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Role of Materials and Labor Allocation in Cost-Effective Soundproof House Construction Projects

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Abstract: There is increase in the issues related to noise pollution due to their negative impacts on the individual. The ability of materials to absorb noise creates future problems for the building and for the residents; although, temporary presence of construction noise holds minor importance for some projects. The study aims to assess the role of materials and labour allocation in cost-effective soundproof house construction projects. The efficiency of synthetic foam, polyurethane and cellular materials was explored in providing insulation in multiple construction projects. Various soundproofing solutions such as rubber, gypsum, homasote, plywood and natural fibres were discussed in the light of cost-effectivity. Soundproofing can be guaranteed by using environmentally-friendly, natural, degradable and recycled products in the construction industry. The study helped in highlighting the materials that can help in building soundproof construction projects. The results indicated the need for applying modern, synthetic, cost-effective and green sound-absorbing systems in construction projects. The safety along with minimal maintenance and longevity of the completed construction projects is maintained by advancements in technological efficiency of building materials. The adaptation of Western construction technologies will ensure success in building construction projects as modern building materials play a significant role in building of sound proof construction buildings.

Key words: Labor allocation, cost-effective, soundproofing, construction projects.

1. Introduction

In recent times, issues over environmental pollution have elevated, and noise pollution has recently been identified as a major concern. Complaints and disputes associated to noise accounted for 80% of all environment-associated disputes throughout the last decade. In addition, complaints and disputes associated to noise generated from construction sites reported for nearly 89% of the overall noise disputes between 2010 and 2016 [1]. The majority of noise disputes are associated to vibration and noise at construction sites, and these constraints associated to construction noise are related with a number of restrictions, which include project delays and cost overruns. The quality of the lives of those living adjacent to construction sites is further negatively influenced [2].

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Natural fibres; like cotton and hemp fibres were also examined for their sound-absorbing properties. Kenaf (*Hibiscus cannabinus*) plant fibres, also known as the Deccan hemp and java jute, are native to South Asia and are extensively used in United States in construction industries to strengthen concrete. The production of sound-absorbing materials using hemp and kenaf fibres resulted in no chlorofluorocarbon (CFC) emission and included a low carbon footprint [3]. Additionally, they can be easily recycled; and therefore, are categorized as ecologically green building materials. They have proven to be a good alternative to synthetic chemical building materials and polymers. Polyurethane is the standard material, used as a sound-absorbing agent. However, there are other varieties of foam that were designed for environments, where corrosion and heat resistance is a requirement. A majority of construction materials absorb sound to some extent; however, acoustical materials are directly associated with better sound

absorption. Here, the use of synthetic fibres has replaced asbestos-based materials. The temporary presence of construction noise holds minor importance for some projects as compared to long-term operational noise that is experienced at the airport runway [4]. Hence, the ability of the materials to absorb noise creates future problems for the building and for the residents as well. To this end, the present study aims to assess the role of materials and labour allocation in cost-effective soundproof house construction project.

Majority of the initiatives have been carried out for mitigating noise persuaded by construction equipment. These encompass the use of facilities, including enclosures, silencers, and soundproof barriers at construction sites [5]. On the contrary, such passive noise control efforts have a restricted influence to reduce physical damage and mental stress suffered by individuals living near construction sites. It is also observed that passive noise control is efficient merely for high-frequency noise and not for low-frequency noise in the presence of combined noise sources [6]. Additionally, it is complicated for selecting adequate noise control measures since majority of construction equipment creates a high noise level. Noise level is referred to A-weighted decibels, indicating the comparative intensity of sounds to be identified by an individual [7]. In addition, the sound pressure level can alter substantially relying on the factors including the types of equipment used and construction activities. Thereby, noise-related disputes at construction sites are mitigated due to a systematic noise management for supplementing passive noise control efforts [8].

Sound-absorbing materials are the core engineering approaches utilized for controlling environmental noise. Sound-absorbing materials are often porous and are being utilized progressively in the mitigation of reverberant noise in buildings and as elements of commercially available noise-isolation composites in varied applications. The major materials integrated for noise control have been made of mineral fibres and glass since the use of asbestos fibre was forbidden in the 1970s. On the contrary, the removal of such types of fibrous materials has become an environmental challenge in landfills. They are complicated to recycle, their industrial production, and their burning causes toxic fumes emission, increasing the emission of carbon dioxide into the atmosphere.

The study holds significance since it will highlight the materials that can help in building soundproof construction projects. Moreover, the study will also provide significant knowledge regarding the composition and applications of the materials that are used for the construction of soundproof buildings. The findings of the study will help the construction builders and managers to incorporate the new advanced techniques to provide maximum comfort to the residents. This study will also help the practitioners to overcome the challenges related to the selection of soundproof material for building purpose.

2. Review of Literature

A detailed research on different sound-absorbing construction materials was conducted by Arenas and Crocker [9] from Auburn University in Alabama. A significant number of materials including fibrous, cellular, and granular were examined and investigated and their absorbing mechanisms were explored. It was found that when porous materials encounter sound, the air molecules within the pores vibrate and lose their energy. Similarly, in fibrous materials, the energy is captivated by the movements of fibres. The scattering of air from granular material is comparable to the mechanism in stationary and rigid porous materials [9].

Metal foams are being used to manufacture filters, heat exchangers, mechanical damping devices, biomedical implants, and lightweight structures [10]. They are fire resistant and can display high stiffness. Moreover, they have low moisture absorption rates, low weights, and can also be recycled. To decrease

noise levels in aircrafts, a new micro-channeled material, consisting of metallic nanotubes, has been developed. The study concluded that in addition to the traditional materials used to soundproof construction, new natural and technologically advanced materials are being used as sound-absorbing materials. These are categorized as green building materials, as they are environmentally sustainable, friendly, and can also be easily recycled without emitting CFC's. These new innovations can help in improving and enhancing existing soundproofing construction materials.

Ilgun et al. [11] explored the introduction of new natural insulators in developing countries. Additionally, different acoustical characteristics of these sound-absorbing materials were also analysed. Forty-eight (48) research papers and reviews were examined; most of which were about natural sound-absorbing construction materials. Scientific advancements in nanotechnology and chemistry have resulted in great developments in production, design, and effectiveness of acoustic materials. These advancements include the application of fibres like flax, bamboo, cannabis, cotton, coconut fibres, and recycled paper waste.

The natural fibre Cannabis grows at a fast rate and does not require the use of any pesticide. The growth of hemp per square meter is much higher than the growth of flax or cotton. Additionally, cannabis fibres are resistant to bacteria, fungus, moulds, insects and ultra violet radiation. All of these features are ideal for the application in soundproofing in open places. The materials, used in various industries for sound absorption and thermal isolation, are a combination of anti-fire products, polyester fibres, and natural flax fibres [9].

In 1970s, the extensive use of asbestos and its negative effects on health raised concern, leading to the development of artificial insulators such as polyurethane and other synthetic foams. Heat insulators like rock wool and fiberglass have been used as sound absorbers in Iran. However, these are associated with significant health risks due to their high density and water absorbing properties, in addition to the presence of metal oxides. These properties have a negative impact on the environment and result in dissemination of greenhouse gases. Consequently, new natural materials such as cotton, hemp, flax and coconut fibres were introduced in the market. These materials have proven to be environmentally friendly and have a low carbon footprint [12]. The study revealed that natural fibres are commonly preferred over synthetic construction materials. These insulators are light weighted, recyclable and easily degradable; and there is a huge market for these absorbents in the developed world. The study recommended the application of these new materials in construction and other industries in the developing world [12].

Lower weight and sound-absorbing modern materials are extensively used in the aircraft, ship, and spacecraft industries [13]. The effectiveness of building material accounts for increased growth in the construction of public and residential buildings as well as capital projects such as bridges, roads and other engineering projects [14]. The finest vibro-acoustical systems are capable of being designed by utilizing different techniques such as statistical energy analysis (SEA) [15].

The process of construction is mainly used for addressing potential noise concerns for specified construction projects [4, 14]. Such construction projects mainly involve the erection of large office buildings. Lack of proper understanding regarding the practices and policies of construction noise is likely to be replaced by persistent misapprehensions and myths. The use of modern building materials as compared to outdated labour-intensive materials is extensively used as insulation, low energy consumption, and sound reduction [14]. Moreover, these modern building materials have a great benefit in cost and application during the design stages of project. Therefore, the present study aims to investigate the

role of materials and labour allocation in cost-effective sound-proof construction projects.

3. Material and Methods

The theoretical and methodological aspects have been based on the development of foreign and domestic research, associated with the construction projects. It has forecasted the behaviour of energy efficient construction materials in different service conditions. The analysis and evaluation have been based on materials and labour allocation, which are available in marketing according to current standards. Synthetic foam, polyurethane and cellular materials were explored with respect to their insulation capabilities in various construction projects. Sound absorbing materials are developed in three categories. They can either be cellular, fibrous, or granular. Construction materials that are made from polyurethane and other synthetic foams are cellular materials. The study has investigated these technologies for creating efficient sound-proof environment. The data obtained through survey have been analysed qualitatively.

The formation of temporal virtual organizations is required for the execution of a construction project, encompassing a variety of individuals from different professional backgrounds with varied preferences. The type of procurement system implemented has a substantial influence on how such individuals are organized thoroughly and identifying their roles, interrelationships, and responsibilities. Therefore, it is obvious that different procurement tactics will have different effects on the procedure to implement sound-absorbing construction materials at project level. It was preferred for restricting the selection of cases to construction projects in order to prevent variances in outcomes between cases because of the variations in procurement approaches.

The use of pilot studies or reference groups is beneficial for ensuring sensitivity to participant privilege and language. Thereby, two pilot interviews were conducted prior to the commencement of the case study. Both interviews were conducted with the members of construction industry having expertise in the sound-absorbing construction materials. These pilot interviews were beneficial in ascertaining any concerns related to clarification of the questions asked. The primary interview guide was polished by altering the phrasing of two questions particularly for receiving the feedback. In addition, notes were made on the interview guide where additional guidance may require to be offered throughout the interviews for obtaining all the relevant information from the participants.

Semi-structured interviews have been used in this study for collecting the data from key informants and experts having expertise in implementing sound-absorbing construction materials. This was chosen because it is flexible; offering new questions to be brought up throughout the interview and further it provides equal opportunities for both interviewees and interviewers. Observation is essential for understanding the activity of individuals on the basis of how, what, and why they are conducting something among the primary data collection techniques. This provides developing confidence for speaking and investigating what is being said and what is actually going on the real setting. In this regard, the current condition of the sound-absorbing construction materials has been observed in the construction projects.

The recorded interviews were transcribed word for word for facilitating coding, manually in MS Word documents. The transcribed files were then imported to NVivo for commencing analysis. In addition, the transcribed interviews were then investigated via the procedures of open coding, selective coding, and axial coding.

4. Results and Discussion

4.1 Offering Soundproofing Solutions

Regarding the soundproofing of buildings, a

respondent of this study stated that;

"It is definitely not possible to completely eliminate noise levels. However, it is seen that the use of soundproofing greatly alleviates noise levels to a tolerable degree."

Anti-noise generators or noise barriers may be employed to combat the sources of noise pollution. However, different methods may be recruited for different houses, due to differences in construction, location, and organizational structure of the buildings under consideration. It was corroborated by another respondent;

"I am greatly enthusiastic that soundproofing methods are the future of noise pollution reduction. There are so many methods for reducing the levels of noise experienced, which cater to the different requirements of buildings based on their geolocation and structure. Soundproof acoustic materials and fabric walls are commonly seen to be used for soundproofing."

The passive method of noise cancellation absorbs sound energy and the active method merely reduces the level of sound. For this purpose, absorbing materials are used that alleviate the noise through conversion of the sound energy into heat. According to a respondent;

"In order to conduct effective soundproofing, it is essential to use porous materials such as mineral or glass wool. Such materials present a very high degree of cost-effectivity and performative abilities."

The necessity of soundproofing for reducing acoustic disturbances in houses was an issue which was raised by existing research [16]. Similar studies additionally highlighted the need for soundproofing in buildings present in zones that experienced a high level of noise regularly [17]. Furthermore, noise reduction techniques may be categorized into two main classifications. These are active noise cancellation methods and passive noise cancellation techniques. Active noise reduction (ANR) relies on the reduction of noise by superimposing an additional sound to cancel out the original noise source [18]. Furthermore, passive noise cancellation refers to an effective blockage of sound [18]. It was suggested that various methods may be employed to mitigate the levels of noise pollution, for instance, the use of laminated materials; such as, gypsum and rubber aid in the provision of effective sound insulation against noise pollution [16].

Moreover, the study conducted by Ghilahare and Pandey [19] discussed the application of enhanced egg carton, gypsum board and sound diffuser for the treatment of acoustics. The Egg Carton, Sound Diffuser, and Gypsum Board are effectively used for the purpose of absorbing the unwanted sounds. Gypsum Board is found to be an effective method that is a simple sound riveting material. On the other hand, sound diffuser is also found to be an effective method for the absorption of sound and sound scattering. Therefore, the following materials can be effectively used to overcome the challenges of unwanted sound during construction projects. On the other hand, the study conducted by Azkorra et al. [20] evaluated the application of green walls for sound insulation. The study also depicted that green walls are an effective initiative, which provide energy saving as well as, noise attenuation. To this end, such method can also be used as an effective solution that can assist in overcoming the issue of noise pollution in buildings.

4.2 Room Soundproofing

Generally, it has been seen that there are a variety of basic techniques through which sound may be alleviated in any room of a house. As discussed by a respondent;

"There can be no disagreement that the easiest way to include soundproofing in a house is during the constructional phase. As an example, sound insulation may be placed in between the walls in the form of insulation mats. Such techniques present extremely cost-effective solutions in the alleviation of noise pollution."

Other basic technique through which soundproofing may be ensured was highlighted by an additional respondent who stated that;

"I don't see the need to use expensive ways for soundproofing a room. In my opinion, the simplest and most effective way to reduce noise pollution in any house is through the utilization of Homasote. This is a recycled-paper product which can be fixed to the walls and helps in reducing noise levels to a very high degree."

Other approaches of soundproofing installation were highlighted by another respondent who stated;

"I have found that a lot of people express the need for soundproofing through the floors. To fulfill their demands, we often make use of a layered plywood system in addition to a three-quarter-inch-thick sound deadening material. In my experience, I have found that up to 90% of noise pollution is alleviated through the use of this method."

The results of the current study were found to be consistent with the case study by Tiwari [21] that illustrated the incorporation of soundproofing during the construction phase of a house through careful selection and design of the doors and windows. For instance, Skaala windows were used due to their excellent soundproofing characteristics. Similar approaches should be adopted by modern construction industries as well. The incorporation of Homasote within soundproofing and blocking systems was carried out by Beresowski [22]. Furthermore, studies highlighted that there is a large variety of ways in which soundproofing installation may be carried out. For example, soundproofing could be installed through the room ceiling, as evident in a study by Clunn [23]. Similar to the present study, Mathur [24] examined the natural composite building materials obtained from the local resources used in construction projects. The building materials obtained from local resources are capable of adapting and utilizing them in construction projects. The results have clearly shown that natural fibres are more cost-effective as compared to expensive construction materials that are used in projects. These materials are extensively used as they are locally available, renewable, and are available in abundance. These results were obtained by evaluating the performance of unsaturated epoxy/polyester resin and polymer composites made from natural fibres after considering humidity, weathering, and hydrothermal conditions [24]. The two natural fibres included sisal and jute. These materials were used as reinforcements in the construction industry. Recently, it has been shown that construction companies have successfully built up sound-proof shuttering doors and laminates/panels. However, these materials are likely to be used as alternate cost-effective composite materials in the construction industry. Moreover, these materials have also fulfilled the Indian Standard Specifications, which are required for the construction sector. Although these materials have not been assessed in the present study, the results have shown that the knowledge of process for the manufacturing of natural fibre panels and shutters has been commercialized [24].

The use of new synthetic construction materials in the cost effectiveness of house construction projects was investigated by Gerasimova [14] in Moscow State University of Civil Engineering. The results were consistent with the present study as they showed that the utilization of effective building materials caused increased growth of the public and residential buildings. This is likely to result in growth and profitability associated with the construction of roadways, freeways, bridges, and similar engineering projects. The use of ecologically responsible and efficient insulation materials is the main priority for good maintenance, safety, and longevity of construction projects. The results have concluded that using insulated and low energy consumption construction material causes a decrease in the operational and maintenance cost within the construction projects [14]. These results also showed that unlike conventional materials, the new

construction materials were relatively more durable. Similarly, the results of the present study have stated that application of western construction technologies and techniques as adapted by the Soviet Union results in efficient soundproofing in buildings.

From the aforementioned findings, this study has recommended a process model and probability of construction project on active noise control as a measure for supplementing the existing limited passive noise control utilized throughout construction. In addition, this study is anticipated to offer to alter the noise management paradigm. In addition, the proposed noise management framework can be utilized as a framework to manage noise induced by construction equipment. Moreover, active noise control is used for noise management in contributing not merely to weaken the noise generated by construction sites, but also to reduce adverse effects such as compensation payments and project delays. As a whole, adequate noise management can mitigate construction-associated noise disputes, which allow for construction projects to advance with respect to their anticipated schedules.

5. Conclusion

The issues related to noise pollution are increasing day by day due to their negative impacts on the individual. To this end, the requirements and demands of customers are being shaped according to the changing environmental hazards. To this end, to gain an insight into the need of soundproof buildings, the study was aimed to evaluate the materials and labour allocation with regards to a cost-effective soundproof house construction project. The results have shown that the application and use of modern, synthetic, indigenous, cost-effective and sound absorbing building materials have played an imperative role in ensuring the success of construction projects. The substantial use of environmentally-friendly, natural, degradable and recycled product in the construction industry has been the most cost-effective way to guarantee soundproofing an enclosed area. Additionally, the application of these materials has seen an increased growth in the construction of high-rise residential and public buildings, bridges, roadways, and engineering projects. Advancement in the technological efficiency of building materials is important for maintaining safety along with minimal maintenance and longevity of the completed construction projects. As compared to the use of outdated labour-intensive material, the use of modern building materials plays a significant role in the building of sound proof construction buildings. The replacement of heavy outdated and labour-intensive building materials with new insulation materials that are light weight, sound absorbing and low energy-consuming is being used extensively for the safety, longevity and maintenance of construction projects around the world.

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