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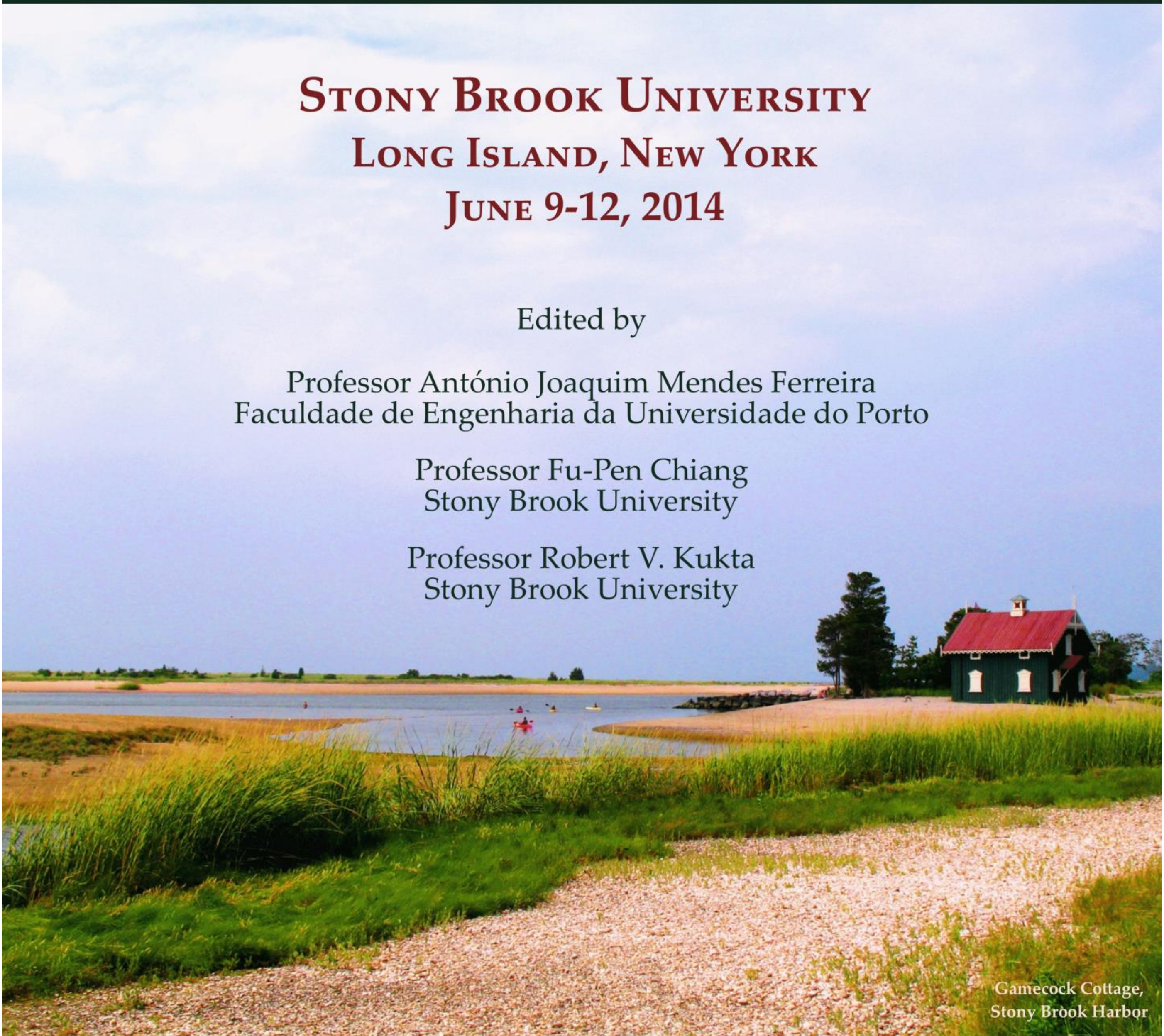

Gamecock Cottage, Stony Brook Harbor

5156 | Strengthening of steel-reinforced concrete structural elements by externally bonded FRP sheets and evaluation of their load carrying capacity to face changed load service conditions

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The present contribution comes out from an application of engineering interest concerning the strengthening of existing steel reinforced concrete (RC) members to face changed (higher) design load conditions. The field of application is that of hospital rooms intended for magnetic resonance imaging (MRI) and computed tomography (CT) equipments. In such circumstances the service loads are very high (about 2500 daN/m2) and, if such equipments have to be installed within an existing building, the strengthening of the existing structures becomes compulsory. Externally bonded steel plates, steel or concrete jackets or external post-tensioning are traditional remedies, however steel can interfere with magnetic fields and then with all the equipments where magnetic neutrality is required.

In such a context, the externally bonded FRP sheets (see e.g. [1, 2]), on taking into account the high tensile strength and the magnetic neutrality of FRPs, represent a very effective solution. The major cost of fibers and resins is largely offset from the lower cost of installation due either to the lightweight of the sheets or to the possibility to conform them to the existing structural geometries. However it is known that FRP reinforcement exhibit a linear elastic behavior up to a brittle failure and this, in general, leads to a reduced ductility of the strengthened RC members. On the other hand, when the bonded FRP sheets exert a confinement action on the steel-RC elements they might provide even an increase of concrete ductility. Indeed, as suggested in many relevant guidelines (see again [1]), at ultimate limit state it should be guaranteed that the existing steel re-bars are sufficiently yielding so that the strengthened member will fail in a ductile manner, despite the brittle nature of concrete crushing, FRP rupture or bond failure.

A limit state design carried out on the base of a plastic approach seems in this context acceptable, but the viability of such an approach needs a validation which is the main goal of the present work. A limit analysis methodology, concerning RC structural elements and belonging to the so-called Direct Methods [3], is here promoted and rephrased to predict the load carrying capacity of RC-elements strengthened by FRP bonded sheets. A MenetréyWillam-type yield criterion, endowed with cap in compression, is employed for the RC members modeling while a Tsai-Wu-type yield criterion is used to tackle the FRP sheets. The numerical limit analysis procedures is carried out within a 3D FE-layered formulation. A comparison of the numerical predictions against experimental findings on large-scale prototypes [4, 5] is used to validate the effectiveness of the promoted approach.

1. FIB Bulletin 14. Externally bonded FRP reinforcement for RC structure, Task group 9.3, International Federation of Structural Concrete, 2002
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3. De Domenico D, Pisano AA, Fuschi P. A FE-based limit analysis approach for concrete elements reinforced with FRP bars. Compos Struct 2014;107:594-603.
4. Hawileh RA, Naser MZ, Abdalla JA. Finite element simulation of reinforced concrete beams externally strengthened with short-length CFRP plates.Composites Part B 2013; 45:1722-1730.
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4822 | Pumping Potential of a Flexible-Matrix-Composite Structure with Negative Poisson’s Ratio

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Pumping potential (PP) is defined as the ratio of the relative volume change to a relative input stroke. It is introduced to evaluate the volumetric efficiency of a pump. The value of the PP is related to the geometric characteristics and the material properties of the pump structure. A single-layer hyperbolic shellof-revolution FMC structure was investigated by Ghoneim and Noor [1]. When under torsion, the rotation of the hyperbolic shell structure causes the throat diameter and the characteristic length to simultaneously decrease, rendering a substantial volume decrease and consequently a high PP. This premise has been confirmed by the investigation.

Materials with negative Poisson’s ratio are called auxetic materials. The most distinguished characteristic of auxetic materials is that they laterally expand under stretching and contract under compression. Therefore, when subjected to axial loading, the relative volume change of a structure made of an auxetic material would be larger than the corresponding one made of a conventional material. When applied to pump structure, this characteristic (negative Poisson’s ratio) is expected to increase the pumping potential due to the larger relative volume change. For FMC laminates, when fiber orientation angles are properly set up, a high in-plane negative Poisson’s ratio is obtained. As a result, structures made of FMC laminates with negative inplane Poisson’s ratio could engender a larger PP.

This paper attempts to improve upon the PP of the single-layer hyperbolic shell structure by using multi-layer FMC materials with negative Poisson’s ratio. The study is conducted both analytically and experimentally. The PP of FMC, with negative Poisson’s ratio, cylindrical and hyperbolic structures using built-in Matlab codes as well as ANSYS FE package, is evaluated. In addition, a hyperbolic FMC structure will be built and tested for the evaluation of the PP. Discussion of the ensuing results will be presented.

[1] Ghoneim, H. and Noor, S., 2013, “Pumping Potential of a Hyperbolic Shell-of-Revolution Flexible-Matrix-Composite Structure”, Composite Structures, pp. 10-15.