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When polymers fail: A case report on a defective epoxy resin flooring

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Abstract

A case of failure of an epoxy flooring is presented. The cause of the damage has been found in a wrong formulation of one of the layers, that contained an anomalous quantity of solvents, which produced a plasticization of the resin with a consequent loss in mechanical properties. Differential scanning calorimetry, solid phase micro-extraction–gas chromatography–mass spectrometry and wide angle X-ray diffraction were employed. No significant difference in the degree of reticulation was detected between the defective samples and a reference specimen coming from the manufacturer. After evaporation of the solvents in excess, the resins completely recovered their mechanical properties. The responsibility of the failure was charged to the negligence of the manufacturer in the formulation of the resins.

Keywords: Forensic engineering; Failure analysis; Chemical analysis; Fitness for purpose; X-ray analysis

1. Introduction

Due to qualities such as versatility, low cost and light weight, polymers are increasingly used in many industries to substitute metals or ceramics. A wise choice of a suitable resin with the right mix of additives, filler and reinforcements allows the production of materials with remarkable properties, useful in a number of different fields of applications. If on one hand formulation is a strength of polymeric materials because it confers a significant versatility, on the other hand it leads to a wide range of components that, if not blended in an optimal way, easily bring about failures and defects. A report by Lemasçon and coworkers [1] showed that nearly in half the cases, manufacturing errors were the cause of failure, as opposed to 31% if metallic parts were considered. The reason for this large dependence of the performance of polymers on the manufacturing process is that a limited standardization of materials exists (and is indeed possible), because the recipe of resins and additives is ever changing as a consequence of the customer's needs, and the fact that, in the case of the most innovative materials, the long-term behavior of the structures has not yet been completely defined.

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Despite the widespread use, most of the published reports in the field of forensic engineering still deal with metallic materials [1–14]. This paper presents a case of product liability in which the plaintiff suffered a significant financial damage due to the inefficiency of his house's epoxy resin floor.

Epoxy resins are prepared from prepolymers containing on average two or more epoxy groups per molecule. When these components react with a suitable curing agent, a cross-linked thermoset polymeric material is obtained, with excellent strength, toughness, chemical resistance and adhesive properties [15]. The optimal mechanical performance is a function of the extent of the curing reaction [16] and of the correct formulation of the system. The identification of what determined the failure of an item is very important in deciding who is to blame for the damage and thus who should be asked for compensation.

2. Case history

A young professional bought a two-storey building, intending to completely renovate it and to set his office on the first floor and his apartment on the second floor. He chose epoxy resin for the flooring. He selected a manufacturer that offered him to produce a resin in any hue he liked. The man asked for a greenish-brown he saw in some architecture magazine. After allowing a few weeks for achieving the right formulation giving the desired color, the resin was delivered and some workers were commissioned with the laying down. Many problems related to the inhomogeneity of the resin arose, to such an extent that they appeared insurmountable even to the manufacturer. The owner agreed to change the color of the flooring, choosing a light gray already in the manufacturer's catalogue. The resin of the new color was laid down over the original greenish-brown, apparently gave better results and so the owner paid for the materials and the work. Soon after having occupied the house, the flooring displayed a rubbery and "orange peel" appearance that easily cracked and peeled (Figs. 1 and 2). This was particularly annoying on the first floor, where the professional met his clients. An office with a cracked floor was not adequate at all to the status of its owner. Moreover, a marked smell of solvents permeated the rooms of the whole building, a worrisome aspect for possible health effects. The owner complained both to the manufacturers and the layers, but received only evasive answers, so he decided to have his flooring examined to assess responsibilities and to identify who to sue.

3. Materials and methods

3.1. Samples

Specimens were taken of both the greenish-brown and the light gray resins. The sampling procedure was repeated in several locations of the house. Table 1 shows the analyzed samples. As a term of comparison, res-

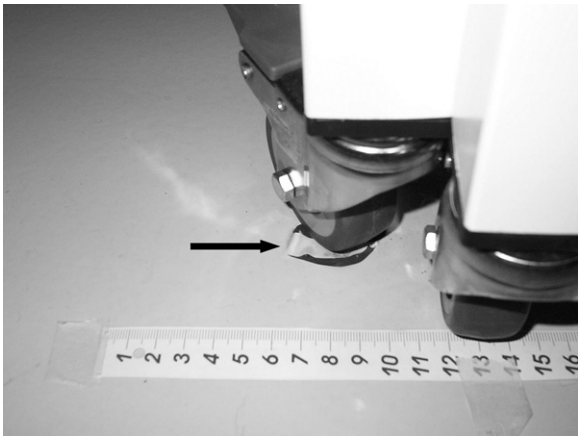

Fig. 1. Particular view of the sampling area A. The laceration under the chair's wheel is indicated by the arrow. Each division in the reference metric bar is equal to 1 mm.