International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Sustainable Space: Surveying the Use of Novel Materials in Upper Atmospheric Construction

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The human factor in engineering, despite the growing importance for machines and automated mechanisms in the building of cutting - edge infrastructure, is emerging as a vital part of modern urban development. Understanding human needs and preferences is vital for the design of user - friendly products and systems, which is something better done by human engineers. Furthermore, an understanding of safety mechanisms, as well as compliance with national and international building regulations can only come from a comprehensive understanding of engineering and design. Though there is a growing demand for automated processes within the engineering world, a human element is vital for safe, ingenious, and human - friendly design and engineering. Therefore, human - factors engineering, despite a growing need for automation, retains its importance. The aim of this paper is to understand the integration of novel materials and methodologies within construction and the importance of human factors engineering. Additionally, this paper will look at the newer, more sustainable building materials used in the 21st century that allow for a cut in costs, time, and effort in manufacturing, and a contribution towards sustainability and long - term safety in building practices.

Engineers often work in multifaceted teams of individuals hailing from a variety of backgrounds. Due to this interdisciplinary working, engineering and design becomes human experience focused, something that is deemed as incredibly important when it comes to the design and structuring of human - used infrastructure. [1] Despite the awareness of the importance of human factors engineering, novel methods and solutions that place machinery and AI at the forefront of innovation and design have begun to emerge in the last few decades. Returning to older methods of engineering and design strategy is important to ensure the efficiency, integrity, and usability of human infrastructure. Lachman et al. (2013) look at the factors of infrastructural design that continue to require a human component in design. Firstly, they argue that deciding where to allocate scarce resources is a human job, and that non - human engineering aides cannot make said decisions. In addressal of this challenge, the authors suggest the emergence and development of sustainable buildings, which are designed to reduce the overall impact of construction on the surrounding environment. [2] With a focus on incorporating sustainable materials in construction, sustainable buildings ensure the creation of healthy indoor environments, the efficient use of fuel and water, and the reduction of waste, pollution, and environmental degradation.

Taking the example of India, Reddy (2023) outlines the usage of improved and more sustainable building materials and the impact of this innovative means of construction. Over time, the use of natural building materials such as clay, stone, mud, and timber has declined due to the questionable state of their durability and stability. With the emergence of the discovery of inorganic binders such as lime - pozzolana (LP) cement, the usage of natural materials declined. Over time, the use of plastics and other man - made materials became widespread. However, with the manufacturing of such materials taking up significant time, effort, and energy, engineers began searching for more sustainable, energy and environmentally safe materials to use for the development of infrastructure. [3] The Indian construction industry is one of the largest in the world, with the demand for building materials rising on an annual basis, due to the ever - rising demand for housing and infrastructural developments. [4] Therefore, the energy and time required to transport hundreds of millions of tonnes of steel, plastics, bricks etc has led to a call for the usage of more sustainable building technologies and materials. However, traditional, more energy - efficient building materials such as mud, clay, and timber, do not adequately meet the demand for durable building materials. Therefore, the urban development industry is looking at various methods towards the optimal usage of available resources, keeping up with the demand for said materials. India's Centre for Application of Science and Technology for Rural Areas (ASTRA) [5] has been working towards this goal since the 1970s, and has since then come up with a variety of solutions to India's ever - growing problem of meeting demands for building materials. The work they do involves studies on using industrial waste, mining waste, and composite mortars to create new green building materials, and the development of energy - efficient, novel and creative methods of safety reinforcement in engineering methods, such as by developing precast roofing systems and new earthquake - resistant building

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[1] Godfrey, S. C. (1924). The Human Factor in Engineering. *The Military Engineer*, *16*(87), 180–183. http://www.jstor.org/stable/44693209

[2] Lachman, B. E., Schaefer, A. G., Kalra, N., Hassell, S., Hall, K. C., Curtright, A. E., & Mosher, D. E. (2013). Buildings and Energy Trends. In *Key Trends That Will Shape Army Installations of Tomorrow* (pp. 111–170). RAND Corporation. http://www.jstor.org/stable/10.7249/j.ctt5hhv93.12

[3] Reddy, B. V. V. (2004). Sustainable building technologies. *Current Science*, *87*(7), 899–907. http://www.jstor.org/stable/24109393

[4] Ibid.

[5] Ibid.

methods. [6] Now, the use of these methods and materials has become widespread across the country, and has allowed India to keep up with the demand for housing and building materials, and do so with the highest quality of materials and construction methods.

Historically and from a more global standpoint, the ecological design movement emerged in the 1970s, which led to a widespread focus on ecologically sustainable building methods. [7] Urban designers and engineers alike came out to speak of sustainability for the masses, with a standpoint of designing for need. This led to the emergence of a variety of greener engineering and building practices, such as that of using more ecologically valid methods and materials in construction. However, this movement was concentrated largely in countries that had the funding to design for need. In smaller, more impoverished areas of the world, it was more difficult for this movement to gain traction due to their governments' lack of funding towards urban development and planning. According to Madge (1993), the third world has repeatedly remained marginalised with respect to newer, more forward - looking strategies of building, construction, and sustainability. However, even in the West, the mass neglect of design within engineering proved to be a cause for concern. For example, projects on fuel - efficient stoves have failed to look at design as a viable explanation for product failure, instead opting to look at more technological explanations. Social, economic, and ergonomic factors that concern the user, if taken into account, would prove to be more useful for the users, rather than an overwhelming focus on technology which may not be economically feasible to develop. [8] Though these issues have been looked at over a period of a few decades, they still come up in modern - day design and development. Global policymakers would do well to remember that socio - political, economic, and ergonomic factors have a huge part to play in the understanding of development within a particular region. By taking these factors into account, policy frameworks and engineering methodology can develop to prove the most beneficial for the individuals they are targeting. After all, human centred design requires the input of human users for positive development!

New developments and advancements in the field of construction and engineering also includes advancements in engineering education. Traditionally, engineers remained focused on technological aspects of their field, working with different types of tools, materials, software, and hardware, but fully ignoring the more design - oriented aspects of their work. Over time, however, due to a return to focus on ergonomic and stylistic elements of design and development, engineering education has pivoted slightly to include user - centric themes and strategies. The Accrediting Board for Engineering and Technology in the United States, for example, entirely changed their standards for accreditation in the early 2000s. [9] By integrating more skills from fields within liberal studies, such as history, ethics, and writing, engineers were given a holistic, well - rounded education, which would ensure the incorporation of social and ethnographic considerations in new, modern methods of construction. As in a point made earlier in this paper, taking such factors into consideration is incredibly important so as to ensure a valuable human user experience. Without the human component in design and engineering, modern infrastructure would remain technologically adept, cost inefficient, and very user unfriendly.

Further to this, let us look at a practical example of how human - focused engineering and urban planning may prove to be sustainable not only for the environment, but for an improved human user experience. A study by Bhochhibhoya, Zanetti, Pierobon, Gatto, Maskey & Cavalli (2017) looked at the long - term environmental impact of different building materials in the Sagarmatha Zone region in northeast Nepal. Taking into account traditional, semi - modern and modern buildings, the authors accounted for different building materials (wood, brick, stone, insulating material), and different building styles. It was found that modern buildings, though better reinforced with more durable materials had the highest percentage of carbon dioxide emissions (taken from the moment of material manufacture to construction, to project completion). This was attributed to the cost and effort it took to produce modern building materials, as well as the processing required to reinforce the structures made up of these materials. For example, the use of glass wool in building is relatively new, though this material requires high energy for production and transportation, which results in 2983.37 g CO_2 of global warming potential. [10] Overall, the study proposed the usage of more traditional materials in the use of developing housing and infrastructure in Nepal. The use of wood, concrete, steel and brick, coupled with modern building techniques allow for an overall greener outcome - with these materials' global warming potential being overall 48% lower than that of glass, and polystyrene. [11] Furthermore, the study suggested that the carbon footprint of building and transporting materials can be reduced by adopting traditional manufacturing methods and techniques using locally available materials. This would significantly reduce the environmental impact of transporting materials, and also proves to be more cost - efficient. Additionally, using local resources to improve infrastructure and development in the area allows for a better socio - economic impact on the region. In poorer areas undergoing development especially, it becomes important for governments to allow for local upliftment through the provision of jobs within the development sector.

[6] Ibid.

[7] Madge, P. (1993). Design, Ecology, Technology: A Historiographical Review. *Journal of Design History*, *6*(3), 149–166. http://www.jstor.org/stable/1316005

[8] Ibid.

[9] Brown, J. K., Lee Downey, G., & Diogo, M. P. (2009). The Normativities of Engineers: Engineering Education and History of Technology. *Technology and Culture*, *50*(4), 737–752. http://www.jstor.org/stable/40345677

[10] Bhochhibhoya, S., Zanetti, M., Pierobon, F., Gatto, P., Maskey, R. K., & Cavalli, R. (2017). The Global Warming Potential of Building Materials: An Application of Life Cycle Analysis in Nepal. *Mountain Research and Development*, *37*(1), 47. https://doi.org/10.1659/mrd-journal-d-15-00043.1

[11] See Bhochhibhoya, Zanetti, Pierobon, Gatto, Maskey & Cavalli (2017).

Another argument made for human factors engineering is that of human safety. A large part of having a team of well - rounded engineers working on a project is the importance of ensuring that structures meant to be used by humans turn out to be safe to use for humans. A study by Lebowitz (1985) looked at how human factors engineering may allow for a reduction in traffic fatalities, specifically train crossing accidents. A large - scale analysis of these fatalities revealed that despite there being clear indicators of an approaching train, motorists decide to cross the tracks anyways - behaviour that is inexplicable, but not wholly unheard of according to train conductors. [12] The authors purport that railway engineers must understand the psychology behind the drivers' behaviour in order to devise a system through which the bells, lights, and gates surrounding a railway crossing are all activated in time for a driver to be alerted about an incoming train, and also for the train to have sufficient notice to hit the brakes if need be. However, when the warning system is designed for the worst case, i. e. with the largest amount of time available for the train to stop, it encourages motorists to attempt a crossing anyways. [13] In certain areas, the gates come down for an indeterminate period of time, leading to uncertainty in how long the train will take to arrive, and encouraging drivers to attempt a crossing despite the safety risks. It is difficult to ascertain a solution for a problem that is so heavily dependent on individuals' own perceptions of safety, and so engineers point out the obvious - that train tracks and motor highways should be separated in a way that prevents any cars driving over active railroads. However, due to economic unfeasibility, governments and railroad authorities have recently begun implementing a warning system that indicates how much time there is between the train passing and the barriers lowering. This appeals to a motorist's psyche, with the concrete warning being enough to indicate to them that crossing will indeed be life - threatening. As compared to a system where there is no certainty in the timing of the trains, an adequate, temporal measurement of oncoming danger may deter motorists from attempting to cross a railroad when they should not. Additionally, local governments should look at promoting safe driving and train safety campaigns, which have been shown to reduce traffic fatalities by a considerable extent. This added social aspect highlights the importance of having human - factors engineering in the development of modern infrastructure and urban development.

Human - factors engineering is the consolidation of human - machine collaboration. With the incorporation of traditional building methods, a shift back to more traditional materials, and modern - day technological advancements in engineering education and practice, it has become increasingly apparent that without a human element in design and building, the experience of using infrastructure becomes rather poor. For human design that is meant to be used by people, it is incredibly important to have a human element to the engineering and building process. Public policy, also, must lend a hand to how modern day infrastructure is created. By taking ergonomic and socio - political elements of a region into consideration, the design and construction of homes, roads, railways and other public infrastructure becomes a lot more accessible to the people that they are being built for. Furthermore, human - factors engineering allows for larger steps towards sustainable building practices, something that has emerged in recent years in light of the global climate crisis. Finally, the crucial aspect of safety becomes apparent when looking at modern engineering and urban design. Human psychology, as made clear in the railroad crossing example, plays a huge role in how infrastructure and practical use of said infrastructure is perceived. It is important to have a human element to design so as to correctly understand the thought behind safety measures in a way that will be understood by a wider population. Taking these advancements and ideas into consideration, it is safe to say that the importance of human factors in engineering, as well as novel materials and practices in building that lend to sustainability efforts, is still very much prevalent in this modern age.

[12] Leibowitz, H. W. (1985). Grade Crossing Accidents and Human Factors Engineering: How a discipline combining technology and behavioral science can help reduce traffic fatalities. *American Scientist*, *73*(6), 558–562. http://www.jstor.org/stable/27853486
[13] Ibid.

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Paper ID: SR231118123934 DOI: https://dx.doi.org/10.21275/SR231118123934