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Strength Modeling and Study of Blast Response on Concrete Compression Members with Micro Reinforcement

Special Concrete

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***Abstract*— Fibre reinforced concrete is gaining more popularity in modern constructions. Durability and ductility of fibre reinforced RCC compression members against blast load is studied in this work. Hybrid Steel and polypropylene fibers can be used in concrete to increase these strength. In this study an attempt to utilize the hybrid fibers in RCC members to increase the compressive strength and also to reduce the response of RCC member due to blast load has been made. The common uses of fibres, properties of fibre reinforced concrete varying with fibre type and length are discussed in the fibre reinforced concrete section. Concrete grade of M30 is preferred and mix proportion is checked for good compaction by carrying out workability tests. The hybrid fibres are added to the concrete in varying volume fraction of 0%, 1%, 2%, 3% and 4% and checked for workability. The column members and cube specimens are to be cast and cured for 28 days. The compressive strength of all the specimens is tested. Using these strength parameters the column is modelled in ANSYS and analysed. Modelling of the detonation process can be attempted using finite element (FE) codes. Indirect methods to model detonation by balloon analogy have been developed and implemented by some researchers in some analysis codes. From the previous experimental investigations by other researchers it is found that increase in fibre contents have shown a significant improvement in compressive strength of the concrete and thereby increasing the resistance to blast resistance.**

I. INTRODUCTION

A concrete is relatively a brittle material and has serious short-coming of poor toughness. Addition of randomly distributed fibres improves concrete structural characteristics viz. A blast loading is a very rapid release of stored energy characterised by an audible blast. Although such events are relatively rare, when they do occur, such extreme loading on the buildings may involve personal causality, financial loses and may also even lead to collapse of the entire structure. In civil engineering the issue of protecting infrastructure against multiple extreme events is gaining importance because of the fact that many of the government buildings, civilian buildings, embassy buildings and bridge structures are at the risk of terrorist attacks. Static flexural strength, ductility and flexural toughness etc., which depend upon fibre type, size, aspect ratio and volume fractions of the fibres used. Recent years have seen considerable interest in the fibre hybridization particularly combinations of metallic and non-metallic fibres.

II. DYANAMIC RESPONSE OF RCC STRUCTURES TO BLAST LOADS

Blast loads have been a design concern for structural engineers for many years. The analysis and design of structures subjected to blast loads requires a detailed understanding of blast phenomena and the dynamic response of various structural elements. In blast resistant design, it is common practice to separate a structure into its major components for purposes of simplified dynamic analyses. The paper explains the procedure to obtain the dynamic response of reinforced concrete flexural members subjected to blast loading. The threat for a conventional bomb is defined by two equally important elements, the bomb size, or charge weight w, and the standoff distance r between the blast source and the target (figure 2). The basic analytical model used in most blast design applications is the elasto-plastic single degree of freedom (SDOF) system. It is common practice to separate a structure into its major components for purposes of simplified dynamic analyses though this do not consider dynamic interaction effects between the components. A series of separate SDOF dynamic analyses are performed for each of the primary structural components using the reaction time history of the supported member as loading input to the supporting member. Computational programs for blast prediction and structural response can be categorized into uncoupled and coupled analyses. The uncoupled analysis calculates blast loads as if the structure (and its components) were rigid and then applying these loads to a responding model of the structure. For a coupled analysis, the blast simulation module is linked with the structural response module and thus model for blast-load prediction is solved simultaneously with model for structural response. By accounting for the motion of the structure while the blast calculation proceeds, the pressures that arise due to motion and failure of the structure can be predicted more accurately. Examples of this type of computer codes are AUTODYN, DYNA3D, LSDYNA AND ABAQUS.

III. SIGNIFICANCE OF MICRO REINFORCEMENT

Steel fibres and polypropylene fibres are the widely used micro reinforcement in the fibre reinforced concrete. There are various types of steel fibres such as wave cut, end large steel fibre, deformed sheet and also hooked end steel fibre. In general, hooked end steel fibres are widely used in the fibre reinforced concrete because it has higher strengthening effect on the cement matrix as compared with others types of steel fibres. The addition of steel fibres to concrete not only results in a large increase in flexural strength, but also a considerable increase in toughness. After cracking, the cracks cannot extend without stretching and de-bonding of the fibres. As a result, a large additional energy is absorbed before complete separation of the specimen occurs. Toughness can be measured in various ways. Static, impact, and fatigue tests have been used. Fibres having lower modulus of elasticity are expected to enhance strain performance whereas fibres having higher modulus of elasticity are expected to enhance the strength performance. Moreover, the addition of hybrid fibres makes the concrete more homogeneous and isotropic and therefore it is transformed from brittle to more ductile material. The presence of micro cracks at the mortar-aggregate interface is responsible for the inherent weakness of plain concrete. The weakness can be removed by inclusion of fibres in the mix. Fibres primarily control the propagation of cracks and limit the crack widths (Qian and Stroeven, 2000). High elastic modulus steel fibres also enhance the flexural toughness and ductility of concrete. Prepare Your Paper Before Styling

Abbreviations and Acronyms

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
CFRP	Carbon Fibre Reinforced Plastic
cm	Centimeter
CFD	Computational Fluid Mechanics
CSM	Computational Solid Mechanics
ϕ	Diameter
FE	Finite Element
FCT	Flux-Corrected-Transport
GPa	Giga Pascal
HSC	High Strength Concrete
HSFRC	High Strength Fibre Reinforced concrete
HyFRC	Hybrid Fibre Reinforced Concrete
HFRC	Hybrid Fibre Reinforced Concrete
IS	Indian Standard
JCI	Japan Concrete Institute
kg	Kilo Gram
kN	Kilo Newton
L	Length
Mpa	Mega Pascal
m	Meter
mm	Millimeter
MRC	Micro Reinforced Concrete
%	Percentage
NRC	Normal Reinforced Concrete.
PEFRC	Polyethylene Fibre Reinforced Concrete
PCS	Post Crack Strength
RSPH	Regularized Smoothed Particle Hydrodynamics
RCC	Reinforced Cement Concrete
RC	Reinforced Concrete
SDOF	Single Degree Of Freedom
SPH	Smoothed Particle Hydrodynamics
SS	Stainless Steel
SFRC	Steel Fibre Reinforced Concrete
TNT	TriNitro Toluene

IV. NEED FOR THIS STUDY

From previous researches, it is found that normal concrete members will have low ductility, low tensile strength and brittleness as a diminishing property for its strength and durability. Hybrid Steel and polypropylene fibres can be used in concrete to increase these strength. The previous experimental investigations with increase in fibre contents have shown a significant improvement in tensile strength of the concrete and thereby increasing the flexural and compressive strength. For optimal behavior, different types of metallic and non-metallic fibres have been combined. The mechanical properties such as compressive strength, flexural strength and flexural toughness etc. of hybrid fibre reinforced concrete (HyFRC) have been investigated previously by different investigators. This project is meant to utilize the hybrid fibres in RCC members to increase the tensile strength and also to reduce the risk of blast loading in RCC members. Also the project aims at reducing the material consumption by reducing the size of the RCC members. To understand the explosions and blast loading on buildings and structures we must understand the structural characteristics of beams and its behavior under common loading conditions. In general the blast loading is divided into two categories namely air burst and surface burst. When an explosion occurs nearby to and above a building structure such that no amplification of the initial shock wave occurs between the explosive charge and the structure, then such blast is referred to as free air blast. When the explosion occurs very near to the ground surface, the blast is considered as the surface blast.

V. SCOPE OF THIS STUDY

Some of the main objectives of this project are,

i. To compare and study the strength variations in normal concrete and concrete with steel and polypropylene fibres often referred as hybrid fibres.
ii. To increase the compressive and tensile strength of concrete members by using the micro reinforcements.
iii. To reduce the percentage of reinforcements in columns by increasing the compressive strength of the concrete.
iv. To reduce the size of RCC members by increasing compressive strength of the concrete.
v. To reduce material consumption by reducing the size of RCC elements.
vi. To check and compare the stability of both normal concrete and concrete with steel and polypropylene fibres under blast loading.
vii. Modelling the effects of detonations of high explosives to inform blast-resistant design.
viii. To assess and model the concrete damages using Finite Element (FE) codes.

VI. BLAST LOADING AND BLAST EFFECTS

Blast Loading Response of Ultra High Performance Concrete and Reactive Powder Concrete Slabs by J.H.J. Kim et al. According to this experimental study there have been numerous explosion-related accidents due to military and terrorist activities. Such incidents caused not only damages to structures but also human casualties, especially in urban areas. To protect structures and save human lives against explosion accidents, better understanding of the explosion effect on structures is needed. In an explosion, the blast load is applied to concrete structures as an impulsive load of extremely short duration with very high pressure and heat. Generally, concrete is known to have a relatively high blast resistance compared to other construction materials. However, normal strength concrete structures require higher strength to improve their resistance against impact and blast loads. Therefore, a new material with high-energy absorption capacity and high resistance to damage is a better material for blast resistance design. Recently, Ultra High Strength Concrete (UHSC) and Reactive Powder Concrete (RPC) have been actively developed to significantly improve concrete strength. UHSC and RPC can improve concrete strength, member size and weight reductions and workability improvement. High strength concrete usages in better earthquake resistance and increase a building height and bridge span. Also, UHSC and RPC can be implemented for blast resistance design of infrastructure due to terror or impact such as 9.11 terror attack. Therefore, in this study, the blast tests are performed to investigate the behavior of UHSC and RPC slab subjected to blast load. Blast wave characteristics, including incident and reflected pressures as well as maximum and residual displacements and strains in steel and concrete surface are measured. Also, blast damages and failure modes were recorded for each specimen. From these tests, UHSC and RPC are shown to effectively resist blast explosions compare to normal strength concrete. Ultra High Strength Concrete (UHSC) and Reactive Powder Concrete (RPC) RC slabs’ response induced by explosive of blast wave pressure are evaluated to understand the blast resistance capacity blast resisting repair materials and retrofitted structure. The reflected blast pressure and impulse values calculated using the Con WEP were in reasonable agreement with the experimental data. The performance comparison of UHSC and RPC specimens to NSC control specimens subjected to blast loads of ANFO 35 lbs has shown the high blast resistance capacity of about 30.9~35.9% increase with respect to average maximum displacement. An average of residual displacements was smaller than normal strength concrete specimen’s residual displacement, even though there was no consistent trend due to variations in environmental conditions. Therefore, to evaluate the damage under blast load, failure mode must be considered. From the test results, the failure patterns of both UHSC and RPC indicate that they are much more resistant to blast loading and have higher blast resistance capacity than NSC.

Concrete Damage Assessment for Blast Load using Pressure-Impulse Diagrams was conducted by Zubair I. Syed et al. According to this experimental study the duration of blast pressure is significantly important along with its magnitude for dynamic response of concrete elements. Pressure-Impulse (P-I) diagrams which include both blast pressure magnitude and duration are often used in concrete damage assessment. Available design guidelines and manuals for protective design are mostly based on the Single degree of freedom (SDOF) approach. Types of resistance function used in SDOF analysis of concrete elements influence the ultimate response and eventually the amount of blast damage. Representation of concrete damage, relating only to the blast pressure magnitude and the over simplification of resistance function, can sometimes be misleading in obtaining the structural responses. This paper explores different methods of obtaining P-I diagrams using SDOF model. Development of nonlinear resistance function using nonlinear material models has also been discussed. Both bilinear and nonlinear resistance functions have been used in SDOF analysis to obtain the P-I diagrams to correlate the blast pressure and the corresponding concrete flexural damage. Realistic combination of pressures and impulses were chosen during analysis to simulate the effect of both the near and far-field blast scenarios. Variation in the post peak response of SDOF models due to use of simplified resistance function has also been presented. Field test result was compared to the analytical result to assess the effectiveness of P-I diagrams in blast damage assessment.

Evaluation of Blast Induced Ground Vibration Predictors by Manoj Khandelwal and T.N. Singh. According to this experimental study the present paper mainly deals with the prediction of blast-induced ground vibration level at a Magnesite Mine in tecto-dynamically vulnerable hilly terrain in Himalayan region in India. The ground vibration was monitored to calculate the safe charge of explosive to avoid the continuous complaints from the nearby villagers. The safe charge of explosive and peak particle velocity (PPV) were recorded for 75 blast events (150 blast data sets) at various distances. These data sets were used and analysed by the widely used vibration predictors. From the four predictors, vibration levels were calculated and compared with new monitored 20 blast data sets. Again, the same data sets were used to validate and test the three-layer feed-forward back-propagation neural network to predict the PPV values. The same 20 data sets were used to compare the results by the artificial neural network (ANN). Among all the predictors, a very poor correlation was found, whereas ANN provides very near prediction with high degree of correlation. Based on the study, it is established that the feed-forward back-propagation neural network approach seems to be the better option for close and appropriate prediction of PPV to protect surrounding environment and structure. The use of any predictor without validation may invite further complication for smooth conduct of mining operations. This study indicates that all predictors used in the paper are either over estimating or under estimating the safe explosive charge to keep the PPV under the safe limit. Both the predictions are not appropriate for the site where populations are residing very near to mine. If more number of data sets are used in ANN, the prediction will be more accurate, because it does not follow the over fitting and under fitting law of curves as in the case of vibration predictors. Blast Loading and Blast Effects on Structures by T. Ngo. P et al (2007). According to this study the use of vehicle bombs to attack city centers has been a feature of campaigns by terrorist organizations around the world. A bomb explosion within or immediately nearby a building can cause catastrophic damage on the building's external and internal structural frames, collapsing of walls, blowing out of large expanses of windows, and shutting down of critical life-safety systems. Loss of life and injuries to occupants can result from many causes, including direct blast-effects, structural collapse, debris impact, fire, and smoke. The indirect effects can combine to inhibit or prevent timely evacuation, thereby contributing to additional casualties. In addition, major catastrophes resulting from gas-chemical explosions result in large dynamic loads, greater than the original design loads, of many structures. Due to the threat from such extreme loading conditions, efforts have been made during the past three decades to develop methods of structural analysis and design to resist blast loads. The analysis and design of structures subjected to blast loads require a detailed understanding of blast phenomena and the dynamic response of various structural elements. This paper presents a comprehensive overview of the effects of explosion on structures. An explanation of the nature of explosions and the mechanism of blast waves in free air is given. This paper also introduces different methods to estimate blast loads and structural response.

The use of Steel Fibre Reinforced Concrete for Blast Resistant Design is a study by Deidra Kalman (2010). Reinforced concrete is a common building material used for blast resistant design. Adding fibres to reinforced concrete enhances the durability and ductility of concrete. This report examines how adding steel fibres to reinforced concrete for blast resistant design is advantageous. An overview of the behaviour of blasts and goals of blast resistant design, and advantages of reinforced concrete in blast-resistant design, which include mass and the flexibility in detailing, are included in the blast resistant design section. The common uses for fibre-reinforced concrete, fibre types, and properties of fibre reinforced concrete varying with fibre type and length, and concrete strength are discussed in the fibre-reinforced concrete section. The first step to designing a blast resistant reinforced concrete structure is to implement proper detailing to ensure that structural failures will be contained in a way that preserves as many lives as possible. Preventing the building from collapse is the first of these priorities. Adding steel fibres to concrete has been shown to enhance the concrete’s post-crack behavior, which correlates to this priority. The second priority is reducing flying debris from a blast. Studies have shown that the failure mechanisms of steel fibre reinforced concrete aid in reducing flying debris when compared to conventional reinforced concrete exposed to blast loading. The major design considerations in designing steel fibre reinforced concrete for blast resistant design include: the strength level of the concrete with fibre addition, fibre volume, and fibre shape. As research on this topic progresses, the understanding of these factors and how they affect the strength characteristics of the concrete will increase, and acceptance into the structural design industry through model building codes may be possible.

An Experimental Study on Blast Resistance of Polyethylene Fibre Reinforced Concrete was carried out by Makoto Yamaguchia et al (2009). In this study, in order to apply polyethylene fibre reinforced concrete (PEFRC) with high toughness to blast resistant structures, experimental investigations were conducted regarding the evaluation of the damage to PEFRC slabs subjected to contact detonation. When designing important structures such as industrial plants and public facilities, it is necessary to ensure their safety against accidental explosions and terrorist bomb attacks. The fracture modes of reinforced concrete (RC) slabs subjected to blast loadings are characterized by spalling due to the tensile stress wave being reflected from the back side of the slab. To protect humans inside a structure under such conditions, it is necessary to prevent the launch of concrete fragments that accompany spalling. Therefore, reducing spall damage is the most important problem in designing blast resistant RC structures. the test results were compared with the formulae for estimating the size of the external damage to normal RC slabs, and then a formula for estimating total damage depth (the sum of crater and spall depths) in PEFRC slabs was proposed.

VII. SUMMARY

From the above chapter of literatures we have carried out under the following topics, viz., Fibre Reinforced Concrete, tests on fresh concrete, tests on hardened flexural members, blast loading and blast effects, applications of ANSYS in blast resistant designs. The suggestions on material quantities and material properties are identified from these literatures. The Compression strength test and blast test performed by other researchers are considered as preliminary tests for this work. Similarly the usage and types of modelling software used by previous researchers are considered.

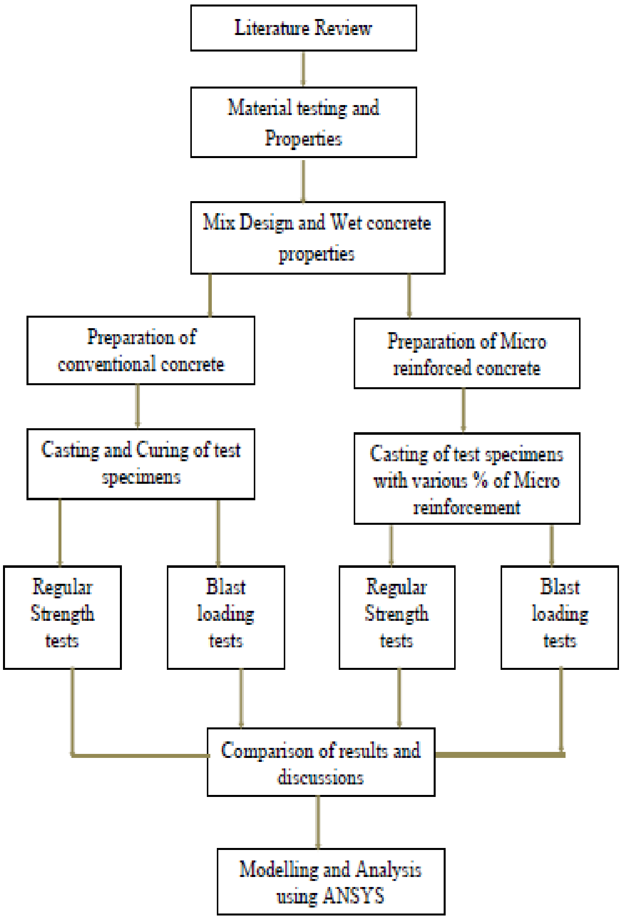
VIII. METHODOLOGY

In order to brief out the aim and outcome of this study, the various methods followed are highlighted here in a sequence. A brief review of literature has been carried out under the following topics, viz Fibre Reinforced Concrete, tests on fresh concrete, tests on hardened compression members, blast loading and blast effects, applications of ANSYS in blast resistant designs. In this experimental study cement, fine aggregate, coarse aggregate, steel fibres, polypropylene fibres were used. All the materials are tested for its basic Physical and mechanical properties. Concrete grade of M30 is preferred and mix proportion is checked for good compaction by carrying out workability tests. The hybrid fibres are added to the concrete in varying volume fraction of 0%, 1%, 2%, 3% and 4% and checked for workability. Results of an investigation conducted to evaluate the compressive strength of Hybrid Fibre Reinforced Concrete by (S.P. Singh 2010), revealed that the optimum fibre combination for maximum compressive strength is 75% steel fibres + 25% polypropylene fibres. Hence in this study the steel and polypropylene fibres are added to the concrete in the ratio of 75% steel fibres + 25% polypropylene fibres for each volume fraction. The compression members and cubic specimens are to be casted and cured for 28 days. The compressive strength of all the specimens with varying volume fraction of fibres is tested.

The results are compared and modelled using ANSYS. The charges due to blast loading are to be selected on the basis of explicit modelling of the detonation process can be undertaken using finite element (FE) codes.

Figures and Tables

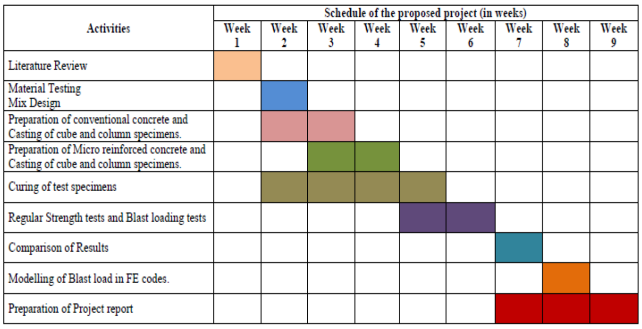
1. *Flow chart of the methodology*



2.Test Specimen Sample requirements

Sample Id	Fibre Vol. in %	No of samples required for regular strength test								No of samples required for blast test	
		Column				Cube				Column	Cube
		7 days	14 days	21 Days	28 days	7 days	14 days	21 days	28 days	28 days	28 days
NRC	0	3	3	3	3	3	3	3	3	2	2
MRC1	1	3	3	3	3	3	3	3	3	2	2
MRC2	2	3	3	3	3	3	3	3	3	2	2
MRC3	3	3	3	3	3	3	3	3	3	2	2
MRC4	4	3	3	3	3	3	3	3	3	2	2
Total		15	15	15	15	15	15	15	15	10	10

3.Work Schedule



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