ISSN 2229-5518

Response of shape memory alloy against seismic force

Akhila.V.S [1].Martina Edward [2]

[1] M-tech Student, SJCET Palai, India

[2] Assistant professor, SJCET Palai, India

Abstract: Seismic waves are produced due to earthquake and volcanic eruptions, which affect the human life in main ways. In this paper a study is conducted on SMA in reducing the effect of seismic force in a structure. The project focus on the structural performance of a beam and beam column joints equipped with steel plate and SMA tendons. The SMA connection specimens normally show excellent re-centring capability and moderate energy dissipation ability. The parameters analyzing will be the change in volume of steel plates and SMA tendons in case of beam and beam column joints, and a comparitative study was conducted by using different types of SMAs.. Here both the specimens were subjected to cyclic loading and the corresponding load displacement relationship of SMA specimens show satisfactory results.

Keywords: ANSYS, shape memory alloy, shape memory effect, super elasticity.

1. INTRODUCTION

Earthquakes are very serious problem since they affect human life in various ways. The earthquake force generated should to be carried out to the foundation by the shortest possible way, any obstruction in its path results in failure of the structure. The behaviour of the building during earthquake depends mainly on its overall size, shape and geometry in addition to how the earthquake forces are carried to the ground. During earthquake the reinforced frame buildings with columns of different heights in one storey, suffered more damage in shorter columns as compared to taller columns in the same storey. The poor behaviour of short column is due to the fact that in an earthquake, a tall column and a short column of same cross section move horizontally by same amount, however short column is stiffer as compared to tall column, and it attracts large earthquake force(9).

The beam column joint is the critical zone in a reinforced concrete moment resisting frame. It is subjected to large force during severe ground shaking and its behaviour has a significant influence on response of the structure. The seismic design philosophy relies on providing sufficient ductility to the structure by which the structure can dissipate seismic energy. Steel do not have sufficient ductility to absorb such energy, and results in the failure of structure. Hence shape memory alloys can be used to avoid such problems. Property of SMA which differs from other material is its shape memory effect and super elasticity. Other than these properties they have high strength, high damping, high energy absorption capacity, good corrosion resistance and good fatigue resistance ability.

A study on beam-column joint equipped with SMA tendons and steel angle was conducted by wei wang. Here energy dissipative performance of steel angle and re-centering capacity of SMA tendons were studied. During loading a v shaped gap was developed due to inelastic deformation of steel angles. An increase in thickness of steel angle results in increase in energy dissipation. In case of SMA tendons an increase in initial pressure the re-centering performance can be enhanced. Thus it can be designed as a main component for re-centering purpose (1). S Ray studies about the application of shape memory alloys in buildings. The phase transformation ability of shape memory alloy makes it possible to be used successfully in retrofitting. It is found that a increase in 38% in the strength of column confined with SMA wire jacket and more circumferential strain recovery with respect to column retrofitted with CFRP(2). K.Gupta conducted a study on different types of SMA. Shape memory alloys are different from other engineering materials due to shape memory effect and super elastic properties. Most popular SMAs are Ni-Ti alloy also known as Nitinol. There are mainly 2 phases in SMAs they are martensit and austensic phase. Common shape memory alloys include copper-aluminium-nickel, copper-zinc-aluminium, and iron-manganese-silica alloys. They are mainly used in bio-engineering, semi-conductors, in large boilers etc (3). A Alaa conducted a test on 7 simply supported beams with conventional steel and nitinol (SMA) as reinforcement. During unloading nitinol represented about 96.6% strain recovering capacity, and in case of conventional steel a strain recovery of about 6.25%. In case of crack width, nitinol was superior to the conventional deformed steel. SMA beam recovered 85% of the midspan displacement, while the conventional beam only relized a recovery of 26 %(4). M Alam conducted a test on SMA RC beam column joint and SMA RC column. Here 3 types of specimen were used (1) reinforced with regular steel bars (2) reinforced with SMA at plastic hinge region of beam along with steel in the remaining portion (3) SMA RC Column. From the result it is found out that hysteresis load displacement curve with SMA exhibit better performance compared with that of steel in terms of residual displacement remaining in the joint after unloading. SMA RC Column also shows better result but its failure is due to crushing and yielding of SMA rebar within the super elastic strain range(5).

2. SCOPE OF WORK

Introduction of a new material (SMA) which have the effect to resist seismic force when compared to other conventional method. SMA has a tendency to regain its original shape after deformation since it has no residual stress.

3. EXPERIMENTAL PROGRAMME

3.1 specimens

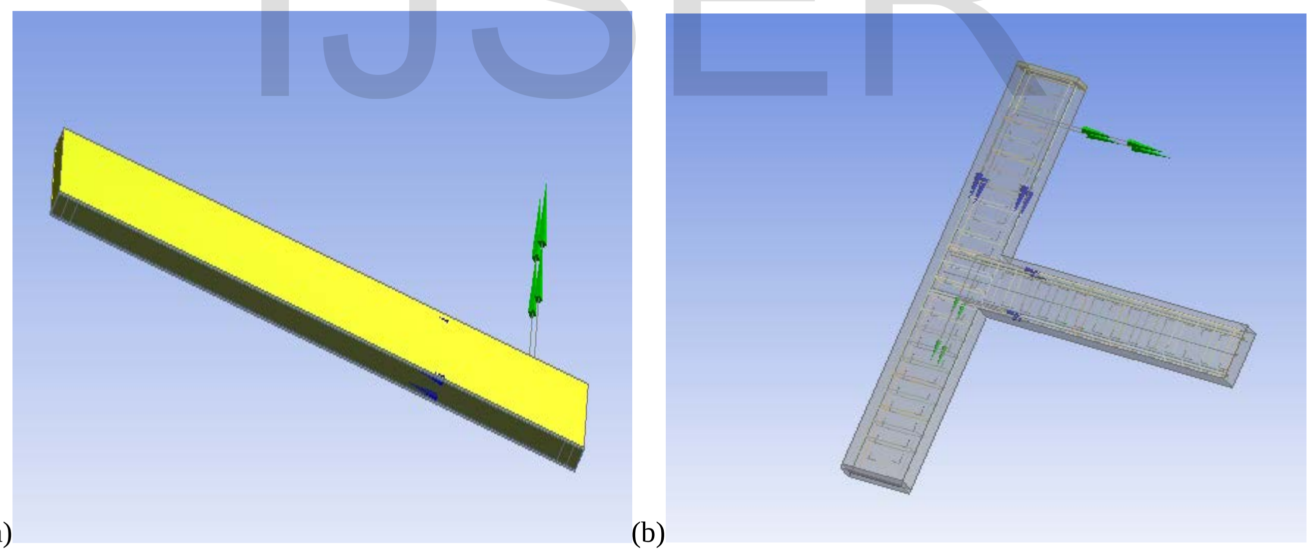
The analysis was conducted on mainly 2 models, one on a beam element and a beam column joint. A comparitative study is being conducted on both models by using steel and SMA and also using different types of SMAs. The material used include concrete, steel, Nitinol, Cu based alloys and Fe based alloys. In case of beam a plate of thickness 5mm, 10mm, 15mm and 20mm thickness is attached at the base, in beam-column joint tendons of thickness 16mm, 20mm, 24mm, 28mm, and 32mm is used. The table 1 shows the geometry of beam and beam-column joint respectively and the figure 1 shows the model of beam and beam-column joint.

Table 1(a) Geometry of beam

BEAM		
Length(mm)	Depth(mm)	Width(mm)
2800	125	250

Table 1(b) Geometry of beam-column joint

BEAM-COLUMN JOINT			
	length(mm)	Depth(mm)	Width(mm)
beam	1650	400	250
Column	3000	400	250

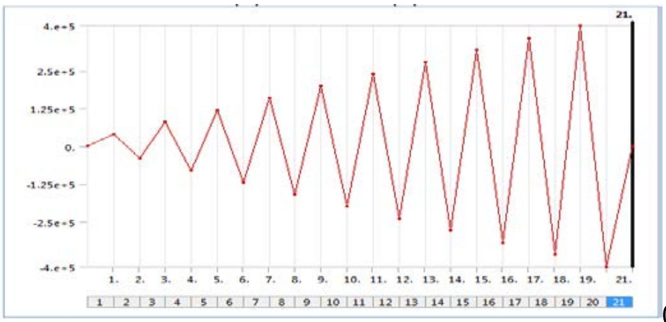


(a) (b)

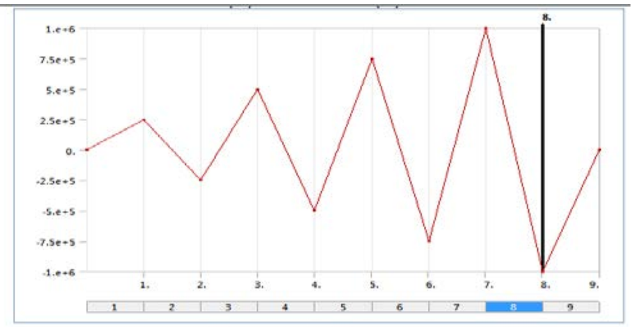
Figure 1 model of (a) beam (b) beam column joint.

3.2 Loading protocol

Both the specimens are subjected to cyclic loading. In case of beam both ends are fixed and a maximum load of 400KN was acted at the centre of the beam and in case of beam column joints both ends of the column is fixed and a maximum load of 1000KN was acted at the end of the beam. The figure 2 shows the loading pattern in case of beam and beam column joint.



(a)



(b)

Figure 2(a) loading pattern in case of beam (b) loading pattern in case of beam-column joint.

4. EXPERIMENTAL RESULT

4.1 Force – displacement response

The beam with SMA plates was found to have better recovering capacity than that of beam with steel plates. In case of steel after each cyclic loading there will be an increase in stress and after reaching the maximum limit results in the failure of structure. In case of SMA the phase transformation results in the recovery of stress after the release of each cyclic loading and reduces stress formation. Hence reduce the total displacement in a structure. The table 2 shows the displacement of beam and beam-column joint with different volume of SMA.

Table 2(a) Displacement of beam with different volume of SMAs.

Beam		
Thickness (mm)	Displacement (mm)	
	Steel	SMA(Nitinol)
5	537.77	11.36
10	346.28	8.2
15	216.5	7.3
20	287.71	13.858

Table 2(b) Displacement of beam-column joint with different volume of SMAs.

Beam –column joint		
Diameter of tendons (mm)	Displacement (mm)	
	Steel	SMA(Nitinol)
16	182.47	77.00
20	177.89	72.868
24	172.67	70.521
28	94.12	64.095
32	95.236	87.152

The nitinol shows minimum displacement than that of other two SMAs because of its strong shape memory effect and pseudo elastic properties. The table 3 shows the displacement of beam and beam-column joint by using different types of SMAs.

Table 3 (a) Displacement of beam with different types of SMAs.

Beam			
Thickness (mm)	Displacement (mm)		
	Nitinol	Cu based alloys	Fe based alloys
5	11.13	14.12	12.18
10	8.20	10.10	9.40
15	7.3	9.10	7.92

Table 3 (b) Displacement of beam-column joint with different types of SMAs.

Beam-column joint

ISSN 2229-5518

Diameter of tendons (mm)	Displacement (mm) Nitinol	Cu based alloys	Fe based alloys
5	77.00	123.32	82.68
10	72.86	113.41	77.68
15	70.52	92.018	73.70

The figure 3 shows the force-displacement graph in case of beam. In case of beam with steel plates there is no recovery in strain after the stress is released, but in case of SMA plates the strain is recovered upon the release of stress.

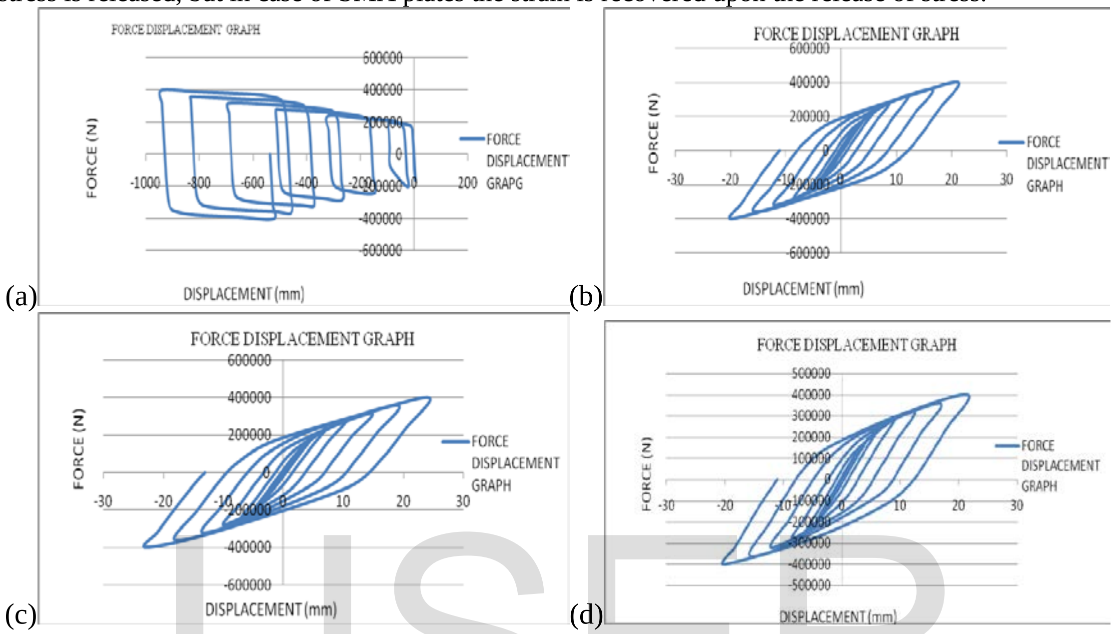


Figure 3 (a) Beam with steel plate of thickness 5mm (b) Beam with SMA (Nitinol) plate of thickness 5mm (c) Beam with SMA (Cu based alloy) plate of thickness 5mm (d) Beam with SMA (Fe based alloy) plate of thickness 5mm.

4.2 Deformation contour

The figure 4 (a) shows the deformation contours of beam with SMA plate. In case of beams the maximum deformation occurs at the centre of beam, it is indicated by red colour and the minimum deformation occurs at the both ends of the beam, which is indicated by blue colour. The figure 4 (b) shows the deformation contours of beam-column joint. In case of beam column joint the maximum deformation occurs at the tip of the beam which is indicated by red colour.

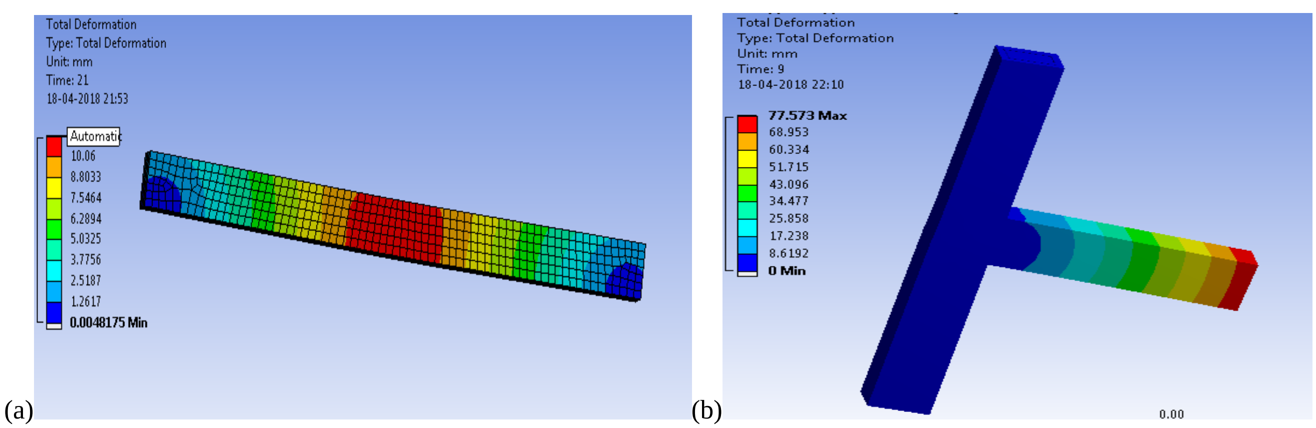


Figure 4 (a) beam with SMA plate of 5mm thick (b) beam-column joint with SMA tendons of 16mm thick.

5. CONCLUSION

This paper aims to investigate the behaviour of steel and different types of SMAs in beam and beam column joints by using ANSYS .From the analysis it seems that the beam with SMA shows better result than that of steel due to phase transformation property of SMAs.

- Beam with SMA plate shows a decrease of about 95% in deflection.
- Beam column joint with SMA tendons shows about 55% decrease when compared with steel tendons.
- SMA plate shows a decrease in deflection with increase in thickness up to 15mm and further increase in plate thickness results in increase in deflection due to increase in weight of plate..
- SMA tendons show a decrease in deflection with increase in diameter up to 28mm further increase in diameter results in increase in deflection due to the decrease in compression taking part.
- Nitinol shows better result when compare to other types of SMAs.

REFERENCES

1. W.Wei et al (2015) Seismic performance of beam–column joints with SMA tendons strengthened by steel angles. *Journal of construction steel research 109 (2015)61-71*
2. S Ray et al (2015) Potential Application of shape memory alloys in seismic retrofitting of exterior RC beam column joint. *SECED 2015 Conference*.
3. K.Gupta et al (2012), Studies on shape memory alloys. *International journal of advanced engineering technology .IJAET Vol 111 issue 1 january-march. 2012 378-382.*
4. A Alaa et al (2013) Behaviour and modelling of super elastic shape memory alloy reinforced concrete beams. *Engineering structures 49 (2013)893-904*
5. M Alam et al (2008) Analytical prediction of the seismic behaviour of super elastic shape memory alloy reinforced concrete elements. *Engineering structures 30 (2008)3399-3411.*
6. C.Eunsoo et al (2009), shape memory alloy bending bars as seismic restrainers for bridges in seismic areas. *International journal of steel structures. December 2009, Vol9 No 4,261-273.*
7. M Masoud et al (2009), Shape memory alloys for civil engineering structures– on the way from vision to reality. *Architecture civil engineering environment.*
8. M.Saiid et al (2009) Cyclic response of concrete bridge columns using superelastic nitinol and bendable concrete. *ACI structural journal.*
9. K.Sathishkumar (2016) **,** Study of earthquake resistant RCC buildings with increased strength and stability. *international journal of innovative research in science, engineering and technology, Vol.4 Issue 6, june 2015*
10. S.Miodrag , Raatko Salatic , Marija Nefovska (2002) , Dynamic analysis of steel frame with flexible connections. *computers and structures 80.(2002)935-955*
11. A.Sergio, C.Rene, P.David Behaviour of precast concrete beam-column connection.
12. A.Deylami, M Tehranizadeh and M.Gholami (2012) Seismic performance of flange plate connections to built-up box column.