Perspective - (2024) Volume 13, Issue 4 Zhang Yun* *Correspondence: Zhang Yun, Department of Materials Science and Engineering, Jilin University, Changchun 130025, China, Email: The realm of smart materials has evolved significantly over the past few decades, reflecting the dynamic nature of scientific and engineering advances. From their early beginnings with shape memory alloys to the contemporary developments in self-healing polymers, these materials have transformed the way we think about functionality and adaptability in engineering and design. Shape Memory Alloys (SMAs) were among the first smart materials to gain prominence. These materials have the remarkable ability to return to a predefined shape when exposed to a certain stimulus, typically heat. The concept dates back to the early 20th century, but it was the development of nickel-titanium alloys, known as Nitinol, in the 1960s that showcased their practical potential. Nitinol demonstrated a unique property: it could "remember" its original shape even after being deformed. When heated above a certain temperature, the alloy would revert to its original form, making it invaluable in various applications from medical devices, such as stents and guidewires, to aerospace engineering [1]. Description The principle behind SMAs involves a phase transformation at the microscopic level. In their martensitic phase, these alloys are relatively soft and easily deformed. When heated to a specific temperature, they transition to their austenitic phase, where they exhibit significant strength and stiffness. This transition is not merely a physical change but a structural one, involving the rearrangement of atomic lattices. The ability to harness this property for practical applications marked a significant milestone in materials science, setting the stage for more advanced smart materials. Following the success of SMAs, researchers turned their attention to other types of smart materials, including those with dynamic properties influenced by external stimuli such as light, electricity, or magnetic fields. Among these, piezoelectric materials emerged as a significant category. Piezoelectric materials generate an electrical charge in response to mechanical stress and conversely, they change shape or dimensions when an electric field is applied. This bidirectional interaction makes them ideal for sensors, actuators and energy harvesting devices. Piezoelectricity is a phenomenon observed in certain crystalline materials, including quartz and various ceramics. These materials have been exploited in numerous applications, from ultrasound imaging to precision movement systems in industrial machines. The development of advanced piezoelectric materials, such as those based on lead zirconate titanate, has expanded their use, enhancing their efficiency and versatility. As the field of smart materials progressed, researchers began exploring polymers with unique properties that could respond to environmental changes. One such breakthrough came with the development of responsive polymers, also known as stimuli-responsive or smart polymers. These materials can undergo significant changes in their physical properties, such as swelling, shrinking, or changing color, in response to external stimuli like temperature, pH, or light [2,3]. Thermoresponsive polymers are among the most studied in this category. These materials alter their solubility or physical state with temperature changes. An example is poly(N-isopropylacrylamide) or PNIPAAm, which exhibits a drastic change in solubility around a specific temperature. At temperatures below its Lower Critical Solution Temperature (LCST), PNIPAAm is soluble in water, but it becomes insoluble above this temperature, leading to phase separation. This property is exploited in applications such as controlled drug delivery systems and tissue engineering scaffolds. The concept of smart materials took another leap forward with the advent of self-healing polymers. These materials possess the ability to autonomously repair damage without external intervention, mimicking biological healing processes. The idea of self-healing materials is rooted in the desire to create structures that can recover from damage and extend their functional lifespan. Self-healing polymers can be classified into two main categories: intrinsic and extrinsic. Intrinsic self-healing polymers contain built-in healing mechanisms within their chemical structure. For instance, some polymers can reform covalent bonds or reversible linkages after being damaged. An example is the use of dynamic covalent chemistry to create materials that can reconstitute their network after cleavage. Extrinsic self-healing polymers, on the other hand, rely on embedded healing agents or capsules that release repair substances when damage occurs. These materials are designed with microcapsules or vascular networks containing a healing agent that is released upon damage. For example, a polymer might be embedded with microcapsules filled with a resin that flows into cracks and solidifies, effectively repairing the material [4,5]. The development of self-healing polymers has been driven by the need for materials that can maintain their integrity in demanding environments. These materials have potential applications in various fields, including aerospace, automotive and civil engineering. For instance, self-healing coatings for aircraft can repair minor surface damage, preventing the need for costly and time-consuming repairs. The progression from shape memory alloys to self-healing polymers illustrates a broader trend in materials science toward creating materials with increasingly sophisticated and responsive capabilities. This evolution reflects the integration of various scientific disciplines, including chemistry, physics and engineering, to develop materials that are not only functional but also adaptive and resilient. Looking ahead, the field of smart materials continues to push boundaries with emerging technologies and novel concepts. Advances in nanotechnology, for example, are enabling the development of materials with unprecedented control over their properties at the molecular level. Nanocomposites, which combine nanoparticles with traditional materials, are offering new opportunities for creating smart materials with enhanced performance and functionality. Furthermore, the exploration of bio-inspired materials is opening new avenues for innovation. By mimicking the adaptive and self-repairing properties found in nature, researchers are developing materials that can exhibit complex responses to environmental changes. These biomimetic materials are poised to revolutionize various industries, from healthcare to construction. Conclusion In conclusion, the evolution of smart materials from shape memory alloys to self-healing polymers reflects a remarkable journey of scientific discovery and technological advancement. As researchers continue to explore new materials and technologies, the possibilities for creating adaptable, responsive and self-sustaining materials are expanding. The future of smart materials holds exciting potential, promising to enhance functionality, extend the lifespan of structures and drive innovation across multiple domains. Acknowledgment None. Conflict of Interest None. References Sinha, Arkabrata, Qi Wang and Jianqiang Wei. "Feasibility and compatibility of a biomass capsule system in self-healing concrete." 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"Poly (vinylidene fluoride) composite nanofibers containing polyhedral oligomeric silsesquioxane–epigallocatechin gallate conjugate for bone tissue regeneration." Nanomaterials 9 (2019): 184. Google Scholar, Crossref, Indexed at DISCOVER OUR LATEST INSIGHTS For latest market insight related to Healthcare, Chemicals and Materials, ICT, Automation, Semiconductor & Electronics, Aerospace and Defense, Telecom and IT, Consumer Goods and Retail, Energy, Food and Beverages industry, visit. Latest Insights Common name widely used for substances, structures, materials or systems which are designed to have a specific response to an external stimulus and be reversible upon removal of stimulus is smart material. Basically smart materials are designed materials with more than 1 property which can be changed in a specific manner to an external stimuli and revert back to their original state upon stimuli removal. The first recorded observation on smart material was seen in 1932 on gold-cadmium. In 1938, the second smart material transformation was observed on brass. In 1962, shape memory effect in Nickel-Titanium was transformed. Following these, several alloys and shape memory effects came into research and smart materials arouse in field of materials science. Smart Materials have several names like intelligent materials, responsive materials etc. and they are of several types depending on their response like Piezoelectric materials, Photomechanical materials, Self-healing materials, Magnetocaloric materials, Thermoelectric materials, Chemoresponsive materials, Electroactive polymers, shape memory alloys and shape memory polymers. Polymorphs, ferrofluids, dielectric elastomers, optical fibers, graphene, carbon nanotubes and quantum tunneling composites are some of the modern examples of smart materials. All over the globe, smart materials research has widened and intensified as they seem to find their applications in several sectors like aerospace, automobile, healthcare, construction, electronics, Mechatronics and so on. Taking for example, NASA's Glen research center has been investigating development of shape memory alloys (SMA's) for application as adaptive structures and actuators. SMA's are alloys which can deform at low temperature, have memory and recover to their original shape upon heating. SMA's have been ideal for high force, large stroke and modest frequency response operations. Recently a SMA has been developed to replace a traditional gearbox/motor actuation system. Several other applications where SMA's can be applied are Adaptive structures, actuators, heat detection devices, medical devices, High-temperature automotive, aeronautics and military. Smart Materials have come into picture, are being researched and hold scope to a large extent in our future. What's your take on future and advancements of smart material applications? Let us know by writing to us at smartmaterials@memeetings.com Best Regards Samantha Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Skip to content Smart materials have the ability to alter one or more properties when a controlled external stimuli such as stress, temperature, moisture, pH, electric and magnetic fields are applied on the material. Piezoelectric, magneto-rheostatic, electro-rheostatic, and other shape memory alloys are the most widely used smart materials. Properties such as viscosity, volume, and conductivity can be altered as per requirement in end applications. The smart material market is segmented on the basis of type, which includes biomimetric materials, piezo-electric materials, thermally responsive materials and others. The piezoelectric materials segment dominated the smart materials market. Smart materials are adaptive to different environmental and operational conditions. Increased investments in R&D to innovate new smart materials has resulted in broadened applications in automotive, construction, healthcare, aerospace, and chemical industries. Shape memory alloys have wide range of applications in manufacturing actuators and motors. Piezoelectric and electro-rheostatic materials are widely used in permeated households and automotive applications. Universities and key players are conducting research on smart materials to increase the elasticity of the materials to increase the application of smart materials in health care industry for artificial muscles in prosthetics. Automobile industry is leaning towards replacing conventional materials with smart materials to manufacture high quality vehicles termed as 'smart vehicle'.The global smart materials market is classified on the basis of the following segments: product type Piezoelectric materials Electro-rheostatic Magneto-rheostatic Shape memory materials Smart fluids Smart hydrogels Electrochromic materials Others Application Actuators & motors Sensors Transducers Structural materials Others End-user Industrial Defense Aerospace Automotive Consumer electronic Healthcare Increasing technological advancements have resulted in increased use of developed materials rather than conventional materials such as polymers, metal, and glass in various industries such as automotive, consumer electronics, and healthcare, among others. The property of smart materials to change one or more of its properties due to external stimulus is driving the usage of smart materials for various applications such as transducers, actuators & motors, structural materials and others. The use of smart materials require high investments. Various governmental and non-governmental bodies are focusing on increasing awareness and fuel uptake of smart materials. For instance, Centexbel launched a new TIS action along with Sirris to educate companies about the various applications of smart materials that are available commercially. The increased demand for consumer electronics and wide range of applications for smart sensors by the end users act as a driving factor for growth of the smart materials market. The introduction of internet of things (IoT) and the increased demand for connected devices is driving market growth globally. Europe contributes a major market share, due to its growing automobile and electronics industries as well as energy sector. Asia Pacific market is expected to be the fastest growing market for smart materials, due to growing electronics market and improved standard of living in emerging economies such as China and India. Use of smart materials in the healthcare sector has led to innovation of medical devices. The key restraint for smart materials lies in manufacturing costs for large quantities in different applications at effective yields. High costs in manufacturing and high investment in research and development hamper growth of the smart materials market. The market has high potential and large numbers of manufacturers are focusing on offering innovative products to enhance their market share. The new prospects for smart material products would have its applications in the engineering sector for manufacturing control devices, self-detection, self-diagnostic and other devices.The global smart materials market is highly fragmented due to the participation of many established and emerging players in the smart materials market. Major players involved in the market include TDK Corporation (Japan), CTS Corporation (U.S.), Optotune AG (Switzerland), AMM Technologies (Italy), Lord Corporation (U.S.), Fort Wayne Metals (U.S.), AI Technology Inc. (U.S.), AVX Corporation (U.S.), Advanced Cerametrics,Inc., (U.S.), Wright Medical Group (U.S.).Increasing development of wearable energy harvesting devices and smart sensors is expected to boost growth of the smart materials market. For instance, on September 04, 2019, Imagine Intelligent Materials, an Australia-based graphene and data analytics company, announced development of integrated sensing solution, the first sensing solution for large surface areas that mimics the way that the human skin transfers information to the brain.In June 2019, researchers from Tohoku University, Japan, reported development of Iron-Cobalt (Fe–Co) magnetostrictive fiber integrated shoes that demonstrated stable energy harvesting performance.In June 2019, researchers from Baise University and Jiangxi Electric Power Research Institute, China, developed a non-resonant piezoelectric current sensing device with high resolution. Email This Post By Anubhab Panigrahi ABSTRACT With the development of materials and technology, many new materials find their applications in civil engineering to deal with the deteriorating infrastructure. Smart material is a promising example that deserves a wide focus, from research to application. With two crystal structures called Austenite and Martensite under different temperatures, smart material exhibits two special properties different from ordinary steels. One is shape memory, and the other is super-elasticity. Both of these two properties can suit varied applications in civil engineering, such as prestress bars, self-rehabilitation, and two-way actuators, etc. One of the main objectives of the research is to investigate the application of smart materials in civil engineering by focusing on the literature review, basic information collection, and basic mechanic properties of smart materials. In axial tension tests, the force- extension curve and stress-strain curve of shape memory and superelasticity materials were measured separately. These curves verify the research of forerunners. Four beam experiments were conducted to evaluate the performance of flexure beams with superelasticity material as reinforcement bars. Load-displacement relationship at the midspan, strains on the surface of the concrete beam, and cracking width for different loads were measured. This research is just the first step in the investigation of the application of smart materials in structural engineering. Some bigger beams are prepared for experiments in the near future. 1. INTRODUCTION Reinforced concrete structures must be designed to satisfy the requirements of both the strength and serviceability limit state. The design for serviceability, however, is not straightforward, since the prediction of behaviour under sustained service loads is complicated by time-dependent deformations in the composite beams due to creep and shrinkage of concrete. It exhibit strains with age of concrete and causes considerable impact on its performance results in deflection as well as affecting stress distribution. It also causes dimensional change in the material under the influence of sustained loading. Therefore it is very important to develop a smart system for reinforced concrete structures, which can minimize internal and external disturbances for structural safety and extension of its service life. Although SMAs have been known for decades, they have not been used much in the civil structures until rather recently. Many research activities are at laboratory stage towards use of SMA in civil structures, but few have been implemented for field applications and found effective. Shape Memory Alloys (SMA, also known as memory metal) are materials capable of undergoing large recoverable strains of the 8% order while producing hysteresis. It is a metal that "remembers" its initial geometry during transformations. After a sample of SMA has been changed from its "original" conformation, it regains its original geometry during heating or, at higher ambient temperatures, during unloading. These extraordinary properties are due to the temperature and stress dependent phase transformation from a low-symmetry to a highly symmetric crystallographic structure. Advertisements 2. HISTORY OF SMART MATERIALS The first recorded observation of smart material transformation was made in 1932 on Gold-cadmium. In addition, in 1938 the phase transformation was observed in brass (Copper- zinc). It was not until 1962, however, that Beehler and co-workers found the transformation and attendant shape memory effect in Nickel-Titanium at the Naval Ordinance Laboratory. They named this family of alloy Nitinol after their lab. A few years after the discovery of Nitinol, a number of other alloy systems with the shape memory effect were found Though product development using smart materials began to accelerate after the discovery of Nitinol, many of the smart materials contained expensive and exotic elements. Only the copper-based alloys came close to challenging the Nitinol family as a commercially attractive system. During the 1980s and early 1990s, a number of companies began to provide Ni-Ti materials and components, and an increasing number of products, especially medical products were developed to market. 3. CRYSTAL STRUCTURES AND ITS BEHAVIOR Like all other metals and alloys, SMAs have more than one crystal structure which is known as polymorphism. The prevailing crystal structure or phase in polycrystalline metals depends on both temperature and external stress. It exists in two different temperature dependent crystal structures, known as martensite at lower temperature and austenite at higher temperature or parent phase. In austenite phase, i.e. at higher temperature, SMAs is stronger and stable and in martensite phase i.e. at lower temperature it is weaker. These two phases differ in their crystal structures. The austenite has a body-centered cubic crystal structure, while the martensite has a parallelogram asymmetric structure having up to 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 is weak and can be easily deformed. In austenite phase, the high temperature causes the atoms to arrange themselves into the most compact and regular pattern possible, resulting in a rigid cubic arrangement and have resistance to external stress. The special property that allows shape memory alloys to revert to their original shape on increase in temperature is that their crystal transformation is fully reversible. The transition temperature of SMAs varies from, about –50 deg C to 166 deg C depending upon their compositions. 4. MATERIAL PHENOMENA SMAs have two unique properties, 1. Shape Memory Effects (SME) 2. Superelasticity. The SME refers to the phenomenon that SMAs return back to their predetermined shape upon heating. For example if a straight bar of austenitic phase SMA is allowed to cool below the phase transition temperature, the crystalline structure will change to martensite. If the bar is subsequently deformed by bending, and then reheated above the transition temperature again, it will return to its original straight configuration as shown in figure. Superelasticity refers to the phenomenon that SMA can undergo a large amount of inelastic deformations and recovers their shape after unloading. On increasing the external stress without thermal actuation the phase transformation of SMA may occur from austenite to martensite which causes superelasticity or pseudoelasticity. A mechanical stress occurs in the material if this deformation recovery is restrained. This recovery stress can be used for introducing forces in concrete structures to improve its resistance towards growth of creep, shrinkage and thermal strains. Due to presence of superelasticity property the SMAs can be used in civil applications as a passive structural control, isolation device and energy dissipation devices. 4.1. SHAPE MEMORY EFFECT (SME) Shape memory is one of those special properties. When the smart material in twinned Martensite phase undergoes external stress, it transforms to detwinned Martensite phase as Procedure 1 indicates .There is no temperature change during this transformation. When the detwinned Martensite material undergoes an increase in temperature, the detwinned Martensite transforms to Austenite as seen in Procedure 2. As Procedure 3 indicates, Austenite will go back to twinned Martensite when the temperature goes down. There are four characteristic temperature points between Procedures 2 and 3, in the ascending temperature sort: Mf, Martensitic finish temperature; Ms, Martensitic start temperature; As, Austenite start temperature; and Af, Austenite finish temperature During Procedures 1, 2 and 3, smart material will experience external stress change, temperature increase, and temperature decrease. Finally, it will go back to its original twinned status. Constraints of Procedure 3, the recovery procedure from Austenite to twinned Martensite, will generate a considerable force. This particular property can be used in many ways in civil engineering structural applications. Transformations between different phases Demonstration of shape-memory effect 4.2. SUPERELASTICITY Superelasticity is another important property of smart materials. When the Austenite finish temperature Af is relatively very low, the superelasticity material will stay as Austenite under room temperature. In this Austenite phase range, the superelasticity material can transform into detwinned Martensite under stress. However, the detwinned Martensite material will go back to Austenite when the external stress is released, as indicated in figure. Stress-induced transformations of Austenite materials Figure b shows the stress-strain relationship of the typical phase changes of superelasticity smart materials under stress. The upper plateau represents the change from Austenite to Martensite under stress while the lower plateau represents the reverse process with stress release. This property can be used to rehabilitate the cracking of concrete when superelasticity smart material is used as the reinforcement bar. Superelasticity material also has some other important features like hysteretic damping, highly reliable energy dissipation capacity through repeatable phase transformation, excellent fatigue properties, and good resistance to corrosion. Advertisements 5. APPLICATION OF SMA IN CIVIL STRUCTURES 5.1. OVERVIEW The properties for which SMAs can be integrated in civil structures are: 1. The large force generated upon returning to its original shape is a very useful property. 2. Repeated absorption of large amounts of strain energy under loading without permanent deformation. 3. SMA has excellent damping characteristics at temperature below the transition temperature range. 4. Excellent property of corrosion resistance (comparable to series 300 stainless steels) and nonmagnetic in nature. 5. SMA has low density and high fatigue resistance under large strain cycles. 6. It has the ability to be heated electrically for recovery of shape. 5.2 APPLICATION OF TENSIONING PROPERTIES OF SMA UTILIZING SHAPE MEMORY EFFECT 5.2.1 SMA as a tendon in concrete structure In concrete members shape memory alloy bars or cables can act as tendons. Studies of Deng.Z., , and Krstulovic-Opara, N., presented the use of SMA as a tendon in concrete members. SMA tendons have several advantages over conventional steel tendons. There are no frictional losses due to development of uniform tension force along the total length of the tendon during initiation of shape memory effects. It is very suitable for curved concrete member or where tendon profile is much curved. Using SMA prestressing tendon, there is no need of anchors. This can be used for tensioning extremely thin concrete members. SMA used as a tendon 5.2.2 SMA as an external tensioning material in concrete structure The deficit in load bearing capacity and the risk of large deformation occurs in concrete structures due to increase in load and time dependent effects of concrete. With age of the concrete structure, it often develops cracks that lead to shortening in its service life. Adding external tensioning element is a well accepted strategy today for countering such problems in concrete structures. Materials like steel and Fibre Reinforced Plastic (FRP) are commonly used for these purposes. In comparison to these materials, SMAs have the ability of being stressed without any tensioning devices, like hydraulic jacks etc. After mounting and anchoring of martensite SMA along the external surface of structure, they need to be heated to initiate shape memory effect. As deformation recovery is restrained due to anchorage with structure, a tension force builds up. Soroushian et al, presented an example of realization of an external post tensioning. Corrosion resistant Fe-Mn-Si-Cr rods were used to enhance the shear resistance of a cracked region of a reinforced concrete bridge girder. Resistance heating was applied at a current of 1000Ampere. 5.3 RETROFITTING OF STRUCTURE USING SUPERELASTIC PROPERTIES OF SMA The superelastic behavior of SMA has attracted the attention of civil engineers. Its major field of application is retrofitting structures in an earthquake design. Graesser E.J successfully used Ni-Ti SMA for damping of seismic loads. The work of Wittig, P.R., used Cu-Zn-Al for torsion, bending and tension dampers. Cardone. D., compare in their work the superelastic bracing of RC-frames with classic steel bracings. A real scale application of a superelastic SMA device is the earthquake resistant retrofit of the Basilica San Francesco at Assisi, Italy Castellano, M.G., and Brite E.,. The historic gable was connected with the main structure by device using SMA rods. The Ni-Ti SMA rods were subjected to tension, although they were designed to take tension and compression forces. Another project was executed to retrofit the earthquake resistant bell tower of the Church of San Giorgio, Italy .Steel tendons were added to increase its tilt resistance with intermediary superelastic SMA devices to act as load limiters to prevent the masonry from compression failure, Indirli, M., and ISTECH . DesRoches, R., proposed increasing the position stability of Simply Supported bridges in earthquake prone regions through connection between the bearings of the bridge and the bridge deck slab using superelastic bars. The result shows that the SMA restrainer reduces effectively the relative hinge displacement at the abutment whereas with conventional steel restrainer cable the elastic deformation range in compression was large. In-addition, the SMA restrainer extremely limits the response of bridge deck to near field ground motion. Sakai et al. carried out research work on self- restoration of a concrete beam using superelastic SMA wires. The results revealed that the mortar beam with SMA wires recovers almost completely after incurring an extremely large crack. University of Houston developed a more efficient way to use superelastic SMA wires to achieve a larger restoration forces in the form of standard cable. A concrete beam (24 in. x 4 in. x 6 in.) was reinforced with fourteen 1/8 in. diameter superelastic stranded cables with 2% pre-strain. Each cable had seven strands and each strand had seven superelastic wires. Special clamps were used to hold the superelastic strands without slippage. There was appearance of large cracks in the test beam under 11000 lbs load. On removal of load the crack on the beam was closed under the elastic restoration force of superelastic SMA. This research also demonstrates that the effective way to use SMAs for civil application is in form of stranded cable. 5.4. APPLICATION OF SMA AS A CONNECTOR BETWEEN STRUCTURAL COMPONENTS Connections of different structural components are more likely to get damaged on occurrence of earthquake. SMA connectors have been designed to provide damping and resist relatively large deformations. Tamai, H., has proposed an exposed type column base with SMA anchorage for seismic resistance. The SMA anchorages were made of Nitinol SMA rods in 20-30 mm diameter and steel bars. The results obtained from the loading test and numerical simulation shows that SMA rods were very effective in dissipating energy and reducing the vibration of building under severe seismic ground motion. It was observed that, in comparison to the accumulated deformation and residual strain in ordinary anchorage, the SMA anchorage can recover their original shape after cyclic loadings. Resistance performance of SMA connectors was kept same to prevent plastic deformation and damage in the structural columns. Martensite SMA tendons were used by Leon et al. as a primary load transferring elements in steel beam-column connection as shown in Figure 13. Based on load test results of full-scale model it was concluded that the connection exhibits stable and repeatable hysteresis for rotation up to 4% and the SMA tendon was able to sustain up to 5% strain without any permanent damage. 6. PROBLEMS IN HIGHWAY AND BRIDGES Differential settlement between bridges and pavements causes bumps or uneven joints at the bridge ends. When vehicles, especially heavy trucks, approach and leave bridges, the bumps cause large impact loads to the bridges and pavements. It is well known that these uneven joints can cause pavement and bridge deterioration, damage automobiles or cause accidents. The damage includes separation of pavement topping from its base, spalling of joints, fatigue cracking of pavements, and fatigue damage to bridges. A similar problem is associated with the uneven settlement between the piers of the bridge or the approach spans. When differential settlement occurs, not only is the drivability of the bridge affected, but additional internal forces are also created for the structure. Maintenance of joints is a big problem and expense for engineers and highway officials. Traditionally, in dealing with these problems, engineers focus on improvement in foundation design. However, they have not been very successful in resolving these problems associated with the unevenness of the joints and differential settlement. Temperature change and time-dependent effects, such as creep and shrinkage, also cause internal restraint forces for indeterminate structures. These forces alone or together with other external load effects cause cracking of existing structures and pavements, or increase the cost for new construction meant to cope with these effects (such as increase in section dimensions). Another problem is that associated with the performance of bridge bearing. Malfunctioning bearings due to material deterioration, clogging of dirt, and other factors result in tremendous stresses near the bearing region. This causes changes in the force redistribution and thus makes the bridges behave differently from the intended design. These problems are common factors in bridge failures and in maintenance requirements. Finding a way to automatically adjust forces among the bearings in order to alleviate all of the above problems is desirable. 6.1. CONCEPT OF SMART BRIDGES The two-way memory effects of SMA can be used to make SMA actuators that can rise and fall to adjust their heights. The SMA can also be used to manufacture smart strands. After mechanically deforming the strands and embedding them in concrete, the prestressing and self-repair effects can be activated as needed during the life of the structure. The smart strands are actually actuators that can be activated by external heating or internal stress changes. The applications of the smart bearings and smart strands can be used to develop a smart bridge as shown in figure 1. The smart bearings will adjust their heights through the shape memory effect of the SMA. This height adjustment will correct the unevenness problem as well as the internal forces induced from differential settlements, time-dependent deformations (creep and shrinkage of concrete, relaxation of prestressing steel), and temperature changes as discussed earlier. When needed, the prestress forces can also be adjusted to deal with cracking issues in both positive and negative moment zones. With the combined application of the smart bearings and smart strands, the bridge can adjust its internal force distribution and mobilize each element to adapt itself to different environmental loads like those induced by differential settlement, time-dependent effects, temperature effects, and over-weight trucks. Sketch of a smart bridge 7. TYPE OF SMA, SUITABLE FOR USE IN CIVIL STRUCTURES However, not all the SMAs have the potential for being used in civil structures due to requirement of special mechanical properties, the specific temperature conditions in civil structures and last but not the least the cost involvement. Fe-Mn-Si-X alloys are low cost SMA with high superelastic properties and good shape memory effects. Comparing the market price of Ni and Ti on the one side and Fe, Mn, Si, Cr on the other side and consider their ratio, it will be a factor of about 8 to 12. So, in terms of cost an iron based SMA could only be a small fraction of that NiTi SMA. The study of Tamarat.K, shows that Fe-based SMA like Fe-Mn-Si-X, Fe-Ni-C and Fe-Ni-Co-Ti also referred to as shape memory steel or Ferrous SMA have the potential for use in civil structures. The shape memory effects in Fe- Mn-Si containing sufficient amount of Mn were detected in 1982 by Sato et al.. In last decades Fe-Mn-Si based alloys with several additional alloying elements were developed and tested. With lots of research work, the poor shape memory effects and inferior corrosion behavior was improved. It was found that 60% to 65% ratio of iron in Fe-Mn-Si-X alloys combine low cost with high strength and high Young's modulus. Corrosion behavior similar to that of stainless steel was achieved by Li. H.J., with addition of 10% chromium and nickel. From the literature of Farjami, S., , Lin. C., and Baruj, A., it was found that addition of Al, C, Co, Cu, N, Nb, NbC, V, VN, and ZrC improves shape memory effect. There is a wide scope of research towards uses of low-cost SMAs for initiating large-scale applications like civil structures. Low-cost SMA has been successfully implemented in bridge rehabilitation by Soroushian et al. . Graesser. E. J., used Ni-Ti for the damping of seismic load successfully. Wittig, R.P., used Cu-Zn-Al for torsion, bending and tension dampers incorporated in bracings. Because of better workability and lower cost of ferrous SMAs, these are more attractive than Ni-Ti SMA's for use in civil structures. 8. EXISTING FIELD APPLICATION OF SMA Retrofitting of the Basilica of San Francesco at Assisi, Italy Retrofitting of the bell tower of the Church of San Giorgio at Trignano, Italy Unseating at in-span hinge during the 1994 Northridge earthquake for (a) an existing bridge and (b) bridge retrofit with SMA restrainer cables Exterior of the Sherith Israel Synagogue retrofitted with SMA devices Use of sma bars to seismically upgrade buildings in Berkley and Oakland 9. CONCLUSION This paper presents a review of the basic properties of Shape Memory Alloys and their applications in passive, active and semi-active control of civil structures. A number of experimental and analytical research works on SMA devices like dampers and base isolators are presented. They are proved to be effective in improving the response of civil structures to any extreme earthquake loading. In particular, the recentring capability of SMAs can be very efficient in reducing the cost of repairing and retrofitting of various structures. Other prospective use of SMAs is in prestressing, which can help the structure to actively accommodate additional loading or remedy prestress losses over time. The self-repairing capabilities of superelastic SMAs may be utilized to regain the preload drop in bolted joints or other type of fasteners, and thus necessary clamping forces can be provided to keep the joint members together. 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 reduces instantaneous and long-term deflections of SMA, RC beams. SMA act as a stiffener in the RC flexural members. 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. Advertisements 10. REFERENCE • Review of Shape Memory Alloys applications in civil structures, and analysis for its potential as reinforcement in concrete flexural members Debbarma.S.R, Saha.S • INTERNATIONAL JOURNAL OF CIVIL AND STRUCTURAL ENGINEERING Volume 2, No 3, 2012 ISSN 0976 – 4399 Applications of shape memory alloys in civil structures" G. Songa,?, N. Ma, H.-N. Li • International Journal of Automation and Control Engineering Volume 2 Issue 1, February 2013 S.M.R. Mortazavi1, M. Ghassemieh, and S. A. Motahari • Seismic Control of Steel Structures with Shape Memory Alloys DesRoches, R., and Delemont, M., • Seismic retrofit of simply supported bridges using shape memory alloys Engineering Structures, 24, 2002, 325? 332. Hodgson, D.E., and Brown, J.W. • Using Nitinol Alloys, Report of Shape Memory Applications Inc., 2000. Maji, A.K., and Negret, I., • Smart Prestressing with Shape-memory Alloy. Journal of Engineerin Mechanics, Vol.124, No.10, Oct. 1998, pp.1121-1128. DesRoches, R., • Application of Shape Memory Alloys in Seismic Rehabilitation of Bridges,Technical Report NCHRP-IDEA project 65, Feb. 2002. • Lagoudas, D.C., Introduction to Shape Memory Alloys, Smart Lab at TAMU, . Dec. 2002. • Muller, I., A Model for a Body with Shape Memory. Architecture Rational Mechanics Analysis, Vol. 70, 1979, pp.61-77. We at engineeringcivil.com are thankful to Er. Anubhab Panigrahi for submitting this paper to us. If you have a query, you can ask a question here. Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. By Mr. S.L. Ghorpade Under the guidance of Prof. A.B. Shendge Dattakala Group of Institutions Faculty of Engineering, Swami – Chincholi (Bhigwan). Abstract- The construction of tunnel is important for different purposes. They can be constructed for railways, roadways, pedestrian footways and can be built in hard rock, soft ground, river bed and are also used to convey Hydroelectric power, water stream, or as a sewer. The construction of Diversion Tunnel, Pressure Shaft, and Tailrace Tunnel to convey water is considered in this project. To identify Scheduling of different activities by various methods Network Diagram, C.P.M., P.E.R.T. and their cycle time is calculated. Scheduling for different activity is carried out with the help of Network Diagram & Primavera Software will be carried out in a project stage II. Study of Estimation for a Diversion Tunnel, Pressure Shaft, and Tailrace Tunnel by both methods. Excavation in heading and benching, Rock bolt support work, lining work is considered for cycle time and cost estimation calculation in Diversion Tunnel, Pressure Shaft, and Tailrace Tunnel. Estimation is also carried out by two methods. The comparison of two methods adopted for excavation work and estimation will be carried out in a project stage II. Keywords- Scheduling, C.P.M., P.E.R.T., Gantt chart, Network Diagram, Estimation, Heading, Benching, Cycle time, Lining, Rock Bolts, Diversion Tunnel, Pressure Shaft, Tailrace Tunnel. Read More