



An investigation into crack and its growth on the seismic behavior of steel shear walls



V. Broujerdian, A. Ghamari*, A. Ghadami

Department of Civil Engineering, Iran University of Science and Technology, Tehran, Iran

ARTICLE INFO

Article history:

Received 26 April 2015

Received in revised form

9 September 2015

Accepted 21 September 2015

Keywords:

Steel shear wall

Crack

Seismic behavior

Response modification factor

Extended finite element method

ABSTRACT

Numerical investigations carried out into the effect of crack and its growth on the seismic behavior of steel shear walls are presented in this paper. Twenty two steel shear walls with initial central or edge crack were modeled using general purpose finite element programs of ANSYS and ABAQUS. The numerical method used in this study is extended finite element method based on cohesive crack approach. Static and quasi-static analyses were done to evaluate the effect of crack and its growth on lateral behavior of system. Both nonlinearities of material and geometry were considered. As there is no experimental study on the cracked steel shear wall system in the literature, only the finite element modeling assumptions and process were validated using some useful laboratory tests. According to the obtained load–displacement curves, central cracks are more critical than edge cracks and have a great impact on the strength and energy absorption of shear wall system. The results show that long central cracks cause the system fails in a brittle manner. In addition, the response modification factors of steel shear walls in the presence of cracks with different lengths were calculated.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Steel shear wall is a lateral load bearing system which has shown good behavior in past earthquakes and its performance is corroborated by numerical and experimental studies [1]. In addition to its ductile behavior, the considerable stiffness and strength of steel shear wall has made it technically and economically suitable [2] to use as a load bearing system in different structures whole over the world [3]. However, there is a constructional problem that could weaken this system and change its behavior to a brittle one.

With respect to the common height of stories in buildings, nearly 3 m, and considering shop executive limitations, an integrated plate is rarely used for a whole panel. Integrated plates are only used in small and full-scale experimental studies [1–6]. As shown in Fig. 1, steel shear walls usually consist of two separate plates welded together in a horizontal joint. On the other hand, defects and cracks in welded joints are probable and they can propagate due to cyclic loading, corrosion, and etc. Although a great deal of research is devoted to crack analysis of steel plates, none of them simulates the steel shear wall boundary conditions. So, this paper investigates the effect of cracks in such system.

Considering a steel plate under pure shear, when the shear

loading reaches a certain value, the plate buckles under the induced diagonal compressive stresses and it shows an out-of-plane deformation. In the steel shear wall system, plate buckling is usually the dominant mode of failure. Therefore, the influence of cracks on the buckling and load bearing capacity of thin-walled panels must be investigated and considered in the design process [7–13].

Sih and Lee investigated the behavior of cracked plate under tensile and compressive axial loads [14]. They showed that as crack length increases, pre-buckling capacity of plate reduces. Huang and Shaw studied the buckling behavior of cracked plate under tensile force using finite element method [15]. In that study, the effect of crack length, boundary conditions and biaxial loading were investigated. Riks et. al. [16] investigated buckling and post-buckling behavior of cracked plate under tensile load using finite element method. According to their results, changing the post-buckling shape would result in stress accumulation at the tip of crack. This accumulation is intensified as the crack length increases. In line with that research, several studies have been conducted into the effect of cracks on thin panels under pure shear [5–7,11], axial compression [17–20] and axial tension [21–23].

Backstrom and Kivimaa [24] investigated critical crack size and growth of cracks at a passenger ship's door corner and their influence on the remaining fatigue life of the door corner and the associated bulkhead. In addition, a fracture mechanics calculation procedure and its software application was developed.

In 2010, a new fatigue crack growth rate model was proposed.

* Corresponding author. Fax: +98 8412242640.

E-mail address: aghamari@cmps2.iust.ac.ir (A. Ghamari).



Fig. 1. Typical implementation of steel shear walls.

Moreover, in order to obtain the fatigue crack growth characteristic of a structural element before carrying out enough fatigue tests, the engineering approach to estimate the model parameters by recurring to some research findings on evaluation of fatigue properties was investigated [25].

Presence of the seismic activities causes significant tether tension variations in the taut-moored compliant structures. In 2014, response analyses of triceratops to seismic activity in the presence of waves were examined. In this research, based on the finite element analysis results, it is seen that the heave and pitch responses of the buoyant leg structures and the deck are significantly high under these tether tension variations [26].

As pointed, previous studies mainly focus on the behavior of individual plates out of the structure.

Therefore, the effects of crack on the behavior of a complete steel shear wall system and its seismic design parameters have not been considered yet. In this study, the effect of cracks in steel shear walls with regard to their effect on the overall behavior of structures is considered. For this purpose, the extended finite element method, briefly called XFEM, is used. This method which originally proposed by Belytschko and Black [27], and Dolbow and Belytschko [28] allows crack modeling via finite element method without need to re-mesh upon crack growth. XFEM has become increasingly popular to solve different fracture problems [27–35].

2. Materials and methods

2.1. Research method

In this paper, the effect of crack on the behavior of steel shear wall is considered from several aspects. First of all, two central and edge cracks are presented in Fig. 2 will be analyzed without considering the crack growth phenomenon. The results will reveal

which crack is more destructive. After determining the type of critical crack, the effect of crack growth will be assessed. In this case, there are three types of comparisons.

1. A comparison between pure crack and propagated crack.
2. Models with buckled crack coinciding with real crack growth at wall are created and will be analyzed to determine the effect of crack growth.
3. In the third step, the effect of initial horizontal crack length on the crack growth will be investigated.

All studies are performed numerically using XFEM. Since the base material is steel, which is a ductile material, the crack is modeled as a cohesive one based on Dugdale model. Due to the geometric nonlinearity of steel shear wall arising from its low thickness, compatibility and equilibrium equations are formulated based on large deformation assumption. To simulate the material nonlinearity, the elastic–plastic behavior with yield surface of von Mises yield criterion is used. ANSYS software [36] is used in combination with ABAQUS [37] to accelerate the modeling and analysis process. The path of crack growth is detected in ABAQUS using Solid elements, and then all elements are simulated in the form of Shell in ANSYS by the use of APDL capability.

2.2. Fundamentals of XFEM method

The XFEM is an extension of classical finite element method using framework of partition of unity. The advantage of XFEM is that it removes the need to re-mesh in crack propagation problems. In the XFEM method, two additional displacement functions are added to the finite element solution space. Discontinuous function is one of these functions which dedicates displacement jump across the crack surface. The second function represents the singularity of crack tip. The displacement function can be

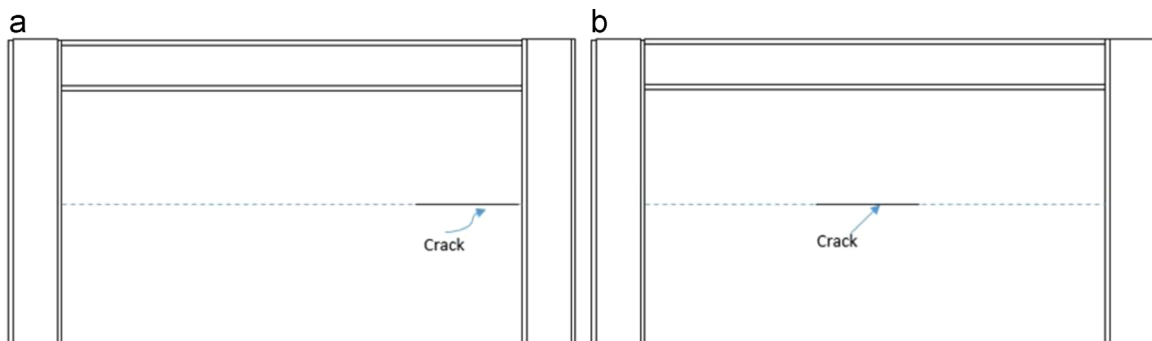


Fig. 2. Presentation of the cracked plate shear walls.

Download English Version:

<https://daneshyari.com/en/article/6779135>

Download Persian Version:

<https://daneshyari.com/article/6779135>

[Daneshyari.com](https://daneshyari.com)