Research Proposal II.3

UMR Node

Fiscal Year 2006

repair of buildings & bridges with composites

UPGRADE OF STRUCTURES WITH SRP AND CFRP COMPOSITES AGAINST EXPLOSIVE DEVICES PLACED VERY NEAR OR IN CONTACT WITH RC MEMBERS

SUMMARY

Recent events have drawn considerable attention to the vulnerability and sustainability of structural members subjected to improvised explosive devices (IED). Since blast protection of structures is never an absolute concept and there is a level of high costs associated with a given damage level of protection, proper assessment tools must be employed to determine within a reasonable degree of accuracy the level of vulnerability of existing and new structures. Furthermore, in blast design, one must also determine an acceptable level of damage that a structure can tolerate. Explosive effects can impact a level of damage that can range from minor damage to complete structural failure and considerable loss of life.

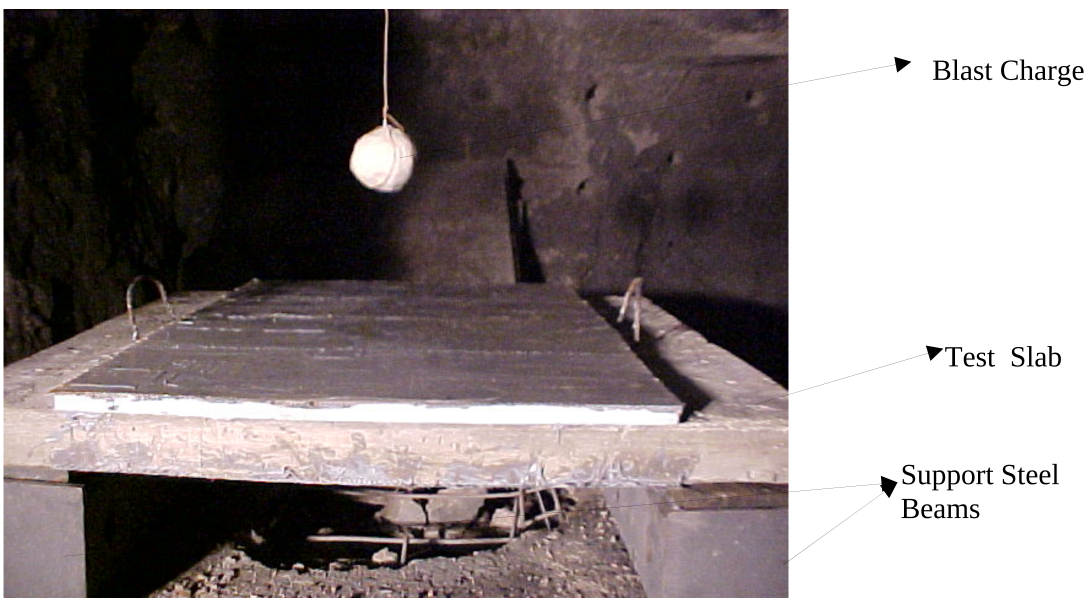

Figure 1. Test Setup

Within this framework, under a SGER-NSF sponsored research program recently completed at UMR, a generalized procedure was developed for estimating the charge weight and standoff distance within the displacement based design (DBD) philosophy. In addition, a RB2C funded research project within FY2005 corroborated that the blast-resistant capacity of RC slabs can be effectively increased by strengthening using FRP composites and that the damage levels observed during testing using real life explosives were predicted by the DBD method.

In order to expand on these research results the main objective of this RB2C proposed research for FY2006 is to develop blast mitigation techniques for IEDs placed very near or in contact with RC members. The technique that will be employed in this research program will consist of applying multiple layers of materials with different density ratios as a means for disturbing the blast contact pressures and as such reducing the blast pressure wave in contact with the main structural member. The multiple layers will be designed to minimize damage on RC slabs. This project will be divided in three tasks and are outlined in this proposal.

BACKGROUND

One of the crucial parameters in applying the displacement based design (DBD) method is the equivalent viscous damping (EVD) ratio. Since the loading characteristics of seismic loads are significantly different than blast loads, the EVD ratio for blast loads proposed herein should also be different than those used in seismic design. Based on the hysteretic response of a RC member under different loading conditions, generalized expressions are proposed for estimating the EVD ratio as a function of the displacement ductility level for individual members. Analytical results indicate that the EVD ratio for seismic loads can be significantly lower than for blast loads.

Successful implementation of the DBD method requires the use of inelastic design response or shock spectra to estimate the design displacement. Nowadays elastic shock spectra are readily available as design charts in the literature that can provide for a reasonable estimate of the response of a structure under a blast loading using these charts. However, inelastic shock spectra for the design of blast resistant structures using the DBD method are not available. Based on the EVD ratios obtained above, the inelastic shock spectra can be equivalent to a substitute structure with the corresponding EVD ratio and is given by:

During the FY2005 a RB2C funded research project was completed to examine the feasibility of assessing the blast-resistant capacity of strengthened reinforced concrete (RC) slabs using the displacement based design (DBD) method. In order to achieve this objective, five RC slabs were tested under real blast loads in the out-of-plane direction. One of the slabs was used as the control unit to establish a baseline for comparison in terms of performance for the other four slabs, which were strengthened with fiber reinforced polymers (FRP). The explosive charge weight and stand-off distance required to impose a given damage level were predicted by the DBD method. Test results showed that the blast loads were effectively estimated and the damage levels observed from the field tests correlated well with the predicted levels. In addition, test results corroborated that the blast-resistant capacity of RC slabs can be effectively increased by strengthening using FRP composites. The main conclusion that can be drawn from these tests using real life improvised explosive devices (IDE) is that RC slabs retrofitted on both sides have a higher blast resistance capacity than those slabs retrofitted only on one side.

The composite materials used in the FY2005 project consisted of carbon fiber reinforced polymer (CFRP) sheets and a new class of composites composed of knitted high strength steel cords designated as steel reinforced polymer (SRP). These materials will also be investigated along with polyurea.

OBJECTIVE

The main objective of this RB2C proposed research is to develop blast mitigation techniques for IEDs placed very near or in contact with RC members. The technique that will be employed in this research program will consist of applying multiple layers of materials with different density ratios as a means for disturbing the blast contact pressures and as such reducing the blast pressure wave in contact with the main structural member. The multiple layers will be designed to minimize damage on RC slabs.

WORK PLAN

This research program consists of three tasks that are described next.

Task 1: Blast testing on control RC slabs: Three control slabs will be tested under real life explosives. The explosives charge weight and standoff distance will be predicted using the DBD method to impart on the control slabs damage levels that will range from no cracking (Level I), minor cracking (Level II), major cracking (Level III) and severe damage (Level IV). A detailed discussion of these damage levels are discussed elsewhere. The slab with no cracking will be subsequently tested to minor cracking. The testing sequence is depicted in Table 1. In addition, the severe damage limit state will be tailored for an explosive placed immediately in contact with the RC slab.

Table 1. Test Matrix – Control Slabs

Slab ID	Level I	Level II	Level III	Level IV
C1	x	x	x	x
C2			x	x
C3				x

Task 2: Blast testing on strengthened CFRP and SRP RC slabs: Nine slabs strengthened with CFRP and SRP sheets will be tested under real life explosives in this task. In units CFPR1-3 and SRP1-3 depicted in Table 2, the polymeric resin used to bond the FRP material is provided by Bondo Corporation and it is designated as "Bondo Structural Epoxy". In units SRP1-3 the SRP material consists of Hardwire's™ high density cord type 3x2. While in Units SRP4-6 Bondo Polyurea with the medium density cord type 3SX will be investigated.

Table 2. Test Matrix – CFRP Strengthened Slabs

Slab ID	Level II	Level III	Level IV
CFRP1	x	x	x
CFRP2		x	x
CFRP3			x
SRP1	x	x	x
SRP2		x	x
SRP3			x
SRP4	x	x	x
SRP5		x	x
SRP6			x

Task 3: Blast testing on multiple layer strengthened RC slabs: Six slabs strengthened with a combination of CFRP and SRP plus polyurea will be investigated in multiple layers with other materials of different density. The technique that will be employed in this research program will consist of applying

multiple layers of materials with different density ratios as a means for disturbing the blast contact pressures and as such reducing the blast pressure wave in contact with the main structural member. The multiple layers will be designed to minimize damage on RC slabs.

In units MC1-3 as depicted in Table 3 CFRP sheets will be investigated in combination with multiple layers, while in units MS1-3 SRP will be used in combination with other multiple layer systems.

Table 3. Test Matrix – CFRP Strengthened Slabs

Slab ID	Level III	Level IV
MC1	x	x
MC2	x	x
MC3		x
MS1	x	x
MS2	x	x
MS3		x

BUDGET

Budget for this project will cover support for one graduate student and adequate funds to conduct the experimental and analytical studies over a period of 12 months for a total budget of $25,000.

CONTACT

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