tubes for drilling, piping for ventilation and air conditioning pipes mainly used in the oil industry, wind turbine blades, etc. The containers reinforced with fiberglass resins are used for the storage of drinking water, and for the collection and storage of wasted water for its recycling or treatment [14, 15]. Because of static and dynamic pressures exerted by fluids at rest, respectively at moving, between mechanical characteristics and thickness of the walls of the storage tanks a report of proportionality should exist.

Resin reinforced with fiberglass products combines the plastic qualities with resistance of resins reinforced with fiberglass fabrics. Thus, the used fiberglass confers tank resistance and the polyester resins have various characteristics related to all utilization areas, such as: fire resistance, resistance to environmental agents (corrosion, temperature variations, solar radiation, etc.). The physical and mechanical properties of polyester resins are shown in table 1 [1].

These characteristics of materials change over time due to stress and environmental conditions.

The resistance and elasticity of the composite materials reinforced with glass fibers are influenced, on one hand by the fiber and matrix mechanical properties, and on the other hand, by volumes rate and the length and orientation of fibers in the frame of the matrix. Polymeric resins reinforced with fiberglass are more resistant to deformation, under the forces action if fibers are parallel with the polymers. Whether these fibers are perpendicular, the material resistance is lower. In the matrix of the polymeric resins, glassfibers might be directed in two-dimensional (BD) and three-dimensional (TD) fabrics and thus, when forces are perpendicular on an orientation, they become parallel with another orientation that removes the risk of reducing the materials strength.

Since 1998, experimental studies performed by different researchers demonstrated that the mechanical resistance of the composite material is reduced with approximately 50% after only five weeks under the ultraviolet ray effect by their exposing to sun light [16].

Considering the diversity of environments where the composite materials products are used, more authors assessed the reliability of the products for long periods of time. Thus, a group of Japanese researchers concluded that the alkaline aqueous solutions had accelerated the

Table 1
PHYSICAL AND MECHANICAL CHARACTERISTICS OF POLYESTER RESINS [1]

Polyester resin	Deformation temperature T_d [°C]	Material density, ρ [kg/m^3]	Elongation ε [%]	Tensile strength σ_t [MPa]	Compression strength σ_c [MPa]	Elastic modulus E [GPa]
	60-100	1140	2-5	50-85	90-200	2.8-3.6

* *email: adriana.tokar@upt.ro*

Fig. 1. Tank manufactured in 2002

a) applying the fiberglass b) roller c) impregnation with resin

Fig. 2. Stages of stratification

degradation of the composite materials in a short period of time, even at relative low temperatures (much lower than that of the hot water), while the basic environments had reduced the degradation degree under the same conditions [17].

The mechanical degradation of composite materials appears frequently in composite structures obtained through the one-directional stratification, especially at those formed of continuous fibers (usually glass or carbon) in an organic matrix [18].

One of the phenomenon that influences the dimensional stability of the composite materials in time is the ageing, as a result of the physical or chemical specific features changes. This ageing is assessed by fabric tensile tests.

Experimental part

Material, equipment and methods

The selection of the composite material used in the water storage tank construction (fig.1) is motivated by its corrosion resistance and low weight advantages compared with those of metallic materials. The material cut-out for the research purpose was made from the tank most exposed area.

The composite material was achieved through manual stratification from the polyester resin of common use 601, reinforced with 1 layer of fiber glass fabric CSM 225, with the specific mass of 225g/m^2, 1 layer of fiberglass fabric CSM 450, with the specific mass of 450g/m^2 and one layer of Tesutino 300, with the specific mass of 300g/m^2.

Polyester resin R601 for general use is a resin based on orthophthalic acid, dissolved in styrene and pre-accelerated thixotropic. The temperature of the deformation in load according to ISO 75-2/1993 is equal to78 °C, and the tensile strength, according to UNI-EN-61, resin reinforced with 30% glass fiber is of 55MPa. Therefore, resin R601 is recommended for products that must have a good resistance [19].

Fiberglass fabrics CSM 225, CSM 450 and Tesutino 300 are type E fibers, uncut and arranged in multiple layers, compatible with polyester resins [19], [20]. The stages of stratification are shown in figure 2.

Fiberglass fabrics are arranged in two or more directions (BD and TD) shown in figure 2. Air bubbles remove from the molding was done by rolling with a spiral roller (fig. 2b). Resin impregnation was performed manually using a brush (fig. 2c). After stratification, the material was placed in a polymerization oven, for 1 h at 60°C.

In order to analyze the aging effect of the composite storage tank (fig. 1), there were taken two sets of samples (I, respectively II). The samples were obtained by cutting with a CNC machine, numbered for identification from 1 to 6. The samples were processed and tested according to parameters specified by ISO 527 [21, 22].

The first analyzed set of samples is taken from a tank manufactured in 2002 that has been subject to natural aging by its exposure to environmental action (high and low temperatures, snow, rain, etc.) for 10 years. The second set of samples was taken from a material manufactured in 2014. Preparation of plate, from which was cut the second set of samples was carried out by reproducing, as much as possible, the container manufacturing method according to the one from which the first set of samples were taken. The plate has the same composition and has not been exposed to the conditions outlined above.

Description apparatus and method of the test

Tests for resistance to static breaking were performed in the Laboratory “Stefan Nadasan” - the Department of Strength of Materials, Faculty of Mechanical Engineering in Timisoara. The tests were made at room temperature (23 ± 2°C) according to Standard EN ISO 527 [20].The longitudinal tensile test of test specimens was performed on a tensile-compression machine Zwick Roell 005 of 5 kN at a constant speed (fig. 3), equipped with clamps for samples and extensometer for measuring lengthening at break.

Fig. 3. Zwick Roell Stand 005 for tensile test compression 5 kN

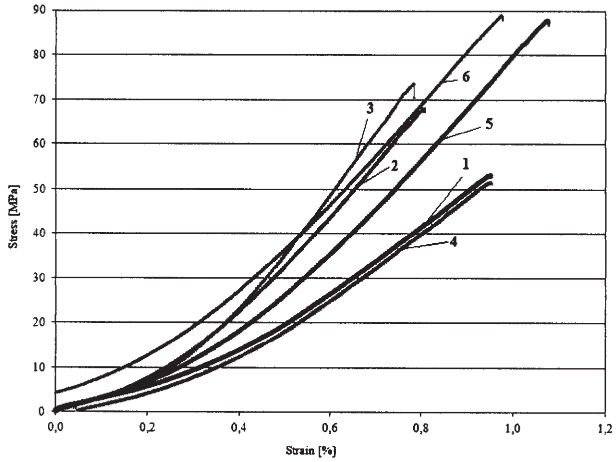
In order to compare the behaviour of new vs. aged material, test specimens having the same shape and size were tensile tested under the same conditions with a loading speed of 5mm/min.

Results and discussions

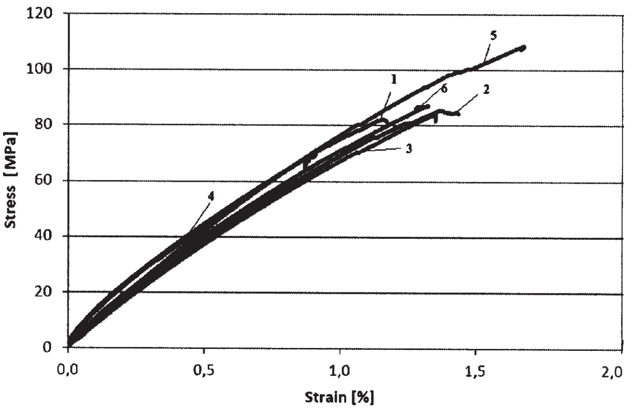
From the samples visual examination it is observed that the phenomenon of peeling and rolling is not appearing.

There were comparatively assessed the mechanical strength and stiffness characteristics of the material of the water storage tank under the action of a long natural environmental factors.

As a result of processing the obtained data there were presented tensile tests diagrams for set I respectively set II (fig. 4a and 4b).



a) Tensile test set I



b) Tensile test set II

Fig. 4 Diagrams of the tensile tests for the two sets of samples

It is noticed that for the set I, the tensile σ_{max} for four of the six samples the values were very similar, while two of them presented different values.

Medium value of tensile strength is as it follows:

-for set I: 74.79 MPa;

-for set II: 86.25 MPa.

Through continuous monitoring of load and displacement, there was drawn the dependence between effort at break and strain. Elongation at break remains proportional to the effort that occurs suddenly, so we can speak of an elastic-plastic behaviour of both sets of samples, the difference consisting in the amount of effort at which the break occurs.

By analyzing the two diagrams, it can be noticed a decrease of tensile strength with 14% for the tank in operation.

As samples 1 and 4 of the set I were taken from the tank area that was exposed to more intense effects of the environment (UV radiation and wind direction), it is noticed that duration of curves is different from the other four samples (fig. 4a). For higher values than 0.9% of elongation, the samples have broken. So, it can be observed that for set I, the samples 1, 2, 3, and 4 have broken in the range of (0.8-0.9) %, and in the case of the sample 5, the breaking occurred at a value of elongation of 1.15%. Regarding the second set of samples is observed that samples 1, 2, 3, 4, and 6 were broken in the range (1.2-1.4) % and sample 6 at 1.75%.

The tensile resistance for the set I is affected by tank exposure to the external environment actions, so this decreases by 14%, which contributes to product lifetime decrease.

Conclusions

Experimental tests indicate significant differences between mechanical properties of the two sets of samples, differences due to the material aging.

From the analysis of mechanical resistance of the material decayed to natural aging under the action of environmental factors determines the lifetime of stationary tanks, especially regarding the overground tanks.

Based on mechanical tests performed on specimens of material decayed to natural aging, connection between phenomena and mechanical behaviour can be interpreted by drawing tensile diagrams. The obtained results made possible the assessment of the aging influence on the analyzed composite material. It is estimated that water storage tanks material manufactured from polyester resin reinforced with fiberglass decayed to the natural environment action, has recorded an impairment of the mechanical characteristics. As a result, the lifetime of the overhead containers is influenced by external environmental factors.

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Manuscript received: 26.06.2014