Scientific Journal of Riga Technical University
Material Science and Applied Chemistry

2011

Volume 22

The Influence of Composition and Technology on the Properties of Composite Material Based on Scrap Tires and Polymer Binder

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***Abstract – The p*resented work is dedicated to the examination of effect of hardening temperature and composition on the mechanical properties of composite material made from mechanically grinded scrap tires and polyurethane type binder with different reactivity. The influence of polyurethane type binder's reactivity on such parameters as Shore C hardness of composite material, compressive stress at 10% deformation in statistic and cyclic mode of loading and compression modulus of elasticity were determined. Special interest was dedicated to the examination of freeze/thaw resistance in corelation with composition of particular samples in order to consider potential use of created composite material. Close correlation between composition, reactivity of the polymer binder and selected properties of the composite material was demonstrated.**

Key words: **composite material, polyurethane type binder, scrap tires, mechanical properties, Shore C hardness.**

I. INTRODUCTION

Utilization of scrap tires remarkably important from the aspect of unloading the environment from non-degradable waste. Various ways of utilization and recycling methods exist due to the complicated structure of vehicle tires which are made of various materials such as synthetic and natural rubber, textile and metal wires /1/. One of the most perspective directions of scrap tire reuse is the production of composite materials (playgrounds, tiles, insulation materials, road barriers etc. /2, 3/) made of polymer binder like polyurethane.

The presented work must be considered as a rational continuation of previous investigations /4/. It is devoted to the clarification of possible correlation between the composition of the composite material based on scrap tires and polymer binder, hardening conditions and definite mechanical properties as well as to acquiring information about the structure of composite material.

During this research composite material based on crumb rubber and polyurethane type binder with different reactivity was created. Various contents of polymer binder and crumb rubber at different formation conditions were used. The correlation between mechanical properties and Shore C hardness was examined as well as special interest was devoted to determination of freeze/thaw resistance of composite material.

II. MATERIALS AND METHODS

Mechanically grinded at room temperature scrap tires (particle size from 0,5 till 5,0 mm) and polyurethane type binder with different reactivity (various isocyanate functional groups content in polyurethane type binder) were used to produce composite material samples for further investigations in presented work. This process involved mechanical mixing of the required components, molding of samples in uniform molds and hardening of samples under definite and variable conditions.

The Shore C hardness (ISO 7619, ISO 868), compressive stress at 10% deformation σ_{10} at different loading modes (static and cyclic) and compression modulus of elasticity E (EN 826) in the correlation with composition (wt.%) of composite material either with following hardening conditions of samples at temperature T(^{0}C) and relative humidity RH (%) were investigated. Tests were performed in order to determine the influence of composite material hardening conditions on ultimate tensile strength (σ_M) of material, moreover freeze /thaw resistance (13 cycles) was investigated for selected samples.

III. RESULTS AND DISCUSSION

Direct influence of polymer binder content, T and RH on investigated parameters was observed. It was clarified that temperature and relative humidity is interdependent; respectively by the increase of temperature relative humidity decreases. It was clarified that the existing polyurethane-type binder becomes hard in moisture cure reactions between isocyanate functional groups in polymer and air humidity /5/. This process has an important role in the hardening process of composite material and it will be considered in further investigations. In the presented work various polymer binder (with reactivity 7,7 %) contents and hardening temperatures were chosen as it can be seen in Figure 1. The obtained results show significant influence of hardening temperature on the tensile properties of composite material. The increase of ultimate tensile strength is potentially possible due to the increase of polymer binder content in the composite material as its role becomes significant in the tensile mode of loading.

In order to consider the potential use of the created composite material special interest was paid to the examination of freeze/thaw resistance in correlation with composition of particular samples and hardening conditions. In order to create uniform samples various binder contents

were used. Part of the samples from one set was subjected to tensile mode of loading before freeze/thaw resistance test, and other set of samples was subjected to 13 cycles of freezing (2h) at temperature T= -21,5 °C and RH= 48,0 % and thawing (1h) at room temperature. Figure 2. presents the correlation between hardening temperature and ultimate tensile strength of samples which increases with the increase of hardening temperature. Nevertheless the ultimate tensile strength does not show signifficant decrease after the freeze/thaw resistance test. To obtain more precise information about the changes at the microscopic level in the composite material after performing the freeze/thaw resistance test, scaninng electron microscopy (SEM) was used.

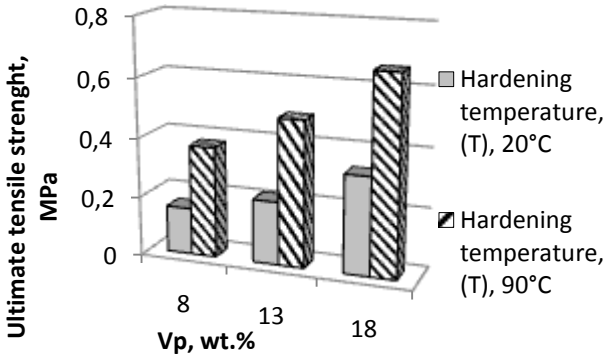

Fig. 1. Correlation between ultimate tensile strength σ_M, MPa, hardening temperature T, °C of composite material and binder (reactivity 7,7 %) content Vp, wt.%; relative humidity RH = 10-30 %.

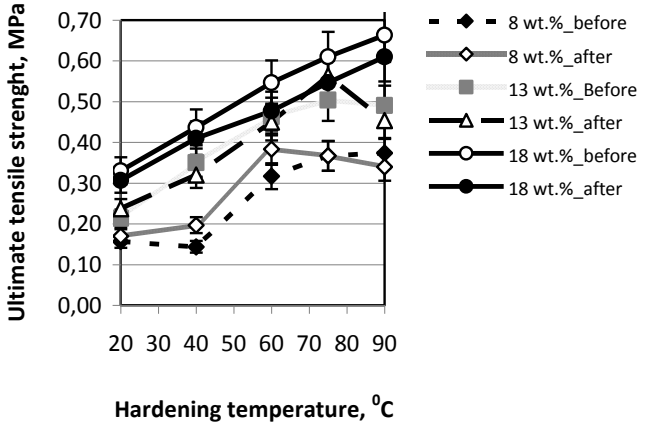

Fig. 2. Correlation between ultimate tensile strength σ_M, MPa, hardening temperature T, °C of composite material and binder (reactivity 7,7 %) content Vp, wt.% before and after freeze/thaw resistance test.

Figure 3 illustrates that there are no significant changes at the interface between both components (polymer binder and rubber particle). Meanwhile this may lead to unproved statement that there is good adhesion between rubber particles and polymer binder, yet this is not proved by experiments in this paper.

Previous investigations /4/ showed that at the compressive mode of testing results are highly dependent on the polymer content in composite material; furthermore present investigations show the influence of content of the existing isocyanate functional groups in polyurethane type binder on mechanical properties of composite material. Figure 4 and Figure 5 illustrate that compressive stress at 10% deformation and compressive elastic modulus increases steadily by increasing of content of isocyanate functional groups in polymer binder.

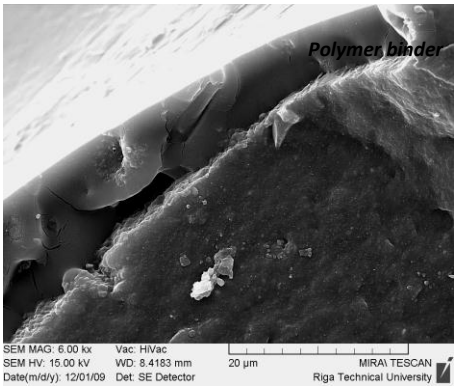

Fig. 3. Scanning Electron microscopy (SEM) illustration (Mag. 6000 x) of rubber particle and polymer binder interface after freeze/thaw resistance test of composite material with binder (reactivity 7,7 wt. %) content Vp, 13 wt.% at relative humidity RH=13,9%, hardening temperature T= 60°C, hardening time 1,58 h.

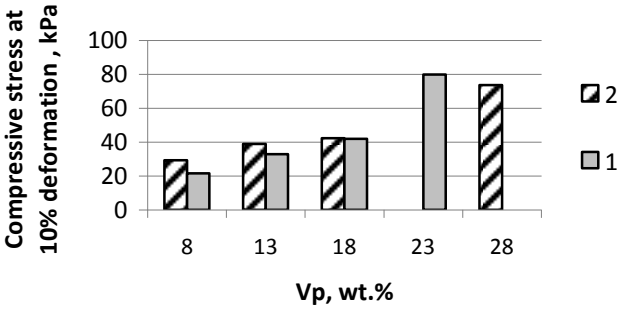

Fig. 4. Effect of material composition (binder content from 8 till 28 wt. %) on compressive stress at 10% deformation: isocyanate functional group content in polyurethane type binder 1- 2,4 %, 2 – 7,7 %.

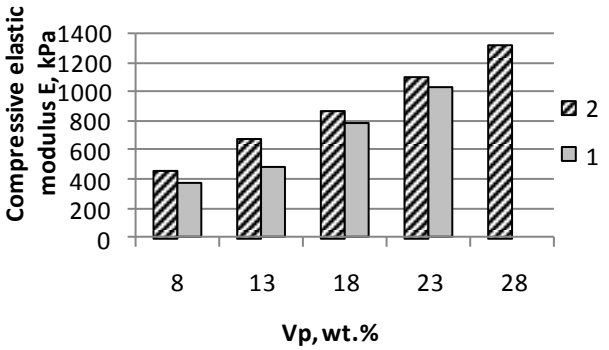

Fig. 5 Effect of material composition (binder content from 8 till 28 wt. %) on compressive modulus of elasticity E (10% deformation): isocyanate functional group content in polyurethane type binder 1- 2,4 %, 2 – 7,7 %.

It is shown that values of Shore C hardness increase with the increase of polymer binder content in the composite

material for both isocyanate functional group contents in polyurethane type binder – 2,4 % or 7,7 %. (Figure 6).

Figures 4 and 5 show that higher content of isocyanate groups in the polyurethane provides higher degree of cross linking of polymer and therefore provokes increase of tested mechanical properties as well as higher Shore C hardness of total composite material sample.

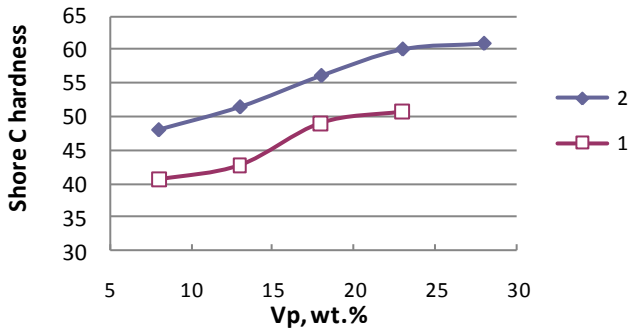

Fig. 6. Correlation between isocyanate functional group content in polyurethane type binder and Shore C hardness of composite material: 1 – 2,4 %, 2 – 7,7 %.

The correlation between hardness and the compressive stress at 10% deformation as well as the compressive modulus of the composite material were determined and the results are illustrated in Figure 7. Thereby determination of hardness may be considered as an express-method for the estimation of the selected mechanical properties (E and σ_{10}) of the composite material without direct experimental testing of given parameters.

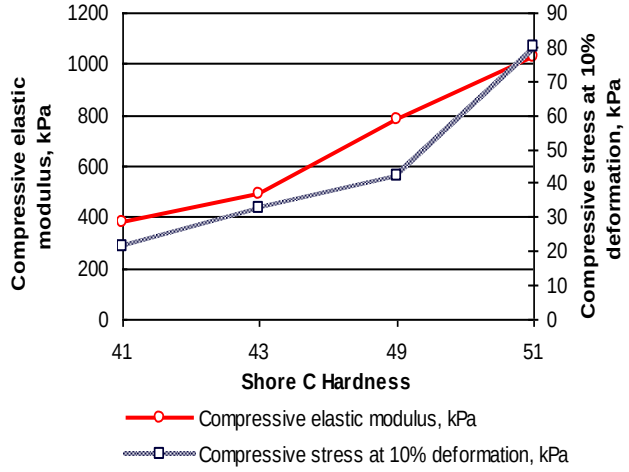

Fig. 7. Correlation between Shore C hardness and compressive stress at 10% deformation and compressive elastic modulus; isocyanate functional group content in polyurethane type binder 2,4 %.

The determination of hardness may be considered as an express-method not only for the estimation of the selected mechanical properties, but also as a tool for measuring hardening kinetics of composite material. The hardening of composite material was carried out at various temperatures and compositions regarding to the used binder content, however main tendency was similar. It can be seen (Figure 8) that hardening temperature does not have great influence on hardness of composite material, probably due to its specific structure. Total hardness of material is highly dependent from the hardness of separate components (tire rubber and polymer binder).

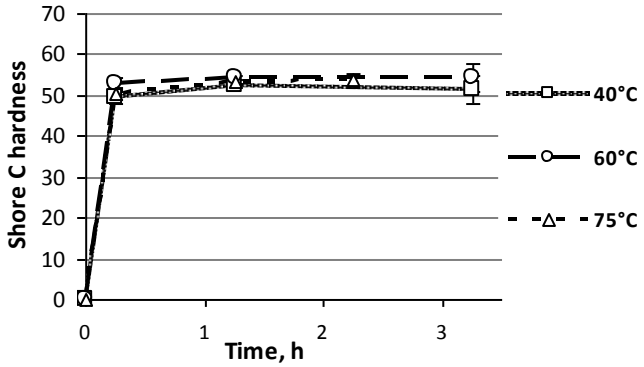

Fig. 8. Shore C hardness as a method for estimation of hardening kinetics of composite material (binder content 18 wt. %): isocyanate functional group content in binder 7,7 %.

In Figure 9 strong influence of composite material composition and type of binder (different reactivity of polymer binder) on compressive stress at 10% deformation in cyclic mode is demonstrated in a selected rage of polymer binder content. Previous investigations in comparison with present examinations showed that compressive stress at 10% deformation does not keep constant values /4/. The observed decrease of compressive stress at 10% deformation is greater in the case of polymer binder with a higher content of reactive groups which lead to higher hardness of composite material as it was shown previously in this paper. Feasibly the conclusion can be made that the strength of composite material under mechanical load – mostly in the frame of first 5 cycles highly depends on the used polymer binder, its properties and the adhesion between two interfaces of used components.

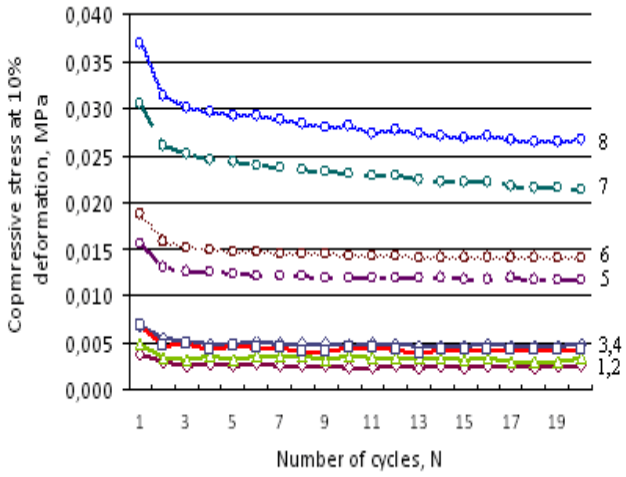

Fig. 9. Effect of loading cycles on compressive stress σ_{10} of composite material. Isocyanate functional group content in polyurethane type binder 2,4 % (1-4), 7,7% (5-8); content of polymer binder 8 wt.% (4,5), 13 wt.% (1,6), 18 wt.% (2,7), 23 wt.% (3) un 28 wt.% (8).

IV. CONCLUSIONS

The obtained results show that variation of compositions of the composite material and reactivity of the polymer binder have strong and predictable influence on the selected mechanical properties of the material.

Selected hardening temperatures have remarkable influence on ultimate tensile strength of the composite material samples. It was shown that composite material demonstrates good freeze /thaw resistance and can be recommended for practical outdoor application.

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Laimonis Mālers, Renāte Plēsuma, Liena Ločmele. Sastāva un tehnoloģijas ietekme uz nolietotu riepu smalkni un polimēra saistvielu saturoša kompozītmateriāla īpašībām

Nolietotu riepu racionāla izmantošana joprojām ir būtiska, realizējot un pilnveidojot materiālu reciklēšanas tehnoloģiju un politiku. Starp dažādiem šī materiāla utilizācijas veidiem kā perspektīvs virziens ir jāmin sasmalcinātu riepu izmantošana kompozītmateriālu izveidē. Šī virziena perspektivitāte iegūst sevišķu nozīmi, ņemot vērā to, ka nolietotu riepu dabiska sadalīšanās notiek ļoti ilgi un nepamatoti tiek noslogoti atkritumu deponēšanas poligoni. Šāda kompozītmateriāla praktiskas pielietošanas iespējas var saskatīt gan būvniecībā, gan citās tautsaimniecības nozarēs.

Šī darba mērķis ir noskaidrot to, kā kompozītmateriāla sastāvs, polimēra saistvielas ķīmiskā aktivitāte un tā iegūšanas tehnoloģija izvēlētajā temperatūras diapazonā pie atbilstoša vides relatīvā mitruma iespaido materiāla mehāniskās īpašības. Noskaidrots, ka polimēra saistvielas ķīmiskā reakcijspēja un tās daudzums būtiski ietekmē kompozītmateriāla mehāniskās īpašības. Konstatēts, ka parauga iegūšanai izvēlētā tehnoloģiskā parametra – temperatūras nozīmīgums intervālā no 20 līdz 90 ^{0}C pēc tā ietekmes uz kompozītmateriāla paraugu stiepes stiprību ir ievērojams. Tika novērtēta materiāla Šora C cietība, spiedes spriegums un spiedes elastības modulis (tai skaitā cikliskas spiedes slogošanas režīmā) un stiepes stiprība saistībā ar kompozītmateriāla sastāvu un saistvielas aktivitāti. Noskaidrots, ka gan saistvielas daudzums materiālā, gan tās ķīmiskā aktivitāte lielā mērā iespaido izvēlētos materiāla kontroles parametrus. Parādīts, ka kompozītmateriāls ir salturīgs.Tādējādi noskaidrots, ka pastāv savstarpēja un prognozējama sakarība starp kompozītmateriāla sastāvu, polimēra saistvielas reakcijas spēju un materiāla īpašībām.

Лаймонис Малерс, Ренате Плесума, Лиена Лочмеле. Влияние состава и технологии получения композиционного материала на основе измельченных шин и полимерного связующего на его свойства

Рациональное использование изношенных шин является существенным фактором при реализации и совершенствовании технологии и политики рециклизации материалов.Среди прочих способов утилизации шин перспективным направлением следует признать использование измельченных шин для создания композиционного материала. Перспективность этого направления приобретает особую важность с учетои того, что естественное разложение шин происходит в течение очень длительного времени и шины необоснованно загружают полигоны размещения отходов. Практическое применение такого материала можно ожидать как в строительстве, так в других отраслях народного хозяйства. Целью настоящей работы является выяснение влияния состава композиционного материала, реакционной активности связующего и температуры получения образцов при соответствующей влажности среды на механические свойства композиционного материала. Установлено, что реакционная активность и количество полимерного связующего существенно влияет на механические свойства композиционного материала. Констатировано также, что значимость технологического параметра – температуры в интервале 20 – 90 ^{0}C по отношению к прочности при растяжении материала существенна.

Оценена твердость по Шору С, напряжение и модуль упругости при сжатии, а также влияние циклической нагрузки композиционного материала во взаимосвязи с составом композиционного материала и реакционной активностью связующего. Установлено, что количество и природа полимерного связующего существенно влияют на контрольные параметры композиционного материала. Выяснено, что композиционный материал обладает хорошей морозоустойчивостью.

Таким образом установлено, что существует взаимная и прогнозируемая взаимосвязь между составом композиционного материала, реакционной способностью полимерного связующего и свойствами материала.