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Mechanical properties of composite material based on scrap tyres and polyurethane binder with different reactivity

To cite this article: R Kurme and L Malers 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **500** 012002

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Mechanical properties of composite material based on scrap tyres and polyurethane binder with different reactivity

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Abstract. Some mechanical properties of composite material based on scrap tyres and polyurethane type polymer binder were investigated to underline the significance of binder reactivity on selected mechanical properties of the composite material. Compressive stress and compressive modulus of elasticity E at 10 % deformation and Shore C hardness were investigated. Connection was observed between the above-mentioned selected mechanical properties of composite material and reactivity of the polymer binder. It was confirmed previously that the crosslinking degree of polyurethane type binder separately and therefore at the same time mechanical properties of binder were strongly connected with water as a significant factor during the hardening of the polymer. The special objective of this work is to investigate connection between selected mechanical properties of the composite material, content and reactivity of the polymer binder under invariable composite material moulding and hardening conditions.

1. Introduction

Utilization and recycling of used vehicle tyres still must be considered as an important way to unload the environment from non-degradable waste [1]. Production of composite materials [2] is one of the most perspective ways for the reuse of scrap tires, and the produced composite material can be used in a wide range of applications, for example, in the production industry as an absorbent of mechanical vibrations, in the road industry as protective barriers, in the building industry as sound insulating and damping material [3].

In our previous investigations, [4,5] optimization of composition and technology of the composite material production from mechanically grinded scrap tyres and polyurethane type binder were realized. It was also elucidated that mechanical properties of the composite material are strongly dependent not only on the composition of the material, but also on technological parameters (moulding pressure, temperature T). Correlation between mechanical properties of polyurethane type binder and selected crosslinking conditions of the polymer was demonstrated in [5].

The special objective of this work is to investigate the connection between selected mechanical properties of the composite material, reactivity and content of the polymer binder.

2. Experimental part.



Grinded at room temperature rubber crumbs (particle sizes ranging from 0.2 to 5.0 mm) from scrap tires and polyurethane type polymer binder with different reactivity (C_{-NCO} 2.4, 5.5 and 7.4%) were used. Composite material samples were prepared by mechanical mixing of required components ($C_{pol.}$ = 8,13,18,23 mass %), moulding of samples in uniform moulds and hardening of samples under defined conditions ($T = 18-23^{\circ}C$; $RH = 28-34\%$; $P = 0.04 \text{ kg/cm}^2$). Shore C hardness (ISO 7619-1; ISO 868), compressive stress at 10% deformation σ_{10} in different loading modes (static and cyclic) and compression modulus of elasticity E (EN 826) in the connection with composition of the composite material and reactivity of polymer were investigated.

3. Results and Discussion

Influence of polymer binder content and reactivity on the investigated parameters were observed. It was established that the existing polyurethane-type binder becomes hard in moisture cure reactions between isocyanate functional groups in polymer and air humidity [5].

It is shown (Table 1) that values of Shore C hardness increase with the increase of polymer binder content in the composite material independently from the isocyanate functional group content in polyurethane type binder.

It was previously demonstrated that a higher content of isocyanate groups in the polyurethane binder leads to a higher degree of cross-linking of polymer [6] and therefore may provoke an increase of the tested in compressive mode mechanical properties as well as higher Shore C hardness of composite material samples. Results presented in present work (Table 1) confirm this presumption.

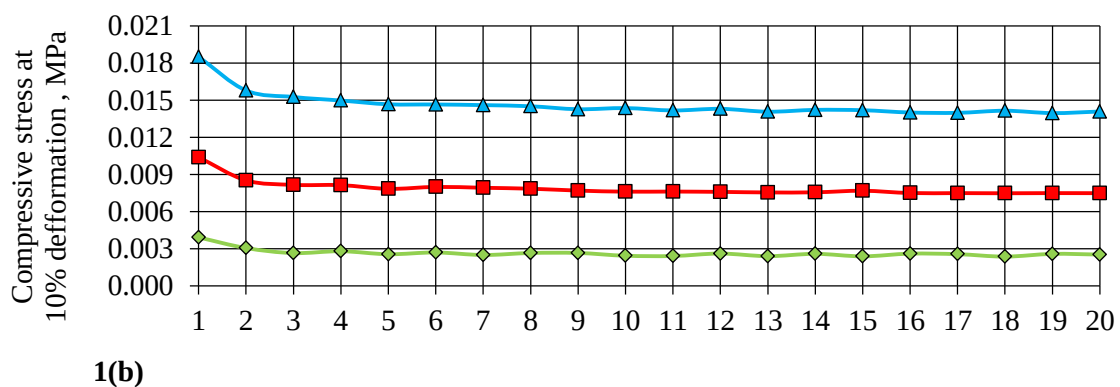
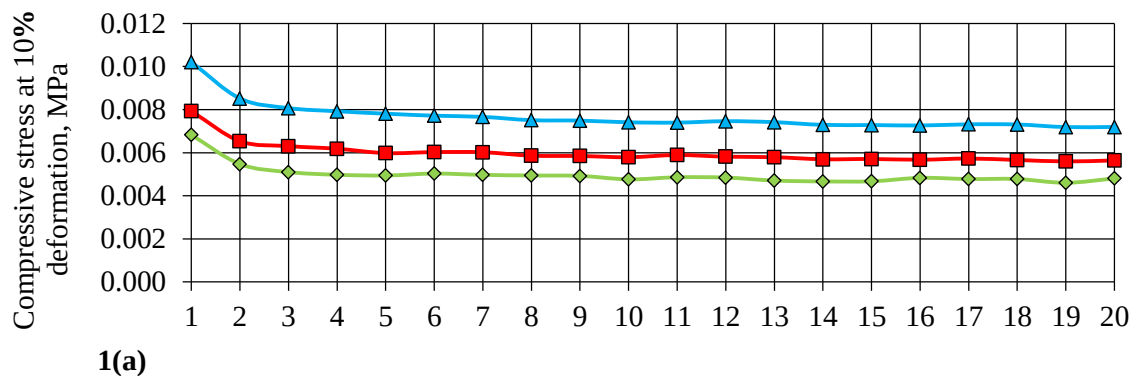
Connection between reactivity of the polymer binder and mechanical properties of the composite material in compressive mode at 10% deformation is demonstrated also in cyclic mode of deformation for the tested composite materials (figures 1a- 1d).

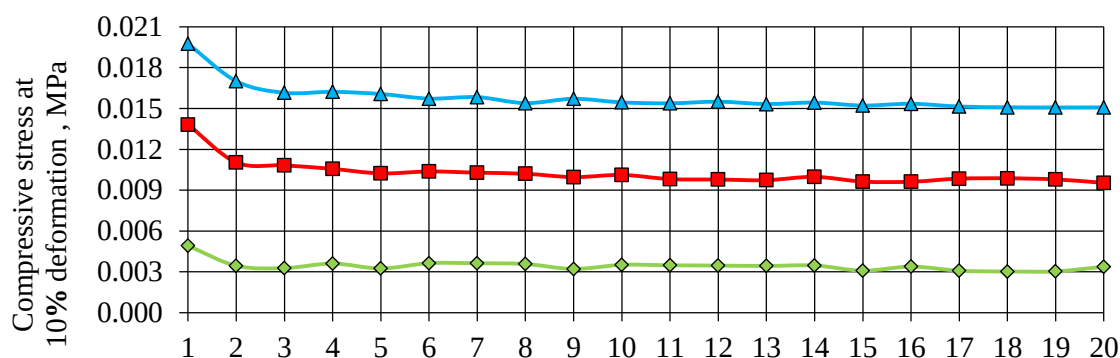
Table 1. Compressive stress ($\sigma_{10\%}$) and compressive modulus of elasticity (E) at 10 % deformation, Shore C hardness of the composite material in dependence of activity and content of the polymer binder.

Nr.	Activity of polymer binder (content of NCO groups, %)	Polymer binder content, Wt., %	Shore C Hardness scale	$\sigma_{10\%}$ kPa	E , kPa
1	2,4	8	40	22	280
		13	43	31	490
		18	47	41	780
		23	51	68	1030
2	5,5	8	41	27	305
		13	44	41	500
		18	48	50	795
		23	53	56	1095
3	7,4	8	45	29	365
		13	52	51	600
		18	53	62	725
		23	61	70	1280

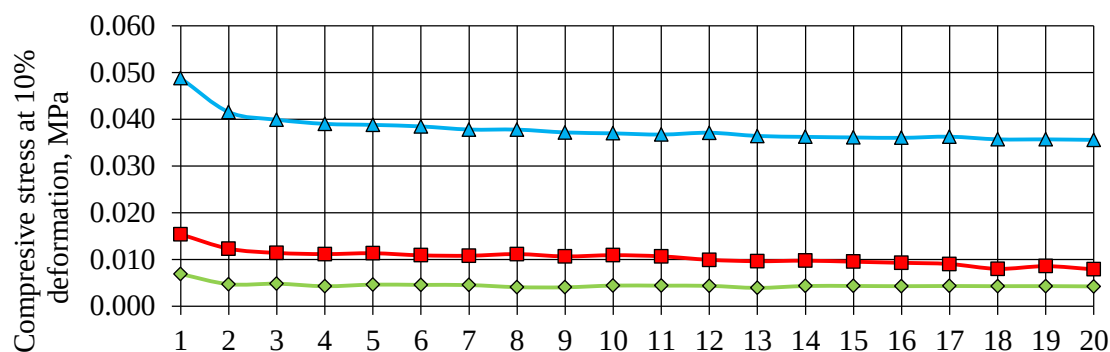
In the same time connection between hardness and the compressive stress at 10% deformation, as well the compressive modulus of elasticity of the composite material were observed (see Table 1).

The results presented in Figures 1a; 1b; 1c and 1d demonstrated changes in compressive stress at 10% deformation with the number of deformation cycles (till 20 cycles) of composite material with different activity of polymer binder (CNO group content - 2,42; 5,3 and 7,4 %) and binder content (8,13,13 and 23 mas.%). It was demonstrated that a more essential decrease of compressive stress at 10% deformation is ascertained during the first cycles of deformation independently from activity and the content of polymer binder. It can be explained with degradation of weaker intermolecular bonds between the rubber particles and polymer binder in the material during the first cycles of deformation. After the first three deformation cycles changes in compressive stress are less intrinsic. Material remains practically with similar and invariable compressive stress values. Relatively higher initial and also compressive stress values during all cycles of deformation were observed for samples with higher content and higher activity of polymer binder. It can be explained with the direct influence of polymer binder activity and content on crosslinking degree of polyurethane binder and therefore higher compressive stress of composite material.





1(c)



1(d)

Figures 1(a) to 1(d) Dependence of the compressive stress at 10% deformation with the deformation cycles (till 20 cycles) for composite materials with different binder content (mas.%) (**1(a)** -8; **1(b)** - 13;**1(c)**-18; **1(d)** – 23) and polymer activity (C_{-NCO} : $\blacklozenge$ - 2,24%, $\blacksquare$ – 5,5%, $\blacktriangle$ - 7,4%)

Purposeful change of reactivity of the polymer binder during the formation of composite material samples, as well as controlled composition of the composite material provoke changes of the selected mechanical properties.

4. Conclusions

The obtained results show that variation of composition of the composite material and reactivity of the polymer binder in defined intervals have influence on the selected mechanical properties of the material.

Increase of the polymer activity through variation of the CNO groups content from 2,4 till 7,4 % and polymer binder content from 8 till 23 mas.% leads to increase of selected mechanical properties of the composite material.

Thus purposeful selection and mutual combination of composition of the material and activity of polymer binder offers possibility to ensure predictable mechanical properties of composite material- Shore C hardness, compressive stress and compressive modulus of elasticity at 10% deformation.

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