HIGH STRAIN RATE CHARACTERISATION OF FIBER REINFORCED CONCRETE AND ITS APPLICATION IN BLAST RESISTANCE DESIGN

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by

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Study hard, acquire knowledge, no matter if it takes time and seems impossible, just pursue with great aim and remember that the feeling of success is the most beautiful thing in the entire world

Dedicated to my Son, Daughter, and Husband.

For their endless affection, support, understanding, and inspiration.

CERTIFICATE

This is to certify that the thesis entitled "**HIGH STRAIN RATE CHARACTERISATION OF FIBER REINFORCED CONCRETE AND ITS APPLICATION IN BLAST RESISTANCE DESIGN**" which is being submitted by **Ms. Kavita Pradiprao Ganorkar (2016CEZ8430)** to the **Indian Institute of Technology (IIT) Delhi** for the award of the degree of **DOCTOR OF PHILOSOPHY** is a record of the student's bonafide research work carried out by her. She worked under our supervision for the submission of the thesis, which to our knowledge, has reached the requisite standard as demonstrated by excellent international publications in journals and conferences.

To the best of our knowledge and belief, the contents of her research work have not been submitted in full or in part to any other university or institute to confer a degree or diploma.

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ABSTRACT

Nowadays, due to the increase in blasts by terrorist activities worldwide, there is a necessity to build blast-resistant structures. For blast resistant design of a structure, understanding the behavior of construction materials under dynamic loading conditions is essential. In recent years, fiber reinforced concrete (FRC) has been used as an impact-resistant material. However, under dynamic conditions, FRC behaves completely different than plain concrete (PC) due to the inclusion of fiber. Hence, finding out the properties of FRC and PC corresponding to varying strain rates is of utmost importance.

Split Hopkinson Pressure Bar (SHPB) is primarily used for the dynamic characterization of materials. In brittle material like concrete, the deformation of the specimen is minimal when subjected to impact loading. Hence in the specimen, it is challenging to obtain the prerequisites of valid SHPB tests like force equilibrium and constant strain rate. Thus, to overcome these issues, the effect of pulse shaper in the dynamic characterization of concrete using SHPB is considered. Parameters such as the effect of the copper pulse shaper's diameter and thickness on the loading pulses are studied, and appropriate dimensions of the pulse shapers are found out. In addition, numerical simulation is also performed, and results are validated with the experimental data.

SHPB device is used to dynamically characterize basalt fibre reinforced concrete (BFRC) for the 30 MPa characteristic compressive strength of concrete to study specimen size effect and its effect on dynamic behavior. For this purpose, plain concrete (PC) and basalt fiber reinforced concrete (BFRC) with a fiber content of 1 % and 2 % are investigated. For dynamic behavior, two different diameters, i.e., 76 mm and 54 mm samples, are prepared with varying slenderness ratios of 0.3 and 0.5. The behavior of PC and BFRC is experimentally studied at different strain rates ranging from 164 /s to 796 /s, with gas gun pressures up to 0.38 MPa. Based on this investigation, it is

observed that the strength of the concrete increases with the increasing strain rates, and the dynamic increase factor (DIF) is ranges from 0.91 to 3.58.

Based on the above study, an appropriate specimen size is found, and further investigation is continued using this specimen size of 76mm diameter and 0.5 slenderness. Dynamic characterization of PC and FRC is carried out to understand the stress-strain response of PC and (BFRC) for 30, 40, and 50MPa grades of concrete for 0.5%, 1%, and 2% with the inclusion of 9mm length basalt fiber. Further, numerical validation of the SHPB test on (BFRC) is performed in the finite element software LsDyna®. Material model Elastic-Plastic Hydro is implemented for the BFRC material, and parameters are calibrated. The blast analysis of a door is then conducted using the obtained parameters, considering that doors are the most vulnerable element in the blast-resistant structure

Keywords: split Hopkinson pressure bar, basalt fiber reinforced concrete, slenderness ratio, strain rate, high strain rate behavior, pulse shaper, blast resistant door

सार

आजकल, दुनिया भर में आतंकवादी गतिविधियों द्वारा विस्फोटों में वृद्धि के कारण, विस्फोट-प्रतिरोधी संरचनाओं के निर्माण की आवश्यकता है। एक संरचना के विस्फोट प्रतिरोधी डिजाइन के लिए, गतिशील लोडिंग स्थितियों के तहत निर्माण सामग्री के व्यवहार को समझना आवश्यक है। हाल के वर्षों में, फाइबर प्रबलित कंक्रीट (एफआरसी) का उपयोग प्रभाव प्रतिरोधी सामग्री के रूप में किया गया है। हालांकि, गतिशील परिस्थितियों में, फाइबर को शामिल करने के कारण एफआरसी सादे कंक्रीट (पीसी) से पूरी तरह अलग व्यवहार करता है। इसलिए, अलग-अलग तनाव दरों के अनुरूप एफआरसी और पीसी के गुणों का पता लगाना अत्यंत महत्वपूर्ण है।

स्प्लिट हॉपकिंसन प्रेशर बार (SHPB) मुख्य रूप से सामग्रियों के गतिशील लक्षण वर्णन के लिए उपयोग किया जाता है। कंक्रीट जैसी भंगुर सामग्री में, प्रभाव लोडिंग के अधीन होने पर नमूने का विरूपण न्यूनतम होता है। इसलिए नमूने में, बल संतुलन और निरंतर तनाव दर जैसे वैध SHPB परीक्षणों की पूर्वापेक्षाएँ प्राप्त करना चुनौतीपूर्ण है। इस प्रकार, इन मुद्दों को दूर करने के लिए, एसएचपीबी का उपयोग कर कंक्रीट के गतिशील लक्षण वर्णन में पल्स शेपर के प्रभाव पर विचार किया जाता है। लोडिंग पल्स पर कॉपर पल्स शेपर के व्यास और मोटाई के प्रभाव जैसे पैरामीटर्स का अध्ययन किया जाता है, और पल्स शेपर्स के उपयुक्त आयामों का पता लगाया जाता है। इसके अलावा, संख्यात्मक अनुकरण भी किया जाता है, और परिणाम प्रयोगात्मक डेटा के साथ मान्य होते हैं।

एसएचपीबी डिवाइस का उपयोग नमूना आकार प्रभाव और गतिशील व्यवहार पर इसके प्रभाव का अध्ययन करने के लिए कंक्रीट की 30 एमपीए विशेषता संपीड़न शक्ति के लिए बेसाल्ट फाइबर प्रबलित कंक्रीट (बीएफआरसी) को गतिशील रूप से चिह्नित करने के लिए किया जाता है। इस उद्देश्य के लिए, 1% और 2%

की फाइबर सामग्री के साथ सादा कंक्रीट (पीसी) और बेसाल्ट फाइबर प्रबलित कंक्रीट (बीएफआरसी) की जांच की जाती है। गतिशील व्यवहार के लिए, दो अलग-अलग व्यास, यानी 76 मिमी और 54 मिमी नमूने, 0.3 और 0.5 के अलग-अलग पतलेपन अनुपात के साथ तैयार किए जाते हैं। पीसी और बीएफआरसी के व्यवहार का प्रयोगात्मक रूप से 164 / एस से लेकर 796 / एस तक की विभिन्न तनाव दरों पर अध्ययन किया गया है, जिसमें 0.38 एमपीए तक गैस बंदूक का दबाव है। इस जांच के आधार पर, यह देखा गया है कि बढ़ती तनाव दर के साथ कंक्रीट की ताकत बढ़ती है, और गतिशील वृद्धि कारक (डीआईएफ) 0.91 से 3.58 तक है।
उपरोक्त अध्ययन के आधार पर, एक उपयुक्त नमूना आकार पाया जाता है, और 76 मिमी व्यास और 0.5 पतलापन के इस नमूने के आकार का उपयोग करके आगे की जांच जारी है। पीसी और एफआरसी के 30, 40 और 50 एमपीए ग्रेड के कंक्रीट के तनाव-तनाव प्रतिक्रिया को समझने के लिए पीसी और एफआरसी का गतिशील लक्षण वर्णन किया गया है, जिसमें 9 मिमी लंबाई बेसाल्ट फाइबर शामिल है। इसके अलावा, SHPB टेस्ट ऑन (BFRC) का संख्यात्मक सत्यापन परिमित तत्व सॉफ्टवेयर LsDyna® में किया जाता है। सामग्री मॉडल लोचदार-प्लास्टिक हाइड्रो बीएफआरसी सामग्री के लिए लागू किया गया है, और पैरामीटर कैलिब्रेटेड हैं। एक दरवाजे का विस्फोट विश्लेषण तब प्राप्त मापदंडों का उपयोग करके किया जाता है, यह देखते हुए कि विस्फोट प्रतिरोधी संरचना में दरवाजे सबसे कमजोर तत्व हैं।
कीवर्ड: स्प्लिट हॉपकिंसन प्रेशर बार, बेसाल्ट फाइबर प्रबलित कंक्रीट, पतलापन अनुपात, तनाव दर, उच्च तनाव दर व्यवहार, पल्स शेपर, विस्फोट प्रतिरोधी दरवाजा

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES