Fatigue Capacity of Plain Concrete under Biaxial Fatigue Stresses with One Constant

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ABSTRACT

The fatigue tests of concrete have been conducted with constant confined stress, including biaxial compression, biaxial tension-compression and alternate tension-compression fatigue loading. The experimental results show that an increase of the horizontal stress leads to a change of the maximum vertical load-carrying capacity. Empirical relationships are proposed for predicting the maximum stress ratio as a function of lateral stress and fatigue life. Also, the observation of the failure modes indicates that concrete possesses similar failure patterns under monotonic and fatigue loadings. The investigation of this paper can provide for the design of concrete structures such as reinforced concrete bridge decks, crane beams, offshore platforms, concrete sleepers, nuclear power plants and pressure vessels. It can also give some suggestions for the revision of existing Design Code.

KEY WORDS: Concrete; constant confinement; biaxial; fatigue; failure criterion.

INTRODUCTION

Many structures are often subject to repetitive cyclic loads. Examples of such cyclic loads include machine vibration, sea waves, wind action and automobile traffic. The exposure to repeated loading results in a steady decrease in the stiffness of the structure, which may eventually lead to fatigue failure. The earliest research on fatigue properties of concrete materials is traced back to the end of the 19th century (Joly, 1898), the compressive fatigue tests so far have been most investigated (ACI Committee 215; Hsu, 1981; Oh, 1991). In recent years, many investigations concerning plain concrete under uniaxial cyclic tension, uniaxial alternate tension-compression and biaxial fatigue load have also been carried out. Very few experimental results on the response of concrete subjected to repeated biaxial loading are available in the literature. Fatigue behavior of plain concrete under biaxial compression (Su and Hsu, 1988), high-strength concrete subjected to proportional biaxial-cyclic compression (Nelson et al., 1988) and steel fiber reinforced concrete subjected to biaxial compressive fatigue loading (Yin et al., 1995) were investigated. Hollow concrete specimens were tested to investigate the fatigue response of concrete subjected to biaxial stresses in the compression-tension region and tension-tension region by Subramaniam et al. (1999) and Subramaniam and Shah (2002).

A review of the available literature indicates that most of the experimental results pertain to proportional fatigue loading. In practical structural applications, however, concrete structures may be subjected to nonproportional fatigue loading, where the load along the one axis are fixed with the fatigue loading imposed in the orthogonal direction. Consequently, it is necessary to research on the fatigue behavior of concrete subjected to nonproportional biaxial stresses. The limited research of plain concrete on nonproportional biaxial fatigue compressive loading was only reported by Lv (2007).

The main purpose of this paper is to investigate the fatigue strength of plain concrete under cyclic compression, cyclic tension and alternate tension-compression cyclic loading with constant lateral pressures. From experimentation we find that fatigue reduction coefficient changes with constant confine stress. Through the analysis of test result, the criterion of concrete under multi-axial fatigue loading has been founded, which can provide information for the fatigue design of concrete members.

EXPERIMENTAL PROCEDURES

Specimen and mix proportions

Plain concrete cubes with a size of 100×100×100 mm were subjected to cyclic compression loads and special dog-bone specimens with 350 mm long, 100 mm wide, 100mm thick were subjected to tension and alternate tension-compression fatigue loading. A detailed diagram for dog-bone specimens used in this paper is given in Fig. 1. All the dog-bone specimens were set by eight pieces of steel bar embedded in their two ends for connection between specimen and testing machine. The concrete used in the study had the following proportions, per cubic meter: cement 383kg; fine aggregate, 663kg; coarse aggregate, 1154kg; and water, 200kg. Commercially available Portland cement was used. Crushed natural stones were used as coarse aggregate with maximum particle size of 20 mm. River sand was used as the fine aggregates. The cubic specimens were cast in steel molds and the dog-bone specimens were cast in wood molds. The molds were removed after 24 h from casting and the specimens were placed in a curing room at a relative humidity of 95% and at a temperature of 20°C for 4 weeks. The 28-day compressive strength and the average modulus of elasticity of concrete, \( E_0 \), obtained by testing standard prism specimens (150...