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Non-linear Study of Various Slit Shear Walls in Steel Structures

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ABSTRACT

Seismic retrofit strategies have been developed in the past few decades following the introduction of new seismic provisions and the availability of advanced materials and methods. It can be observed that new approaches to deal with more lateral forces are more innovative and more energy absorbent . In line with this, there is a growing trend toward the use of steel shear walls as a system with too much energy dissipation, low weight, and compatible architecture.This study has evaluated some Lateral Forces Resisting Systems (LFRS) for retrofitting of steel buildings specially Slit steel panels as an effective and economical method. The main concept of these panels is for the steel plate between the Slits to behave as a series of bending links, which undergo big flexural deformations relative to their shear deformation. Each flexural link can be examined independently from one another, and its behaviour can be approximated to a double curvature column in the sense that each flexural link develops plastic hinges at the ends. Some models in ABAQUS were conducted. The observations indicate that without changing the property of panel (i.e., material or dimensions), stiffness and strength can be finely-tuned by changing the geometric parameter. This thesis focuses on achieving the proper region for determining the geometry factors; in addition to brilliant design to obtain the acceptable responses in Slitted shear walls.

Keyword: Retrofitting, Steel Buildings Slit steel shear wall, damper device, Non-linear analysis

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B = width of shear wall panel;

b = width of flexural link;

E = Young’s modulus of steel;

G = shear modulus of steel;

h = height of wall;

K_{we} = measured initial stiffness;

K_{wo} = shear stiffness of panel without Slits;

K_{wt}=estimated initial stiffness;

k =shape factor for rectangular section =1.2

k(α,β) = multiplier reflecting flexural link's imperfect

rigidity on its ends;

L = the frame bay width

t_p = the infill plate thickness

l = length of flexural link;

m = number of flexural link layers;

n = number of flexural link in one layer;

Q_{wo} = shear yield strength of steel panel without Slits;

Q_{wt}= full plastic strength of flexural link neglecting effect of shear stress

F_{yp} =is the yield strength of the infill plate

A_b = cross-sectional areas of the storey beam

A_c = cross-sectional areas of the column

I_c = The moment of inertia of the column

I_b = The moment of inertia of the beam

V_{yp} = Probable storey shear strength:

α=shear span aspect ratio

β =ratio of total link length in the vertical direction to the wall height

CHAPTER 1

INTRODUCTION

1.1 Background

Seismic retrofitting is the modification of existing structures to make them more resistant against seismic activity, ground motion, or soil failure due to earthquakes. With better understanding of seismic demand on structures and with our recent experiences with large earthquakes near urban centres, the need of seismic retrofitting is well acknowledged. Prior to the introduction of modern seismic codes in the late 1960s for developed countries (US, Japan etc.) and late 1970s for many other parts of the world (Turkey, Iran etc.), many structures were designed without adequate detail and reinforcement for seismic protection.

In recent decades, most of the structural engineers with the introduction of systems with high energy dissipation, concentrate on retrofitting structures and suggest new approaches dealing with more ductility.

According to the seismicity and the increasing need of retrofit design based on performance levels, necessity of selecting systems which are seismic resistant, relied on documented scientific researches rather than more engineering judgments, is felt more than ever. Modern design codes are increasingly necessary to have ductility tendency related to the Lateral Force Resisting System (LFRS).We know that perhaps over 90% of the buildings in our country are required to retrofit because they are designed based on old codes and almost all of them have lack of satisfying LFRS.As it is clearly known, there is no exact answer to choose LFRS for special case study. But with the improvement of our knowledge about seismic behaviour of LFRS can assist our engineering judgments. Numerous research programs have confirmed the introduction of LFRS with strategy of avoiding brittle fractures of the frame. To reach this idea, it is needed to use nonlinear analysis methods such as rigid-plastic hinges, to approximate the post-yield behaviour of structural elements.

To sum up, this thesis is a brief review in some LFRS choices for retrofitting of steel structure.

1.2 Objective and Scope

The initial motivation and scope of this thesis is based on study and evaluation of some different LFRS for using in retrofitting project and it specially concentrates on steel shear wall as one of the best selections with high energy dissipation in the structural system.

To comply with this serious need, this research proposes an alternative method for seismic which Strengthened with LFRS especially for steel structural system. This thesis first demonstrates an application of conventional LFRS such as X-brace or Chevron, by introducing special case-study and presentation of quantitative and qualitative study, but it has a special focus only on improving seismic parameters of construction for lateral force.

Another choice that is evaluated in this thesis is the steel shear wall to resist lateral earthquake forces in both new construction and seismic upgrade of existing structures.

This study never aimed at going into great details of retrofitting; it only draws the analogy among some LFRS as some options for retrofitting.

Finally, to bring the thesis to a conclusion, it should be noted that the main idea of the thesis is proposing the new generation of steel shear walls that are called *steel Slit shear walls* (Toko Hitaka and Chiaki Matsui) as development of a passive damper device, consisting of a steel plate shear wall with vertical Slits.

1.3 Chapter Overview

This section provides an overview of remaining content of the thesis.

Chapter 2 provides quantitative and qualitative study for special case study and presents push over analysis for different X-brace system and chevron system in two direction of x and y actually this chapter is an excuse to remember quantitative and qualitative study stages. On the other hand, chapter 2 only decides to shape thinking about different LFRS and is not entered in details of retrofitting stages or achieving the exact solution for case-study.Fundamentally, this chapter is a kind of introduction for the other chapters.

Chapter 3, at first, presents a brief chronological summary of previous research on conventional steel plate shear wall, and then uses this LFRS for case-study of chapter 2 and finally discusses some problems that are involved in this system and recommends two methods for the solution of these problems: 1. Design of optimal Configuration for stiffener 2.The use of Slit steel panels.

17 steel panel specimens with the same geometry and different Stiffeners Configuration are compared with one another by the push over analysis in chapter 4 providing so, optimal design as a solution for problem that proposed in the previous section.

Chapter 5 introduces Steel Slit shear panels and presents philosophy of this system. After that, it discusses procedures of stress Distribution in Slit panels and then presents a formulation for the estimation of the stiffness and strength of Slit steel panels.

The next section investigates the effect of varying term k (α, β) on seismic capacity of the wall. Observations make significant recommendation on the range of geometric notations (α, β) for design of slitted panels.

In the final part of this chapter, the effect of connection details between Slit plate and adjacent column was evaluated. To acheive this purpose, 3 three story frames in 1/3 scale were modeled in ABAQUES and the results were compared.

Chapter 6 supplies a summary of the research conducted and presents conclusions and suggestions for future studies.

CHAPTER 2

CASE-STUDY

2.1 Introduction

May be over 90% of buildings in our country are required to retrofit since they are designed by old codes. They also have less than 18 meter height. In fact, most structures which engineers are dealing with them for retrofitting are limited to short structures. This object demonstrates the necessity of important focus on this type of structures. On the other hand, one of the most common ways to brace steel structures is, using X-brace system bracing and also chevron system. It is clear that these options with an acceptable stiffness can be considered a proper complementary for flexural frames which have high ductility. However, the question which is discussed for structures with specific geometry conditions is that which of the special bracing systems has better performance levels as well as has the higher seismic capacity graph(pushover graph). This chapter first demonstrates an application of conventional Lateral Forces Resisting System (LFRS) such as X-brace or Chevron, with introducing a special case-study and presenting quantitative and qualitative study but it has a special focus only on improving seismic parameters of construction for lateral force. The case study related to a dormitory in Mashhad, centre of khorasan province. This case study is introduced because it has no lateral resisting force system. And the objective of this thesis is to present some procedures for retrofitting of buildings to deal with lateral forces.

2.1.1 What is the qualitative evaluation of buildings?

The qualitative evaluation is the first stage of the seismic strengthening. In this stage, the general recognition is obtained based on structure seismic behaviour, and primary information is collected based on structure site and its specifications. Considering that they have seismic region conditions and based on previous earthquakes experiences, and regarding to the fact that qualitative methods have seismic region conditions, particular forms of gathering information is used.

If gathering information of qualitative studies cannot be done correctly based on qualitative evaluation, in some cases demand or lack of demand of retrofitting in the same stage can be recognized ; and it can be avoided to do quantitative evaluation stage, which it is much time-consuming and high- cost whether it is to calculating information or not. Generally, the qualitative evaluation is a introduction to the quantitative evaluation; and when it is critical to the structure seismic strength situation in the qualitative evaluation, it can be made a correct decision about changing application or destructing it in the same qualitative evaluation stage, and it can be avoided to start the quantitative evaluation stage and finally to investigate the structure strength-making approaches.

2.1.2 The stages of the qualitative evaluation:

In this section, we are not going into details because the main goal of this study is focusing on LFRS**.**

2.1.3 Gathering primary information:

Location:

The structure topology is in Razavi khorasan province, Mashhad

Structure specifications:

There is no design document of the structure by considering the year of built (1350). This structure has four roofs, which include the steel frame with arching roof, also it should be noted additionally that there is not any column in two end sections of the buildings and resistance of the lateral forces are supported by proper walls that not exist in underground story. Fig.2.1 to 2.4 show facades and plans of dormitory. And tables2.1 to 2.4 has some general informative data about building.