FACULTY OF ENGINEERING AND ARCHITECTURE

DEFENCE

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NEW TECHNIQUE TO PROTECT RC STRUCTURES AGAINST EXPLOSIONS

Introduction

In recent years, numerous explosions related to terrorist attacks and industrial accidents have occurred all over the world. These explosions directed towards vulnerable structures cause considerable damage and loss of life.

Before the explosion

After the explosion

Industrial accident in Tianjin, China 2015

Terrorist attack at Zaventem Airport, Belgium 2016

Upgrading of structural robustness is necessary !

How can we improve the resistance of existing RC structures?

Composite Materials in Civil Engineering

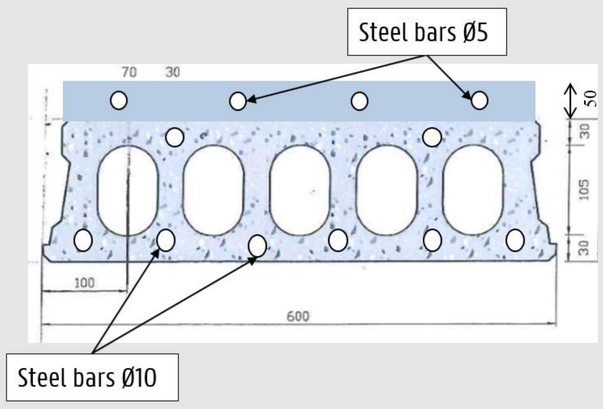
One of today's state-of-the-art techniques for strengthening of reinforced concrete structural elements is the use of Carbon Fiber Reinforced Polymer (CFRP) composite strips as Externally Bonded Reinforcement (EBR). This is justified for quasi-static loads by the high strength, light weight and excellent durability characteristics of CFRP EBR in combination with their ease of application.

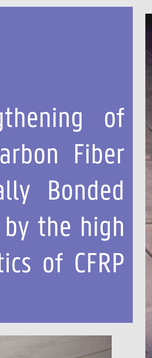
The use of FRP as EBR has been demonstrated as a very efficient technique mainly for static load conditions

Time to test EBR under explosion !

Scenario of the explosion

To investigate the feasibility of strengthening RC structures using CFRP under explosion, a simply supported Hollow core slabs with a span of 6m are tested under an explosion of 1,5Kg of C4 at a distance of 0,5m from the target. One of the slabs is used as a reference and the remaining slabs were strengthened with different ratios of CFRP.





Slab A1

Slab A2

Slab A3

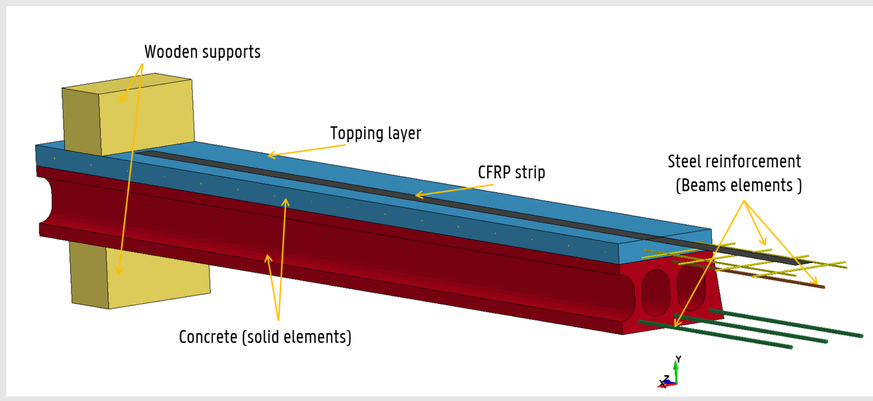
Height (mm)	220
Width (mm)	600
Thickness of the compression layer (mm)	50
Compressive strength of the compression layer (MPa)	35
Steel grade	S500

Simply supported hollow core slab

Fireball of the explosion

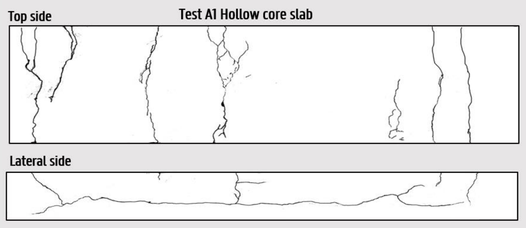
Non linear finite element modelling

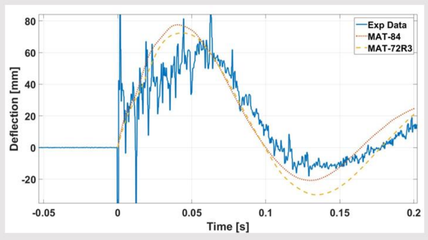
A numerical analysis is carried out using the finite element software LS-DYNA to complement the experimental results. The hollow core slabs are modeled with Lagrangian formulation. Due to the symmetry of the geometry and the blast loading, taking into account the time cost of the simulations, a quarter model is adopted.



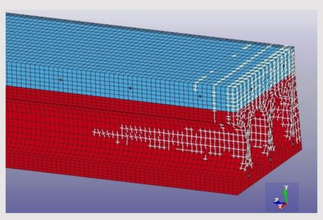
Experimental and numerical analysis

The experimentally obtained cracks at the top surface and the longitudinal crack on the lateral side at the mid span of the reference specimen A1. This distribution of cracks at mid span of the slab is well predicted by both material models for the concrete, as shown in Figure. Compared to experimental data, both model variants yield a good prediction of the maximum deflection at the mid span of the slab.

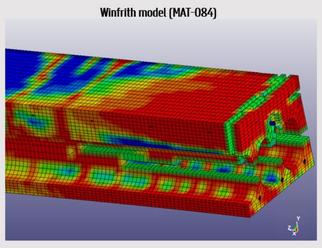




Deflection time history at the mid span of the RCHC slab



Winfrith model (MAT-084)



Concrete Damage Release 3 model (MAT-072R3)

Tests	CFRP reinforcement ratio (mm^2/m)	Exp max deflection (mm)	Num max deflection (mm)	Exp/Num
Slab A1	-	65,5	67,4	0,97
Slab A2	200	55	58	0,95
Slab A3	250	46	49	0,94

Conclusions

CFRP strips as EBR are an efficient technique to upgrade the blast resistance of the hollow core slabs and increase significantly the flexural strength and the stiffness of the slabs under blast loads.

The maximum upward deflections are reduced by 16 to 30 % when using CFRP reinforcement ratio equals 200mm^2/m and 250mm^2/m, respectively.

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