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A Review on: Applications of Shape Memory Alloy in Construction

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Abstract:*Shape memory alloys (SMA) are unique materials which have ability to undergo large deformations and also regain its undeformed shape by removal of stress or by heating. This unique property could be effectively utilized to enhance the safety of civil structures. This paper presents the fundamental characteristics of shape memory alloy and some of the application of shape memory alloy in civil structures.*

Keywords:*Shape memory alloy; shape memory effect, super elasticity, phase transformation, applications of SMA.*

I. INTRODUCTION

Civil structures undergo substantial damages due to earthquakes [1]. The civil structures reinforced with conventional steel are designed against collapse, where the earthquake energy dissipation is provided through yielding of reinforcement and plastic deformation. The deformation of these civil structures encourages damages and therefore economics losses, so the seismic design of structures has progressed towards a performance based approach, where we require robust structural members and systems that have ability to enhance deformation capacity and ductility, and regain or restrict permanent deformation [2]. Our main aim is to develop and implement a smart material into our civil structures, so it can provide functions like sensing, actuation and information processes which is used for monitoring, self-adapting and healing of structures. There are different types of smart materials like piezoelectric materials, shape memory alloys, magneto-rheological fluids and electro-rheological fluids. Now a day's shape memory alloys have found its application in many different areas because of its unique properties like high power density, solid state actuation, and high damping capacity, durability, fatigue resistance, shape memory effect and super elasticity.

II. BASICS ABOUT NITINOL SHAPE MEMORY ALLOY

In 1932, chang andread observed a reversible phase transformation in gold-cadmium (AuCd), which is the first record of the shape memory transformation. At Naval Ordnance Laboratory, Buechler and his co-researcher in 1962 discovered the shape memory effect in nickel-titanium. They named this material Nitinol after their workplace.

Till now many different types of shape memory alloys have been discovered. Among them, Nitinol has excellent thermo-mechanical and thermo-electrical properties. Most commonly used SMA is Nitinol. Nitinol has two unique properties and that are:

2.1.Shape memory effect

A phenomenon that the SMA materialwill return to its undeformed shape by heating a material [3].

2.2.Super elasticity

A phenomenon that the SMA material can undergo large inelastic deformation andrecover its original shape after unloading. These unique properties are the results ofreversible phase transformations of Shape memory alloy [4].

III. PHASE TRANSFORMATONS

SMAs possess more than one crystal structure having the same chemical composition. The predominant crystal phase in a polycrystalline metal depends on both stress and temperature and is controlled by both chemical composition and thermo-mechanical processing [5]. At a low temperature, SMAs exist in the martensite phase. When heated, it undergoes a transformation to the austenite phase. In the stress free state, SMAs are characterized by the following four distinct transformation temperatures as shown in figure. 1; martensite start (M_s), martensite finish (M_f), austenite start (A_s), and austenite finish (A_f).Typical values of transformation temperatures for several alloys in a stress-free state are presented in table 1.A SMA exists in a fully martensite state when its temperature (T) is less than M_f and in a fully austenite state when T is greater than A_f. During the phase transformation from martensite to austenite and vice versa, both martensite and austenite phases coexist. The phase transformation of SMAs during heating and cooling is qualitatively shown in figure. 1. When the material is heated to A_s, its phase starts to change gradually from martensite to austenite. At a temperature of A_f, this transformation is complete. Cooling the material will result in a phase change from 100% austenite at a temperature greater than M_s to 100% martensite when the temperature M_f is reached [6].

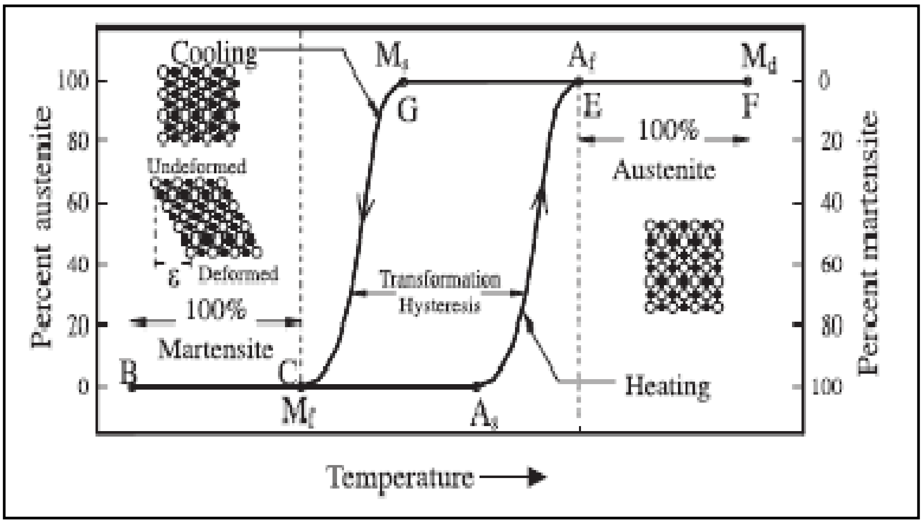

Figure 1: Phase transformation and change in crystalline structure of shape memory alloys from martensite to austenite and vice versa as a function of temperature [6]

Table 1: Chemical composition and phase transformation temperature of different shape memory alloys [6].

Alloy	**Source**	**Composition (%)**	**M_s(K)**	**M_f (K)**	**A_s (K)**	**A_f (K)**
Ni - Ti	Strnadel et al. 1995	40.0, 50.0, 10.0	314.6	294.1	325.9	339.8
Ni - Ti	Manach&Favier 1997	50.5, 49.5	306.0	277.0	317.0	335.0
Ni - Ti	DelgadilloHoltfort et al. 2004	50.8, 49.2	252.0	227.0	270.0	284.0
Ni - Ti	Hesse et al. 2004	55.7, 44.3	278.0 ± 2.0	233.0 ± 2.0	291.0 ± 0.3	324.0 ± 1.5

IV. USE OF SHAPE MEMORY ALLOY IN NEW STRUCTURES

4.1. Applications of shape memory alloys in civil structures

Shape memory alloys have load to many applications in civil engineering due to its unique characteristics.
Now many researchers have been carried out by using SMA's in new construction in form of reinforcement, pre-stressing strands, bracing and bolted connections.

4.1.1. SMA isolation devices

The passive structural control using SMAs takes advantageof the SMA's damping property to reduce the response andconsequent plastic deformation of the structures subjected tosevere loadings. SMAs can be effectively used for this purposevia two mechanisms: ground isolation system and energydissipation system [30]. In a ground isolation system, SMAmadeisolators, which are installed between a super-structureand the ground to assemble an uncoupled system, filter theseismic energy transferred from the ground motion to the superstructureso that the damage of the super-structure is attenuated.On the other hand, via the energy dissipation mechanism,martensite or austenite SMA elements integrated into structures absorb vibration energy based on the hysteretic stress–strain relationship [7].

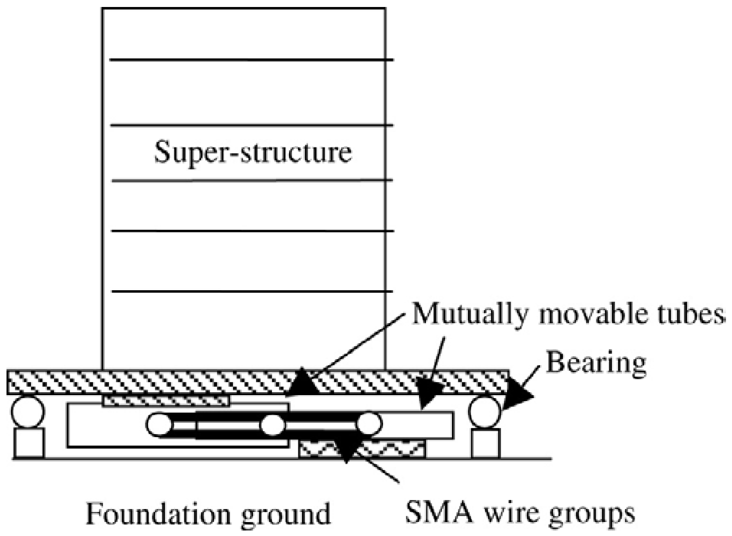

Figure 2: Schematic of the SMA isolation system for buildings [7].

4.1.2. Reinforcement in concrete structure

Due to excessive lateral displacements several damages takes place in bridges and buildings in seismic region. So, an earthquake resistant structure should be so designed which can behave elastically under medium magnitude of earthquakes. It is not economically possible to design a structure which can perform elastically under strong magnitude of earthquakes. Steel is a conventional material used in seismic design and it is expected to yield to dissipate energy while undergoing permanent deformation. Conversely, if SMA is used as reinforcement in a reinforced concrete structure, it will yield when subjected to high seismic loads but it will recover a significant permanent deformation because of its unique characteristics if the load is in permissible limit beyond which it will undergo plastic deformation [8].

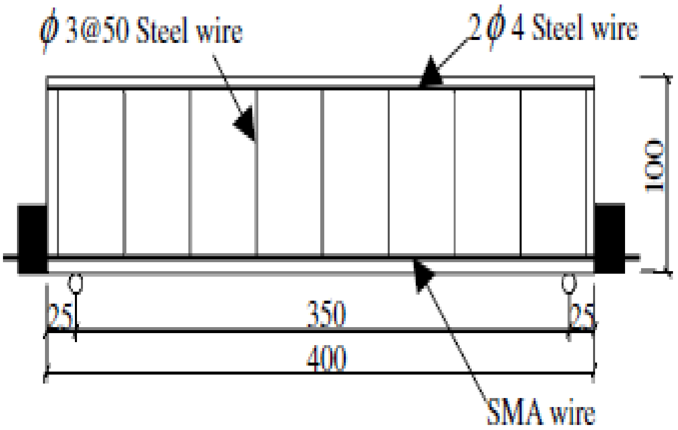

Figure 2: Schematic of the SMA isolation system for buildings [8].

4.1.3. Bolted joints

During earthquake event, beam-column and column-foundation are often weakest link of a structure. By using such super elastic SMA in a joint we can able to reduce damages by dissipating large amount of energy through large inelastic deformation and then it can be recovered [9].

4.1.4. Bracings

A numerical study on a one-storey prototype building model strengthened with super elastic SMA (NiTi) diagonal bracing wires which are subjected to a harmonic base excitation [9]. From the result they concluded that the additional damping is being provided by super elastic SMA hysteresis that reduces the peak displacement and also prevents the damage compared to the steel bracing with similar stiffness. Even after a large earthquake we can repair a frame easier because of its lower–level of damage.

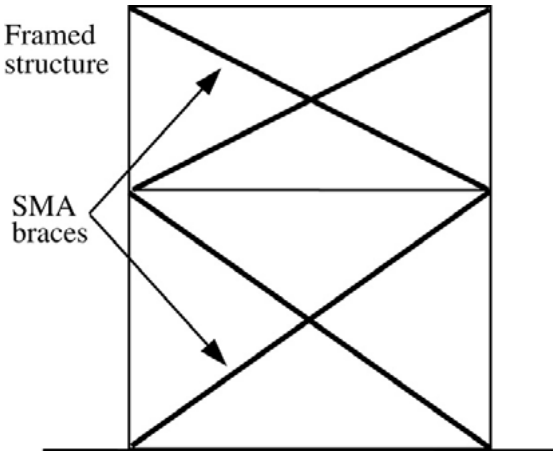

Figure 3: Schematic of the SMA braces for a two-story steel frame [7].

4.1.5. Pre-stressing

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Pre-stressing concrete and masonry structures with SMA strands wires are another alternative. Both pre-tensioning and post-tensioning can be done using SMAs [9]. The benefits of using SMAs in pre-stressing are:

Active control on the amount of pre-stressing with increased additional load-carrying capacity
No involvement of jacking or strand-cutting
No elastic shortening friction and anchorage losses over time.

V. CONCLUSION

This paper presents a review of the basic properties of Nitinol shape memory alloys (SMA) and their applications of shape memory alloys in civil structures. Shape memory alloys can be used in different ways to control civil structures. The SMAs can be used in different form like bars, wires, and plates, etc. Due to its unique properties of SMAs, i.e. super elasticity and shape memory effect in has seeks more attention for researchers. Number of analytical and experimental studies of SMA devices proved to be effective in improving the response of civil structures under earthquake loading. SMA has opened the door of opportunities and made one of the construction materials for the future because of its self-repairing and self-healing capacity.

REFERENCES

[1] Inel M, Ozmen H. B, Bilgin H. Re-evaluation of building damage during recent earthquakes in Turkey. EngStruct 2008; 30:412–27, 2009.
[2] Alam, M. S., Moni, M., &Tesfamariam, S. "Seismic overstrength and ductility of concrete buildings reinforced with superelastic shape memory alloy rebar". Engineering Structures, 34, 8–20. doi:10.1016/j.engstruct.2011.08.030, 2012.
[3] Balapgol, B.S, ”Finite Element Analysis of Shape Memory Alloy Composite Plate"s, PhD thesis, Indian Institute of Technology Bombay, 2006.
[4] Surajit Das, "Geometrically and Materially Nonlinear Finite Element Analysis of Shape Memory Alloy Smart Structures", PhD thesis of Indian Institute of Technology Bombay, 2012.
[5] Dolce, M., &Cardone, D. "Mechanical behaviour of shape memory alloys for seismic applications 1. Martensite and austenite NiTi bars subjected to torsion", 43, 2631–2656, 2001.
[6] Alam, M. S., Youssef, M. A., &Nehdi, M. "Utilizing shape memory alloys to enhance the performance and safety of civil infrastructure : a review", 1086(Ullakko 1996), 1075–1086. doi:10.1139/L07-038, 2007.
[7] Song, G., Ma, N., and Li, H.-N. 2006. Application of shape-memoryalloys in civil structures. Engineering Structures, 28: 1266–1274.
[8] YachuanKuang and JinpingOu, “Self-repairing performance of concrete beams strengthened using superelastic SMA wires in combination with adhesives released from hollow fibers”, Smart Material Structure 17 (2008).
[9] K.M.Bajoria, Shreya Kaduskar, “A Review on: Shape Memory Alloy and Its Application in Civil Structures”, International Journal of Engineering Research, volume No.5 Issue: Special 3, pp: 721-724, 2016