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Seismic Control Of Structures Using Shape Memory Alloys

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Abstract: *Although there has been an increase in the use of concentrically braced frame systems , damage during past earthquakes suggests that braced systems may perform poor due to limited ductility and energy dissipation , failure of the connection between the braces and the frame and asymmetric behavior of the brace in tension and compression. One way of improving the performance of CBF systems in terms of limiting inter story drifts is the use of innovative materials in the bracing system. Shape Memory Alloys (SMAs) are a novel functional material which can exhibit little residual strains under cycles of loading and unloading even after passing the yield zone. They have the ability to remember a predetermined shape even after severe deformations which enable them to be widely used in numerous applications in the area of smart materials or intelligent materials. In this study, the behaviour of steel braced frames and SMA braced frames are compared by performing time history analysis. The effect on displacement and stress distribution was analyzed and discussed.*

Keywords *- Pseudoelasticity , Seismic response ,Shape Memory Alloys ,Shape Memory Effect*

I. Introduction

Earthquake events cause destructions including permanent damage and failure of many buildings. Steel structures are mostly designed for safety conditions, where the earthquake energy is mainly dissipated through yielding of their nonlinear deformation. Structures are allowed to undergo severe damage – this means saving lives at the expense of structures incurring excessive economic losses. Recently, the seismic design of structures has evolved towards a performance-based approach in which there is need for new structural members and systems that possess enhanced deformation capacity and ductility, higher damage tolerance, and recovered or reduced permanent deformations.

Under great earthquake ground motions, the flexibility of steel moment-resisting frames may result in great lateral drift induced non-structural damage. In steel frames, the inter-story drift ratio should be limited in design due to the weak seismic performance to resist earthquake related to geometric nonlinearities and brittle failure of beam-to-column connections. Therefore, the inter-story drift ratio should be limited in design, and hence larger bracing member sizes are required. Limited ductility and low energy dissipation capacity due to braces buckling is one of several reasons for the weak performance of steel braced frames. High ductility, enhanced energy dissipations and symmetrical hysteric response in tension and compression are the main characteristics of braced systems.

In the 1960s, Buehler and Wiley developed a series of nickel-titanium alloys, with a composition of 53 to 57% nickel by weight, that exhibited an unusual effect: severely deformed specimens of the alloys, with residual strain of 8-15%, regained their original shape after a thermal cycle. This effect became known as the shape-memory effect and the alloys exhibiting it were named shape-memory alloys (SMAs). It was later found that at sufficiently high temperatures such materials also possess the property of super elasticity, that is, the ability of recovering large deformations during mechanical loading-unloading cycles performed at constant temperature. Due to their unique properties, not present in most traditional materials, in recent years SMAs have attracted significant attention from the scientific community. Shape Memory Alloys have been widely used in many different fields, in particular for aerospace, automotive and biomedical applications. In this paper the seismic analysis of different types of braced frames using both steel and SMA in ANSYS 14.5 is done.

II. Shape Memory Alloys

One of the important properties that make SMA an innovative is its superelasticity. A superelastic SMA can regain its initial shape spontaneously, even from its inelastic range,on unloading. Among various composites, Ni-Ti has been found to be the most efficient SMA for structural applications because of its large recoverable strain, superelasticity and good resistance to corrosion.

When an SMA specimen is undergoing cyclic axial deformation within its superelastic strain range, it dissipates a certain amount of energy without permanent deformation. This results from the phase transformation from austenite to martensite during loading and the reverse transformation during unloading release of net energy occurs.

SMA with superelasticity has an advantage over other common metals alloys is that besides dissipating a considerable amount of energy under repeated load cycles, it has a negligible residual strain. Since most civil engineering applications of shape memory alloys are related to the use of bars and wires, one-dimensional phenomenological models are often considered suitable. The parameters used to define the material model are σ_s^{AS}(austenite to martensite starting stress) , σ_f^{AS} (austenite to martensite finishing stress) , σ_s^{SA}(martensite to austenite starting stress) , σ_f^{SA} (martensite to austenite finishing stress) ,ε_L maximum residual strain; and modulus of elasticity, E_{SMA}.

III. Scope

Failure of structures designed by conventional methods during recent earthquakes lead to the more effective methods. Passive control techniques are effective and novel alternative to conventional design methods. Shape Memory Alloys (SMA) are smart materials which can be utilized in structures aimed at eliminating the limitations of conventional methods. In the present study, analysis of buildings with steel braces and SMA braces under non-linear time history analysis is going to be study.

IV. Finite Element Analysis

The frame considered is of 3 storied having span of 9144 mm and storey height of 3962.4 mm. For braces ISMC 175 ,for Beams ISMB 150 and for columns ISMB 200 are considered.

TABLE 1. Details of Material Properties of SMA

Parameter	Value
σ_S^{AM}	520 MPa
σ_f^{AM}	600 MPa
σ_S^{MA}	240 MPa
σ_f^{MA}	200 MPa
E_A	60 GPa
Density	6450 kg/m^3
Yield Strength	550 MPa
Poissons ratio	.33
Recoverable elongation	8%

V. Comparison Of Steel Braced Frame And Sma Braced Frame

5.1Single- diagonal braced frame

5.1.1 Comparison of Inter storey drift of single – diagonal alternate braced frames with both steel and SMA

TABLE 2. Comparison of Inter storey drift of Steel and SMA

Storey	Steel	SMA
1	0.67	0.252
2	1.33	.725
3	1.01	0.83

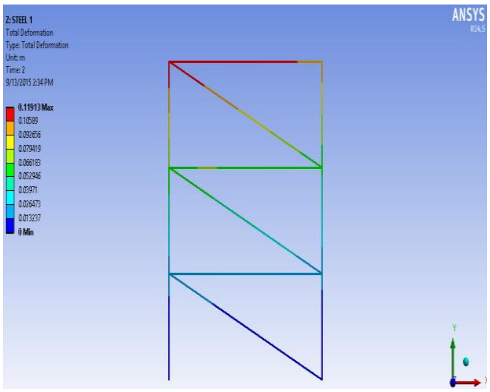

Fig.1.Deformation of single-diagonal braced frame with Steel

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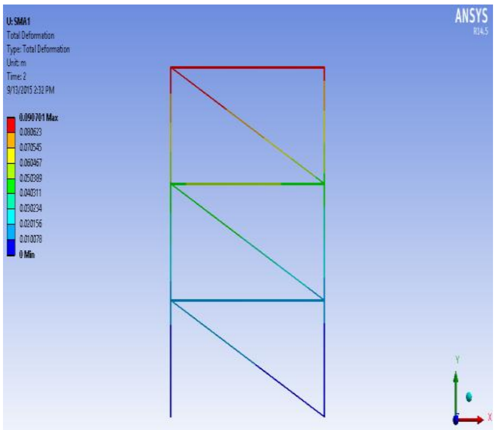

Fig.2.Deformation of single-diagonal braced frame with SMA

The output results from FE analysis show reduction in inter storey drift when SMA braced frame is used. The inter storey drift and maximum combined stres of building frame were decreased about 18% by the use of SMA braces

5.2 X-braced frames

TABLE 3.Comparison of Inter Storey Drift of Steel and SMA

Storey	Steel	SMA
1	0.413	0.29
2	1.663	1
3	1.70	1.165

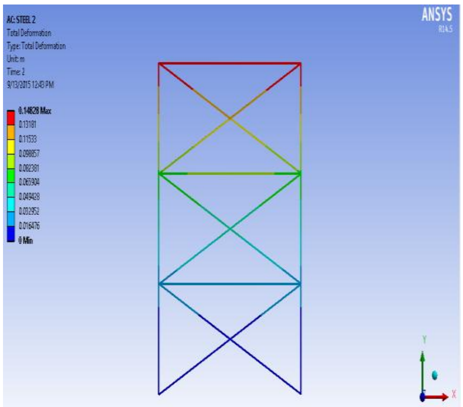

Fig.3. Deformation of x- braced frame with steel

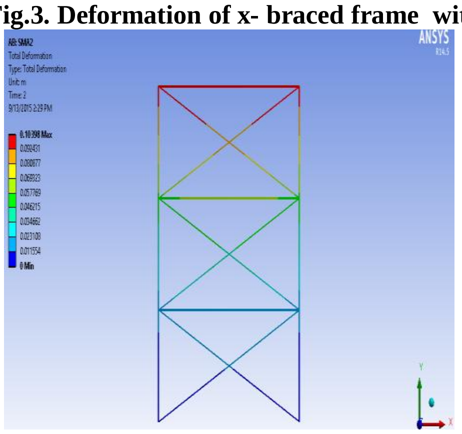

Fig.4. Deformation of X- braced frame with Steel

The output results from FE analysis show reduction in inter storey drift when SMA braced frame is used. The inter storey drift and maximum combined stress of building frame were decreased about 32% by the use of SMA braces

5.3 Single – diagonal alternate braced frames

TABLE 4.Comparison of Inter storey drift of Steel and SMA

Storey	Steel	SMA
1	0.317	0.25
2	1.277	0.89
3	1.38	0.952

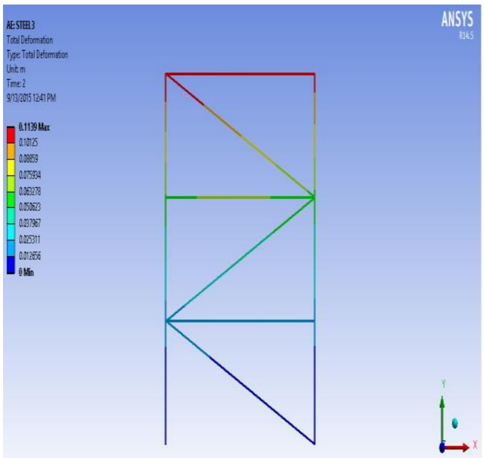

Fig.5.Deformation of Single – diagonal alternate braced frames with Steel

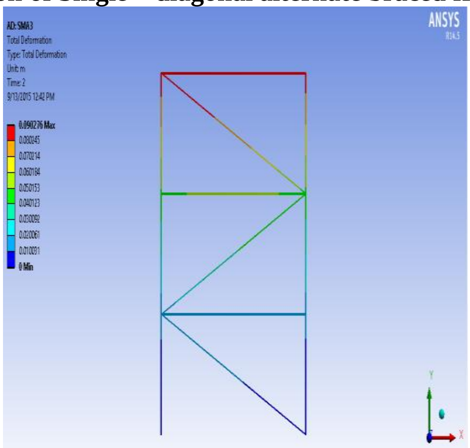

Fig.6.Deformation of Single diagonal alternate braced frames with SMA

The output results from FE analysis show reduction in inter storey drift when SMA braced frame is used. The inter storey drift of building frame were decreased about 43% by the use of SMA braces

VI. Conclusion

During this study, finite element analysis was carried out on braced frames. A study was achieved by considering different types of commonly used bracings with both Steel and SMA. The inter storey drift of single- diagonal braced frame were decreased about 18% by the use of SMA braces. The inter storey drift of X-braced frame were decreased about 32% by the use of SMA braces. The inter storey drift of single-alternate diagonal braced frame were decreased about 43% by the use of SMA braces. The inter storey drift of SMA braces is less than that of steel braces for different type of conventional braced frames. Shape Memory Alloys (SMA) are smart materials which can be utilized in structures aimed at eliminating the limitations of conventional methods. Different can be the directions that may be pursued for further research in the field like analysis of reinforced-concrete structures endowed with superelastic SMA braces, analysis of structures isolated by SMA-based devices, analysis of multistoried buildings with SMA as braces.

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