



## Protective polyurea coatings for enhanced blast survivability of concrete

N. Iqbal<sup>a,b</sup>, P.K. Sharma<sup>a</sup>, D. Kumar<sup>b</sup>, P.K. Roy<sup>a,\*</sup>

<sup>a</sup> Centre for Fire, Explosive and Environment Safety, DRDO, Timarpur, Delhi 110054, India

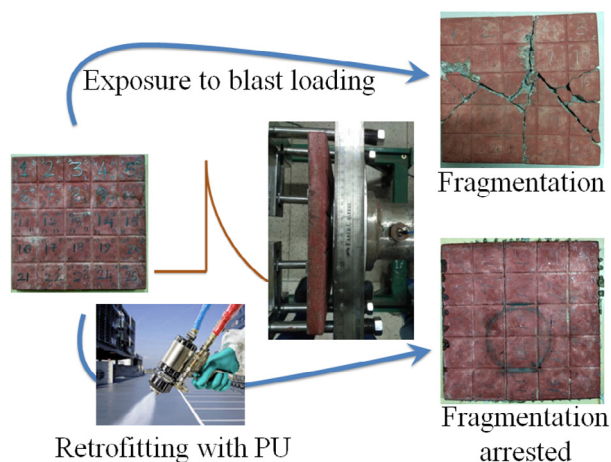
<sup>b</sup> Department of Applied Chemistry and Polymer Technology, Delhi Technological University, Delhi 110042, India



### HIGHLIGHTS

- A chain-extended polyurea has been coated on concrete substrate.
- The efficacy of polyurea towards shock loading has been demonstrated.
- The effect of coating thickness towards blast survivability has been studied.
- Detailed mechanism for explaining the improved blast resistance has been discussed.

### GRAPHICAL ABSTRACT



### ARTICLE INFO

#### Article history:

Received 5 February 2018

Received in revised form 6 April 2018

Accepted 24 April 2018

#### Keywords:

Polyurea  
Concrete  
Dynamic glass transition  
Blast mitigation  
Shock tube

### ABSTRACT

Polyurea is a synthetic high-strength elastomeric coating that can be sprayed over existing structures for protection against weathering effects. In view of the fast kinetics associated with the isocyanate-amine reaction, practical processing of polyurea is performed using spray coating technique. In this paper, we report the effect of varying the type and amount of chain extender on the mechanical properties of spray coated polyurea. An optimal ratio of aromatic: aliphatic chain extender was found to result in optimal H-bonding, which in turn reflected in terms of improved mechanical properties of the coating. In this paper, the efficacy of polyurea towards improving the performance of the substrate towards shock and ballistic loading is demonstrated. Polyurea coated concrete tiles were subjected to controlled blast loadings, and an attempt was made to understand the mechanism responsible for the improved blast survivability. Unreinforced concrete tiles underwent extensive fragmentation at peak pressures <50 psi, while polyurea coated tiles could withstand much higher peak pressures. The extent of mitigation increased with the coating thickness and composites with 6 mm polyurea could withstand substantially higher pressures. Upon further loading, polyurea-concrete debonding was evidenced, however the membrane arrested the fragments formed. Dynamic mechanical studies revealed that polyurea remains as an elastomer under the frequency range associated with the shock tube testing and behaves as a catcher system for the fragments formed due to blast loading.

© 2018 Elsevier Ltd. All rights reserved.

\* Corresponding author.

E-mail address: [pkroy@cfes.drdo.in](mailto:pkroy@cfes.drdo.in) (P.K. Roy).

## 1. Introduction

Polyurea is a polymerization product resulting from the reaction between diisocyanates ( $-\text{NCO}$ ) and diamines ( $-\text{NH}_2$ ). In view of the fast kinetics associated with this reaction, practical processing of polyurea is only possible through a reactive spray coating technique, where the reactants are stored separately and directed to react in the mixing-module, just prior to being pushed out under pressurized conditions through an orifice [1]. Spray coating yields a continuous membrane devoid of seams and joints, which improves the abrasion, corrosion and chemical resistance of structures. In view of the zero Volatile Organic Content (VOC) content of polyurea, the Environmental Protection Agency (EPA) has also approved their use as a coating over concrete.

What renders polyurea particularly interesting is the possibility to tune its mechanical properties by tinkering with the reaction chemistry involving the isocyanate, amine and the chain extender. The properties of the polyurea coating can further be enhanced by tuning the processing conditions, and most commercial formulations are sprayed at elevated temperatures ( $\geq 70^\circ\text{C}$ ) and pressures  $\sim 2000$  psi or higher.

In addition to enhance the structural performance of concrete [2–4], coating with polyurea has been found to lead to improvement in the blast survivability as well. Most of the existing masonry structures were originally designed to withstand static loads and in view of the increasing terrorist threats, it is highly desirable for all vulnerable buildings to possess an additional capability to withstand dynamic loads. In this context, preliminary studies were performed by the Air Force Research Laboratory, where polyurea coating was used towards strengthening of masonry and light weight steel structures [5]. Coating polyurea on the interior face of walls was found to be more beneficial, in comparison to the blast facing side and both side application was found to be economically prohibitive [6]. Polyurea reinforced masonry structures, upon being subjected to transient dynamic loads, were found to undergo large deflections thereby endowing the much-needed ductility during flexural failure of the masonry walls [7]. Polyurea coatings have also been reported to improve the survivability of substrates like steel plates [8–10] and fiber-reinforced face-sheets [11–15].

In view of the commercial aspects involved, the details of polyurea formulations are unavailable in open literature. Polyurea formulations are usually available as dual component system: part 'A' being the isocyanate and part 'B' being the amine resin blend. In addition, the latter component also contain chain extenders, however, there are no guidelines to delineate their optimal amounts, which result in superior performance of the material. In this paper, we establish the effect of nature and amount of chain extender on the material properties of polyurea formulation. Concrete tiles were subsequently coated with the developed polyurea formulation with an aim to establish the effect of increasing coating thickness towards improving its blast survivability.

Another aim of the present work is to establish the underlying contributory mechanism behind the role of polyurea towards improving the blast resistance of the composite. Several mechanisms have been reported [14,16–19], including a dynamic "Rubber-glass transition" where a vitrification process reportedly transpires in the polyurea coating upon being subjected to blast loads [16,20]. However, we hypothesize that the occurrence of such a dynamic transition is unlikely, as exceptionally high frequencies would be required for its incidence: conditions not achievable under blast loadings. Such conditions can be simulated by systematic dynamic mechanical studies over a wide range of frequencies. In the present study, time-temperature superposition (TTS) is used to establish the mechanical properties of polyurea

using the dynamic mechanical analysis data, since direct measurement over such a broad frequency range is not possible. Of particular interest is to identify the frequency associated with the dynamic loading process, which can initiate the dynamic 'glass transition' process in polyurea coating.

## 2. Experimental

### 2.1. Materials

Concrete tiles conforming to IS 8112-1989 (M35 Grade, 28 day compressive strength 35 MPa) were used as the underlying substrate for polyurea spray coating. The details of the concrete used for the present work are presented in the [supplementary section \(Section S1\)](#). Commercial isocyanate prepolymer, Suprasec 2054 (Huntsman), NCO = 15.5% was used without any further purification. Poly(propylene oxide) (PPO) based polyether amines JEFFAMINE<sup>®</sup>D-230 and JEFFAMINE<sup>®</sup>D-2000 were procured from Huntsman: the designation number referring to the approximate molecular weight of each species, with D referring to the functionality (D: difunctional). An aromatic chain extender, diethyltoluenediamine (DETDA 80, Lonzacure<sup>™</sup>) was used without any further purification. The same has been reported to be a mixture of 3,5-diethyltoluene-2,4-diamine (2,4-DETDA) (75–81%), 3,5-diethyltoluene-2,6-diamine (2,6-DETDA) (18–20%) the remaining being dialkylated m-phenylenediamine (0.5–3%). Coatosil MP 200 (Momentive) was included in the formulation to improve the adhesion of the coating with the concrete tile. The structure of the reagents used for preparation of polyurea coating are presented in [Table 1](#).

### 2.2. Polyurea processing

Suprasec 2054, duly diluted with propylene carbonate, was used as isocyanate, and a formulated mixture containing requisite amounts of D-230, D-2000 and DETDA was used as the amine blend for polyurea preparation. The amount of each of the component was calculated as follows:

$$m_{iso} \cdot n_{eq,iso} = [m_{amine} \cdot n_{eq,amine}]^{i_{NCO}} \quad (1)$$

where,  $m_{iso}$  and  $m_{amine}$  refer to the mass of isocyanate and amine respectively and  $n_{eq,iso}$  and  $n_{eq,amine}$  are the equivalent number of isocyanate and amine respectively. The isocyanate index ( $i_{NCO}$ ) refers to the desired NCO index, which was maintained at 1.1 for all formulations. The amount of amine (parts by volume) used for preparing different polyurea formulations are presented in [Table 2](#), with the volume percentage of Suprasec 2054 and propylene carbonate being 90.8 and 9.2 respectively for each formulation. The amount of the hard segment content (HS) was determined as per established procedure (Eq. (2)) [21].

$$HS = \frac{m_{iso} + m_{chain\ extender}}{m_{iso} + m_{chain\ extender} + m_{amine}} \quad (2)$$

It is to be noted that the  $m_{iso}$  used for the calculation of hard segment refers to the mass of isocyanate prepolymer which also includes the contribution of the long polyether chain. Detailed calculations involving the individual contributions of amines and the chain extenders to the total urea present in the sample is presented in the [supplementary section](#), and have been tabulated and depicted pictorially in [Table S1](#) and [Fig. S1](#) respectively. The samples have been designated as PU followed by the (%) contribution of aromatic chain extender in the polymer.

Download English Version:

<https://daneshyari.com/en/article/6713666>

Download Persian Version:

<https://daneshyari.com/article/6713666>

[Daneshyari.com](https://daneshyari.com)