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COMPREHENSIVE FREQUENCY SPECTRUM ANALYSIS OF METRO RAIL NOISE FOR ENVIRONMENTAL AND ACOUSTIC INSIGHTS

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ABSTRACT

The development of metro systems has brought heightened concerns regarding noise pollution generated by metro rail operations. This study delves into the assessment of noise levels and spectrum characteristics within metro stations during both with and without metro operations. Utilizing the 1/3-octave-band measurement and analysis system, the study emphasizes the significance of the octave band in capturing noise frequency traits effectively. Through meticulous statistical and frequency spectrum analyses, it was unveiled that metro rail presence contributes an additional noise ranging from 1.5 to 4.4 dB(A) across various stations. Noteworthy peaks in noise levels were observed in both low and high-frequency ranges, with dominant contributions from frequencies like **40 Hz, 63 Hz, 80 Hz, 800 Hz, 2500 Hz, 3150 Hz**, and **6300 Hz**. These findings encompass metro rail noise components, including aerodynamic and wheel-rail noise. This study highlights the importance of metro noise characterization as a foundation for targeted abatement strategies. By identifying key frequency ranges, it emphasizes monitoring noise in nearby residential areas to understand propagation and inform effective mitigation measures, ultimately reducing metro-related noise pollution.

Keywords: Transportation, metro noise, frequency characterization

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1. INTRODUCTION

Metro rail systems have experienced significant development in recent years [1]. These systems offer several advantages, including high capacity, rapid transit, and enhanced safety, making them a preferred solution for addressing urban transportation challenges [2-3]. Due to their comparatively lower environmental impact, metro rail systems are prioritized by traffic authorities in major cities, with continuous efforts directed toward their improvement. Despite these benefits, metro rail systems contribute substantially to noise pollution, particularly when combined with existing road traffic noise [4]. Several studies have focused on assessing noise levels at metro station platforms [1-2,5]. Research findings indicate that metro rail noise frequently exceeds permissible daytime limits [5-7]. The operation of metro rail systems has been associated with an increase in ambient noise levels by approximately 2–3 dB(A) in areas with medium to high traffic density [8]. Metro rail noise consists of a combination of high-frequency noise (HFN) and low-frequency noise (LFN), primarily generated by rolling noise and aerodynamic noise [9]. Various noise components, including low-frequency noise (10–250 Hz) and high-frequency noise (250–20,000 Hz), have been identified as potential sources of annoyance [10]. Frequency characterization plays a crucial role in noise pollution mitigation, as the effectiveness of mitigation strategies depends on the specific frequency range of the noise. This study seeks to bridge existing knowledge gaps by analyzing noise levels and spectral characteristics within metro stations under both operational and non-operational metro rail conditions.

2. MATERIAL AND METHODOLOGY

2.1 Data collection

The study area included two recently operational elevated metro corridors in Mumbai, Maharashtra, India, with MS1 and MS2 located along **Metro Line 2A** and MS3 and MS4 situated along **Metro Line 7**. Noise data were recorded using a Class 1 sound level meter equipped with a 1/3 octave band analyzer for a duration of 15 to 20 minutes during the peak hour of day.

2.2 Data analysis and frequency characterization

The measured noise data were analyzed to determine the equivalent continuous sound level (L_{eq}) and background noise level (L_{90}). The instrument utilizes 1/3-octave band analysis, covering frequencies from 6.3 Hz to 20,000 Hz. Under all circumstances, including with and without metro rail movement, differences in sound intensity were noted across these frequencies.

3. RESULT AND DISCUSSIONS

3.1 Noise levels at metro stations

The background noise levels and Leq values at four metro stations on Metro Lines 2A and 7 (MS1, MS2, MS3, and MS4) were analyzed with and without metro rail operations **(Fig. 1)**. At Dahanukarwadi, the overall L_{eq} was 72.6 dB(A) with an L_{90} of 65 dB(A). Without metro rail, the L_{eq} was 69.5 dB(A), increasing to 77.0 dB(A) during metro operations. At Goregaon, the overall L_{eq} was 72.4 dB, rising from 71.4 dB (without metro) to 75.2 dB (with metro). Similarly, at another station, the overall L_{eq} was 77.4 dB with an L_{90} of 72.9 dB, increasing from 76.7 dB (without metro) to 79.5 dB (with metro). At Magathane, the overall L_{eq} was 76.3 dB with an L_{90} of 73.3 dB, rising from 75.7 dB to 77.9 dB during metro operations. The analysis shows that metro rail contributes an additional noise impact of 3–7 dB, varying by location. Gundavali exhibited the highest noise levels, indicating a need for mitigation measures. Elevated background noise at Magathane and Gundavali suggests significant non-metro sources, such as high traffic density and construction activity.

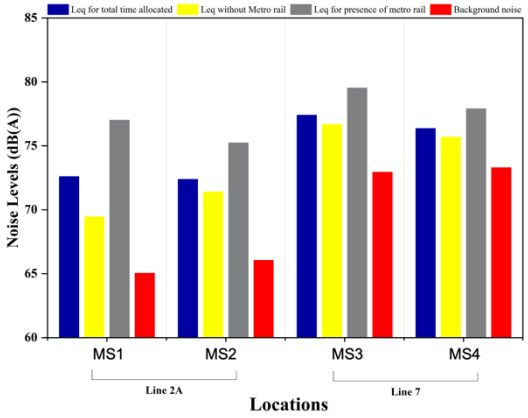

Figure 1. Noise levels at metro stations (MS1, MS2, MS3 and MS4)

3.2 Frequency spectrum characterization

The frequency spectrum diagram in **Fig. 2** presents a detailed frequency analysis, showcasing noise levels across various frequency bands over time. Using 1/3-octave band analysis, the spectral characteristics at metro stations—both with and without metro rail operations—highlight distinct peaks in noise levels at different frequency ranges. A detailed statistical and frequency spectrum analysis of all metro station locations reveals significant peaks in noise levels across both low and high-frequency ranges. Key contributing frequencies include 40 Hz, 63 Hz, 80 Hz, 800 Hz, 2500 Hz, 3150 Hz, and 6300 Hz, representing metro rail noise components such as aerodynamic and wheel-rail noise. Notably, the highest peak noise level is consistently observed at 800 Hz across all locations, marking it as a distinctive signature of metro rail noise.

4. CONCLUSION

This study identifies a distinct signature of metro rail noise, enabling a comprehensive characterization of its impact. The findings support the development and implementation of targeted noise mitigation measures and guidelines, specifically addressing the identified frequency ranges.

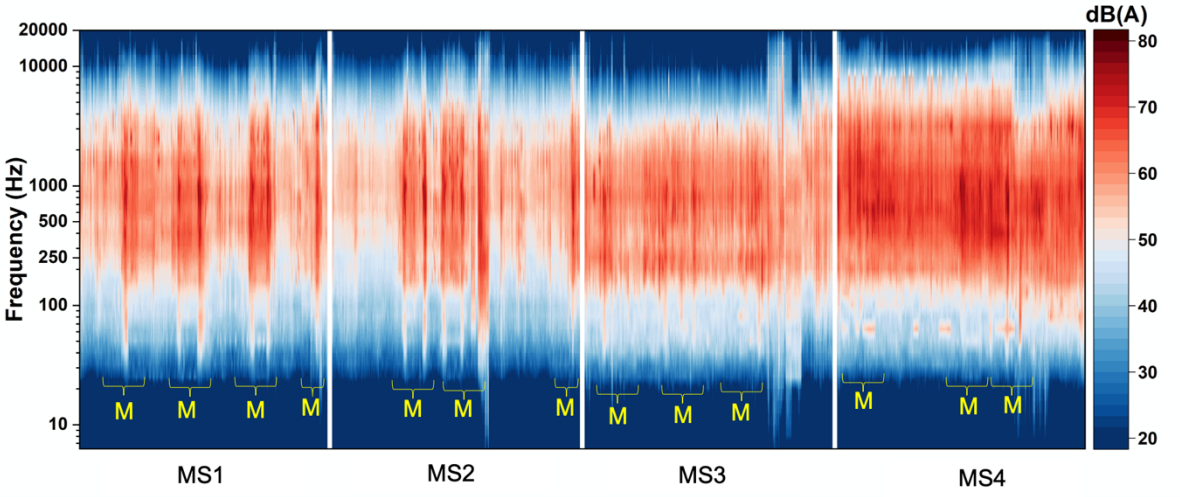

Figure 2. Frequency characterization metro noise at metro stations

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