

Comparative Study on the Effect of RC Beam And Shape Memory Alloy Beam

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ABSTRACT: A basic description of SMA alloys is studied and also its properties carried well. Shape memory alloy (SMA) is a novel functional material and has found increasing applications in many areas. Recently, research efforts have been extended to using SMA for control of civil structures. This paper presents a review of applications of the SMA materials for passive, active and semi-active controls of civil structures. The characteristic of SMA is presented. The pseudoelasticity and the shape memory effect (SME) are the two major properties of SMA associated with the thermal-induced or stress-induced reversible hysteretic phase transformation between martensite and austenite. The unique properties of SMA to be used as actuators, passive energy dissipators and dampers for civil structure control. Current research using SMA-based devices for passive, semi-active or active control of civil structures are also presented. SMA beams were compared with deflections of similar beams reinforced with conventional steel to present the potential of SMAs in restricting loads. Finally, a new scope of experimental research work is proposed utilizing SMAs as prestressing design applications and retrofitting techniques.

KEYWORDS: Shape memory effect, Superelasticity, Analysis of reinforced concrete beam, Analysis of shape memory alloy beam

I. INTRODUCTION

Reinforced concrete structures must be designed to satisfy the requirements of both the strength and serviceability. The design for serviceability, however, is not straightforward, since the prediction of behavior under sustained service loads is complicated by time-dependent deformations in the composite beams due to creep and shrinkage of concrete. SMAs exhibit strains with age of concrete structures and causes considerable impact on its performance which results in deflection as well as affecting stress distribution. It also causes dimensional change in the material under the influence of sustained loading.

Occurrence of creep & shrinkage in concrete members depend upon the uncertainties of inherent material variations as well as modelling. Studies of uncertainties in creep & shrinkage effects were performed by the various factors commonly classified as internal and external factors. The internal factors are the variation in quality and mix composition of the materials which is used in the concrete and the internal reinforcement where as external factors are the changes in environmental conditions, such as humidity, temperature etc. The time dependent effects in RC structures due to creep and shrinkage have not been controlled rationally. Therefore it is very important to develop a smart system for reinforced concrete structures.

Smart systems for civil structures are described as systems that can automatically adjust structural characteristics in response to external disturbances and/or unexpected severe loading toward structural safety, extension of the structure's life time, and serviceability. the development and implementation of smart materials, which can be integrated into structures and provide functions such as sensing, actuation and information processes essential to monitoring, self-adapting and healing of structures. Some examples of smart materials are piezoceramics, shape memory alloys (SMAs), magneto-rheological (MR) fluids, and electrorheological (ER) fluids.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

SMA's have found so many applications in many areas due to their solid state actuation high power density, high damping capacity, corrosion resistant, durability and fatigue resistance. When SMA's integrated with civil structures, it can be passive, semi-active, or active components to reduce damage caused by environmental impacts or earthquakes. In 1932, Read and Chang are observed a phase reversible transformation in gold-cadmium (AuCd) alloy, which is the first record of the invention of shape memory transformation. It was after 1962, when Buechler and co-researchers discovered the shape memory effect (SME) in nickel-titanium at Naval Ordnance Laboratory (they named the material Nitinol after their workplace), that both in-depth research and practical applications of shape memory alloys emerged.

Up to date thirty different types of shape memory alloys have been discovered. Among them, the three main types of SMA are the copper-zinc-aluminum-nickel, copper-aluminium-nickel and nickel-titanium (NiTi) alloys.

Nickel-Titanium (Ni-Ti) SMA alloys have been found to be the most flexible and beneficial in engineering applications due to its superior thermo-mechanical and thermo-electrical properties. It can recover from large amount of bending and torsional deformations as well as small amount of strain. The deformation and shape recovery process can be repeated millions of times. Like all other metals and alloys, SMA's have more than one crystal structure which is known as polymorphism. The crystal structure or phase in polycrystalline metals depends on both temperature and external stress. It exists in two different temperature dependent crystal structures:

At lower temperature it is weaker while the martensite has a parallelogram asymmetric structure having upto 24 variations. When, SMA in martensite phase is subjected to external stress, it deformed through a detwining mechanism and transforms different crystal structure variations to a particular one variation which can accommodate maximum elongation. Due to parallelogram structure, the martensite phase transformation is weak and can be easily deformed.

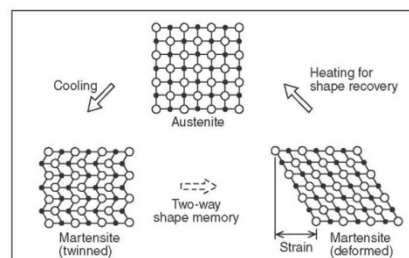


Fig. 1 Materials crystalline arrangement during shape memory effect

It is a body-centered cubic crystal structure and high temperature causes the atoms to arrange themselves into the most compact and regular pattern possible, resulting in a rigid cubic arrangement and relatively have a stronger resistance to external stress. The special property of shape memory alloys is to revert to their original shape on increase in temperature and their crystal transformation is fully reversible. The transition temperature of SMA's varies from, about -50 deg C to 166 deg C depending upon their compositions. Simplified two-dimensional representation of the materials crystalline arrangement is shown in figure 1.1.

Shape memory effect is the phenomenon which is the SMA's return back to their shape upon heating. For an example if a straight bar of austenitic phase SMA is allowed to cool below the phase transition temperature, the crystalline structure will undergo a change to martensite. If the bar is reheated above the transition temperature again, it will return back to its original straight configuration. Super elasticity is the phenomenon that SMA can undergo a large amount of inelastic deformations and recovers their shape after unloading. Beams are most essential element to carry the loads acting on a structure. Normal RC concrete beams were used all over the world in most constructions. As the material cost is increasing day by day it is relevant to find alternatives. SMA beams can be chosen as such alternatives as it can reduce material and construction costs. The super elastic properties act as tremendous resistance against loads. The behaviour of RC beams under various loads may be different from that of the behaviour of SMA beams, so that it is an essential requirement to study its behaviour under various loads especially under lateral and shear load. The influence of various parameters on the column behaviour is also an important factor. The advancements in SMA, rehabilitation and repair techniques gained large importance in construction field.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 6, June 2017

The main objective of this project is to study To study properties of shape memory alloy. Flexural test on RC beam and SMA beam. Comparative study between RC beam and different types of SMA alloyed beam. Find out the parameters stress, strain, deformation, crack float.

II. RELATED WORK

The geometry of the beam was prepared using workbench platform of ANSYS 16.2 Finite element Analysis software. Geometry of RC beam and surface laminated Ni Ti SMA beam are given below:

Table1. Details of Beam

Identity	Dimensions (mm)	Type of bar	Number and Size of bar	% area of rebar
B1-a	125x250x2000	Fe 415	4 nos 12mm	.64
B1-b	125x250x2000	Ni Ti SMA	4 nos 12mm	.64

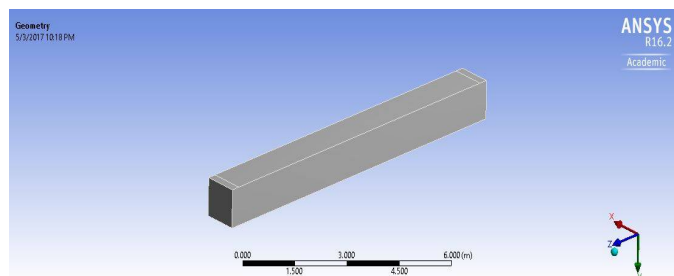


Fig. 2 Geometry of RC beam

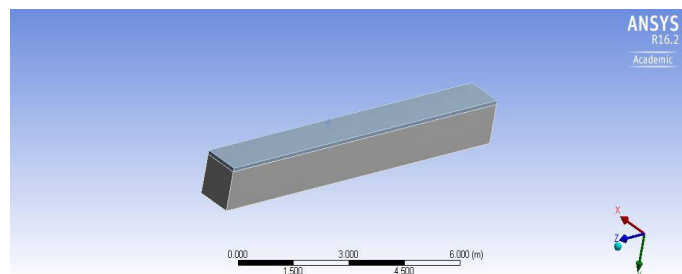


Fig. 3 Geometry of SMA beam

Concrete with Young's modulus of 3×10^{10} and Poisson's ratio of 0.2 is used. Steel with Young's modulus of 2×10^{11} and Poisson's ratio of 0.3 is employed.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 6, June 2017

Table2. Material properties of Ni Ti SMA

Material Property	Sigma SAS(MPa)	Sigma FAS(MPa)	Sigma SSA(MPa)	Sigma FSA(MPa)	Epsilon(mm/mm)	Alpha
NiTi SMA	520	600	300	200	.07	0

III. MESHING AND BOUNDARY CONDITION

The size of the mesh is a measure of accuracy of the result and the time required for the computation of results. Coarse mesh gives less accuracy and lower time for computation. As the mesh becomes more and finer, the accuracy increases so as the time.

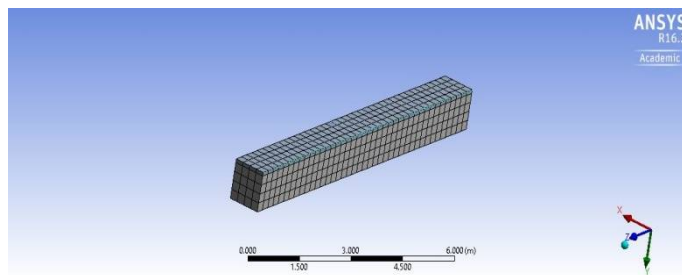


Fig. 4 Meshing diagram

The two end of beam is simply supported. A load of 2.127×10^5 N is given at the mid span of the beam. The load is assumed to act along the edges also. The connection between the concrete and SMA is assumed to be frictionless.

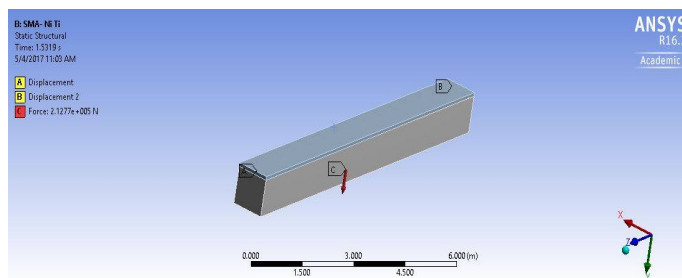


Fig. 5 Boundary condition and loading of Beam

IV. RESULT ANALYSIS

The total deformation, normal stress and shear stress of the RC Beam and NiTi SMA Beam where shown below:

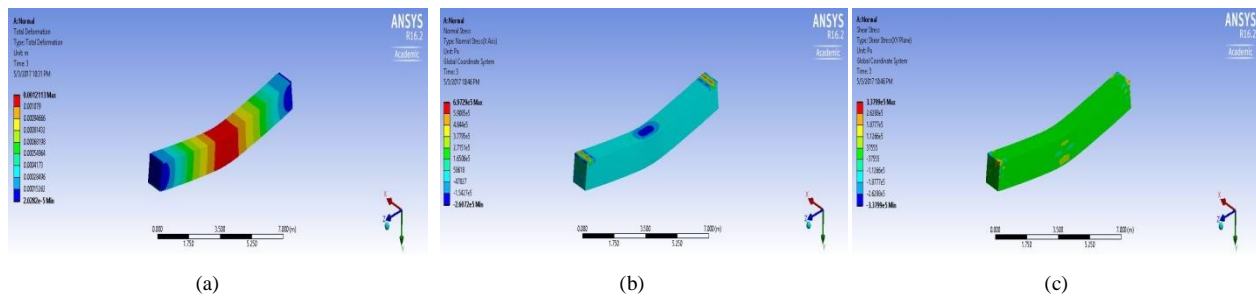


Fig. 6 Result Analysis of RC Beam (a) Total deformation (b) Normal stress (c) Shear stress

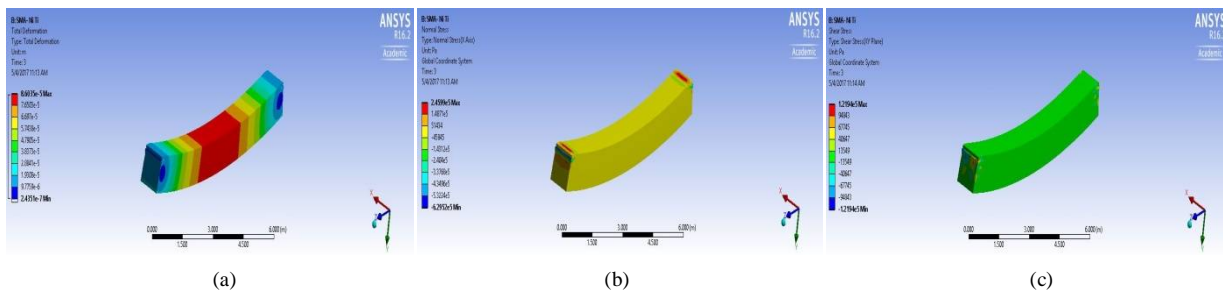


Fig. 7 Result Analysis of NiTi SMA Beam (a) Total deformation (b) Normal stress (c) Shear stress

Table3. Analysis Result

Result		
(Maximum in)	RC Beam	NiTi SMA Beam
Total deformation (mm)	1.21	.086
Normal Stress (MPa)	3.202	.245
Shear stress (MPa)	0.3379	.122

The result analysis which gives that the Total deformation is less in SMA Beam and also the normal stress and shear stress are also less as compared with RC Beam. This is because of the super elastic property of the SMA alloys. Shape-memory alloys are the high level of recoverable plastic strain that can be induced. The maximum recoverable strain these materials can hold without permanent damage is up to 8% for some alloys. This compares with a maximum strain 0.5% for conventional steels.

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Vol. 6, Issue 6, June 2017

V. COMPARATIVE STUDY ON LOAD DEFORMATION GRAPH

5-1 INTRODUCTION

The comparative study of reinforced concrete beam and three shape memory alloyed beam was making the knowledge about the deflection behaviour in the flexural members. So that here we are discussing about the comparative study of RC beam with SMA alloyed beam comparing with the results of load-deformation graph and also the stress-strain curve at the center of the beam. The load-deformation curve gives the each critical points of the member and stress-strain curve gives the elastic behaviour of the beam.

The analysis is done for all the four beams with the geometric specifications are same as that for the validated model. The load-deformation and stress-strain curve is drawn.

5-2 REINFORCED CONCRETE BEAM

Load-Deformation curve and Stress Strain graph of RC beam is shown in below.

The purpose of these graphs is to understand the characteristics of the same load application and to manipulate the most effective one of the beam. We can also understand the elastic behaviour of the beam with respect to the same load combination.

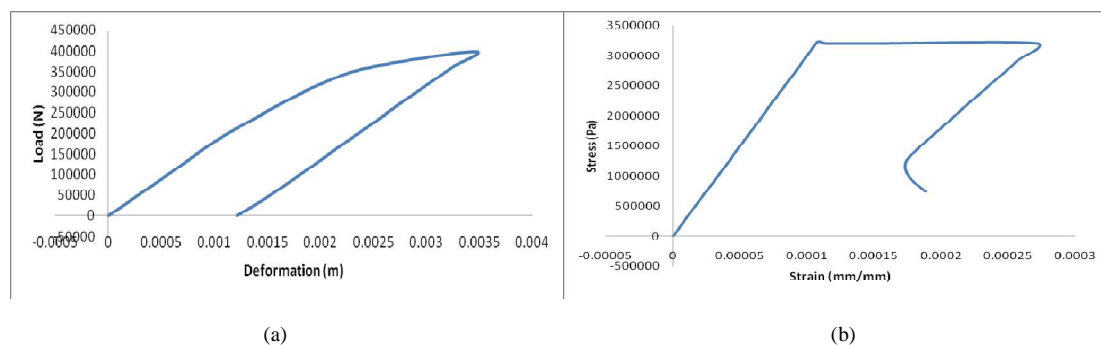


Fig. 8 RC Beam (a) Load deformation graph (b) Stress Strain graph

Load-Deformation curve:

Table 4. Result from Load-Deformation curve

Deformation under	Load (kN)	Deformation(mm)
Starting (loading)	40	0.220
Changing (Unloading)	400	3.45
End (No load)	0	1.21

Stress-Strain Curve:

The above curve shows that at a particular point stress-strain is linear elastic nature. Then curve shows a constant stress with increase in strain. At the end of failure point curve is falls down. Failure limit Stress is 3.200 MPa and Strain is 2.7122×10^{-4} .

5-3 Ni Ti SMA BEAM

Load-Deformation curve and Stress Strain graph of the Ni Ti SMA Beam is shown in below.

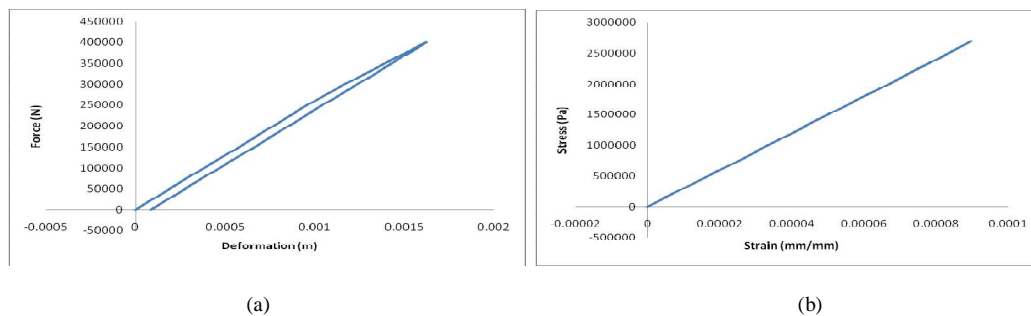


Fig. 9 NiTi SMA Beam (a) Load deformation graph (b) Stress Strain graph

Load-Deformation curve:

Table5. Result from Load-Deformation curve

Deformation under	Load (kN)	Deformation(mm)
Starting (loading)	40	0.153
Changing (Unloading)	400	1.62
End (No load)	0	0.086

Stress-Strain Curve:

The above curve shows a linear elastic nature at the entire point of stress-strain distribution. This is because of the super elastic property of alloys. So here the failure limit is not exceeded. So that after unloading it regains its original state.

5-3 Critical Loads and Maximum Deformation

The maximum load which can carry in both of the beam was shown in below. It shows that the maximum load which is carried over is Ni Ti SMA Beam as compare with the RC Beam. And also the minimum deformation is in Ni Ti SMA Beam as compare with the RC Beam.

Table6. Result of RC beam and SMA beam

MODEL	CRITICAL LOAD	DEFORMATION(Max)
RC BEAM	400 kN	3.45 mm
Ni Ti SMA BEAM	585 kN	2.37 mm

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Vol. 6, Issue 6, June 2017

VI. CONCLUSIONS

As per the above results comparing with RC beam and Ni Ti SMA alloys we got that SMA alloyed beam is most effective. The super elastic property of this alloy gives tremendous resistance against load. Ni Ti alloyed beam gives small deformation at particular critical load. And after unloading stage it regains its original position in elastic nature. The variation of deformation at the end load is also very small. Therefore Ni Ti SMA alloyed beam is most effective. Although there has been substantial research work on civil structures utilizing SMAs, the short and long-term deflection behavior of concrete flexural members with SMAs are yet to be investigated through experimental program. The analysis for deflection behavior of SMA & steel RC beams under various service loads had been carried out and their differences are presented. The analytical results show that, the mid-span deflection in SMA RC beams were less compared to steel RC beams of identical cross-section, length and grade. High rigidity and superelastic properties of SMA increase this load carrying capacity and reduce deflection of SMA beams compare to RC beam. SMA acts as a stiffener in the flexural members. The stress-strain characteristics of the RC and SMA beams are also verified. Increase in percentage area of reinforcement, cross-sectional area and span of SMA RC beams results in increase of resistance to the deflection under service load. These analytical results are further required to be validated through experiments.

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