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Investigating affecting angle changes of polymeric carbon fibers on the behavior of reinforced FRP steel shear wall

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ABSTRACT

Studies conducted about seismic behavior of steel shear wall and the experience of past earthquakes is the promising of an effective and ductile system against lateral loads. Despite the high advantages of steel shear wall compared to other lateral bearing systems, the factors prevent the development of implementing these walls.

The seismic behavior of composite steel shear wall with different fibers angles has been investigated by the nonlinear analysis. Comparison of results shows that in stiffness, over strenght and shear capacity increase in the composite wall with coating of carbon polymer fibers and energy absorption considerably increases which improves the behavior of steel shear wall. But carbon polymer fibers decreases ductility of system. Also, the bidirectional fibers and fibers with different angles have been examined in composite walls which angles show a different effect on seismic parameters in various angles.
Keywords: *steel shear wall, polymeric carbon fibers, nonlinear analysis, finite elements, the angle of the carbon polymer fibers.*

INTRODUCTION

Observation of buildings performance in earthquake has had the fundamental importance in the genesis of earthquake engineering science. The first seismic design criteria was formed following viewing delegation of Italian engineers from the damaged buildings in the devastating earthquake of Messina, Reggio in 1908 [1].

High information has been obtained bout the behavior of a variety of structures against earthquake frequency over time and growth of structure dynamics and especially after entering the computer to the scene of engineering researches which in turn has led to improvements in seismic standards, but scientific findings strongly have required experimental confirmation.

High approximation of mathematical methods and models, as well as the properties of material, fittings and structures can lead to irrelevant and reverse results and for this reason, they should be tested in practice to verify and calibrate the relationship and coefficients.

Studies conducted about seismic behavior of steel shear wall and past earthquakes experience is promising of an effective and ductile system against lateral loads. Despite high advantages of steel shear wall compared to other lateral bearing systems, factors will prevent the development of implementing these walls.

Including the lack of information and being new issue related to the design of such structures and the deficiency of information on the seismic behavior as well as the lack of a effective and reliable analysis instrument and other obstacles are located on the way of using widely from these systems.

The most ideal behavioral condition of this system is that the steel plate is submitted before buckling. Several methods are used to prevent the buckling of the steel plate in elastic area such as using hardeners, the concrete coating as well as the polymeric carbon fibers coating.

Mechanical behavior of composites

Researchers tested cementing composites to concrete and roof for the first time in Europe and America in 80s AD. Positive test results also inclined the scientific society to cover the rest of the structure parts by

composites and study them. Then, it was found in Japan that this method can be an appropriate response for the severe earthquakes which threatens that country. Japanese for the first time used commercially composites for repair and rehabilitation of structures in the world [2]. Amirkabir Technology University conducted the numerical and experimental studies on steel shear wall and introduced the third generation of this type wall as reinforced steel shear wall with polymeric fibers in 2003. [3]
Rahai and Alipour [3] conducted studies on system of the reinforced wall with FRP. Their results showed which shear capacity of system can be increased from 7.5% to 20% compared to bare steel. The FRP layer did not change significantly the stress distribution in of the steel sheet.
Damage to the fibers is expected in the corners of the plate and in direction of the stress field due to stress concentration and the development of tensile stress to plate diameter. Also, Nateghi and Kharrazi [2] studied analytically the nonlinear behavior of composite steel shear wall by using glass fibers reinforced polymer (GFRP) and layering.
The results showed that the ultimate shear capacity and shear stiffness of reinforced shear wall with GFRP layer compared to unreinforced SPSWs increases. If the main direction of GFRP layering stress is in the direction of stress field line, the shear capacity and stiffness will increase for system. The main directions of GFRP layering on filler plate have a negligible effect on the cumulative dissipated energy field. The latest research was conducted on composite system at Amirkabir Technology University in 2014 [4]. Properties of steel shear wall have been studied numerically and experimentally in order to study the effect of fibers angle on LYP.
Studies have been conducted in three stages. First, LYP was displaced by normal steel shear wall. The results indicate which the stiffness, resistance, ductility, energy absorption and over strenght coefficient increase in steel of LYP.
Second, LYP steel shear wall is LS with CLS, CFRP strengthened. The results show that stiffness, resistance, energy absorption and over strenght coefficient increase. however, ductility decreases. CLS transfers a lower stress to the border frame of SS and LS. Finally, the effect of CFRP fibers angle has been studied.
Mechanical behavior of the composite layers depends on the characteristics and cumulative percentage of the fibers and resin as well as the direction of fiber. The different parts of a structure composite fiber can obtained from a few layers with various directions. Single-layer behavior is very important structurally in a macro mechanical scale and studying the structural relationships has several applications in this scale. Material behavior can be studied in the macro mechanical level after the selection of composite composition macro mechanically. Identifying elements is not discussed in macro mechanical scale and relationship stress - strain is determined by matrix of stiffness which its elements have been identified by tension test.

Carbon fibers

Carbon fibers are of the most important used reinforcements in the advanced composite materials and a evolution has been created in materials technology by its manufacture. Graphite fibers are the most important form of carbon structure in terms of industry.
But, generally carbon has two well-known crystalline structures (diamond and graphite) and is also found in the semi-crystalline and glassy states. The graphite structure consists of hexagonal layers with a shared strong bond. The layers are located on each other with the layout arrangement of Figure 1 which junction between the layers is of Van der Waals weak type.

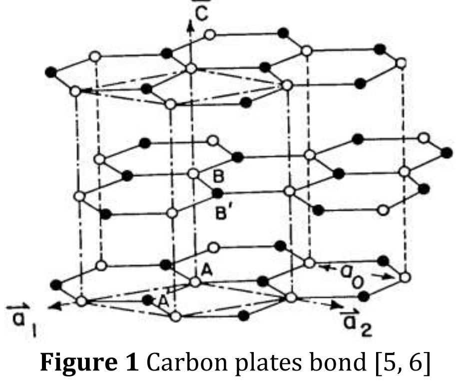

Figure 1 Carbon plates bond [5, 6]

Graphite properties are highly anisotropic because of the tremendous difference of intra inter plate bonds so that the direction of elasticity modulus is theoretically 1000 Gpa in fundamental plate and is only 30

Gpa along with perpendicular to this plate. Due to the low density of these substances, finally the fibers with a high modulus are achieved.

Numerical modeling

A model of steel shear wall and six models of shear wall coated by polymeric carbon fibers with a thickness of 2 mm were created to compare the behavior of steel and composite shear wall with polymer fibers coating of carbon as well as the impact of the fibers angle on the behavior of composite shear wall by finite elements modeling method and geometric and material nonlinear analysis.

Thickness of steel plate for all samples is 7mm and frame dimensions are as 3m height and 6 m width of span (Axis to Axis). Geometric properties of the peripheral frame beam and column has been shown in Figure 2.

Table 1 Samples introduction

Sample	Fibers angle (degree)
SSW	----
Cssw-1	Bidirectional
Cssw-2	0
Cssw-3	30
Cssw-4	45
Cssw-5	60
Cssw-6	90

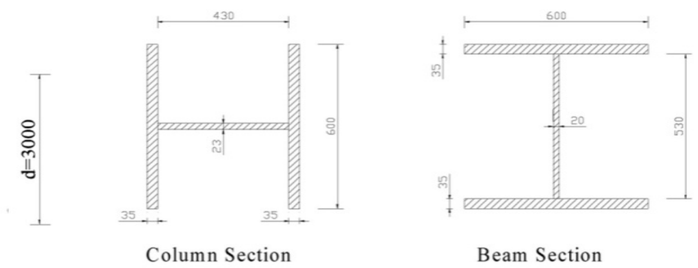

Figure 2: the beam and column section of peripheral frame

Verifying modeling

Laboratory reference model [3, 4] has been used to ensure the accuracy of the composite shear wall finite element modeling with polymer fibers.

The experimental model has been shown in Figure 3 as finite element modeling of Figure 4 and analyzed. Peripheral frame has formed from 2IPE200 with 12mm plate on their wings. Number of meshes has been selected in modeling the grid (meshing) of elements so that the nodes of the beam, steel column and sheet as well as polymeric carbon fibers reach each other in a point.

Then, these points were mixed together to form an integrated system. Beam-to-column connection is also considered by this technique. Model view after analyzing has been displayed in Figure 6*.*

Figure 3 The geometry of experimental model [3, 4]

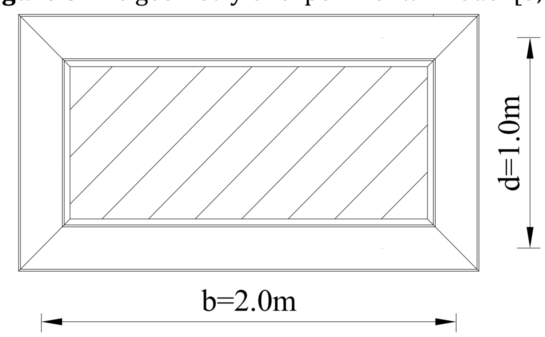

Figure 4 Finite elements modeling

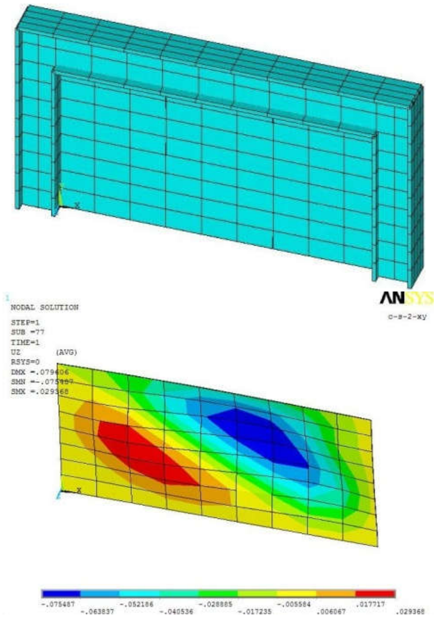

Figure 5 Displacement in outside of plate

ANSYS powerful software was used for finite element modeling that has the capability of elastic and ductile behavior. Shell element with the ability to model large deformations, limit strain, ductility, nonlinear behavior, buckling of outside plate has been used for finite element modeling of steel components.

Solid element with 6 freedom degrees at each node has been used for modeling FRP. Using these elements has been also proposed in [4]. Finite element analysis and experimental results have been compared with each other in Figure 6 which shows the high convergence of results. Therefore, other models with the actual dimensions can be analyzed by ensuring the results of ANSYS that will be presented in later sections.

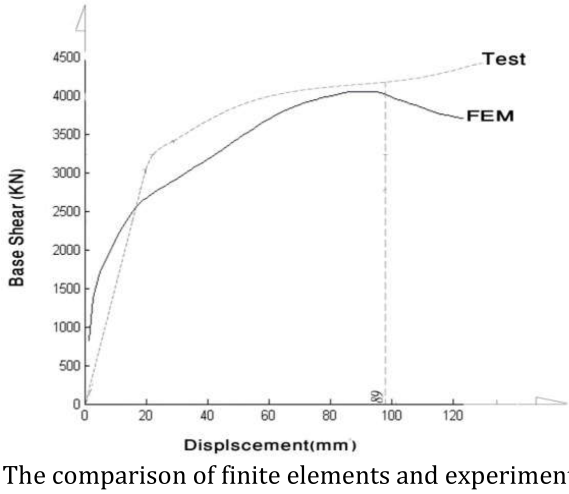

Figure 6 The comparison of finite elements and experimental results

COMPARISON OF STEEL AND COMPOSITE SHEAR WALL

The load-displacement diagram of steel and composite shear wall has been compared with each other in Figure 7. The diagrams of this figure show that if there isn't limitation of lateral displacement, the capacity of composite shear wall will have ascending trend but the steel shear wall behaves as perfect elasto-ductile. Seismic parameters proportion of composite steel shear wall (with bidirectional fibers) to steel shear wall has been given for a more detailed comparison of the two systems in Table 2. The results of this comparison shows which polymeric carbon fibers coating causes until stiffness and over strenght increase 80 and 16%, respectively.

Also, the energy absorption and shear capacity become respectively 3.63 and 2.93 fold that this proportion has been a substantial increase and improves the behavior of steel shear wall. But, polymeric carbon fibers reduce the ductility of system.

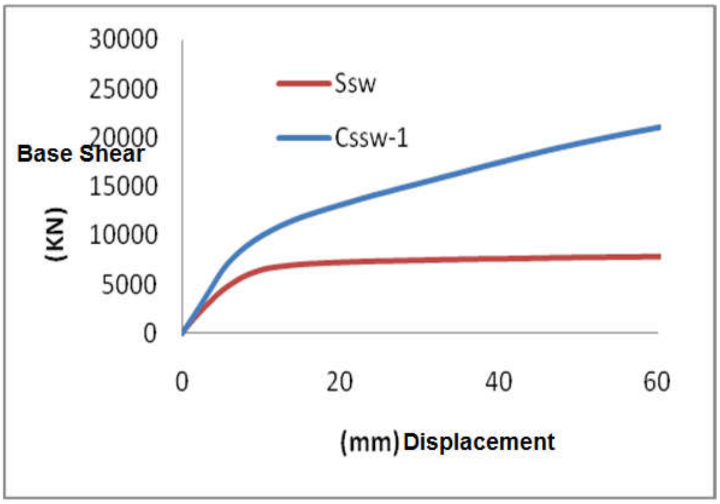

Figure 7 Diagram of load-displacement

Table 2 Comparison of steel and composite shear wall

Ratio	Absorbtion Energy	Ductility	Over Strength	Stiffness	Capacity
Cssw-1/ Ssw	3.63	0.61	1.16	1.80	2.93

INVESTIGATING THE ANGLE OF FIBERS

The behavioral comparison of composite steel shear wall with bidirectional fibers and fibers with different angles is observable in Figure 8. The system with 45 ° angle has higher energy absorption capability than other fibers angles and this capability of system decreases by increase of fibers angle.
Also, results show which the ductility increases only to 11% value and other parameters decreases at 90 ° (40%, energy absorption; over strenght, 22%; stiffness, 8% and capacity, 18%). Stiffness degree and energy absorption increase about 10 and 24%, respectively and high changes don't occur in over strength and ductility at 45 °. The ductility and over strenght of system are reversed at angles of 30 and 60 ° and energy absorption of system increases at both angles.

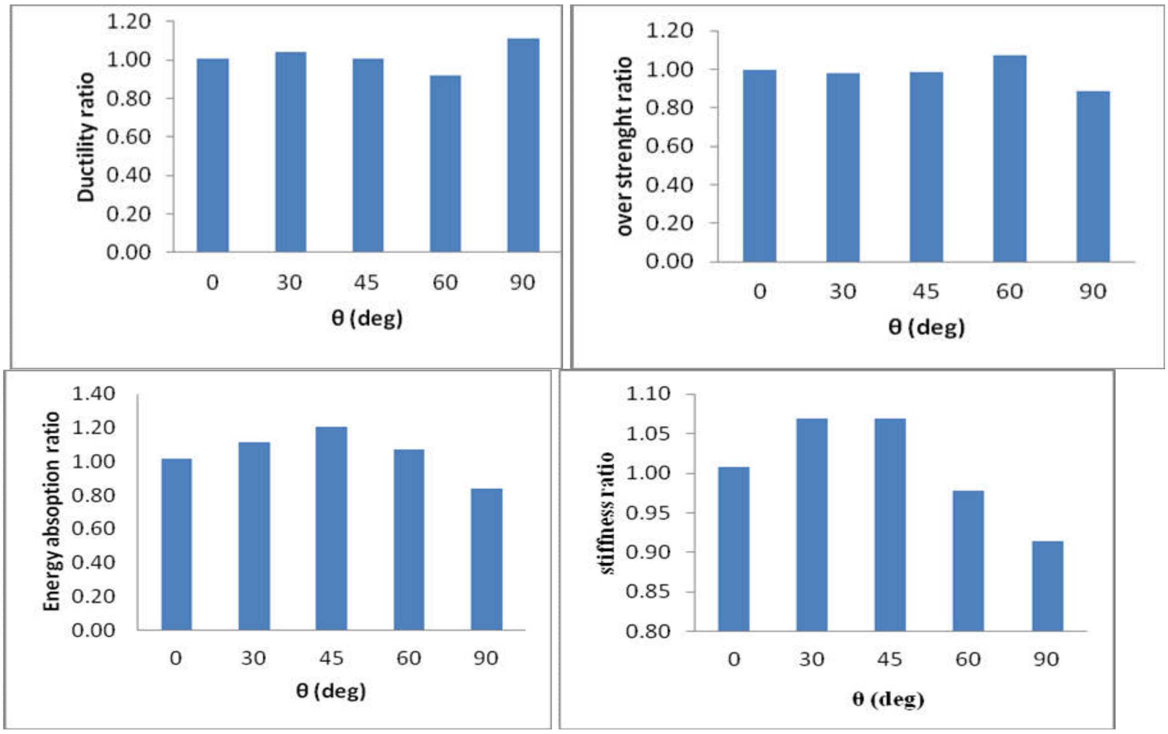

Figure 8 Diagram of seismic parameters ratio

CONCLUSION

Comparison of results shows which stiffness, over strenght and shear capacity increase in composite wall

with polymeric carbon fibers coating. Also, its energy absorption increases considerably that causes to improve the behavior of steel shear wall. But polymeric carbon fibers reduce the ductility of system.
The comparison of composite walls as bidirectional fibers and fibers with different angles shows that ductility increases at 90 degrees and other seismic parameters (stiffness, energy absorption and coefficient of over strenght) reduce. Stiffness and energy absorption increases and change doesn't occur in the ration of over strenght and ductility at 45 ° angle. The system behavior is reversed in ratios of over strenght and ductility at 30 and 60 ° angles. Also, energy absorption of system increases in both angles.

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