Finite Element Analysis of FRP Reinforced Concrete Slabs Under Thermal Gradients and Mechanical Loads

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Introduction

Reinforcing concrete with steel is a very effective way to combine the high compressive strength of concrete with the high tensile strength of steel. However the steel corrosion can strongly reduce the durability of the concrete structure. For this reason efforts are made in Canada to replace the steel reinforcement by non-metallic Fibre Reinforced Polymers (FRP).

Fibre Reinforced Polymers (FRP)

FRP reinforcing bars are manufactured from continuous fibres, (such as carbon (CFRP), glass (GFRP) or aramid (AFRP)) embedded in matrices (thermosetting or thermoplastic). The fibres transmit the forces while the matrix protects the fibres against mechanical abrasion and transfers stresses between the fibres.
Compared with steel the FRP reinforcement has got a very high tensile strength and a small weight.
A large disadvantage is the low thermal compatibility between FRP reinforcement and concrete.

Thermal material properties

Table 1 shows the thermal expansion coefficients of different types of FRP and concrete. Under thermal gradients the difference in longitudinal direction results in self-equilibrating stresses. The high transverse expansion of FRP bars leads to cracks around the reinforcing bars reducing the bond between concrete and FRP.

Coefficient of Thermal Expansion ($*10^{-6}$ /°C)				
Direction	**Concrete**	**GFRP**	**CFRP**	**AFRP**
Longitudinal	9.9 to 12.4	6 to 10	-1 to 0	-6 to -2
Transverse	9.9 to 12.4	21 to 23	22 to 23	60 to 80

Table 1 Coefficient of Thermal Expansion

Numerical analysis

At the University of Calgary experiments were performed on square concrete slabs reinforced with steel and different types of FRP. They were exposed to thermal gradients and mechanical loads.

For verification of the experimental results, the experiments were modelled and analysed utilizing the finite-element program ADINA. Because of the symmetry of the slab and the load cases, modelling of one quarter of the slab was sufficient. (Fig. 1)

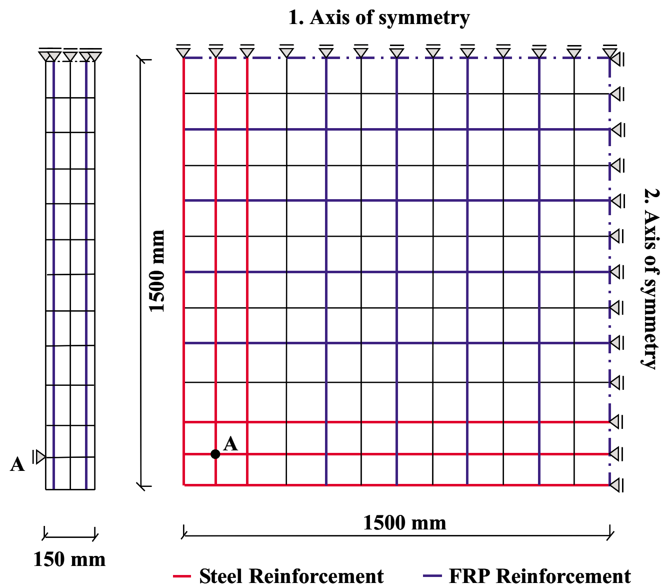

Fig. 1 Finite element grid

Fig. 2 shows large differences between the calculated and experimental results, but in general the development of the results with increasing thermal or mechanical loads was similar. Better correspondence might be achieved by optimizing the finite-element grid.

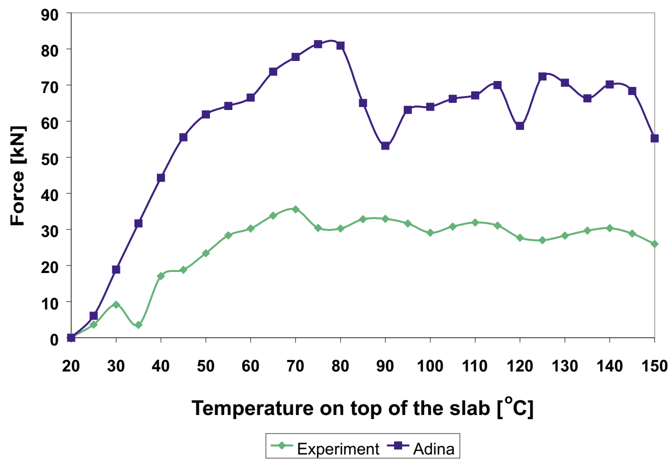

Fig. 2 Comparison of numerical and experimental results