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New technique for reinforcement of concrete columns confined by embedded composite grid

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Abstract

Reinforced concrete structures are often very sensitive to accidental loads, leading to deterioration, failures and human life fatalities. Our concern is to reinforce the concrete columns by composite materials judiciously integrated in order to ensure, on one hand, a return of sufficient rigidity and strength preventing overall collapse and, on the other hand, to preserve external and esthetic aspect of reinforced concrete works.

The experimental and numerical studies in the present work represent a promising revelation regarding the effectiveness of the proposed confinement process by integrating a composite grid with rectangular mesh containing glass fibers inside the reinforced concrete matrix.

Keywords: Concrete; Composite grid; Confinement; Compression testing

1. Introduction

The integrity of structures in service depends mainly on the evolution of their mechanical characteristics during their lifetime. In the civil engineering field, the cracks due to statical and dynamic accidental stresses are common and represent the starting point for all kinds of failure sources. The pathological study of vulnerability of concrete structures [1] led towards the use of composite materials as reinforcement ensuring a restoration of stiffness and strength. Considering the high mechanical performance of composite materials combined with their lightness, it becomes judicious to associate them in the composition of the concrete members, to better resist external loading.

Fig. 1 shows the failure mode of a structure under the effect of seismic actions. A sight of the collapse of a reinforced concrete building is clearly observed. In despite of the adequate compressive strength, sudden rupture takes place under lateral dynamic loading. In addition to the need to improve the ultimate strength, this kind of failure underlines the necessity to avoid brittle failures for evident reasons of saving human lives.

Recently, the use of fabric E-glass composite for repairing infrastructures has been widely increased. This concept has emerged as a novel alternative for rebuilding as well as for repairs of damaged structures. Although that many studies have been carried out on confined concrete cylinders [2,3], different technologies can be applied for repairing, such as steel tubes and fiber reinforced polymers (FRP), tube encased concrete columns [2], concrete columns reinforced by non-adhesive filament wound hybrid composite [3] and polypropylene fiber reinforced concrete (FRC) [2].

The repair technologies of concrete structures knew important progresses in the last years, and several approaches for concrete confined by composite have been developed. A first one consists in reinforcing the concrete by a percentage of fibers made of glass, carbon and other

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Notations

A_b rough composite cross-section
A_v cross-section of the space in the composite
b_f width of FRP strips
D diameter of concrete cylinders
E_c modulus of elasticity of concrete
E_f elasticity modulus of FRP
E_l confinement modulus of FRP
f'_{cc} ultimate compressive strength of FRP-confined cylinders with strain-hardening
f'_{co} compressive strength of unconfined concrete cylinders
f'_{cp} peak stress of FRP-confined concrete
f'_{cu} ultimate compressive strength of FRP-confined cylinders with strain softening
f_f ultimate tensile strength of FRP
f_l confinement strength of FRP
k effectiveness coefficient of FRP-confined concrete
s_f net space of each FRP strip
t_f total thickness of FRP
α influence coefficient of unconfined concrete strength
ε_c axial strain of concrete
ε'_{cc} ultimate axial strain of FRP-confined concrete with strain-hardening
ε_{co} axial strain in peak stress of unconfined concrete
ε'_{cu} ultimate axial strain of FRP-confined concrete
ε_{cu} ultimate axial strain of unconfined concrete
ε_{fu} ultimate tensile strain of FRP
ε_r lateral strain of FRP-confined concrete
λ boundary value of strain softening and strain-hardening
λ_0 ratio of FRP-confinement modulus to the concrete modulus
λ_1 influence coefficient of FRP-confinement modulus and the concrete modulus
ρ_f volumetric ratio of FRP to concrete

materials [4]; in this case, only the tensile strength is improved, but it cannot prevent total or partial collapse of the structure. A second technique is based on composite jackets (FRP) glued on external area of RC members [5]; this method increases the rigidity and the bearing capacity of the confined concrete in a considerable way and modifies the behavior in large deformations. In the case of composite reinforcement stuck on the outer column face, it is necessary to take account for surface treatment, slip influence and interface premature failure, in order to take account for direct influence on stiffness and strength. This type of interfacial connection is not permanent in nature. Different studies [6–8] have shown that adhesive failure implies sudden failure of concrete specimens. These works showed either an interface failure by the coupling of shear and normal stresses or a tension failure of concrete layer located between the composite material and the steel. In fact, the state of stress in the FRP must be always limited for rheological reasons, mainly related to creep behavior. A recent technique was presented by Wu [9], which consists in partially wrapping the column surface by FRP composites; this study underlines the limiting values of the confinement level. All these reinforcement technologies aim to prevent more or less the sudden failure as well as the risk of partial or total collapse. The choice of the best technology depends on mechanical and commercial benefits.

In order to provide higher mechanical effectiveness of confined concrete by composite meshes, the new technique proposed in this work consists in incorporating composite grids within the concrete members. In this first stage of research, the present study is focused on preliminary investigation of structural behavior when the RC columns are subjected to axial compressive load. The effectiveness of this methodology has been experimentally evaluated on the basis of test results.

Fig. 1. Failure of a structure under the effect of the seismic action [1].