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Analytical Study on Different Types of Steel Slit Dampers

Akhil T Mani[1], Shilpa Sara Kurian[2]

[1]*Mtech Student, Computer Aided Structural Engineering, SNGCE, Kadayirippu P.O Kolenchery, Kerala, India*
[2]*Assistant Professor, Civil Department, SNGCE, Kadayiruppu P.O, Kolenchery, Kerala, India*

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Abstract - *The seismic resiliency of reinforced concrete (RC) structures can be significantly improved by using hybrid coupling beams installed with metallic dampers. Inelastic deformation is concentrated in the shear link during a severe earthquake thus the damper yields first and absorbs a large amount of energy, protecting the RC part of the structure. This paper presents an analytical study on different steel slit patterns, including an angle of 45 degree slit, 30 degree slit, 15 degree slit, 0 degree slit and circular slit patterns, to examine the ductile behavior and to identify the best steel geometry. Non-Linear dynamic analysis is conducted in ANSYS workbench 16.1 to observe the cyclic behaviour of steel plates with different slit patterns. Peak load and displacement with corresponding time is observed for comparison. It was found that load carrying capacity and number of cycle's increases in 15 degree steel slit as compared to other type of steel geometry.*

***Key Words*: Hybrid coupling beams, Metallic damper with slits, cyclic behaviour, dynamic analysis, shear link.**

1. INTRODUCTION

1.1 General Background

Recent major earthquakes including the 2010 Maule earthquake (Chile, Magnitude of 8.8), 2011 Tohoku earthquake (Japan, Magnitude of 9.0) and 2011 Christchurch earthquake (New Zealand, Magnitude of 6.3), have demonstrated that our built environment and infrastructure, Particularly in the urban context, need to be more resilient to earthquakes. In order to ensure minimal disruption to everyday life and business in urban society, prompt post-earthquake recovery of buildings is a clear need [1]. The coupling beam plays as the first protection in the reinforced concrete structures. In order to dissipate more energy, a hybrid coupling beam is developed which consists of a metallic damper in series with the concrete coupling beam. The strength of the metallic damper is carefully selected so that the RC part of the coupling beam remains elastic, while all plasticity goes into the metallic damper. This mechanism protects the RC part from seismic damage. And the metallic damper can be quickly replaced once it is damaged. This significantly enhances the reparability of entire structure, making it possible to be immediately functional after earthquakes. Coupled wall systems are often used in high-rise buildings due to their superior lateral strength and stiffness. In such a system, coupling beams are designed to undergo inelastic deformation and dissipate seismic energy [1]. This paper presents an analytical study on different patterns of steel, including an angle of 45 degree slit, 30 degree slit, 15 degree slit, 0 degree slit and circular slit patterns, to examine the ductile behaviour and to identify the best steel geometry.

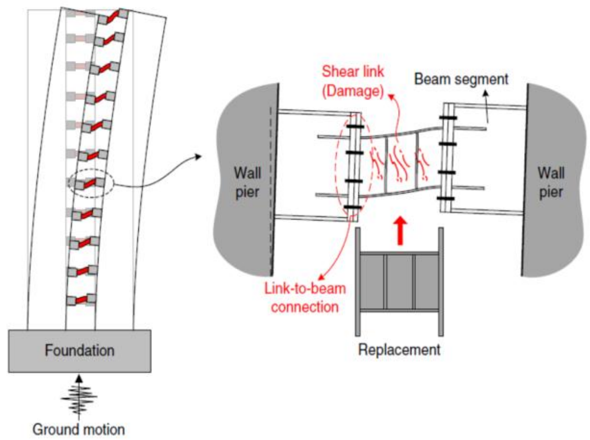

Fig -1: Replaceable steel coupling beam

2. NUMERICAL INVESTIGATION USING ANSYS WORKBENCH 16.1

2.1 Base Model

Numerical modelling of Steel plate with patterns of slit models were done using ANSYS 16.1 WORKBENCH, a finite element software for mathematical modelling and analysis. The dimensions of all the 5 specimens are same. Width of plate is 6 mm, depth is 150 mm and the length is 476 mm.
The steel plates were given slots of different patterns, including an angle of 45 degree slit, 30 degree slit, 15 degree slit, 0 degree slit and circular slit patterns. For each plate an equal area of slots were driven out. The Analysis requires input data for material properties are as shown in Table 1. Figure 2 showing the modelled view of Steel with 45 degree slit angle. Figure 3 showing modelled view of Steel with 30 degree slit angle. Figure 4 showing modelled view of Steel with 15 degree slit angle. Figure 5 showing modelled view of Steel with 0 degree slit angle. Figure 6 showing modelled view of Steel with circular slit.

Table -1: Material Properties of Steel.

Young's modulus of Steel (Gpa)	206
Poisson's ratio of Steel (ν)	0.3
Density of Steel, (kg/m^3)	7850
Yield Stress (Mpa)	458

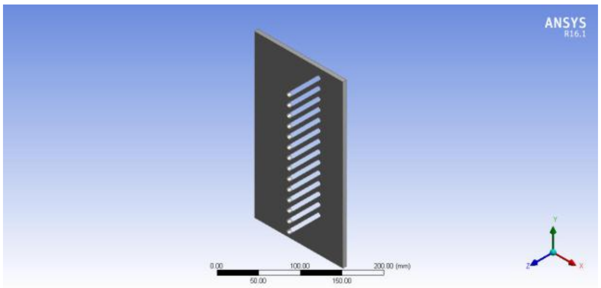

Fig -2: Modelled view of Steel with 45 degree slit angle.

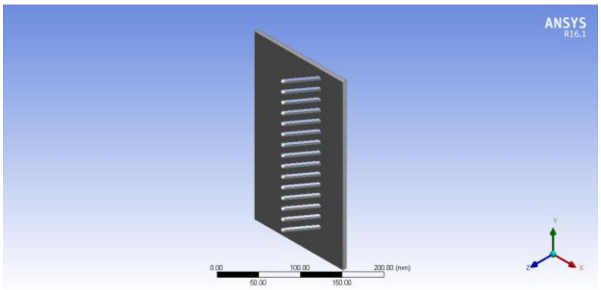

Fig -3: Modelled view of Steel with 30 degree slit angle.

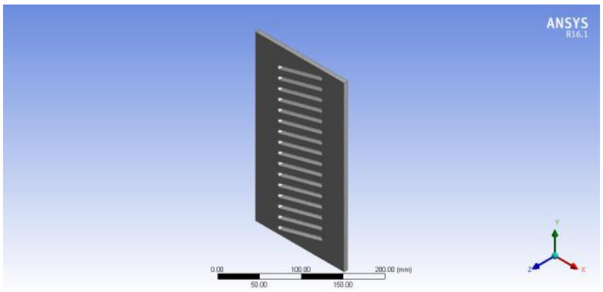

Fig -4: Modelled view of Steel with 15 degree slit angle.

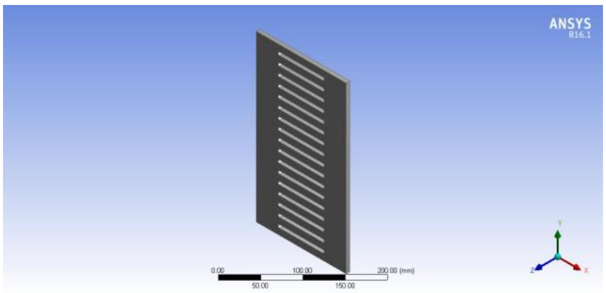

Fig -5: Modelled view of Steel with 0 degree slit angle.

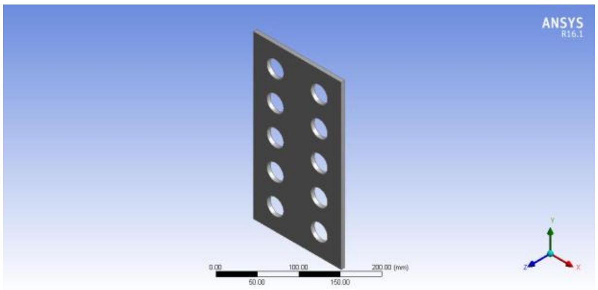

Fig -6: Modelled view of Steel with circular slit.

Non-Linear Dynamic loading is given at one point where the other end is made fixed to restrain axial deformation for each steel plates having different steel geometry. The displacement history comprises of 2 identical cycles at 5,10,15,20,25,30,35,40,45,50,55,60 mm [2] see Chart 1.

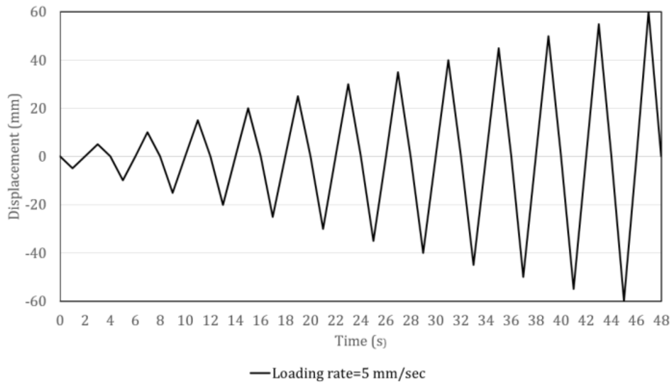

Chart -1: Loading Protocol.

3. EXPERIMENT RESULTS AND DISCUSSIONS

3.1 Hysteretic behavior

The analytical force-displacement hysteresis curves for the specimens are given below. It is observed that all the specimens shows stable hysteresis curves not experiencing any sudden stiffness and strength degradation. The specimen with circular slit shows high load carrying capacity with lower displacement value as compared with other specimens. Specimen with 45, 30,15 and 0 degree slits formed almost parallelogram-shaped hysteresis loops.

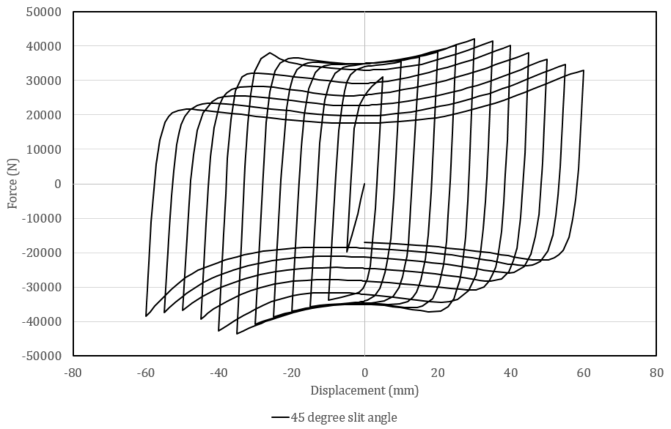

Chart -2: Hysteresis curve for Steel with 45 degree slit angle.

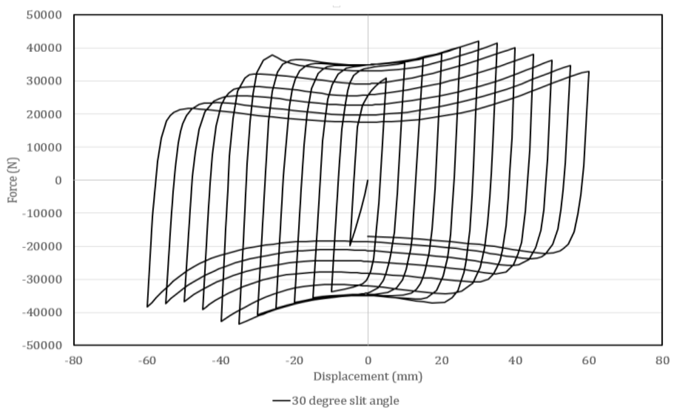

Chart -3: Hysteresis curve for Steel with 30 degree slit angle.

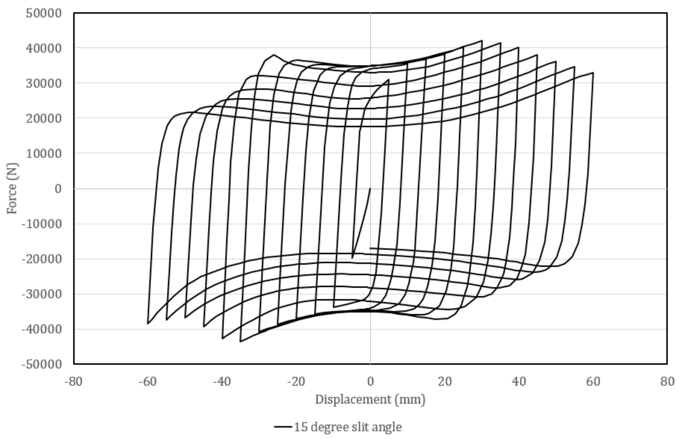

Chart -4: Hysteresis curve for Steel with 15 degree slit angle.

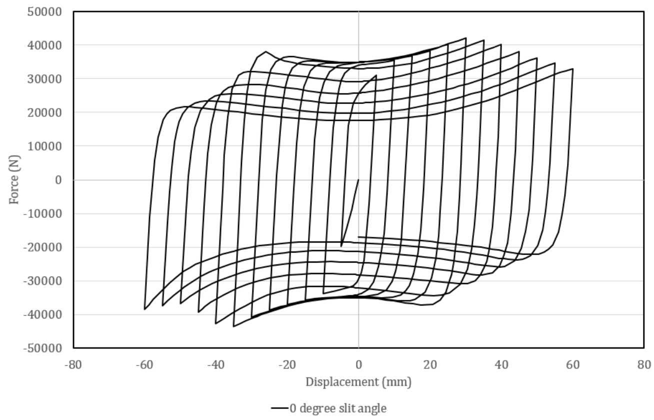

Chart -5: Hysteresis curve for Steel with 0 degree slit angle.

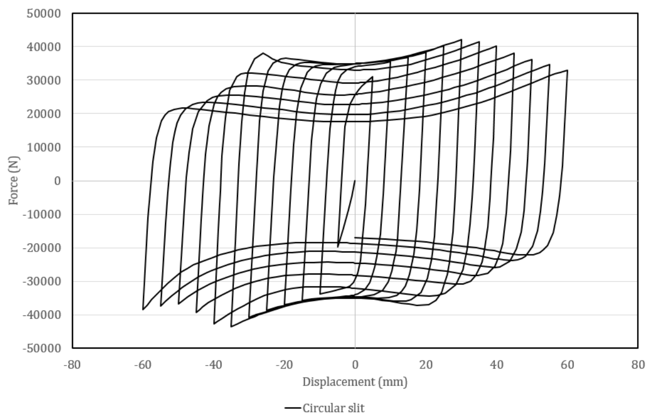

Chart -6: Hysteresis curve for circular steel slit.

3.2 Load Deflection Analysis

From the graph show in chart 7 represents the Load Deflection for different types of slit patterns. It is observed that for circular slit pattern the ultimate yielding point is at lower displacement value. Whereas 15 degree steel slit angle specimen have higher yield value and large deflections when comparing it with other specimens. Due to this reason the plastic nature of steel specimen increases enhancing high ductile value. Load carrying capacity and displacement capacity should needed to be balanced for better seismic resistance. Figure 7 to Figure 11 shows the total deformation in different steel geometry.

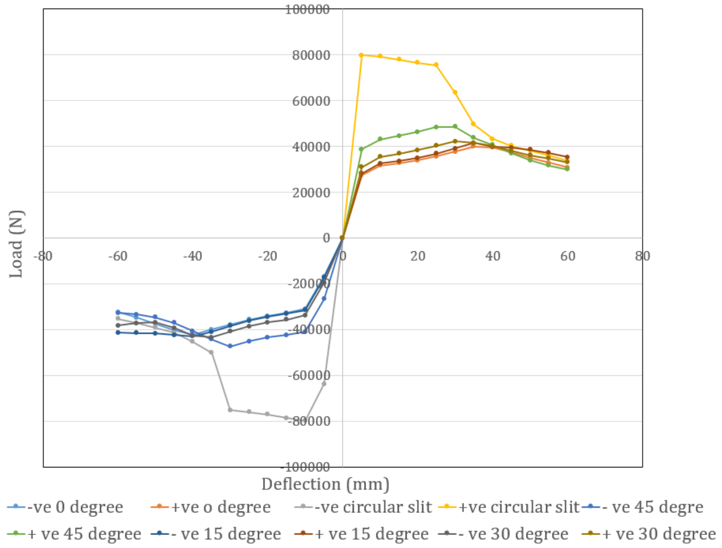

Chart -7: Load-Deflection graph.

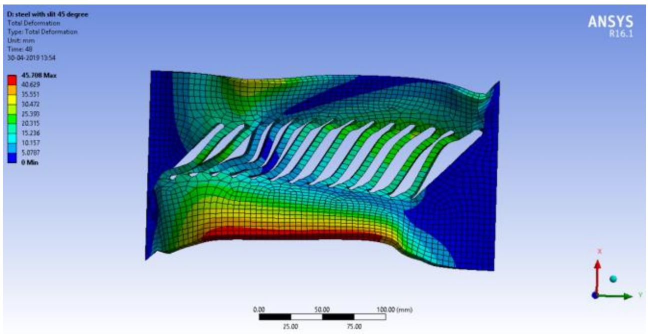

Fig -7: Total deformation for 45 degree slit angle.

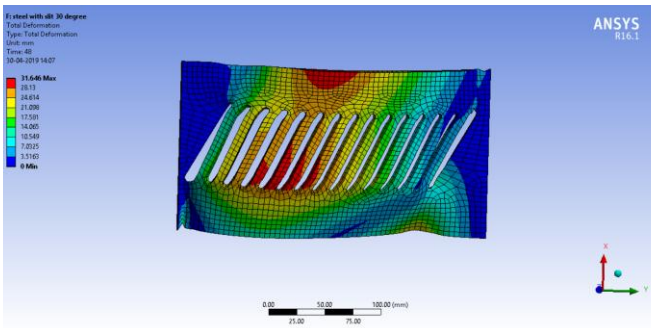

Fig -8: Total deformation for 30 degree slit angle.

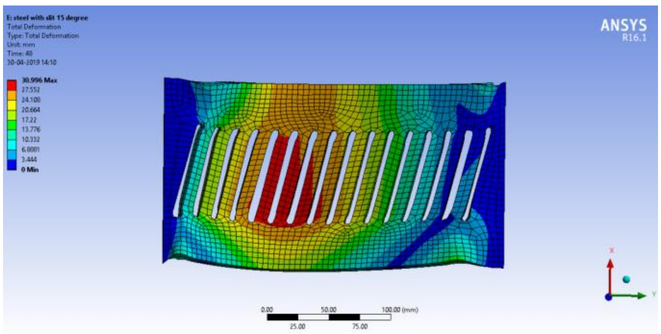

Fig -9: Total deformation for 15 degree slit angle.

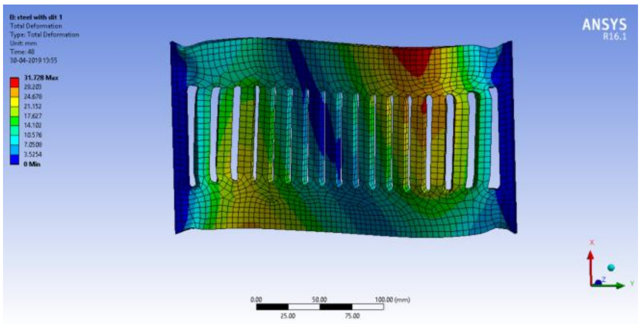

Fig -10: Total deformation for 0 degree slit angle.

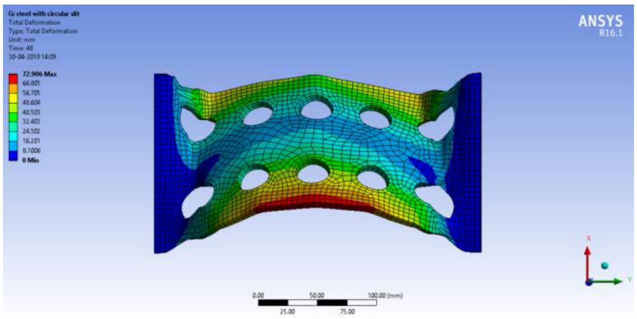

Fig -11: Total deformation for circular slit .

3.3 Comparison of results

Non-Linear dynamic analysis is conducted to observe the cyclic behavior of steel plates with different slit patterns. Table 2 and Table 3 shows the comparison of test results for positive and negative cycle loading. Parameters like Peak load, displacement and corresponding time interval is observed for the comparison of results. By comparing the load carrying capacities of each plates, we can see that steel plates with circular slit pattern exhibit more load carrying value and also steel with 45, 30,15,0 degree slit patterns shows only slight variations in their loading values. As comparing the number of cycles corresponds to each displacement value, 0 and 15 degree steel plates shows an increase in values. Whereas number of cycles for circular slits decreases rapidly when compared with 15 degree slit patterns. For improving the ductile nature of steel plates, 15 degree steel plate can be selected.

Table -2: Comparison of result for positive cycle.

Comparison of result for positive cycle				
	Time (s)	Cycle = t/4	Load (N)	Displacement (mm)
45 degree	27	6.75	39988	35
30 degree	23	5.75	48609	30
15 degree	27	6.75	41440	35

0 degree	23	5.75	42137	30
Circular slit	6.140	1.535	80240	1.4088

Table -3: Comparison of result for negative cycle.

Comparison of result for Negative cycle				
	Time (s)	Cycle = t/4	Load (N)	Displacement (mm)
45 degree	29	7.25	-42248	-40
30 degree	21	5.025	-47330	-30
15 degree	29	7.25	-42945	-40
0 degree	25	6.25	-43471	-35
Circular slit	4.308	1.077	-80262	-3.0875

4. CONCLUSIONS

This study proposed a new configuration consisting of a steel plate damper with different slit patterns, the conducted analytical study on the steel plate damper result in following conclusions:

- The force-displacement hysteresis curves of the tested specimens were stable and possessed high dissipation capacities due to specimen being resistant to buckling.
- Due to this reason that steel with 15 degree slit angle poses a high plastic nature and it enhances high ductility. Load carrying capacity and displacement capacity should needed to be increased for better seismic resistance.
- The number of cycles for circular slits decreases rapidly when compared to 15 degree slit patterns. By comparing both number of cycles and load carrying capacity 15 degree angle slit can be more preferably selected for improving the ductile nature.

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