NOISE MANAGEMENT IN CONSTRUCTION AND APPLICATION OF NOISE MITIGATION TECHNIQUES AND ITS ANALYSIS IN A REAL-TIME PROJECT

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Abstract – *The construction industry faces numerous challenges, and one often overlooked issue is noise management, especially in India. Ignoring the dangers of construction noise can have serious health effects on workers and disrupt the surrounding environment. This study thoroughly examines the characteristics of noise from construction activities. It conducts a comprehensive analysis of noise management through a review of literature, journal studies, and online and live case studies. Additionally, the research identifies various noise mitigation strategies for construction projects to prioritize the health and safety of workers. By selecting a real-time construction site for this research, suitable noise barriers are chosen and its cost-time analysis is conducted to compare with the overall project budget for the noise barrier implementation.*

Key Words: **Construction, Noise, Workers, Health, Safety, Surroundings**

1. INTRODUCTION

Construction activities are known to generate high levels of noise which can potentially expose workers to hazardous noise levels. Excessive exposure to noise can have both Auditory and Non-Auditory effects. The Auditory effects include noise-induced hearing loss, tinnitus, and hyperacusis while the non-auditory effects include sleeping disturbances, irritability, stress, poor concentration, difficulties in speech comprehension, annoyance, and cognitive impairments. Additionally, noise can cause increased blood pressure and heart disease. To mitigate these risks, regulatory bodies such as the Occupational Safety and Health Administration (OSHA) and the Indian Ministry of Forest and Environments have recommended a maximum allowable noise exposure level of 90 decibels for 8 hours. Any exposure to noise above 85 decibels is not recommended. Unfortunately, many workers do not wear adequate hearing protection further increasing their susceptibility to permanent hearing damage. According to the Centre for Disease Control and Prevention, 22 million workers are exposed to potentially damaging noise at work each year. Safety managers are crucial in mitigating these risks by providing comprehensive information on the dangers of construction noise exposure and enforcing safety measures to ensure the safety and well-being of workers and surroundings.

1.1 Aim

The primary aim of the study is to identify the characteristics of construction noise generated by various construction activities and to reduce the noise levels by implementing effective noise mitigation strategies such as noise barriers. The study will also analyze the cost and time involved in implementing these strategies, compare them with the overall budget, and ensure the health and safety of construction workers and the surrounding environment.

1.2 Objective

The Primary Objective is to assess High-noise construction operations and recommend an appropriate Noise Barrier in real-time at a construction site to mitigate the associated noise. This includes analyzing the cost and time implications and ensuring the health and safety of workers and the surrounding environment.

2. METHODOLOGY

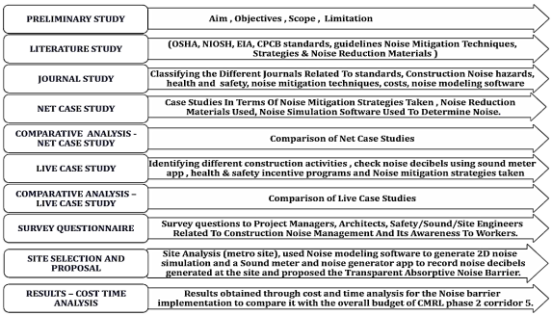

Fig - 1: Methodology

3. LITERATURE REVIEW

3.1 Standards

Area Code	Category of Area	CPCB Limits dB (A) Leq		WHO Guideline (LA eq dB)	
		Day time*	Night time	Day time	Night time
A	Industrial area	75	70	70	
B	Commercial area	65	55	70	
C	Residential area	55	45	55	45
D	Silence Zone**	50	40		

Fig - 2: CPCB guidelines for ambient noise levels

3.2 Different Types of Noise Barriers

Photovoltaic Noise Barriers (PVNBs), Echo Barriers, Polycarbonate Noise Barriers, Timber Noise Barriers, Green Wall Barriers, Absorptive Noise Barriers, Reflective Noise Barriers, Concrete Noise Barriers, Metallic Noise Barriers.

3.3 Different Types of Noise Reduction Materials

For Machineries and Equipments - Perforated Vinyl Foam, Proprietary Fiber Blend, Acoustic Floor Mat Treatments, Sound Dampening Mats, Nubbed Foams, Soundproofing Blanket.

3.4 Journal Study

The Journal study consists of 20 research papers related to noise management in construction, which also include OSHA standards, personal protective equipment, methods and analysis to detect construction noise, noise mitigation techniques, different types of noise barriers, noise reduction materials, cost analysis, compensation claims due to construction noise, 2D and 3D noise simulation software used to generate noise data, and health impacts on workers and the surrounding environment.

4. CASE STUDY

4.1 Net Case Studies

4.1.1 Photovoltaic Noise Barriers, Turkey

Photovoltaic Noise Barrier (PVNB) technology involves the combination of noise control measures with the generation of renewable power energy. The effectiveness of this approach is demonstrated in a real settlement situated alongside roads. Noise control efficiency was analyzed using Sound PLAN software. Additionally, the evaluation process utilized the TOPSIS method, a widely used multi-criteria decision-making technique (MCDM). The results showed a 44% reduction in noise, while also being capable of generating 524804 kWh of electricity annually.

4.1.2 Xuan Wu District, Beijing, China

The case study used the DALY metric to assess health risks from construction noise. It found that individuals near construction sites are most affected. Contractors should consider these risks and implement environmentally friendly construction practices to minimize the impact on nearby residents.

4.1.3 Metro Line 3, 7 Th District Tehran - Iran

This study was carried out in a residential context around the auxiliary tunnel of line 3 metro- Abbas-Abad district-Tehran- Iran. The William Fine Method revealed that construction policies fail to consider all necessary environmental conditions in urban development and inadequate monitoring led to construction noise pollution becoming a significant problem for Tehran citizens.

4.2 Live Case Studies

4.2.1 Case Study 1

The typology of the structure is that of a hospital, situated within the institutional campus in Ramapuram, Chennai. The total built-up area of the hospital building amounts to 132,000 square feet, and it is structured as a G+10 building. The project commenced in 2022 and is currently in progress.

The primary aim of selecting this case study is to measure the decibel levels of construction operations that generate high noise, along with the types of equipment involved, and to analyze the characteristics of the resulting construction noise.

The Site has experienced high Noise levels due to various Construction activities including Concrete Mixing, Wood Cutting, Granite Polishing, Floor Tile Polishing, Tile Cutting, Concrete Drilling, Excavation for Pile Foundation, and Pile Foundation Works. The Noise Decibels and Frequency graph have been accurately recorded using the Sound Meter & Noise Generator App.

Following the measurement of Noise Decibel levels during construction activities, Interviews were conducted with the construction workers to assess their understanding of the hazards associated with construction noise and its impact on their health. Subsequently, Safety and Site Engineers, along with the Project Manager, were interviewed to ascertain compliance with safety measures such as providing Audiometric tests, Ear muffs, and Earplugs for high-noise operations. Furthermore, interviews aimed to ascertain if safety incentive programs were in place to educate workers about health and safety during construction.

4.2.2 Case Study 2

The construction works for the MMRC metro Line 3 in the Colaba - Cuffe Parade area have led to significant noise disturbances for nearby residents.

These construction activities, occurring both during daytime and nighttime, have caused sleeplessness, disturbances, and increased blood pressure among children and elderly individuals. In response to the complaints, the Mumbai Pollution Control Board (MPCB) was contacted, and a case for noise pollution was filed. The National Environmental Engineering Research Institute (NEERI) intervened and instructed the Mumbai Metro Rail Corporation Ltd (MMRCL) to conduct a noise assessment study on the Colaba – Cuffe Parade stretch and implement necessary noise control measures at the construction site. NEERI emphasized that while the noise may not pose a direct health risk or cause hearing damage, it significantly affects people's quality of life. The construction noise can lead to irritation, stress, and sleep disturbances, ultimately contributing to higher blood pressure and anxiety.

Following NEERI's directives, noise decibel levels were recorded at various points near the metro site, and the Mumbai Metro Rail Corporation (MMRC) commenced the installation of noise barriers near residential areas to mitigate noise levels. These noise barriers are composed of polycarbonate. After their installation, the noise barriers have resulted in an overall noise reduction of 20 to 25 decibels.

5. SURVEY QUESTIONNAIRE

This survey aims to gather insights on construction noise, its hazards, and noise management from Architecture and Civil Engineering students, site/civil engineers, architects, project managers, and safety managers. The survey comprises 15 questions and has received responses from a total of 110 participants.

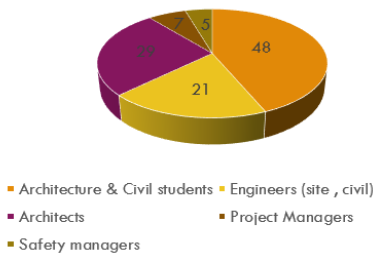

Chart - 1: Participants for survey questions

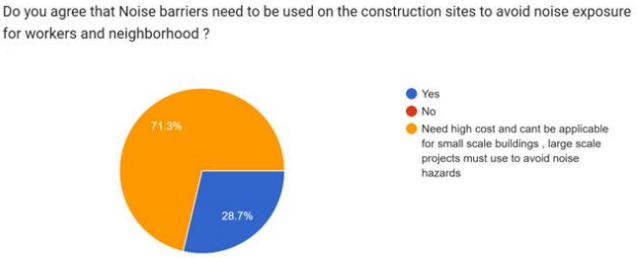

Chart - 2: Survey results on implementing noise barrier

Based on the survey results, it is evident that there is a need for noise barriers in the busiest urban areas to mitigate construction noise.

5. PROPOSAL FOR IMPLEMENTING NOISE BARRIER

5.1 Site Analysis

The selected site is Kendriya Vidyalaya Metro Construction site, situated within the CMRL Phase 2 Corridor 5. CMRL Phase 2, Corridor 5 spans from Madhavaram to Sholinganallur, covering a total distance of 47.0 km, with 41.17 km being elevated and 5.83 km underground. The Kendriya Vidyalaya stretch encompasses a distance of 0.9 km.

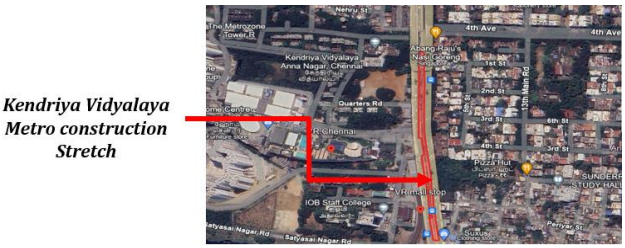

Figure 3 Google map of Kendriya Vidyalaya metro site

Figure 4 KV Metro Construction Site

Reason for choosing the KV Metro site

Phase 2 of the Corridor 5 metro construction is taking place on the bustling 100-foot Grand Northern Trunk Road in Anna Nagar, Chennai.

The construction activities, particularly during night hours, have been significantly impacting the residents, especially the elderly and children, leading to sleep disturbances, headaches, high blood pressure, stress, and even cardiac issues due to exposure to excessive noise levels. Subsequently, the affected residents have lodged a formal complaint with the Pollution Control Board.

Implementing noise mitigation strategies, such as noise barriers, helps reduce the adverse effects of construction and traffic noise in the area.

The important landmarks and major point sources where the noise decibels are recorded near the Kendriya Vidyalaya metro construction site are Kendriya Vidyalaya School, VR Mall, IOB Staff College, Be Well Hospital, and Central Govt Officers Quarters. These are where the point sources are taken for recording noise decibels.

Noise Decibels have been generated using the Sound Meter & Noise Generator app.

Table - 1: Noise decibels recorded during the Day

SOURCES	LEQ	LMAX
1	89	103
2	88	93
3	84	101
4	92	99
5	78	90

Table - 2: Noise decibels recorded during the Night

SOURCES	LEQ	LMAX
1	86	91
2	73	87
3	69	79
4	75	89
5	78	96

As per the guidelines of the Central Pollution Control Board (CPCB) for ambient noise decibel limits, the recorded noise decibels at the site exceed the permissible levels. Consequently, nearby residents are being exposed to prolonged periods of heavy construction noise, leading to adverse health effects.

5.2 Cost Analysis – CMRL Phase 2, Corridor 5

Table - 3: Estimated Cost of CMRL Corridor 5 (Crores)

S.NO	ACTIVITIES NEED TO BE DONE	COSTS ALLOTED
1	Land	2133.2
2	Alignment and Formation	2849.61
3	Station Buildings incl. Civil works, EM works, ECS, TVS, Lift, escalators & Architectural Finishes etc.	3162.44
4	Depot including civil, EM, Machinery & plants, general works	379.9
5	P-Way for main line, depot and depot connectivity	365.34
6	Traction & power supply for main line and depot incl. OHE, ASS, GIS etc	559.65
7	Signaling and Telecom. Incl. AFC, Platform screen doors, CCHS etc.	971.84
8	Rolling Stock	716.76
9	Environment	22.76
10	R & R incl. Hutments etc	140.01
11	Misc. Utilities, road works, Topographic Surveys, Geotechnical Investigation, Barricading, Tree Cutting and replanting, other civil works such as signage's, Environmental protection and traffic management	285.05
12	Capital Expenditure on Security including civil and EM works	17.76
13	Staff Quarters and buildings including civil, electrical works and green building concept	86.8
14	Capital Expenditure on Inter modal integration including Footpath for pedestrians, Feeder Buses and Bicycles @2% of Total Cost excluding Land	144
15	Total of all items except Land and R&R	9182
16	General Charges incl. Design charges, (Civil+EM works) @ 5% on all items except Land and R&R.	459.1
17	Total of all items including G. Charges	9641.1
18	Contingencies @ 3 % on all items except Land and R&R	289.23
19	Cost including Contingencies & excluding Land and R&R Cost	9930.34
	Total Cost including Contingencies & including Land and R&R Cost	**12583.44**
	Central Taxes & Duties	870.43
	State Taxes & Duties	730.07
	Total Taxes & Duties	1600.5
	Gross Total including Taxes & Duties	**15784.44**

Table - 4: Estimated Cost of Environmental Management

S.NO	ACTIVITIES NEED TO BE DONE	COST ALLOTED
1	Compensatory Afforestation	211.87
2	Diversion of forest lands	3.18
3	Noise Barriers	387.03
4	Rain water harvesting including depot	763.33
5	Sewage treatment plant	78.11
6	Effluent treatment plant	95.7
7	Environmental monitoring	147.96
8	Training and extension	12.6
9	Environmental division	171.46
10	Solar system	405
	TOTAL COST	**2276.24**

(Costs that are estimated in the above table in lakhs)

Overall cost and Budget for CMRL, Corridor 5

The overall budget for corridor 5 = Rs.**15,784.44 Crores**

Budget for Environmental Management = Rs.**22.76 crores**

Cost allotted for Noise barriers **= Rs.3.87 Crores**

Though separate costs have been allotted for Noise barriers, no Noise Barrier is implemented in any of the Chennai Metro sites.

5.3 Noise Barrier Analysis

5.3.1 Transparent Absorptive Noise Barrier

Absorptive Noise barriers, on the other hand, don't reflect sound. This material is suitable for building noise barriers to protect residents living alongside roads or railways. It offers high transparency and sound insulation (up to 32 decibels), comes in a wide range of colors, is easy to assemble and maintain, is highly resistant to UV rays and corrosion, durable, and lightweight. The proposed noise barrier has a design life of approximately 25 years, with a height of 5m on each side and bay widths of 1m. The barrier materials consist of PMMA and aluminum with a 15mm thickness. The estimated installation cost for the noise barrier is 5800 per square meter, resulting in a noise reduction of approximately 32 decibels. These noise barriers can be securely affixed using either concrete foundations or by bolting them to a continuous concrete strip.

Fig - 5: 3D View of Transparent Absorptive Noise Barrier

Fig - 6: Transparent Absorptive Noise barrier

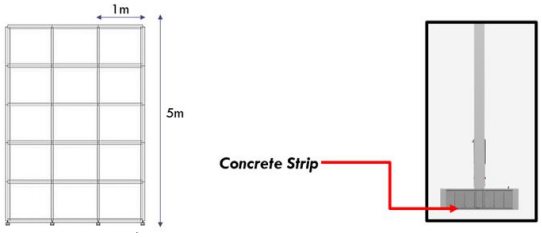

Fig - 7: Noise Barrier elevation and its dimensions

5.3.2 Cost Analysis - Noise Barrier Implementation

Concrete Strips for Bolting Noise Barriers

Length = 2952.76 ft **; Width =** 1 ft ; **Height =** 6 inches **Concrete grade** = M25

Materials Required:

Cement (No. of bags) = 236 bags ; **Sand =** 12 tons **; Aggregate =** 24 tons

Cost:

Cement = 236 x 380 = Rs. 89,680 **; Sand =** 12 tons x 1600 = Rs.19,200 **; Aggregate =** 24 x 1150 = Rs. 27,600

Total Cost for one side of the road = Rs.1,36,480

The construction of concrete strips on both sides of the metro stretch will result in a doubling of the overall cost.

Total cost for concrete strips = Rs.2,72,960

Cost of Noise Barrier installation = 5800 / sq.m

Length = 900m + 900 m **; Height =** 5m

Total area = 4500 + 4500 = 9000 sq.m

The total cost of Noise barriers for one side of the stretch = Rs.2,61,00,000

We need to calculate the cost of installing noise barriers on both sides of the metro construction stretch.

Total cost of the noise barriers = Rs.5,22,00,000

Total cost for concrete strips = Rs.2,72,960

Total cost of the noise barriers = Rs.5,22,00,000

Overall Budget required = Rs. 5,24,72,960

Rs. 5,24,72,960 > Rs. 3,87,00,000

The budget needed for the installation of noise barriers at the KV metro station stretch exceeds the allocated budget for noise barriers for corridor 5, which is **Rs. 1,37,72,960**

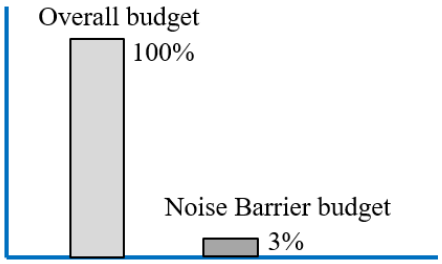

Chart -3: Percentage of overall and Noise Barrier budget

5.3.3 Time Analysis

Noise barrier installation work = 150 sq.m/day

Time required for (4500+4500) 9000 sq.m = 60 days

6. RESULTS

Estimated Budget for the Noise Barrier installation at the KV metro site (0.9 km) is **Rs. 5,24,72,960 Crores**

As per CMRL data, Total Budget allotted for the Noise Barrier Installation for the entire Phase 2 Corridor 5 (47 km) is **Rs. 3,87,00,000**

Estimated budget for Noise Barrier installation (47kms) is **Rs. 246.28 Crores**

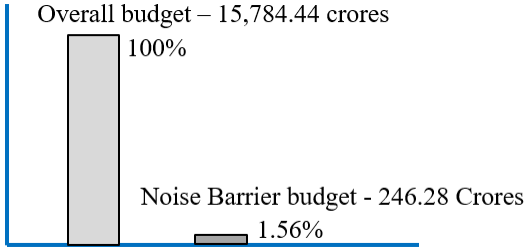

Chart - 4: Percentage of Overall CMRL Phase 2, Corridor 5, and Noise Barrier budget

Overall Budget Required (with noise barrier installation costs) = 16,030.72 Crores

7. CONCLUSION

The selected Metro site for analysis is situated on one of Chennai's most heavily trafficked roads, which is already subject to substantial traffic noise and ongoing construction activities, particularly at night. As a result, the neighborhood is experiencing heightened levels of noise pollution. Consequently, the proposal to implement Transparent Absorptive Noise barriers aims to mitigate the overall noise levels along this stretch, which encompasses schools, colleges, hospitals, commercial complexes, malls, and residential apartments. The installation of these noise barriers will also serve to reduce residents' exposure to excessive noise. Given that the Chennai Metro Rail Limited (CMRL) has yet to complete metro construction at the selected site, the concurrent installation of the noise barriers can be seamlessly integrated with the construction of Metro Corridor 5.

8. RECOMMENDATION

It is evident from the findings that the construction industry and government in metropolitan areas such as Chennai are not adequately addressing construction noise pollution and its associated risks. While the immediate impact of construction noise may not be substantial, prolonged exposure to high levels of noise can have adverse effects on the health of both construction workers and residents in proximity to construction sites. The Central Pollution Control Board (CPCB) has identified Chennai as one of the noisiest cities in India, yet there has been a notable absence of noise management strategies in the city.

Although the implementation of noise barriers and associated costs may present additional expenses, it is imperative to consider and enact noise mitigation technologies and strategies, especially in densely populated urban areas and major infrastructure projects. This approach is crucial not only for safeguarding the health and well-being of workers but also for fostering a pollution-free environment in society.

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