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Virtual laboratory for testing anchors under static and cyclic loads

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ABSTRACT

From single-family homes and schools to high-rise office towers, today's designers are taking a longer view of the reliability and sustainability of building construction. Testing of each component is now broadly recognized. By extending this process right down to the smallest structural fastener, designers can justify and specify more fastening products made of higher grade materials.

Metal anchor bolts are frequently used in modern construction in order to ensure the connection between different building components and to allow loads transmission between different elements of a structure. In the past, the development of concrete anchors was largely based on allowable stress design concepts. Testers used a hydraulic system to pull an anchor out of the concrete and then calculated allowable shear and tension values by dividing the ultimate value by a safety factor.

Professional engineers who specify anchors for use in commercial projects must now consider additional factors other than the anchor’s ultimate load. In order to determine an anchor’s load value, the professional engineers need to address the different categories of testing (reference, reliability, service conditions) and failures such as steel failure, concrete failure and pull-out failure. Manufacturers can make it easier for professionals by providing their test data and creating tables within specific guidelines. Today, the qualification of building products such as anchors is currently made by testing following a relevant design value procedure. Such a safer and reliable product procedure is time consuming; besides its implementation to provide a completely satisfying description of the product behaviour is very expensive. Indeed, it does not seem efficient to perform a complete test program combining all the possible influencing parameters.

The project of testing building components by computer simulation has been launched at CSTB a couple of years ago: The virtual laboratory (VL), a project which “*involves the development of simulation tools composed of a range of intercommunicating software and databases, thus making it possible to analyse the performance of building components or parts of building structures*” [1]. To deal with this project, a strong partnership has been initiated between CSTB and CS [2].

A new milestone has been reached in the framework of IOLS, a project carried out within the French System@tic Cluster, funded by DGE, CG92 and CRIF [3]. Two simulation tools of the VL have been designed, implemented and validated by the CSTB in the framework of IOLS project: The “Digital Concrete Tool” in order to study the 2D thermo-Hydro-Mechanical

behaviour of cement-based materials under fire conditions and the “Fluid Structure Interaction Tool” for Bridges and toll buildings subjected to high speed winds.

EHPOC [4] will lead us to extend the “Digital Concrete Tool” to 3D and to make it operational within The Open Source Integration Platform for Numerical Simulation SALOME [5]. It will also enable us to improve the “VL Tool for Anchor Tests”. Thanks to these improvements, the Virtual Laboratory will help the manufacturers to design new anchors, to optimise the number of pre-qualification and qualification tests and improve the design code. Based on the feasibility demonstration of the damage model adopted for the cyclic behaviour of concrete [6], the behaviour under monotonic and alternate shear loads of a single expansion anchor will be implemented. The aim is to predict the failure modes, the failure load and the global load-displacement behaviour on the one hand and to compare the anchor behaviour under static load versus alternate load on the second hand. Thanks to numerical simulation using the finite element method, different types of non linearity will be considered: non-linear behaviour laws for steel and concrete, geometrical non linearity due to the large displacements and non linearity due to the contact conditions.

The cracking progress in concrete is modeled with a damage model, MODEV, developed at CSTB. It takes into account the specific nonlinear effects involved in the deterioration process of concrete such: unilateral effect and stiffness recovery due to the cracks closure, inelastic strains, and the coupling between damage and inelastic strains. By analogy with Mazars’s model, 2 equivalent strains; $\tilde{\varepsilon}^s$ and $\tilde{\varepsilon}^d$ translating respectively local sliding and crack opening are introduced. The model considers two scalar damage variables, corresponding respectively to each degradation mechanism.

$$\tilde{\varepsilon}^d = \sqrt{\left(\underline{\underline{\varepsilon}}^d - \underline{\underline{\varepsilon}}_d^{an}\right):\left(\underline{\underline{\varepsilon}}^d - \underline{\underline{\varepsilon}}_d^{an}\right)} + \alpha\varepsilon^H \quad (1)$$

$$\tilde{\varepsilon}^s = \left\langle \varepsilon^H \right\rangle \quad (2)$$

$$d_d = 1 - A_C \exp\left[-B_C\left(\tilde{\varepsilon}^d - \tilde{\varepsilon}_0^d\right)\right] - \left(1 - A_C\right)\frac{\tilde{\varepsilon}_0^d}{\tilde{\varepsilon}^d} \quad (3)$$

$$d_s = 1 - \left(\frac{\tilde{\varepsilon}_0^s}{\tilde{\varepsilon}^s}\right)^n \exp\left[-B_T\left(\tilde{\varepsilon}^s - \tilde{\varepsilon}_0^s\right)\right] \quad (4)$$

Where ε^H is the volumetric strain, $\underline{\underline{\varepsilon}}^d$ the deviatoric part of the strain tensor $\underline{\underline{\varepsilon}}$, $\underline{\underline{\varepsilon}}_d^{an}$ the deviatoric part of the inelastic strain tensor $\underline{\underline{\varepsilon}}^{an}$, α is a coupling coefficient, $\langle X \rangle = \frac{X + |X|}{2}$, and where B_t, A_c, B_c, are material parameters, obtained by standard experiments.

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[3] J. DUYSENS, “IOLS: A French Initiative for Developing Platforms and Software Dedicated to High Performance multi-physics and multi-scale Global Design Optimization”. In, WCCM VII, July 17, 2006

[4] EHPOC, *French acronym of “High performance environment for optimisation and design”*, is the continuation of project IOLS and is carried out within the French System@tic Cluster, funded by DGE, CG78, CG91 and CRIF.

[5] SALOME: The Open Source Integration Platform for Numerical Simulation. http://www.salome-platform.org/home/presentation/overview

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