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Behavior of reinforced concrete walls subjected to monotonic pure torsion—An experimental study

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ABSTRACT

An experimental investigation was conducted on the behavior of eight half-scaled reinforced concrete (RC) cantilevered walls subjected to monotonic pure torsion. The wall specimens were designed with the same thickness but various lengths and amounts of torsional reinforcement. Firstly, the test program was presented. Secondly, the test results including the failure mechanism, experimental torque–twist curve, torsional strength and torsional stiffness were discussed. Test results indicated that the whole cross sections of the test wall units, with the largest aspect ratio of 8, could be fully mobilized to resist the applied torque. Finally, the calculations obtained from various analytical models and the ACI Code were compared with the experimental results of the cracking torque, the maximum torque and the torque–twist curves. It was found that the ACI code provided overall conservative predictions except that it gave high (unsafe) theoretical maximum torque for walls with moderate to heavy reinforcement content. The Softened Membrane Model for Torsion (SMMT) could provide a realistic prediction of torque–twist curves till the peak but it could not provide a good simulation of the post-peak curves. The test results also confirmed that the calculations of T_{cr} and T_{max} using Jeng's and Rahal and Collins' simplified non-iterative methods, respectively, were suitable for design applications.

1. Introduction

In seismic design, it is common practice to provide a multi-wall system for an asymmetric reinforced concrete (RC) building to resist the torsional force. The resistance mainly comes from the base shear distributed among the wall elements, and the torsional resistance of each individual wall is acquiescently ignored (e.g. [1,2]). However, in the case of an asymmetric RC frame building with a single major wall, which is called a single-wall-frame structural system in this paper, the torsional resistance of the wall might have a considerable contribution to the overall resistance since the extreme structural asymmetry would lead to a large twist and hence mobilize the torsional resistance of the single wall. There is a lack of information about the torsional response of a single-wall-frame structural system. Furthermore, asymmetric reinforced concrete buildings with a single major wall are not uncommon in regions of low-moderate seismicity which include Hong Kong. Thus, the investigations of such a structural system are essential. Nevertheless, the performance of the single-wall-frame system cannot be realistically understood without the knowledge of the torsional behavior of the single wall element. On the other hand, it is stated by ACI-318-08 [3] that for torsion design of solid sections with an aspect ratio of three or greater, it shall be permitted to use another procedure, the adequacy of which has been shown by analysis and substantial agreement with results of comprehensive tests. This study may also contribute to the related area.

During the last decades, extensive experimental work has been performed to investigate the behavior of RC elements subjected to pure torsion (e.g. [4–10]) and combined loadings (e.g. [11–14]). These previous experimental studies of torsional members were mainly conducted on beams, from which the torsional strength and stiffness, twist angle, crack patterns as well as failure modes were found to be a function of concrete strength, amount of torsional reinforcement, aspect ratio of cross section, spacing of stirrups and thickness of concrete cover. However, the experimental researches on the behavior of wall type elements subjected to either pure torsion or torsion combined with other loadings were rather limited. Since the geometrical configuration and reinforcement details of a RC wall are rather different from those of a beam, the applicability of the existing torsional mechanisms and analytical models, which are developed on the basis of the beam tests, needs to be investigated. The objectives of this study are to experimentally examine the torsional behavior of RC walls and to verify the applicability of the existing analytical torsion models. The test data and investigations reported herein would provide valuable information for both research and design applications.

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