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Influence of the drop height of a mass on the behavior of a concrete slab reinforced by a composite cork plate: Numerical Analysis.

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ABSTRACT — The reinforcement of a concrete structure improves the mechanical characteristics of its elements so that it provides better behavior. To increase strength and rigidity and to preserve the load potential of a concrete slab, it is necessary to reinforce it with other materials such as a composite materials which present highly appreciated mechanical performances. The reinforcement by composite plates is an interesting and cost-effective solution. This numerical study aims to investigate the effectiveness of strengthening reinforced concrete slabs by external bonding of a cork composite plate subjected to dynamic load caused by the drop of a mass according to the height of fall on improving the resistance and capacity.

Keywords: reinforced, composite cork, dynamic loading, modeling.

I.Introduction

Behavior analysis of reinforced concrete slabs subjected to dynamic loading is a very current theme. Reinforced slabs when subjected to point loads, they develop more resistance at low month. The rupture is due to the shear stress developed in the heavily compressed zone [1],[2],[3]. In most cases, deterioration of the concrete material results in loss of strength and other weaknesses which require reinforcement of the structure to improve the mechanical characteristics of the elements composing it [4]. The reinforcement of concrete elements by composites involves increasing the level of service and, in particular, increasing ductility and strength to meet new exploitation exigencies or unanticipated conditions during the design and calculation phase. A nonlinear finite element modeling [5] based on a local approach is introduced in this paper to predict the behavior of a loaded concrete slabs reinforced by fiber-reinforced a composite cork plate. The influences of the drop height of the projectile mass on the performances of the new slab are measured and analyzed to investigate the effectiveness of strengthening reinforced slabs. Also, the numerical results in terms of overall and observed response are emphasized and discussed. The results represent a promising revelation regarding the improvement in terms of ductility for reinforced concrete slab.

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II. Finite element analysis

A numerical analysis based on finite elements is carried out in a three-dimensional space on concrete slabs reinforced by external bonding of a composite plate, using the computation code [5]. The dimensions and all the mechanical properties of the various materials have been carefully introduced. The cork composite plate and the slab elements are modeled separately with their mechanical and geometrical properties, the adhesion between these components is perfect assumed.

Table 1.Variation of the drop height of the projectile

Slab	*Drop Height (m)*	*Speed (m/s)*	*Impact energy*
Reinforced slab	0.14	0.15	0.42
	0.15	0.15	0.45
	0.16	0.15	0.49
Unreinforced slab	0.11	0.15	0.33
	0.12	0.15	0.36
	0.13	0.15	0.39

Thereafter, the reinforced slabs are subjected to a loading caused by the fall at different heights of a projectile of mass 3 kg. The variation of the drop height of the projectile is depicted in table 1.

II.1. Meshes and Geometric modeling

Hexahedral solid linear finite elements (HEX8) with a Lagrangian formulation and 2 cm dimensions in three directions are used to mesh the slab. However, the cork composite plate is modeled by quadratic finite elements models (2D) to four nodes with 8 degrees of freedom with a dimension of a 1 centimeter in both space directions, which ensures a very fine mesh.

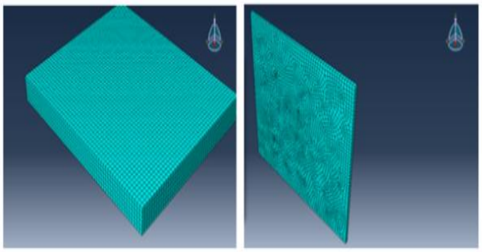

Fig. 1 Geometrical model for simulated the concrete slab and the cork plate.

II.2. Modeling of materials

The Concrete damaged plasticity model takes into account the dissymmetry of the behavior of the concrete in compression and in tension, is used. Plasticity problems associated with damage are considered. It assumes that the two main mechanisms of rupture are: cracking and crushing of the concrete in compression. The stress-strain relation is defined by:

$$\sigma = (1-d) D_0^{el} : (\varepsilon - \varepsilon^{pl}) = D^{el} : (\varepsilon - \varepsilon^{pl}) \quad (1)$$

D_0^{el} : The matrix of elastic stiffness.

$D^{el} = (1-d) D_0^{el}$: Represents the stiffness matrix after damage.

$\bar{\sigma}$: The effective stress tensor.

The use of the principle of the effective stress leads to a relation linking the real stress to the effective stress given by: allowing us to connect the effective stress tensor to the elastic stress tensor by: $\sigma = (1-d)\bar{\sigma}$ Which allows us to link the effective stress tensor to the elastic stress tensor by:

$$\bar{\sigma} = D_0^{\mathbf{el}} : (\varepsilon - \varepsilon^{pl}) \quad (3)$$

The degree of degradation of the material under external loading is represented by a single scalar variable of damage "d" affecting the Young's modulus. The composite materials are modeled according to an elastic orthotropic model in the hypothesis of plane stresses with the Hill-Tsai rupture criterion. The stiffness and rupture parameters of this model are identified from the characterization tests.

II.3. Loading Setup

The modeling of this loading is carried out using a cylindrical steel projectile of mass 3 kg with a constant loading speed of 0.15 m / s, however the height of fall is considered variable.

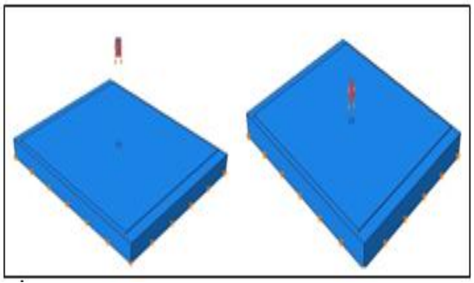

Fig. 2. Loading and Boundary conditions

III. Results and Discussions

The overall responses of the studied concrete slabs are given by the force-displacement curves measured at the center of the concrete slab until ruptures are shown by Fig 3.

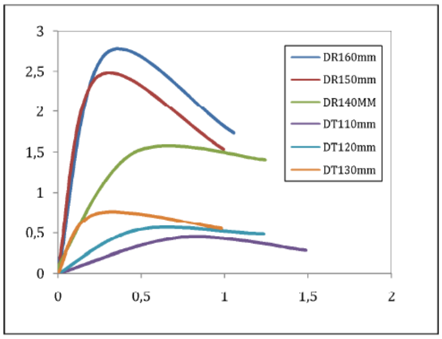

Fig. 3 Force-displacement curves for different drop heights.

The dynamic parameters of the concrete slabs are significantly influenced by the variation in the height of fall. The increase in the ultimate load is accompanied by an increase in ductility. This leads to an improvement in the rigidity of the rupture energy compared to the control concrete plate.

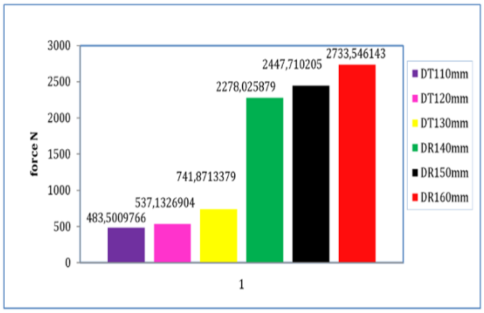

Fig. 4. Histogram of ultimate forces.

The Fig 4 show that the maximum ultimate strength achieved is 741.8N for unreinforced concrete slabs and 2733.5N for reinforced slabs. The rupture energy of the unreinforced slabs is evaluated at 3.9 joules, whereas for the reinforced slabs, the rupture energy is given by the 160mm variant which is of the order of 4.8 joules, the damping of the impact is ensured by the composite to protect the slabs. The Fig. 5 shows the energy of rupture under impact for different heights considered.

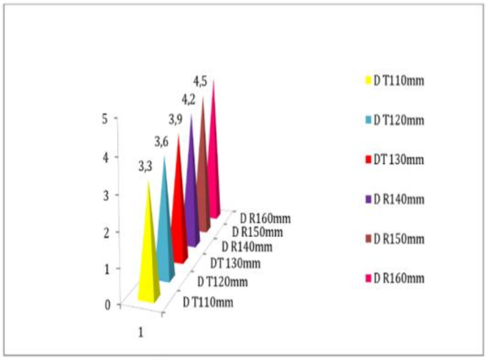

Fig. 5 Rupture energy under impact.

IV. Conclusions

The results analysis makes it possible to draw the following conclusions:

• Damage is greatly reduced by resistance to bending and impact forces.

• The dynamic parameters of the concrete slabs are highly influenced by the drop height of the mass.

• The behavior of reinforced concrete slabs is influenced by the mechanical and geometrical properties of the composite plate.

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