Available online at www.sciencedirect.com

ScienceDirect

Procedia Structural Integrity 6 (2017) 244–251

Structural Integrity Procedia

www.elsevier.com/locate/procedia

XXVII International Conference "Mathematical and Computer Simulations in Mechanics of Solids and Structures". Fundamentals of Static and Dynamic Fracture (MCM 2017)

Strength analysis of nuclear power plant structures in case of aircraft crash impact

Fedorenko R.V.[a,*], Kudryavtsev A.A.[a], Lukin A.V.[a],Modestov V.S.[a], Murtazin I.R.[a]

[a] *Peter the Great St.Petersburg Polytechnic University, Institute of Applied Mathematics and Mechanics, dep. of Mechanics and Control*

Abstract

In this article the results of the strength analysis of nuclear power plant structures in case of aircraft crash impact problem are presented.Finite element analysis was performed using ABAQUS CAE system. Nonlinear material models were used, such as "Concrete damaged plasticity" and "Drucker-Prager" for concrete and elastic-plastic model for steel.For the purpose of verification of the mathematical models and engineering methods used in reinforcement concrete buildings strength analysis under different loads (static and transient temperature, structural and other loads), the following computational simulations were carried out: uniaxial compression of the cylindrical concrete specimens; reinforced concrete beams analysis under the static loads;reinforced concrete slab analysis under dynamic loads; reinforced concrete slab analysis under the missile impact. Experimental data for the aforenamed verificatory tasks was found in periodicals.

Keywords: finite element method; nuclear power plant; strength analysis; reinforced concrete; aircraft impact; stress-strain state; Riera method.

1. Introduction

One of the nuclear power plants (NPP) engineering problems is strength calculation and loading bearing capacity (in particular, analysis of the NPPs' outer containment) under aircraft crash impact. In addition, important aspect is

* Fedorenko Roman. Tel.: +7-921-921-11-17.
E-mail address: fedorenko_rv@spbstu.ru

10.1016/j.prostr.2017.11.037

the analysis of dynamic loads upon NPPs safety important equipment and pipelines. In this article, the results of the strength analysis method development and its practical use in the Aircraft crash impact problem are presented.

2. Mathematical models of reinforced concrete creep (deformation) and strength

Traditionally, reinforced concrete is considered as composite material, consisting of two co-operating materials – concrete and steel [1].

In order to considernumerous concrete and reinforced concrete nonlinear mechanical propertiesand features in real constructions various deformation and strength theories of concrete can be used. Validationof used mathematical models is necessary on basis of the experimental data.

CAE systems support many reinforced concrete models, which take into account different nonlinear physical and mechanical properties of concrete and reinforcing steel. Table 1 shows a list, which cannot be regarded as complete, of the reinforced concrete models in different CAE systems [2-4]. Italics shows concrete models, that, in the opinion of the authors, to the fullest extent describe features of this material and have broad engineering use.

Table 1. Concrete deformation and strength models.

CAE system	Concrete deformation and strength model
ANSYS, ANSYS/LS-DYNA	*Drucker-Prager Concrete*, Geological Cap Model, *RHT Concrete Strength.*
LS-DYNA	Solid and Foam Model, *Pseudo-Tensor*, Oriented Crack, Geological Cap, Concrete Damage, *Concrete Damage Rel3*, Brittle Damage, Soil Concrete, *Winfrith Concrete*, *Johnson-Holmquist Concrete*, Schwer-Murrat Cap, *CSCM Concrete.*
ABAQUS	Concrete Smeared Cracking, Cracking Model for Concrete, *Concrete Damage Plasticity*

In simulation of the reactor building aircraft crash impact ABAQUS “Concrete damage plasticity” material model was used [5]. Cracks formation and propagation and concrete damage are accounted for towards introduction of the isotropic scalar stiffness degradation factor. This approach was developed by Kachanov [6] and further expounded by Rabotnov [7] and other authors. This model offers many possibilities: it provides powerful capabilities to model concrete and other quasi-brittle materials for the full range of constructions (beam, shell and solid) under static and dynamic loads.

It is assumed, that the prominent mechanism of the concrete failure is the distress distortion in the setting of tension and destruction in the setting of compression. Evolution of the strength surface is specified by two hardening parameters called effective plastic strain of tension and compression respectively.

One of important aspects is the method of reinforcement modelling. In CAE systems, alongside with direct solid modelling of reinforcement rebars, there are following models of reinforcement [8]: discrete, embedded and smeared. In the first model nodes of reinforcements beam elements coincide with nodes of concrete solid elements. In the second model reinforcement and concrete nodes are not coincident, but they are tied by compatibility equations. In the smeared model it is estimated that reinforcement is regularly spaced distributed in concrete mesh elements.

In ABAQUS system embedded or smeared methods are usually utilized. Embedded method of reinforcement modelling is implemented with “embedded elements” technology. It forms constraint equations between degrees of freedom of the concrete solid mesh and of the reinforcement beam mesh nodes. Smeared method is implemented with “rebar layers” technology. It allows for considering the existence of the geometrical reinforcement arrays with the use of geometrical surfaces (plains, cylindrical or other surfaces) and reinforcement parametrization: reinforcement rebars spacing, rebars diameter, reinforcement material properties. In both cases nonlinear mechanical model for steel can be used.