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Properties of polymer concrete based on unsaturated polyester resin modified with diethanolamine

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INTRODUCTION

It is known that, by comparison with silicate concretes, polymer concretes have a number of advantages, primarily mechanical strength, chemical resistance, lower water absorption, and increased technological effectiveness [1, 2]. The wide use of polymer concretes is limited by their high cost, and therefore, in a number of cases, critical elements of polymer concrete are incorporated into normal ferroconcrete constructions, which requires increased adhesion between these materials. However, on account of the fact that they are different in nature – organically hydrophilic (polymer concrete) and minerally hydrophilic (silicate concrete) – the adhesion at butt joints of these materials is extremely weak [2]. This greatly limits the application of polymer concretes in sectional building constructions. One of the ways of solving this problem is to make the polymer binder of polymer concretes hydrophilic, which is achieved, for example, by forced "hydrophilisation" of unsaturated polyester resin (UPR) through its treatment with aqueous ammonia [3, 4] or by a cement test [5]. The obtained hydrophilised unsaturated polyester resin readily forms aqueous emulsions, and, in the case of curing with a peroxide initiator, the composites based on them (polymer concretes) give a fairly strong material [3]. In the present work an attempt has been made to increase the hydrophilic nature of UPR by its modification with diethanolamine (DEA) in order to increase the compatibility of the polymer concrete with silicate concrete (including wet concrete). In connection with this, investigations were carried out to establish the effect of DEA on the process of radical polymerisation of UPR.

EXPERIMENTAL

Feedstock and Materials

Unsaturated polyester resin (UPR) of the orthophthalic type (VIAPAL VUP 4627 E/61 Vianova resin; Austria) with a molecular weight of about 1200 and containing 35% styrene.

Initiator:	Methyl ethyl ketone peroxide (MEKP) (Peroximon K4; ATO Chemie, France), 50% solution in dibutyl phthalate.
Accelerator:	Cobalt octoate (accelerator NZ495; AKZO, The Netherlands) containing 1% Co^{++}.
Modifier:	Diethanolamine (DEA) (Lukoil, Bulgaria) was introduced into the binder in a quantity of 0.5–2 g-equ. (4.5–17 wt.%).
Filler:	whiting with a particle size of about 100 μm.

Methods of Investigation and Specimens

1. The kinetics of polymerisation of UPR was assessed from exothermic curing curves taken for 50 g resin containing 1% MEKP and 1% cobalt octoate.

2. The compression strength of polymer concrete, σ_{comp}, and its relative deformation at break, ε_{rel}, were determined on a TT-DM Instron-85 dynamometer in accordance with ASTM D695 on cube-shaped specimens.
3. Polymer concrete specimens containing 20 wt.% initial or DEA-modified binder and 80 wt.% filler were obtained by hand mixing of the binder, modifier, accelerator, and filler. A polymerisation initiator was added to the finished mixture and remixed, and then compaction of the polymer concrete was carried out in a special mould with an antiadhesive coating during vibration at a frequency of 10 Hz (10 min). After curing of the polymer concrete at room temperature (24 h), it was heat treated at 100°C for 8 h. Cube-shaped specimens measuring 25 × 25 × 25 mm were cut out from rectangular plate on a diamond disc.

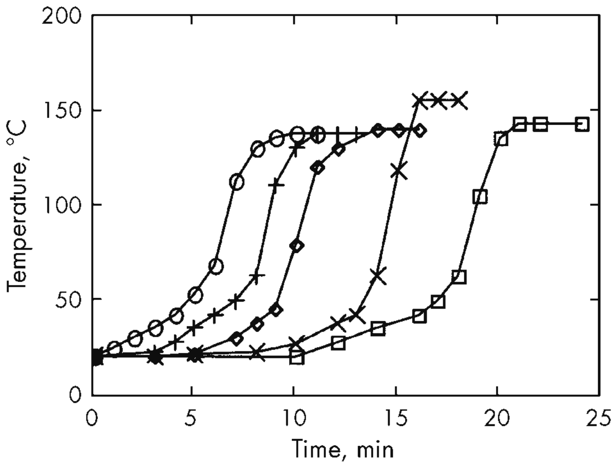


Figure 1. *Influence of dose of diethanolamine on adiabatic curing curves of UPR. Figures by curves [sic] indicate molar ratio of components (g-equ. DEA/g-equ. UPR): 1 – 0:1; 2 – 0.5:1; 3 – 1:1; 4 – 1.5:1; 5 – 2:1*

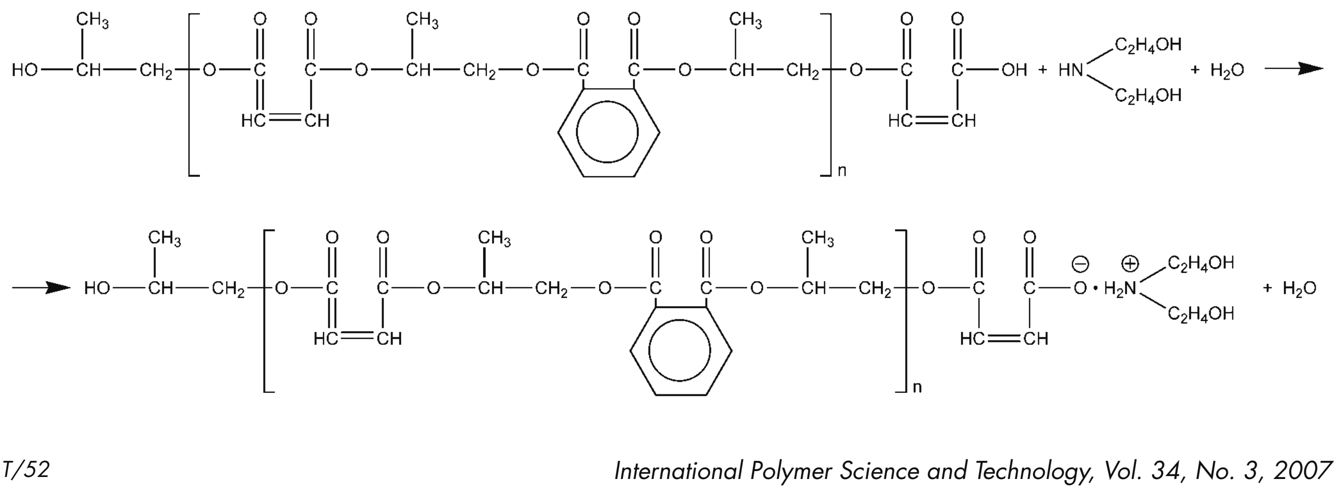
RESULTS AND DISCUSSION

The inclusion in the composition of the UPR of additional end hydroxyl and nitrogen-containing groups actually improves the hydrophilic nature of the resin. However, the use for this purpose of aqueous solutions of ammonia, albeit making it possible to produce quaternary ammonium salts, may nonetheless break down the main chains of the polyester, lowering its molecular weight and consequently also the uniformity of the network in the cured polymer [6]. In addition, the ammonia odour is capable of creating additional technological problems. Ethanolamines, which are anhydrous organic liquids, are to a large degree free of these shortcomings. If it is expected that, at a moderate DEA concentration, amidisation will occur in the mixture, the scheme of which is shown below. The product formed will undoubtedly possess increased polarity, but its reactivity may also change.

To check the change in reactivity of DEA-modified UPR, an evaluation was made of the influence of its concentration on the exothermic heating of the resin during adiabatic curing (**Figure 1**).

From **Figure 1** it can be seen that the addition of DEA accelerates considerably the process of adiabatic curing of UPR. Here there is a reduction not only in the time of achievement of the exothermic peak (the time of complete curing) but also in the gelation time, which can be assessed from the start of deviation of the course of the process from the isothermal. The maximum temperature of spontaneous heating, proportional to the heat effect of the curing reaction, as can be seen in **Figure 1**, changes little in practice.

To compare the mechanical properties of modified polymer concretes, their compression strength was selected. This index is used most frequently to assess the properties of building materials. **Figure 2** shows that, with increase in the modifier content, the strength of polymer concrete, especially in large doses, decreases. This appears to indicate a certain deterioration in the strength properties of the polyester binder during its modification. However, the obtained strength values of polymer concrete at moderate doses of modifier DEA are 2–3 times higher than the maximum strength of



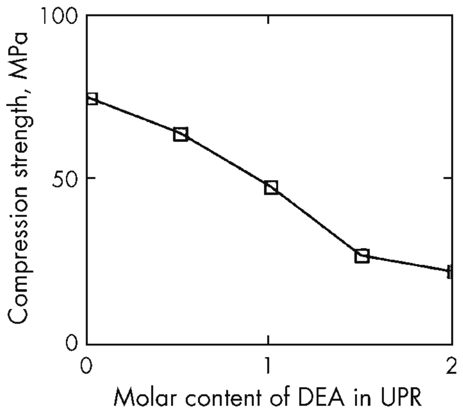


Figure 2. *Dependence of compression strength of polymer concretes on DEA content in binder (g-equ./g-equ. UPR)*

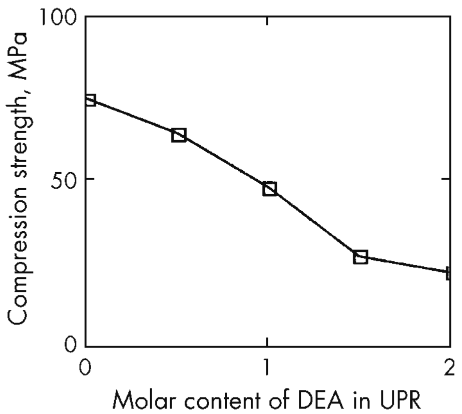


Figure 3. *Dependence of compressive strain of polymer concretes on DEA content in binder (g-equ./g-equ. UPR)*

normal silicate concretes. The observed reduction in strength of polymer concrete may be due to a certain degradation of the UPR under the action of DEA, which at high doses may break down the initial chains of the polyester polymer [6], but in our opinion this reduction is more likely to be caused by plasticisation effects.

A more interesting relationship is obtained in assessing the deformability of modified polymer concrete (**Figure 3**).

Tests showed that the nature of failure of polymer concrete under compression changes from brittle to plastic. If account is taken in this case of the good compatibility of the modified polymer concrete with dry and wet silicate concrete [5], then the developed direction of research must be recognised as being extremely promising.

CONCLUSIONS

The conducted investigations showed that hydrophilised polyester polymer concretes can also be obtained in anhydrous media (ignoring, of course, the water formed when UPR interacts with DEA). Even these amounts of water are sufficient to form DEA-based quaternary ammonia bases which ensure good adhesion between modified (hydrophilised) polymer concrete and wet silicate concrete. A feature of modified binders is accelerated curing and reduction in the strength properties at high modifier doses. However, polymer concrete based on modified polyester binder possesses a plastic nature of failure, which ensures a deformability far greater than that of silicate concretes.

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(*No date given*)