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# From Smart Materials to Lifetime High Performance Structures

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## Concepts and Implemented Researches

The major challenge in today's structural engineering is to better design structures against the damaging effects of natural hazards and terrorist attacks. Smart structural systems are an innovative concept that has been proven to be very effective in protecting structures. These systems absorb damaging energy and/or counteract damaging force on the structure, and thus reduce structural response and possible damage. Smart structure technology is being improved every day, and there is a great need for documented references in this field.

Advanced research has discovered natural and man-made materials with unusual properties, called smart materials, and systems that can automatically adjust themselves to environmental changes, called adaptive systems. These discoveries led to the innovative concept of smart structures [1]. A smart material is defined as any material that is capable of being controlled such that its response and properties such as stress, temperature, moisture, pH, electric or magnetic fields can be significantly changed in a controlled fashion by external stimuli. [2,3] Have classified these materials in several subcategories based on their fundamental properties (Figures 1 and 2).

There are a number of types of smart material, some of which are already common. Some examples are as follows:

- *Shape-memory alloys* and *shape-memory polymers* are materials in which large deformation can be induced and recovered through temperature changes or stress changes (pseudoelasticity). The shape memory effect results due to respectively martensitic phase change and induced elasticity at higher temperatures [4,5].
- *Self-healing materials* have the intrinsic ability to repair damage due to normal usage, thus expanding the material's lifetime [6]. One of the most recent advancement in this field resulted in a new type of concrete named "bioconcrete" which can repair its own cracks. The use of bacterial concrete can in theory lead to substantial savings, especially in steel reinforced concrete. It will also mean durability issues can be tackled in a new and more economical way when designing concrete structures. Bacterial concrete is ideal for constructing underground retainers for hazardous waste, as no humans would have to go near it to repair any occurring cracks. For residential buildings, however, it does seem the traditional repairing of cracks will remain the most economically attractive solution for now [7,8].
- *Smart Nano materials and composites:* One well-known example of this type in the construction industry, is the Nano-cement particle which can accelerate cement hydration due to their high activity. Similarly, the incorporation of nano-particles can fill pores more effectively to enhance the overall strength and durability. Thus nano-particles can lead to the production of a new generation of cement composites with enhanced strength, and durability [9].
- *Magnetostrictive materials* exhibit change in shape under the influence of magnetic field and also exhibit change in their magnetization under the influence of mechanical stress [10].
- *Magnetic shape memory alloys* are materials that change their shape in response to a significant change in the magnetic field [11].
- *Piezoelectric materials* are materials that produce a voltage when stress is applied. Since this effect also applies in the reverse manner, a voltage across the sample will produce stress within the sample. Suitably designed structures made from these materials can therefore be made that bend, expand or contract when a voltage is applied [12].
- *pH-sensitive polymers* are materials that change in volume when the pH of the surrounding medium changes [13].
- *Temperature-responsive polymers* are materials which undergo changes upon temperature [14].
- *Halochromic materials* are commonly used materials that change their colour as a result of changing acidity. One suggested application is for paints that can change colour to indicate corrosion in the metal underneath them [15].
- *Dielectric elastomers (DEs)* are smart material systems which produce large strains (up to 300%) under the influence of an external electric field [16].

Smart materials have properties that react to changes in their environment. This means that one of their properties can be changed by an external condition, such as temperature, light, pressure or

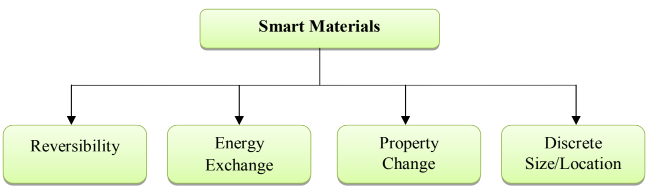


**Figure 1:** Smart Materials Classification [2].

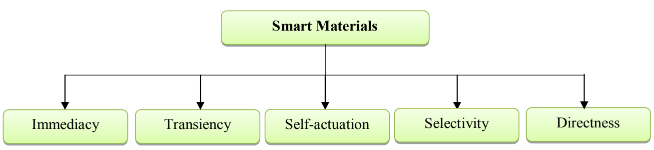


**Figure 2:** Smart Materials Fundamental Properties [3].

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electricity. This change is reversible and can be repeated many times. There are a wide range of different smart materials. Each offer different properties that can be changed. Some materials are very good indeed and cover a huge range of the scales. The priority of these materials over the conventional materials such as bricks, concrete and steel is that, they can be used to construct high performance structures for the severe environmental conditions. These materials will give the structural engineers to design high performance structure/infrastructure for the cases of extreme loading under explosion and/or seismic events.

## Significance of Smart Structure Technology for Civil Engineering Structures

Civil engineering structures, such as buildings, bridges, and towers, may vibrate severely or even collapse while subjected to strong wind or earthquake excitations. Designing structures to withstand seismic damage remains a challenge for civil engineers. Despite intensive effort toward wind- and earthquake-resistant designs in code development and construction, structures are still vulnerable to strong wind or earthquake excitations. This is because structures designed using the traditional approach have limited capacities of load resistance and energy dissipation. Such structures totally rely on their own stiffness to resist earthquake force and on their own small material damping to dissipate dynamic energy. These structures are passive in that they cannot adapt to ever-changing and uncertain wind and earthquake excitations. In order to withstand a stronger excitation, an increase in structure strength and ductility is required, but high-strength and ductile construction materials are usually expensive. Increasing strength by enlarging cross sections of partial constituent members of an indeterminate structure actually attracts more demand force on these members, subsequently requiring even greater strength. This can result in a fruitless spiral design. Moreover, there is no way to improve damping for common construction materials, such as reinforced concrete or steel.

The ineffectiveness of traditional wind- and seismic-resistant designs led to the application of innovative smart structure technology to civil engineering structures in the 1970s. It has steadily gained acceptance as research findings and practical implementation continue to show that this concept is a promising way to protect structures from wind and seismic excitations [17-27].

### References

1. Srinivasan AV, Mc Farland DM (2001) Smart Structures: Analysis and Design. Cambridge University Press, Cambridge, UK.
2. Gharabaghi M, Asadollah Naghdi (2015) Identifying Smart Materials and Applying Them in Residential Spaces in Cold Climate Case Study: City of Hamadan. International Research Journal of Applied and Basic Sciences 9: 51-62.
3. Mechelle A, Daniel S (2005) Smart materials and technologies: For the architecture and design professions.
4. Wilkes KE, Liaw PK, Wilkes KE (2000) The fatigue behavior of shape-memory alloys. JOM 52: 45-51.
5. Lendlein A, Behl M (2007) Shape-memory polymers. Materials Today 10: 20-28.
6. Zang MQ (2008) Self-healing in polymers and polymer composites. Concepts, realization and outlook: A review. Polymer Letters 2: 238-250.
7. Wiktor V, Jonkers HM (2011) Quantification of crack-healing in novel bacteria-based self-healing concrete. Cement and Concrete Composites 33: 763-770.
8. Luo M, Qian CX, Li RY (2015) Factors affecting crack repairing capacity of bacteria-based self-healing concrete. Construction and Building Materials 87: 1-7.
9. Li H, Xiao HG, Yuan J, Ou J (2004) Microstructure of cement mortar with nano-particles. Composites Part B: Engineering 35: 185-189.
10. Joule JP (1847) On the Effects of Magnetism upon the Dimensions of Iron and Steel Bars. Philosophical Magazine 30: 76-87.
11. Karaman (2007) Energy harvesting using martensite variant reorientation mechanism in NiMnGa magnetic shape memory alloy. Applied physics letters 90: 172505.
12. Gautschi G (2002) Piezoelectric Sensorics: Force, Strain, Pressure, Acceleration and Acoustic Emission Sensors, Materials and Amplifiers.
13. Petereit (2009) pH-sensitive polymer. US Patent No. 7, 553, 918.
14. Koningsveld R, Walter H, Nies E (2007) Polymer Phase Diagrams, Oxford University Press, Oxford, UK.
15. Chen SY, Chang SF (2009) A review of Smart Living space development in a cloud computing network environment. Computer-Aided Design and Applications 6: 513-527.
16. Pelrine R, Kornbluh R, Kofod G (2000) High-Strain Actuator Materials Based on Dielectric Elastomers. Advanced Materials 12: 1223-1225.
17. Applied Technology Council (ATC) (1993) Proceedings of ATC-17-1 Seminar on Seismic Isolation: Passive Energy Dissipation and Active Control, San Francisco, California, USA.
18. Cheng FY, Pantelides CP (1988) Algorithm development for using optimal control in structural optimization subjected to seismic and wind forces. NSF Report, NTIS No. PB90-133471/AS, Fairfax, Virginia, USA.
19. Cheng FY (1996) Theoretical and experimental studies on hybrid control of seismic structures.
20. Chu SY, Soong TT, Reinhorn AM (2005) Active, Hybrid, and Semi-Active Structural Control: A Design and Implementation Handbook. John Wiley & Sons, Chichester, England, UK.
21. International Association of Structural Control (IASC) (1998) Proceedings of the First, Second, and Third World Conferences on Structural Control, California, USA.
22. Kelly JM (1993) A state-of-the-art and state-of-the-practice in base isolation.
23. Kobori T (1994) Future direction on research and development of seismic-response controlled structure.
24. Soong TT (1990) Active Structural Control: Theory and Practice.
25. Soong TT, Constantinou MC (1994) Passive and Active Structural Vibration Control in Civil Engineering.
26. Soong TT, Dargush GF (1997) Passive Energy Dissipation System in Structural Engineering.
27. Soong TT, Spencer BF (2002) Supplemental energy dissipation: State-of-the art and state-of-the-practice. Engineering Structures 24: 243-259.