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Potential of Recycled Polystyrene and Xylene Liquid for A Wood Glue: A Comparative Study

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Abstract

In formulating a wood glue, stronger binding of the wooden structure is challenged since the active ingredient in a strong glue can be harmful to humans and is not environmentally friendly. To reduce the toxicity level from xylene, this paper studies the use of polystyrene in xylene liquid for wood surface glue. The purpose of this work is to investigate the effectiveness of our proposed glue with the conventional glues on the market. The mixture for the proposed glue includes 200 g solid polystyrene waste dissolved in 500 ml of xylene liquid. The strength of the glue on the wood surface was evaluated by taking 36 plywood samples with three different groups of storage times. The time taken before adhesion failures occur recorded for each increment of loads at each sample test. The outcome indicated that the proposed glue could withstand the adhesion failure at 400 g load at maximum and, for this case, applicable for 1 hour storage time. The reliability of the proposed glue was determined based on comparative results from 3 different conventional wood types of glue on the market with the same setup.

Keywords: - Polystyrene, xylene liquid, wood glue

1. Introduction

Solid polystyrene is widely applied in certain packaging and insulating products since this material is light and cheap. It is important to find an alternative solution to re-apply this non-degradable nature material to another application since recycling will lead to environmental pollution (Zhou et al., 2022). In addition, more cities and local authorities, especially in Malaysia, have banned polystyrene usage in food packaging and even fined the traders who violate this enforcement (Abdullah & Lamat, 2015).

The studies of glue had been extended in many applications, such as for medical purpose using fibrin glue for wound healing (Ortiz et al., 2021). Besides, this fibrin glue on the medical application is capped to surgery like liver and a post-laser in situ keratomileusis (LASIK) epithelial ingrowth for eye whereby during the hemostasis procedure, this glue will stop bleeding from the damaged blood vessel. Hence, the operating time and postoperative discomfort compared with sutures are minimized (Uy et al., 2005).

Based on the study conducted by Grøstad and Pedersen (2010), the use Emulsion Polymer Isocyanate (EPI) as glue able to compete with established poly (vinyl acetate) (PVAc), urea-formaldehyde (UF), melamine-urea-formaldehyde (MUF), phenol-formaldehyde (PF) and phenol-resorcinol-formaldehyde (PRF) glues (Hu et al., 2006). This is due to the comparative outcome showing an advantage of EPI in short pressing times at room temperature and high moisture resistance for wood surface gives a strong bond between two surfaces. But for a large surface area is not recommended as the glue dries for a short duration. Besides, this glue is not recommended for cold areas by means water-resistant glueline took 25 hours under 5^0C.

One of the novelties can be seen based on the experimental results by Voulgardis, Passialis, and Philippou (2003) discovered that polystyrene is good in water repellency and performs well for glueing on wood surface. The polystyrene itself is not strong enough glue, hence it needs to be mixed with other compounds. Studies have shown that xylene is one of the best options to be mixed since it is widely recognized as glue (Dotson 2018). In accordance with the advantage in water resistance, xylene is not recommended to be used without mixing with another compound since it is flammable at room temperature and cannot be exposed since the chemical contained inside it is widely recognized to increase the risk of cancers such as leukemia and hematopoietic cancers (Schnatter et al., 2012 and Lim et al., 2014).

This paper is intended to develop polystyrene and xylene mixing glue for a wood surface purpose. The solid polystyrene waste is taken as a sample for the proposed glue to reduce the recycling process that can cause harm to the environment. Section 2 discusses the methodology for this glue development, including mixing polystyrene and xylene and sample applied and experimental setup. Section 3 discloses the results for the proposed glue implementation and, for this case, applied on a wood surface for a varied weight concerning time.

2. Methodology

2.1 Mixture

The mixture quantity for a proposed polystyrene and xylene liquid glue is illustrated in Table 1 by mixing 200 g of solid polystyrene waste gradually into 500 ml of xylene liquid. From a study conducted by Kwon et al. (2007), xylene liquid is widely applied in household products, especially wallpaper. The author observed that almost 18% of xylene emission occurs at 59 household products, including cleaning products, deodorizers, glues, paint, polishes, and nail color removers. In a positive point of view, xylene is one of the options for making glue, but a large quantity of this compound can cause harm to the environment (Wang, Wang & Tang, 2002).

Table 1. Mixture quantity for a proposed glue

Item	Quantity
Solid polystyrene waste	200 g
Xylene Liquid	500 ml

Considering the disadvantages of xylene, especially for the environment, a solid polystyrene waste was dissolved in xylene liquid to reduce the negative effect. In addition, the higher quantity of polystyrene added increases the notation numbers, hence being suitable for making glue (see Fig. 1). Using a solid polystyrene waste is one of the efforts to recycle this material rather than burn it, which can introduce carbon dioxide (Zhang et al., 1995).

Fig. 1. Proposed polystyrene and xylene liquid glue

2.2 Wood Sampling

A sample of 36 saw cutting plywoods was taken to determine the proposed glue's reliability. These plywoods were cut into 150 mm length × 20 mm width × 5 mm height as graphically shown in Fig. 2. The plywood had been exposed to an indoor temperature within the range of 23°C to 26°C under Malaysia climate. Water exposure is not considered in this experiment. A radius of 1.25 mm hole is drilled in a non-glued sample end 10 mm from the plywood end grain.

The glue will be applied within an area of 20 mm × 20 mm in an amount of 150 g/m^2, as marked in Fig. 2. The glued and non-glued zones were separated with a 0.08-mm-thin Teflon tape wound around the border. A spatula spreads the glue adhesion within the glue area on plywood.

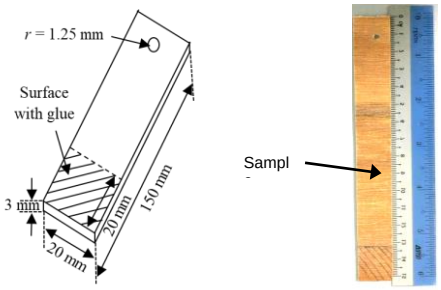


Fig. 2. Sketch showing sampling from plywood

2.3 Glue Adhesion Tests

Fig. 3 illustrates the experimental setup for the strength test. The plywood sample is glued to a wood plank surface on a testbench. The storage time vary from 1 minute, 1 hour and 1 day, and each of the storage times requires 12 samples for every increment of loads as tabulated in Table 2. A pressure of 0.08 MPa, which is just below the lowest recommended glue pressure, was applied for 1 minute in a laboratory bench-scale press with a press area of 20 × 20 mm covering the glued area. Four replicates from each sample of woods were used for each storage time (Tsetsekou, Platanianaki & Pournou, 2018).

Table 2. Sample for strength tests

Sample	Storage Time	Load
A	1 minute	80 g / 100 g / 150 g / 200 g / 300 g / 400 g / 500 g / 600 g / 700 g / 800 g / 900 g / 1000 g
B	1 hour	
C	1 day	

Different storage time which are 1 minute, 1 hour and 1 day is used to ensure the film formation process and the chemical reactions in the glueline are finished. Different glue has different storage time and to speed up the process, the sample should be kept under warm conditions (Grøstad & Pedersen, 2010). For our case, the samples are stored under room temperature considering the real situation on site.

For each sample group that had been attached to wood plank surface on a testbench, the load varied from 80 g to 1000 g were hinged in the fixture with a hook inserted in a radius of 1.25 mm hole drilled in the sample before as shown in Fig. 3. This test is replicated from static shear test which is like ASTM D1002 standard, but with low-cost testing machine and wood sample rather than metal. The selected static shear test is conducted for screening and comparison purposes, however with disadvantage of lacking suitable engineering data for modelling because of inherent peel introduction. The time until the adhesion failures occur is taken and capped to 10 minutes. The strength of the glue is considered high if the duration before adhesion failure occurs longer, and every increment of loads can shorten the duration of adhesion failure.

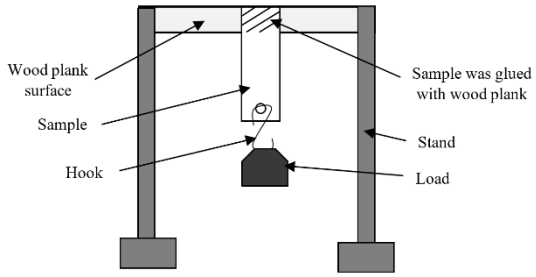
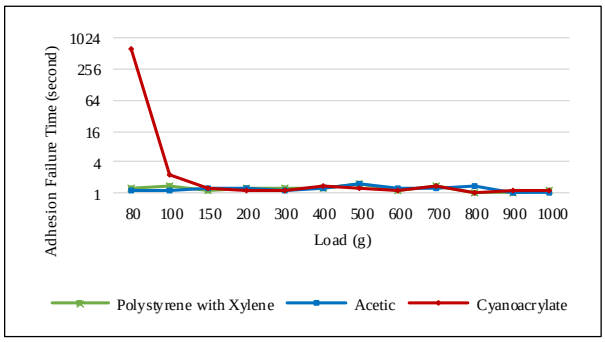


Fig. 3. Strength test setup

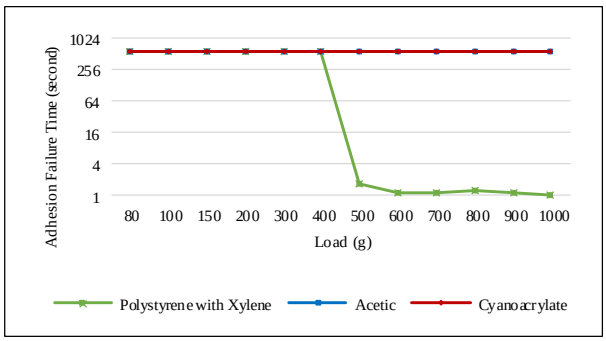
3. Result and Discussion

The strength test was performed for three different types, including the proposed polystyrene with xylene liquid. Another two established wood glues, acetic and cyanoacrylate, were selected as a benchmark. The adhesion failure was recorded by means of the bonding time is unable to withstand 600 seconds, the glue bond is considered to fail. The experiment was conducted at room temperature, and no water exposure test was considered. Results in Fig. 4 illustrate samples A (1 minute), B (1 hour), and C (1 day) for three different types of glue.

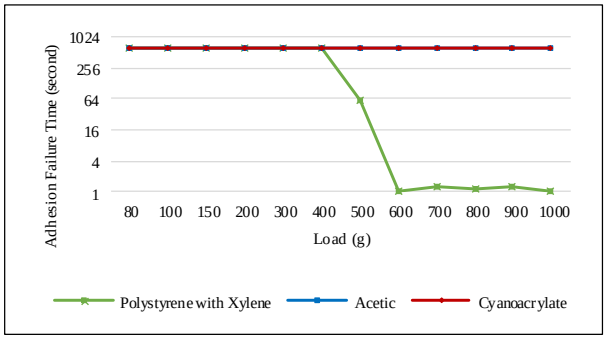
The strength test in Fig. 4 (a) indicates a ranging at low < 2 seconds for all the loads, by means all glues are considered to fail. Cyanoacrylate glue seems to pass the 80 g test. It had been supported by Abud, Mounayer, Benndorf, Piotin, Spelle, and Moret (2004) for the reliability of cyanoacrylate glue for higher degrees of devascularization. The advantage of fast drying enables the sampled plywood to be attached with the wood plank. Results as tabulated in Fig. 4 (b) for 80 g to 400 g indicate all three types of glue able to withstand the loads for more than 600 seconds, and in this case, the rest time is more than 1 hour. However, the proposed polystyrene with xylene glue shows a dramatical reduction of adhesion failure time for 500 g and the time is maintained below 2 seconds until 1000 g. From a physical observation, the bond between sampled plywood and wood plank is loose although the glue has already dried.



(a)



(b)



(c)

Fig. 4. Strength test for various glues for (a) 1 minute storage time, (b) 1 hour storage time, and, (c) 1 day storage time

A similar outcome is shown in Fig. 4 (c) at 500 g, where proposed polystyrene with xylene glue fails for the strength test. But the adhesion failure time is extended to 62.17 seconds. Both acetic and cyanoacrylate glues are completed with more than 600 seconds for varying loads of 80 g to 1000 g. This study showed that adhesive types were effective relative to bonding strength. Glue-bond strength for polystyrene with xylene is generally poor and not recommended for heavy use. Although this glue cannot compete with established glues on the market (i.e acetic and cyanoacrylate), the benefit of using polystyrene as part of the recycling process should be considered.

The mixing content between polystyrene and xylene liquid should further be investigated to increase the glue strength. In addition, another compound mixture should be considered in improving the adhesion strength as this paper is intended to introduce the solution to polystyrene waste. The type of wood chosen may affect the test and study conducted by Sogutlu (2017) proved that wood type that having low values of roughness produced a higher bonding strength hence the novelty of the proposed glue can be highlighted.

4. Conclusion

A potential glue using recycled material has been studied and developed by combining polystyrene and xylene liquid. The strength test of the glue before adhesion fails time occurs taking a sample of 36 saw cutting plywoods for the glue's reliability is conducted. The experiment was set up with three setting times of 1 minute, 1 hour and 1 day and the measurement was taken for load ranging between 80 g to 1000 g. The proposed polystyrene with xylene glue is benchmarked against acetic and cyanoacrylate glues. The outcome indicates that the proposed glue can withstand the load of 400 g at maximum with a resting time of more than 1 hour. Further study should be carried out on mixture quantity to ensure the glue strength can be increased.

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