



## Study on the application of oligomers in paper reinforcement protection

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**Abstract:** In order to improve the strength of paper, solve the problem of poor permeability of traditional resins to paper, the low molecular weight hexamethylenediisocyanate (HDI) trimer was investigated, and the chemical and physical properties of paper samples were tested in this work. Results showed the paper treated by HDI trimer had good mechanical property, the tensile strength was increased from 1105 to 4151 N/m, the folding endurance was increased from 20.8 to 275; and had good glossiness and brightness. Therefore, the prepared HDI trimer has great application prospects in the protection of paper.

**Keyword:** Low Molecular Weight; Hexamethylene Diisocyanate (HDI) Trimer; Paper Protection.

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## 1 Introduction

Paper is subjected to numerous deterioration processes, such as climate, air pollution, mold, and mechanical stress[1-7]. Preventive conservation is an important element of museum policy and collection care[8]. It is necessary to carry out preventive conservation. So, conservation science focused on chemical materials that are able to protect the artistic substrate[9].

The main raw materials of paper are plant fibers, among which cellulose, hemicellulose and lignin contain a large amount of hydroxyl, and the hydroxyl between the fibers is connected by hydrogen bond, which constitutes the main physical strength of paper. At the same time, the presence of a large number of hydroxyl groups has brought about many adverse effects. Hydroxyl hygroscopicity leads to the increase of paper moisture content, which not only reduces the paper strength, but also easily leads to the acid degradation of paper fibers. Microbial hydrolysis and enzymatic hydrolysis degradation accelerate the aging of the paper.

Resin reinforcement is one of the methods to strengthen and protect paper relics in recent years[10]. A two-phase composite material system made of reinforced resin and paper fibers, can effectively improve the strength of the paper, delay the degradation of paper, but also bring new disadvantages: reinforced resin usually has a high molecular weight, it has a poor permeability to the fibers, lead to resin not well penetrated into the interior of the fibers[11]. Compared with the resin, the low molecular reagent has good wetting and permeability performance. HDI trimer was the low molecular weight and non - yellowing polyurethane material. It has a good prospect of application in the reinforcement of paper cultural relics.

In this study, HDI trimer was applied to protection of paper cultural relics. Results showed that the mechanical properties, wet ability of paper by adding HDI trimer were increased greatly.

## 2 Materials and Methods

### 2.1 Materials

HDI trimer, CP, Bayer, Germany; Ethyl acetate, AR, Aladdin; Xuan paper, Market purchase.

Tensile strength Tester, PN-TT300, Folding endurance Tester, PN-NZ135, Glossiness Meter, PN-GM, Brightness Tester, PN-48B, are all from Hangzhou Pinghong Technology Co., Ltd..

### 2.3 Methods

HDI trimer were diluted with ethyl acetate to a mass fraction of 10%. One set paper is soaked in HDI trimmers liquid for 1 min. Another set of papers was reserved without any treatment for comparison. Then all paper samples were dried at room temperature

### 2.4 Analysis and testing methods

The tensile strength of paper: according to the national standard GB/T12914-2008. The folding endurance of paper: according to the national standard GB/T 457-2008. The glossiness of paper: according to the national standard GB/T8941-2013. The brightness of paper: according to the national standard GB/T 7974-2002. The test of dry heat accelerated aging: according to the national standard GB/T 464-2008



### 3 Results and discussion

#### 3.1 Effect of polyurethane reinforcement liquid on the mechanical property of paper

The mechanical properties of the paper samples were studied and results are presented in Fig.1 and Fig.2. Fig.1 shows the tensile properties of the paper treated with ethyl acetate were decreased, and the paper treated with HDI trimer liquid was significantly enhanced compared to uncoated paper. The tensile strength of the paper coated by HDI trimer liquid increased from 1105 to 4151 N/m, the elongation increased from 0.8% to 3.48%.

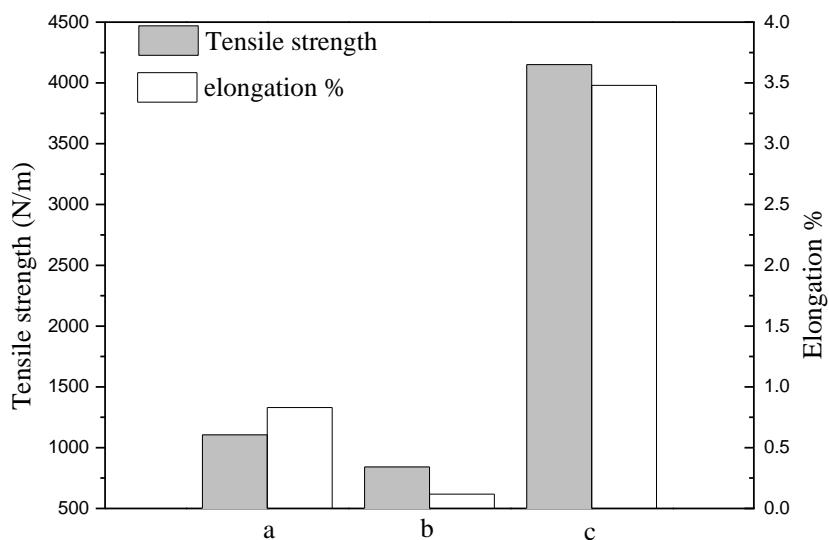


Fig.1 The tensile properties of paper samples

**a.** uncoated paper; **b.** coated by acetic ether; **c.** coated with ethyl acetate liquid of HDI trimer

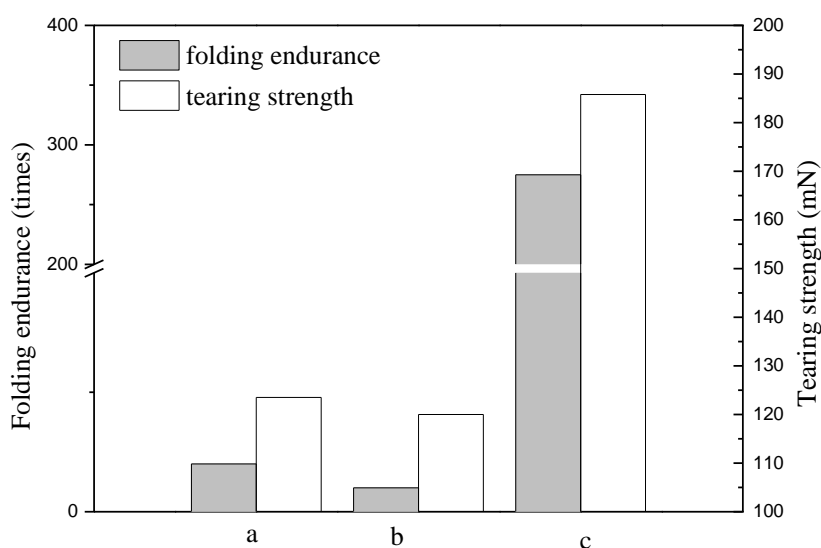


Fig.2 The folding endurance and tearing strength of paper samples

**a.** uncoated paper; **b.** coated by acetic ether; **c.** coated with treated with ethyl acetate liquid of HDI trimer

Fig.2 shows the folding endurance and tearing strength of paper samples. Compared with the untreated paper, the folding endurance and tearing strength of paper treated by HDI trimer liquid was significantly enhanced. This is due to the fact that the isocyanate group has high reactivity, which is known to react with hydroxyl of paper fiber at room temperature. In addition, from the comparison of sample **a** and **b** in the Fig.1 and Fig.2, it can be seen that the strengthening effect of the HDI trimer liquid on the paper is nothing to do with ethyl acetate.

### 3.2 Effect of HDI trimmers liquid on the appearance of paper

Additionally, the glossiness and brightness of paper is listed in Table 1 and Table 2. It can be seen from Table 1 and Table 2, the glossiness of the coated paper at 75°C was slight decreased respectively , but you can't really tell ; the brightness of the coated paper at R457 has a certain decrease. This is consistent with the principle of "keeping the old as the old" in the protection of paper relics.

**Table 1.** Effect of HDI trimer on glossiness of paper

	G75Glossiness/ Gu				
Uncoated paper	4.5	4.5	4.8	4.4	4.5
Coated paper	4.3	4.2	4.2	4.5	4.1



**Table 2.** Effect of HDI trimer on brightness of different paper

	R457Brightness/ %				
Uncoated paper	85.2	85.3	84.2	82.0	83.1
Coated paper	71.1	71.2	71.5	71.6	70.8

#### 4 Conclusions

In this research, the HDI trimer liquid for reinforcement of paper were investigated. Results showed that the mechanical properties of paper coated by HDI trimer have increase greatly, but there are little decrease on the brightness of the paper. Therefore, HDI trimers as great application prospects in the protection of paper.

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