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Behaviour of concrete-filled steel columns subjected to lateral cyclic loading

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ABSTRACT

This paper reports the findings of an experimental study that was undertaken to investigate the cumulative damage of in-filled steel columns subjected to quasi-static loading. The parameters studied are, the diameter-to-thickness ratio of the steel tube and two types of in-fills namely Plain cement concrete and Steel fiber reinforced concrete. This paper summarizes the results of phase I testing that consisted of benchmark tests to establish the hysteresis behaviour under variable amplitude cyclic loading and phase II testing that consisted of constant amplitude cyclic loading that focused on the effects of amplitude and number of cycles on damage accumulation of in-filled columns. Findings of these studies highlight the significant increase in ductility and energy absorption capacity and decrease in the damage index of Steel fiber reinforced concrete-filled steel columns compared to plain cement concrete-filled columns. A simplified equation for cumulative damage has been proposed to predict the damage index of in-filled columns. This index can be used as a measure for predicting the safety of new and existing in-filled columns against earthquake.

1. Introduction

Post earthquake reconnaissance and follow up research have indicated that most of the damage in structural members like columns is a result of insufficient column ductility and energy absorption capacity to sustain the large lateral displacement. In-filled steel columns are effective structural forms for such purposes because of their high compressive strength, energy absorption capability and ductility. Under the action of seismic forces, the damage induced in critical regions of in-filled steel tube columns is due to the cumulative damage of the steel tube caused by repeated cyclic loading in the post yield strain region. [1]

To investigate the seismic behaviour of concrete in-filled steel tube (CFT) columns, many quasi-static cyclic loading tests have been carried out in the past, such as Sakino and Tomii [2], Nakanishi et al. [3], Nakahara et al. [4], Elremaily and Aziznamini [5], Xiao et al. [6], Marson and Bruneau [7], Amir fam et al. [8], Kingsley et al. [9], Yaochun Zhang et al. [10]. All the aforementioned studies focused on standard loading protocols with ramping drift amplitude to obtain the cyclic behaviour. Studies on the effects of amplitude and number of cycles on damage accumulation are found lacking. Therefore issues related to correlation of observed hysteretic behaviour to damage of columns are found to be necessary to model and calibrate cumulative seismic damage of in-filled columns. The effort described in this paper is an initial step in this direction.

In this paper, a detailed experimental study on circular CFT columns has been undertaken under constant and variable amplitude loading combined with constant axial load. This study has been extended to steel fiber reinforced concrete in-filled steel tube (SCFT) columns and the results have been compared with CFT columns. The system variables and measured response were tailored to model and calibrate the cumulative seismic damage.

2. Experimental investigation

2.1. Details of experimental program

The experimental program consisted of tests on CFT and SCFT columns of diameter-to-thickness ratio (D/t) 38 and 57. The tests were conducted in two phases. Phase I testing consisted of benchmark tests on CFT and SCFT columns under variable amplitude loading combined with constant axial load. Phase II testing consisted of tests on CFT and SCFT columns under constant amplitude loading histories.

The hollow steel tubes used were 1 m long and were seam welded along the length. The range of steel tube diameter-to-thickness ratio chosen satisfies the limitations specified by various codes, namely, AISC LRFD $[D/t \leq (8E/f_y)^{1/2}]$ [11], CAN/CSA-S16.1-4(1994) $[D/t \leq (28\,000/f_y)]$ [12], and AIJ (Qie 1994) $[D/t \leq (23\,520/f_y)]$ [13], where f_y is the yield strength of steel and E is the modulus of elasticity of steel. All specimens were welded and strengthened with four numbers of 6 mm thick gusset plates at the bottom to ensure a strong connection with the footing. The columns were fixed at the bottom. The details of specimens and loading pattern are elaborated in Table 1.

2.2. Material properties

Tensile tests were carried out as per ASTM-A370 [14], on coupon samples that were cut from the steel tubes used to fabricate the columns. The

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