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Smart Materials; Awareness and Impact in the Construction Industry in Lagos State

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Abstract *— The recent development in material science and material technology has led to the discovery and development of improved materials (smart materials, composite materials, soft materials, etc.) with efficient and versatile applications. Smart materials possess the ability to adapt and conform to service conditions. Smart materials quickly adapt to the environment, thereby bringing smartness to construction. Shape Memory Alloys (SMAs), fiber optics, piezoelectric materials, Magneto-Rheological (MR) fluids, Electro-Rheological (ER) fluids, and magnetostrictive materials are some smart materials with potentially good applications in the construction industry. Research into the development and applications of smart materials is worthwhile for all fields of science and engineering. When smart materials are subjected to different temperature treatments (Austenite and Martensite), they exhibit two special properties that are distinct from ordinary steels. These properties are shape memory and superelasticity. The advantages of these two important properties can be enjoyed in several areas of applications in civil engineering and the entire construction industry, such as prestress bars, self-rehabilitation, two-way actuators, etc. This research assesses through a survey the level of awareness and impact of smart materials amongst the construction stakeholders in Lagos State, Nigeria. A questionnaire through hard filing and Google Forms was used to collect data from the respondent. The population for the study comprises all construction stakeholders in Lagos State. The data obtained were analyzed through the use of means and standard deviation. The findings from the study revealed that About 91.5% of the stakeholders believed smart materials could help reduce the rate of building collapse in Lagos State.*

Keywords— *Building collapse, Construction stakeholders, Lagos State, Shape Memory Alloy (SMA), Smart materials.*

I. INTRODUCTION

Material is the bedrock of technology, engineering, science, and construction. Materials play an important role in construction development and have a wider application in several other fields. The recent development in material science and technology birthed the development of new materials known as smart materials which majorly found their applications in construction engineering and several areas of engineering and sciences. The application of proper materials and systems in structures results in improved structural performances that satisfy the stakeholders' requirements in the construction industry Mohammad and Peyman (2019). Structures designed with conventional materials and traditional systems have limited capacities in providing high performances (Cheng et al., 2008). This has then challenged the construction sector to research materials that can help improve and even eradicate these challenges. The primary objective over the past few years has been the quest for unconventional materials and unconventional structural solutions to satisfy high-performance criteria (Saadat et al., 2002). The name smart material naturally creates market and acceptability for the material (Worden et al., 2003) but in principle, the material is said to be smart if it can respond to changes in services conditions based on situations in the environment by changing one or more of its properties to produce a reversible useful effect or response upon receiving an excitation Mohammad and Peyman (2019). This can be either active or passive, occurring respectively with or without the need for external sources of energy. The main difference between conventional and smart materials is that smart materials are good in producing useful and extraordinary responses because all the materials react in any form to their environment. This extraordinary response to a form of engineering and environmental excitations (Schwartz, 2009) is provided by different mechanisms such as a change in crystallographic structure. Smart systems are similarly defined as systems with a certain level of smartness or autonomy toward structural safety and serviceability as well as the extension of structural service life, relying on inherent properties of materials or embedded functions of added sensors, actuators, and processors that can automatically adjust structural properties in response to excitations (Otani et al., 2000). The ever-growing construction sector in Lagos state, Nigeria has in recent times experienced diverse challenges such as the recent hike in the cost of building materials, reoccurring cases of infrastructural collapses, and the increase in the need for infrastructure due to the increasing population, environmental pollution by construction materials, etc. Smart materials are a category of materials capable of improving the performances of civil structures and the entire construction industry. Although the research into smart materials and their usage has begun decades back in more developed countries such as the United States, the United Kingdom, Germany, and several others. It is at its nascent stage in Nigeria, the incorporation of smart materials into the construction industry since its discovery increased rapidly globally, by being corroborated with other construction materials. Smart material applications is capable is able to cater for various needs such as determining cracks at early stages, to regulate the stresses and strain-induced on members, etc. It is the peculiar nature of smart materials that makes them our go-to materials to help us combat some of the numerous problems we face in the construction industry. In recent times in Lagos State, we have experienced a significant rise in the cost of construction materials, which are the traditional fine and coarse aggregate, binders, reinforcement steels, etc. which have no special importance asides from adding to the strength, stability, longevity of structures amongst others, which will neither inform us of the reaction of the building to various climatic conditions, loading variations, nor when the building needs any form of repair before it becomes visible, hence extra cost has then to be spent on regular routine checks on the structure. But the introduction of these smart materials will not only reduce the cost of construction but also make detection of any form of structural failure early. When the environment changes around them, smart materials—whether created artificially or naturally—produce favorable qualities (Abhilash et al., 2021). This means that they are able to change their properties when subjected to stimuli such as heat, waves, chemicals, pressure, and temperature, even when there are variations in the loading system of the structure, etc. This also means they are intelligent materials with special traits exhibiting different properties depending on the condition they are subjected to (i.e active or passive). The objectives of this research are;

- to access the construction stake holders level of awareness of smart materials in the construction industry based in Lagos State, Nigeria.
- to understand the impact smart materials, have on construction.
- to understand the prospect of smart materials in the construction sector

Classifications of Smart materials

1. Sensing smart materials

These are materials that are capable of sensing the intensity of external or internal stimuli such as stress, strain and physio-chemical, light, heat, electricity, magnetism, radiation, and other effects, which are usually used to make sensors (Sijia, 2021).

2. Actualizing smart material

The other category is actuating materials, which respond to changes in software conditions or internal states. Depending on the functional or environmental needs, these materials can be transformed into a variety of actuating or driving elements (Sijia, 2021).

Types of Smart materials

1. Shape Memory Alloys (SMAs)

Such materials possess the ability to regain some previously defined shape or size when subjected to appropriate thermal changes. Shape memory alloys are used in novel ways in civil engineering, particularly for the protection of buildings against earthquakes. Shape memory alloy is used in civil engineering for a variety of purposes, including the repeated absorption of strain energy without permanent deformation, obtaining a wide range of cyclic behavior, resisting fatigue under high strain cycles, and long-term dependability and durability.

2. Magnetostrictive Materials

These materials undergo mechanical deformation in proportion to the square of the electric field, which refers to the material quality of changing size in response to either an electric or magnetic field, and conversely, producing a voltage when stretched. These materials show promise in applications ranging from pumps and valves to aerospace wind tunnels.

3. Piezoelectric Materials

These are the materials that possess the capability to produce voltage when surface strain is introduced. Conversely, the materials undergo deformation (stress) when an electric field is applied across them. A piezoelectric material produces an electric field in response to mechanical forces when it is included into a structural part. Piezoelectricity is said to be the most effective mechanism for making mainly sensors and actuators. Piezoelectric materials can be divided into single-phase piezoelectric materials, piezoelectric composites, and inorganic piezoelectric materials.

4. Electrorheological Fluids

They are colloidal suspensions that undergo changes in viscosity when subjected to an electric field. These fluids are extremely sensitive and react right away to any alteration in the applied electric field. discover their use in shock absorbers.

5. Electrochromic materials.

When voltage is applied, these materials' characteristics related to light transmission change. (the constructor). They are capable of varying their coloration and transportation to solar radiation, in a reversible manner, when they are subjected to a small electric field. The main materials with electrochromic properties are metal oxides of transition, in particular WO_3, MoO_3, etc.

6. Photoactive materials

There are several types: electroluminescence emits light when they are fed with electrical impulses, fluorescents reflect light with greater intensity and phosphorescent are able to emit light after the initial source has ceased.

Other types include Biomimetic materials, Fullerenes, Thermo-responsive materials, Rheological materials, Carbon fiber reinforced concrete (CFRC), etc.

Application of smart materials in civil engineering

As the construction industry experiences changes, the importance of smart materials becomes more glaring as the need to corroborate these materials into the construction processes increases.

The heterogeneous usage of smart materials by various professions is perhaps another interesting angle to smart materials, as it can serve various needs ranging from

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construction, computer engineering, medicine, and many more. But the area of concern to us is it used in construction such as in architecture, civil engineering, building, etc. (Johnson, 2023).

Application of smart materials in the construction industry

At present, intelligent material systems are mainly focused on the following three aspects. One is the real-time detection and monitoring of structural health. The civil engineering industry frequently uses huge structures that, once constructed, are challenging to alter without making significant component adjustments. The load-bearing capacity of a structure will be reduced as a result of material aging and even normal use, even if the structure has been in a normal external environment for a long time. This is true regardless of the material used to build the structure. This is why we need an efficient and convenient structural health inspection system for timber projects, in order to determine in real-time whether defects exist, where they are located and the extent of damage, so that the structure can be repaired or reinforced in time to prevent irreparable damage and ensure the integrity and safety of the structure (Sijia, 2021).

These smart materials can also be combined with traditional building materials to monitor the integrity of structures, where the fiber optics are embedded in the structure, they are used to locate areas that have problems, and they can be used to help in controlling and monitoring the structures durability, to determine faults in structures before they escalate beyond repair and also they can be used to monitor the variation of loads (El-Khodary, 2016).

II. RESEARCH METHODOLOGY

The method employed for data collection was the use of a questionnaire through Google Forms. A total of 70 responses were collected. Responses were collected from the following professionals' occupations: Construction Engineer, Material Engineer, geotechnical engineer, Structural Engineer, Quantity Surveyor, and Architect. The data analysis and visualization were carried out with the use of Google Form Analytics and Statistical Package for Social Sciences (SPSS). The results generated through the questionnaire were analyzed and discussed to draw a useful conclusion on the level of awareness of smart materials and their impacts on building in the construction industry.

III. RESULTS AND DISCUSSION

The occupations of the various professionals who responded, as shown in Table 1, depict that more of the construction stakeholders are quite aware of smart materials used in the construction industry; 42 of the stakeholders are aware of smart materials, which is equal to 60% of the total construction stakeholders captured in this research. The result showed that Construction Engineers are the most informed about smart materials, followed by Structural engineers, with a total response of 39 and 14, respectively, which translates to 55.7% and 20% of the construction stakeholders captured in this research.

TABLE 1: Occupation of Respondent

Occupation of Respondent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Consruction Engineer	41	57.7	58.6	58.6
	Civil engineer	3	4.2	4.3	62.9
	Agricultural and Bio-Environmental enginee	1	1.4	1.4	64.3
	Plumbing Technician	1	1.4	1.4	65.7
	Structural Engineer	14	19.7	20.0	85.7
	Architect	3	4.2	4.3	90.0
	Quantity Surveyor	1	1.4	1.4	91.4
	Field service engineer	1	1.4	1.4	92.9
	Highway engineer	2	2.8	2.9	95.7
	Geotechnical Engineer	2	2.8	2.9	98.6
	Official	1	1.4	1.4	100.0
	Total	70	98.6	100.0	
Missing	System	1	1.4		
Total		71	100.0		

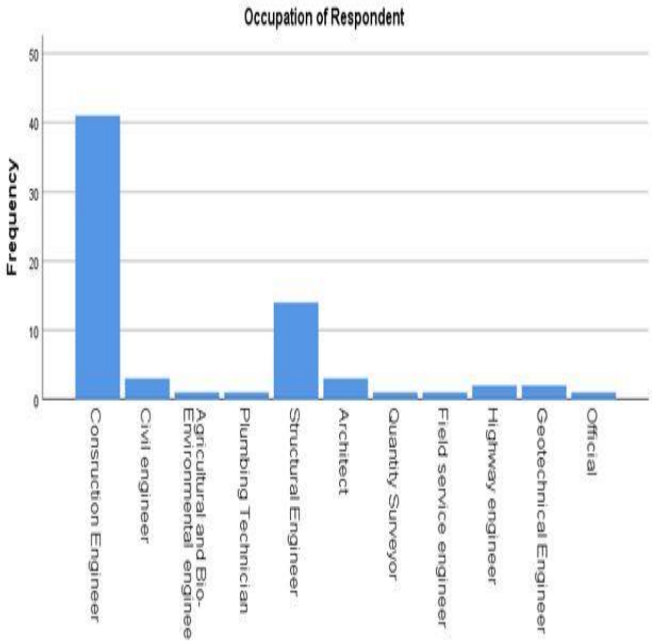

Figure 1. Histogram showing the occupation of respondent

TABLE 2: Smart materials and its level of awareness

Have you heard of smart material used in civil engineering construction?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	42	59.2	60.0	60.0
	No	28	39.4	40.0	100.0
	Total	70	98.6	100.0	
Missing	System	1	1.4		
Total		71	100.0		

The majority of construction professionals believed that smart materials had a positive impact on the cost of construction. They stated the following as purposes of smart

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materials for construction: quality construction, prevention of energy loss, and safety.

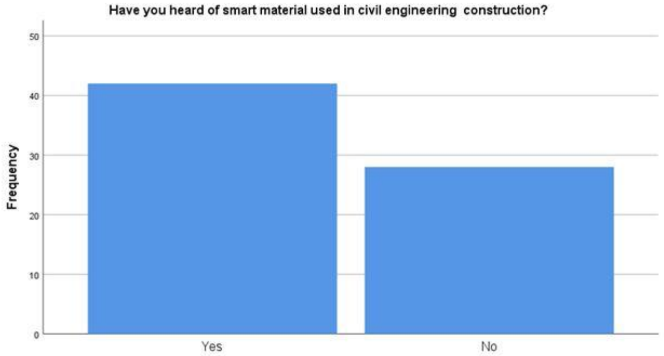

Figure 2: Histogram showing the level of awareness of smart materials

TABLE 3: Various types of smart materials used in construction

What type of smart materials do you use in construction?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Shape memory alloys	16	22.5	34.8	34.8
	Piezoelectric Materials	8	11.3	17.4	52.2
	Plastic and ceramic materials	1	1.4	2.2	54.3
	Electrochromic Materials	9	12.7	19.6	73.9
	Electrorheological fluids	2	2.8	4.3	78.3
	None	2	2.8	4.3	82.6
	8.00	1	1.4	2.2	84.8
	Global Positioning System (G.P.S)	4	5.6	8.7	93.5
	Total station 9	1	1.4	2.2	95.7
	Electromagnetic theodolite	1	1.4	2.2	97.8
	Total filling station gas	1	1.4	2.2	100.0
	Total	46	64.8	100.0	
Missing	System	25	35.2		
Total		71	100.0		

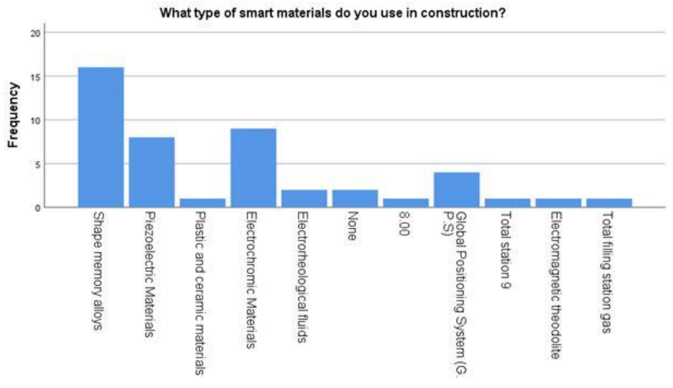

Figure 3: Types of Smart materials

In accordance with the stakeholders' response, Shape Memory Alloys (SMAs) have more usage in construction with 31.9%, followed by Electrochromic materials and then Piezoelectric Materials. Every other smart material, however, has relatively the same level of usage in the Lagos State construction industry.

About 91.5% of the stakeholders believed smart materials can help reduce the rate of building collapse in Lagos State and 59.6% also expressed those smart materials can help reduce the cost of construction materials.

TABLE 4: Perception of stakeholders on Smart materials and building collapse in Lagos State

Do you think smart materials can help reduce building collapse in Lagos State?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	43	60.6	91.5	91.5
	No	4	5.6	8.5	100.0
	Total	47	66.2	100.0	
Missing	System	24	33.8		
Total		71	100.0		

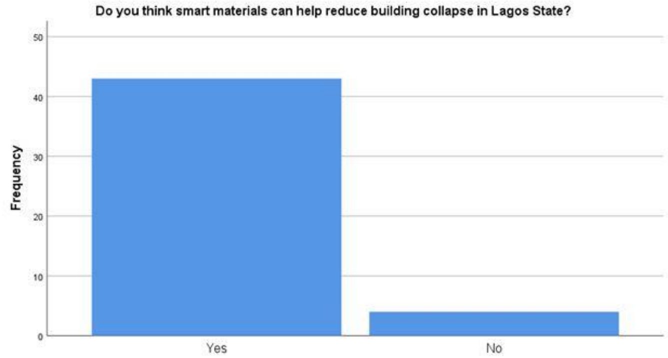

Figure 4: What construction stakeholders think of smart materials and building collapse

from the responses in the questionnaire, it is deduced that smart material;

(i) gives construction better strength
(ii) improved safety level
(iii) enhances the design of smart buildings
(iv) vibration control, noise mitigation, and better performance
(v) reduce construction cost
(vi) aesthetics
(vii) increase construction lifespan
(viii) assures structural strength
(ix) safe time, cost, and easy to use
(x) enhances high performance in civil engineering
(xi) serves as a mechanism to sense and respond to structural changes or failure
(xii) reduces material wastage

TABLE 5: Effect of cost of smart materials on its usage in the construction industry

Is the cost of smart materials an obstacle to the widespread use of the smart material?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	27	38.0	58.7	58.7
	No	19	26.8	41.3	100.0
	Total	46	64.8	100.0	
Missing	System	25	35.2		
Total		71	100.0		

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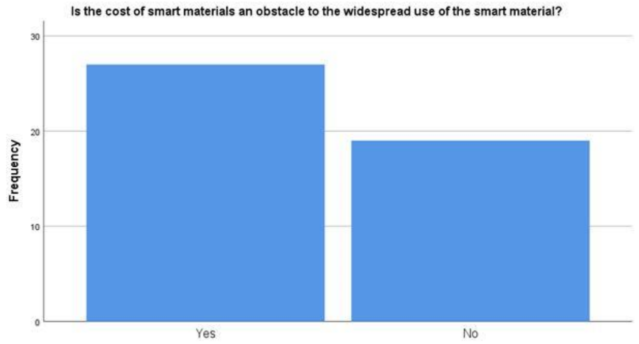
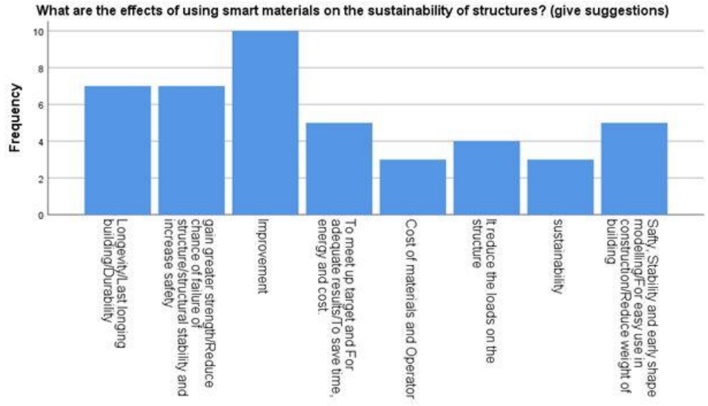


Figure 5: Effect of cost of smart materials on its usage in construction

The major factor that has affected the widespread use of smart materials in Lagos State construction is the cost and availability of smart materials. 58.7% of construction industry professionals agreed on this one factor.



IV. CONCLUSION

The construction stakeholder groups involved in this research expressed a high level of awareness for smart material usage in construction works, especially SMA. Also, most of the stakeholders believed smart materials could help reduce the rate of building collapse in Lagos State. With the level of understanding established thus far, when the professionals were asked what their perspective was on the prospect of smart materials in the Lagos State construction industry, their response ranked the prospects of smart materials very high in the near future.

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