申请同济大学博士学位论文

同济大学

博 士 学 位 论 文

混凝土随机损伤数值仿真

（副标题）

邬 翔

指导教师姓名 李 杰

申请学位级别 工学博士 专业名称 结构工程

学位授予单位和日期

建工学院

200 年 月 日

摘 要

作为一种准脆性材料，混凝土的开裂行为及破坏机理一直是力学、材料学和土木工程学科的研究热点和难点。

数值仿真技术的兴起为研究者提供了强有力的工具来模拟材料细观性能与宏观现象之间复杂的关系。通过数值仿真再现物质世界中的各种现象，一方面可以使人们对其过程有深入了解，另一方面，也可以检验、校正人们对事物本原认识(基本原理、假设模型)上的偏差。数值仿真技术既是研究的工具，也是检验的手段。沿着这一方向，本文通过数值仿真技术研究混凝土的开裂行为及破坏机理。

首先，借助数字图像处理技术对真实混凝土试件截面进行图像处理，得到具有重要原始信息(位置、形状、尺寸)混凝土数值模型。其次，在细观分析基础上，将混凝土分为骨料、硬化水泥浆体及界面过渡区三相介质材料；对各相材料细/亚细观结构进行了考察，提出了细观各相本构关系。最后，将这些本构关系赋予具有真实混凝土内部信息的数值模型，建立了基于微观结构，具有真实物理背景的细观损伤数值试件。

通过系统安排，一方面对数值试件进行仿真分析，另一方面对真实试件进行加载试验，以混凝土单轴拉、压试验来校正数值试件参数。在校正基础上对混凝土的重复加载试验进行数值仿真，并对重复加载过程中的能量耗散问题进行了讨论。然后，将混凝土数值试件外推至二轴受力状态，进行了二轴拉/拉、二轴拉/压以及二轴压/压的数值仿真，并与真实试验结果比较。基于上述数值试件，对混凝土材料中随机性的影响问题进行了初步研究。

为解决具有真实混凝土内部信息的数值试件获取不易，数量不多的缺点，同时考虑到目前绝大多数的研究是建立在人工算法生成的数值模型上，本文也采用常用的算法生成一批数值模型，将本文建议的细观三相介质本构关系结合人工算法生成的数值模型进行了研究。考察人工算法生成的数值试件与具有真实混凝土内部信息数值试件之间的差别，以判断现有研究成果的可信度。

最后，本文对弹性模量与强度关系、损伤局部化等土木领域较为关心的问题进行了初步探讨。

关键词：数值仿真，混凝土，图像处理，本构关系，细观损伤

ABSTRACT

Cracking action and damage mechanism of concrete have always been one of the most important hotspot of mechanics, materials and civil engineering, as concrete is a quasi-bittle material different from other brittle material.

Arisen of simulation technique provide a powerful tool to simulate the complex relations between meso-property and macro-phenomenon of material for researcher. Through simulation various kinds' phenomenons of physical world can reappear. One hand, this make people understand the process during phenomenon deeply, on the other hand, this make people correct the bias about the origin of object. Simulation technology not only tool for research but also facility of verify.

Based on the knowledge about meso-structure and meso constitutive relations, the theory about random analysis combine with computational mechanics can be used to forecast the macro property of material, and simulate the macro response of structure. This is the one of three main research directions in the field of meso-computational mechanics. Obey this way, this paper investigates the cracking and damage process in concrete.

For the first step, with help of digital image process technique, the image of real concrete sample can be transfer to numerical model which with original information of concrete such like aggregate position, shape, size and so on. Then, based on meso analysis, the numerical model is divided into three phases material which including aggregate, harden mortar and Interfacial transition zone, three constitutive relations have been propose for each phase. At the last step, each element of three phases in numerical model is endowed with the constitutive relations which based on meso/sub-meso research. So, a numerical sample that has the physical background and based on meso structure has been build.

Through systematically arrangement, numerical samples have been simulated by computer. At the same time, real samlpes have been tested under uniaxial tension (T) and pressure (P). The test results are used to correction the parameters of numerical sample through compare results with simulation's results. After correction, the numercial sample had been loaded under circle loading. The energy dissipation in the process of circle loading be discussed. Then, extension the simulation to biaxial loading, including T/T, T/P and P/P three type simulation, finally, compare the results with the date get form real test.

According to source of randomness, three kinds of simulation based on the numercial model had been designed. The effection of randomness had been discussed briefly too.

However, the generation of numerical sample with original information is not so easy. The number of numercial sample with original information is not enough, and at the same time, most

results of other researcher's had been established on the samples which were generated by algorithm. For solve this problem that a batch of sample with the constitutive relation proposed in this paper had been generated by algorithm. Compare the samples generate by algorithm with those generate by real sample's digital images, the realiability of results get form other researcher can be known.

Finally, some problems just like the relation between Young's modulus and strength, localization of damage and so on which we care about lot had been dicussed simply.

Keywords: simulation, concrete, image process, constitutitive relation, meso-damage

目 录