International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 3, Issue 07, July-2017

Use of Shape Memory Alloy for different components in steel structures

Abhijeet G. Gangal[1], Akshata Deshpande[2]

[1]*M.Tech. Student, Department of Structural Engineering, Sardar Patel College of Engineering,*
[2]*Assistant Professor, Akshata Deshpande, Sardar Patel College of Engineering,*

Abstract*—The structure is said to be smart structure if the behaviour of the structure will change depending on the conditions. To make the structure smart or to make them capable for various conditions mainly there are major two approaches are there. First one is to use some better structural system which is mostly used by all the designers. Lot of work has been done already by this approach. Here you provide moment resisting frames or diagrid structure or tubular structure or different type of bracing or shear walls. The other approach is to introduce some different type of element in the structure. Depending on the material properties and behaviour of the material the amount of use and at which position it is to be used needs to be decided. Not much amount of work has been done by this approach. Researcher has developed new materials called as smart alloys or shape memory alloys. It has got super elastic properties so that on large deformation also the come back to its original shape. So the residual deformations in the structure formed after the earthquake can be reduced and the capacity of the structure will increase. The nitinol is one of the shape memory alloy is used in the steel structure at different locations keeping the train restricted up to 8% only and the effect of that element on other steel element is observed for static conditions. The best possible location is checked for the dynamic condition and it is found that if the steel connections are replaced by SMA connections then the residual deformation and stress in the structure can be reduce to very large extent.

***Keywords*— Shape memory alloy, Nitinol, Connection, Ansys, Steel Structure**

I. Introduction

The main purpose of any structure is not to fail under any conditions and it will be serviceable throughout its lifespan. When any earthquake takes place the serviceability of structure gets lost so there is formation of permanent deformation in the structure. Because of which either the whole structure have to rebuild or that particular part needs to be reconstructed. So to overcome this problem the structure should behave smartly and for that there is need to introduce some new materials in the steel industry. The property of superelasticity of the shape memory alloy will give new dimension to the structural industry. Because of the superelasticity the structural component tend to come back to its original shape upto a greater extend. But how effectively the shape memory alloy to be used in the structure is need to be studied. Along with that what effect will it make on other structural components needs to be studied.

Saeed Reza Massah and Hosein Dorvar[1] suggested a hybrid device of steel and SMA placing it at the end of Bracings.total 12 models of 4,9 and 14 storied structure with different beta angle were studied. They concluded that structure with beta angle 25^0 gives best result. ChuangSheng Walter Yang, Reginald DesRoches, Roberto T. Leon,Journal[2] considered the hybrid device on both direction for the bracing for different models and found out best configuration. Jason McCormick, Reginald DesRoches, Davide Fugazza and rdinando Auricchio[3] replaced the steel bracing with SMA bracing for three and Six storied structure and concluded that SMA is most effective for lower stories. Hooshmand, M., Rafezy, B., Hosseinzadeh, Y. and Ahmadi, H.[4] varied tha percentage of SMA in bracings for three storied frame and concluded that best composition is 20% SMA and 80% steel.

II. Methodology

To compare the difference in behaviour of the structure with SMA and with STEEL a 3D steel frame is modelled. The frame is basically a three storied steel frame with x-type of bracing in it. The model is made in the SOLIDWORKS and the analysis of the structure was done using ANSYS by the method of finite element analysis. To model the structure SOLIDWORKS was used because as it is a three-storied building and detailed modelling was required so there are almost 300 individual components in it. And it is very difficult to model this type of detailed structure in ANSYS. But in SOLIDWORKS it is possible to model each component individually and then to assemble it. Then by importing the model from SOLIDWORKS to ANSYS analysis was done.

TABLE I
EMBERS DETAILS IN STRUCTURE

STOREY	BRACES	BEAMS	COLUMNS
1	HSS 8x8x0.5	W 18x46	W 12x106
2	HSS 6x6x0.5	W 18x46	W 12x106
3	HSS 5x5x0.375	W 18x46	W 12x106

In ANSYS the new material is defined. Shape memory alloy named NITINOL (NiTi) is used in the structure. Nitinol is basically a combination of the Nickel and Titanium. Along with the other general properties of the material the special properties of shape memory alloy i.e super elasticity property (phase transformation) is defined. As the model is imported loading on the frame along with the support conditions are defined. UDL of 60 Kn/m is applied on the beach of each floor and fixed support at the base is provided. Then the main component is of meshing the 3-D structure. Meshing can be done depending on the accuracy of the result required. By doing auto-meshing of moderate type we can get the meshing done appropriately by the system itself. Total 1060 contact connections in the whole structure are selected by the system and are defined.

The main evaluation criterias are deformation, stress and strain in the structural members. The reduction in the amount of deformation, stress and strain in the structure is tried to achieve. To see the effect of replacement of steel component by SMA component for different structural members, total 24 trial for static analysis are carried out. These different trial includes replacement of the nut, bolt, beam, bracing and column in the structure. By this we get the trial with best result and that component trial we tested for dynamic analysis. In dynamic analysis any difference in stiffness and structure's natural frequency in all 6 direction is checked. Then for different ground frequencies the structural frequency and the amount of stress and deformation generated in the structure is checked. It is compared with the results of steel structure.

III. RESULTS

From the results it was observed that the replacement of connection gives best results. Hence the results of the connection replacement trial are given below.

Static Analysis
Deformations, Stress and Strain in different elements is shown in Fig.1, Fig.2 and Fig.3 respectively.

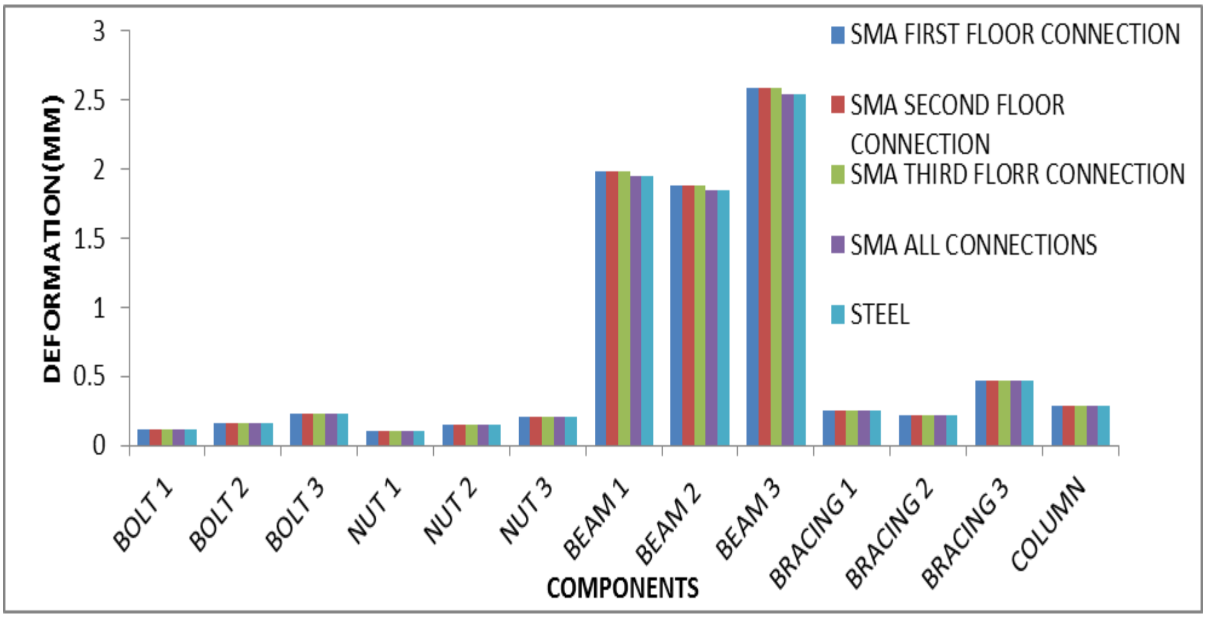

Fig.1 Deformation in components when connections are replaced

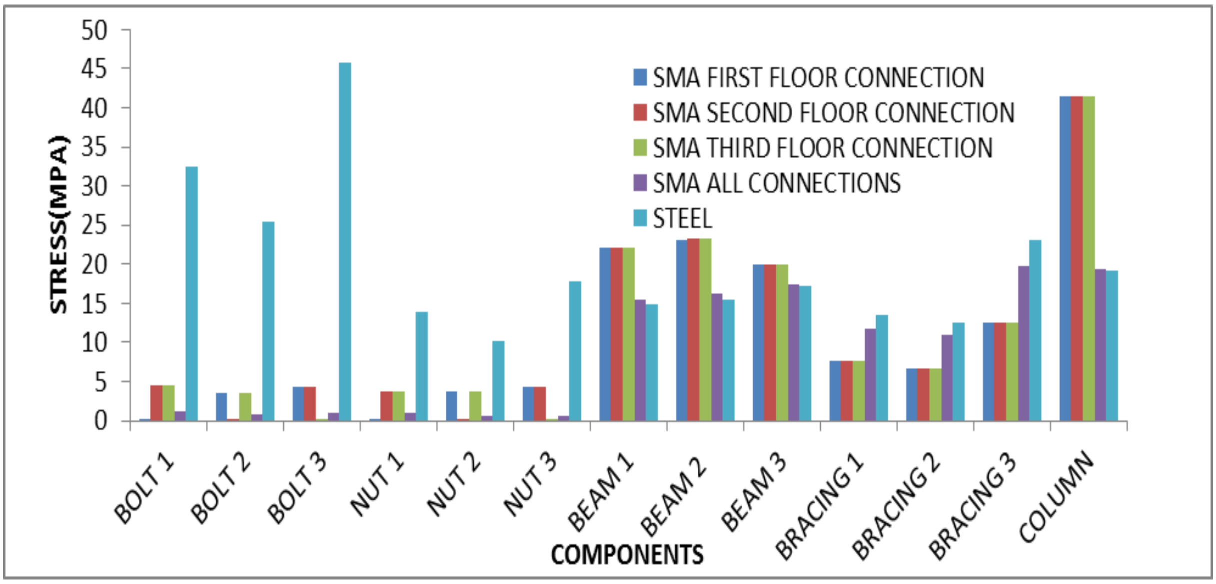

Fig.2 Stress in components when connections are replaced

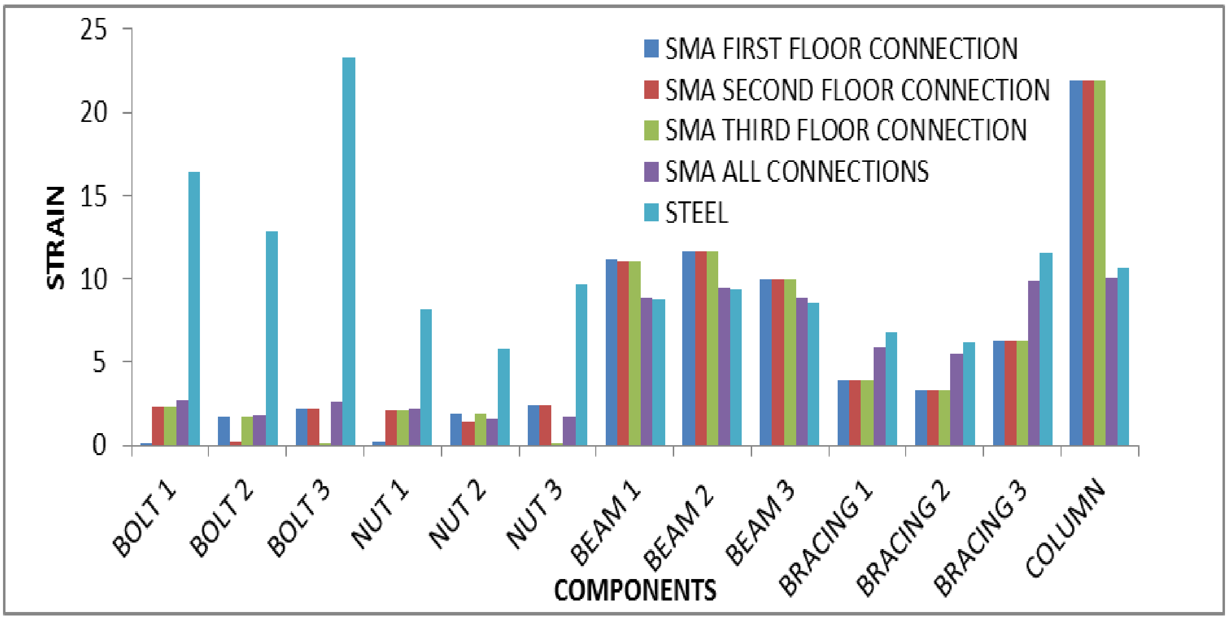

Fig.3 Strain in components when connections are replaced

DYNAMIC ANALYSIS

The natural frequency of both the structure is as in Fig.4 in all six directions. The stresses and deformations in structure for different time interval are shown in Fig.5 and Fig.6 respectively.

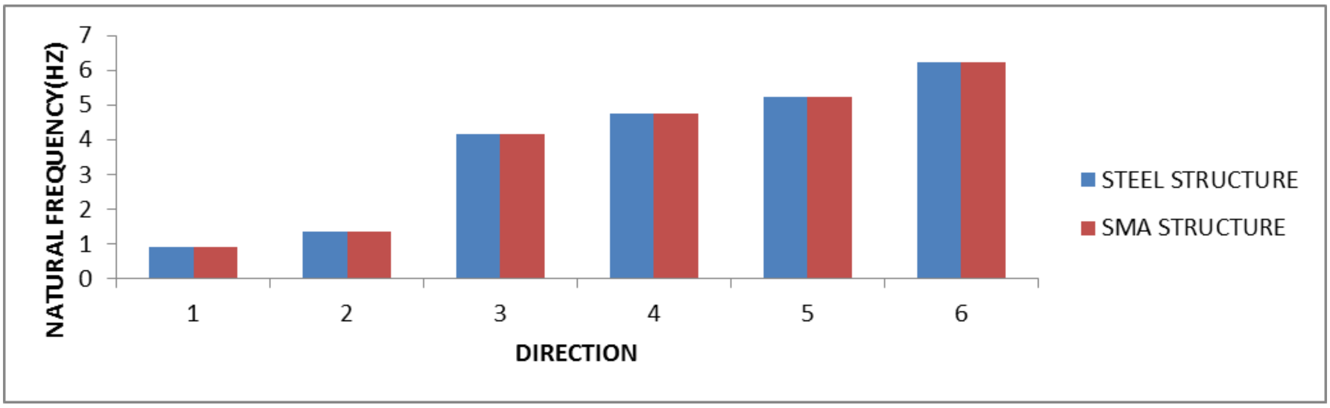

Fig.4 Comparison of natural frequencies

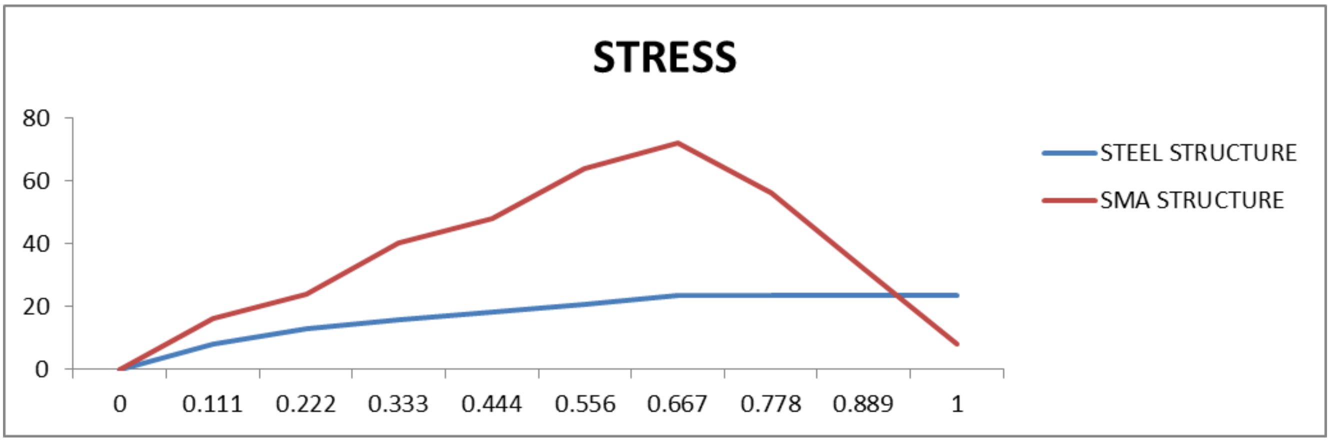

Fig.5 Stresses in structure at different time interval

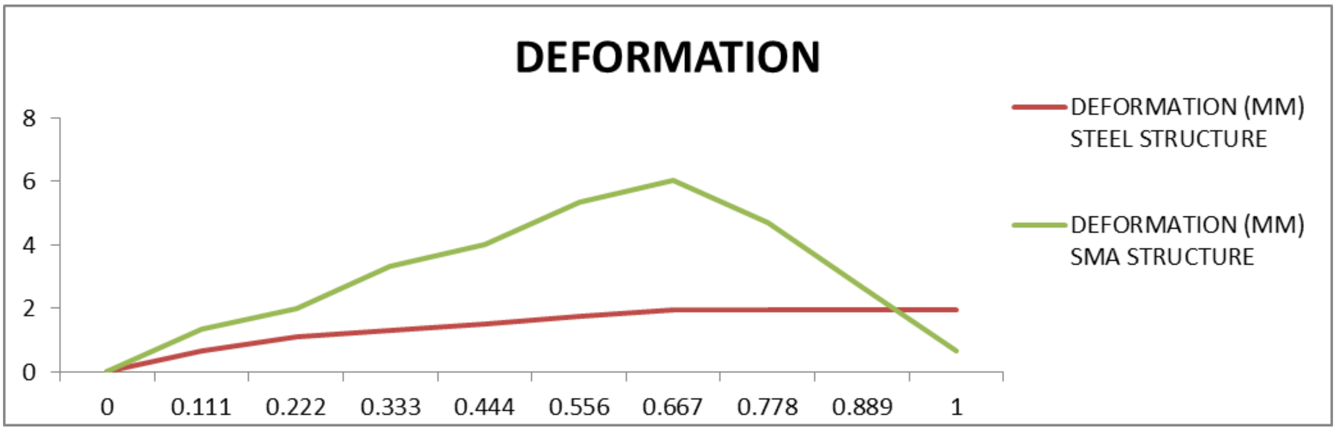

Fig.5 Deformations in structure at different time interval

IV. CONCLUSIONS

The static analysis is performed and the results were compared of the same component of SMA with the steel component and we can conclude that

- When the beams are made of SMA in the structure the deformations in all components increases upto 2% and stresses along with strain increases to significant amount of 20-30% in beams and 200% in columns.
- If the bracings are made of SMA the deformation increase is 5-20% and stress and strain increases in beams 40% and in 130% column.
- The column in structure is replaced SMA all element deformations increases by 50-300% and stress in beams increases 80% and strain in beams and column also increases upto 100% and 250 % respectively.
- If all the structural members in any floor are replaced the deformations remains same for all components only stress and strain of beam and column increase by 20-50%.
- By replacing all the components in the structure the deformations increases in all components is 200-400% and the increase in the stress and strain of beam and column by 40%.
- The nuts or bolts are used of SMA deformations remain same but increase in stress and strain in beam and column is 20-50%.
- The main increase is observed in stress and strains of beam and column so this is solved by the connection replacement. When connection of the structure are of the SMA there is no deformation changes. The stress and strain in the beam remains same along with that amount of stress and stress reduction in the connection is 85-96 % and in bracing is 15-40%. Hence the best replacement is the connection replacement for static conditions.

When the dynamic analysis was performed for the steel frame with SMA connections in it conclusions are

- The natural frequencies of the structure in all six directions remain same so there is no change in the stiffness of the structure.
- When the behaviour of structure was checked for different ground motion frequencies then there is increase in the stress and deformation initially as compare to the steel connection. The maximum value of stress and deformations recorded were 200% more for SMA connections as compare to that of the steel connections.
- But when the ground motion was stopped the amount of final stress and deformation in SMA connection was 66% lower than the steel connections i.e. the residual stress and deformation in the structure gets reduced.

REFERENCES

.

[1] Saeed Reza Massah and Hosein Dorvar, IOP Science Journal ,OCTOBER 2014
[2] ChuangSheng Walter Yang, Reginald DesRoches, Roberto T. Leon,Journal of engineering structures, OCTOBER 2009
[3] Jason McCormick, Reginald DesRoches, Davide Fugazza and rdinando Auricchio, Journal of structural engineering, JUNE 2007
[4] Hooshmand, M., Rafezy, B., Hosseinzadeh, Y. and Ahmadi, H. Civil Engineering Infrastructures Journal,DECEMBER 201