

STUDY ON NOISE ABSORPTION AND REFLECTION BEHAVIOUR UNDER DIFFERENT TYPES OF ROAD PAVEMENTS

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Abstract- Pavement with higher noise absorption proficiency can significantly decrease the roadway transportation noise. There has been always a need to focus on this field to build a model for the roadway pavements without damaging its capacity to mitigate the noise. Many solutions exist in the market and several proprietary products are available. Also, there are diverse methods available to assess the noise generated by traffic. These methods are extensively using in various applications areas from noise assessments to innovative study. The methods employed generally based on the nature of the work and the materials on which acoustic performance will be evaluated. Therefore, in this paper we have studied various models and techniques that would be valuable in order to investigate future development of road traffic noise and its consequences under Indian road conditions. Some appropriate solutions for road surfaces beyond today's technology are investigated.

Key words: Traffic noise, Noise absorption, Normal incidence absorption coefficient (NIAC), Surface assessment, roadway pavements.

1. INTRODUCTION

Noise is considered a pollutant under the law of Prevention and Control of Pollution Act, 1981. The noise is frequently termed as an unwanted sound. Noise contains the unnecessary, obtrusive, unpleasant, annoying, or distracting sounds that affect the ability to enjoy the life or concentration of the mind in some way. Preventive actions are more practical than their removal to diminish the pollutants from the air [1-4].

According to a study which was confirmed by CSE's findings, examined data of two lakhs individuals in 50 cities in the world, comprising two Indian metropolitan cities also, Delhi and Mumbai. Unfortunately, the poorest noise pollution among all the cities was reported in Delhi. Residents of this city has the maximum number of hearing loss with respect to oldness. The study revealed that 64 per cent of hearing loss was caused by Noise pollution, which is a major issue of concern for health. The CSE findings also revealed that at the ITO intersection in Delhi recorded noise levels 106 decibels (dB) because of continuous beeping of vehicular and dense Jams [5-9]. Although, the standards projected by the Central Pollution Control Board for noise is set 50 dB for the silence zone and 55 dB for residential zone. Also, the CSE findings has exposed that India lacks of data on unnecessary sounds as well as monitoring capacity.



Figure 1: Environmental pollution due to unwanted sound

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2. LITERATURE REVIEW

The objective of this review paper is to study the noise absorption methods/techniques, modelling for various road surfaces in the current scenario. This study can give an immediate impact on the change of quieter roadway traffic and reduction of noise levels by providing better road surfaces with more capable to absorb the noise. This study will be valuable contribution in the area of noise management/abatement, especially at planning stage and re-development of urban roads. Traffic noise is a problem everywhere throughout the world. The roadway traffic noise can be diminishing with the high acoustic retention ability on the pavements. At the point when sound waves crash into a material, structure alludes to absorb sound energy. Noise retention coefficients of surfaces of road pavements recently have turned into the subject of a significant research effort [10-12].

Tian et al, 2014 [13] examined the impact of Portland cement porous concrete (PCPP) on the road/pavement tier acoustic drop. The fundamental goal was to assess the impact of this cement on the reduction of the pavement noise. The close and pass-by (PB) strategies were the two ordinarily utilized techniques for field findings. The CPX strategy straightforwardly assessed the noise, created on the tire-pavement edge by putting a microphone close to road interface. The outcome clearly affirmed that noise of the tire-pavement incremented when the vehicle speed goes up. This has shown, PCPP can fundamentally diminished the tire-pavement produced unnecessary sounds from 4 to 8 db.

Liu et al, 2013 [14] proposed a method of measuring NIAC for impedance tube. This provided the noise and the particle speed at an equivalent position with comparing the absolute transfer function method which generally depends on the two pressure microphones. The method is as similar as the transfer function method. However, the effect of transducer mismatch on the transfer function method was removed with the help of a very basic sensor-switching technique. No other equivalent way of removing phase and amplitude mismatch between the two transducers of the p-u probe. Therefore, they should be calibrated within a tolerance of 0.5 dB and 2°. Zhang et al, 2013 [15] developed a method to evaluate the mean texture depth (MTD) esteem, using Principal Component Analysis (PCA). It determined pavement quality, microtextured, utilizing measurements from a microphone fixed under the automobile.

Arenas and Crocker, 2010 [16] studied the sound-absorbing materials which absorbs the most of the sound energy coming to them, and making them extremely helpful for the control of sound. The porous sound-absorbing materials are more technologically optimized and environmentally friendly. These materials are constantly identified to incorporate the reduction of levels of reverberant sound pressure, thus, the dropping in the reverberation time in roads. The utilization of dynamic noise control with passive control to create hybrid sound absorbers. It has been concluded that, the thicker the porous surface, the lower the pinnacle frequency. Paje et al, 2009 [17] explored a few attributes of the rolling sound from a bituminous porous surface. The tire/pavement sound level from the collaboration of the references tire and the porous surface PA-12 was investigated in every third-octave band somewhere in the range of 200Hz and 16 kHz. The outcome showed that the variety in the coefficient B increased nonlinearly with frequency.

Jha and kang, 2009 [18] projected an organization's traffic noise model which was implemented in the region to control noise levels because of vehicular traffic. The TNM method utilized to foresee the noise levels of vehicular traffic both consistent and interfered with streams in isolated networks. The methods could consequently recognize pavements portions where establishment of sound obstructions may be applied.

Ongel et al, 2008 [19] determined the noise levels of various sorts of asphalt pavement with different surface mixes. The 23 test sections were examined with different asphaltic surfaces related to their noise level, roughness, permeability, texture, friction, air-void content and condition. It was found that open graded mixes often tend to decrease tire/pavement noise level up to 4.5 dB. The quantity of reduction was correlated moderately with the air-void content and surface texture. Growing either the thickness or the air-void content may resulted to the reduction of the tire/pavement noise, but further investigation is required. Dai et al, 2008 [20] explored a quantitative system for assessing the impacts of the major factors, for example, traffic flow, kinds of vehicle and noise energy on the traffic noise, based on an exhaustive experimental examination performed on test ARC and ordinary streets. The acoustic reaction of ARC pavements was methodically contemplated, and the traffic noise on the ARC and ordinary pavements was resolved with a model set up comparing to given traffic parameters. They suggested over half noise energy was decreased with ARC pavement.

Tiwari et al, 2004 [21] focused on to illustrate the noise preoccupation parameters of cement matrix as well as the asphalt concrete. They assumed it, the component of cenosphere substance and thickness over the frequency scope of 0-400Hz. It was recognized the ideal measure of cenosphere needed to expand the sound absorption. Experimental outcomes demonstrated that a 40% share of cenospheres to cement expanded the noise reduction coefficient by 100%.

Zannin et. al., 2002 [22] performed the noise monitoring experiments at various urban zones of the city Curitiba, considering ideal meteorological conditions. Previously, large number of noise monitoring studies in urban areas throughout the world have been reported. The authors projected an efficient approach named "PU free field surface impedance approach" which casted off a Microflown velocity sensor and a sound pressure microphone. In this technique, the sensors were placed in one probe which positioned close to the material, and a sound source was positioned at a fixed distance. The ratio of pressure and velocity resulted impedance. Further, material reflection and absorption can be determined. A model was casted-off to correct for the spherical waves and calculate the plane wave impedance.

Time windowing approach was formulated to filter the reflections at the pavement [23-24]. When several reflections are taken place, the outcome should follow the real impedance. Nevertheless, when the real impedance has a sharp change, so

attention is needed and averaging is omitted. If durable reflection is found, the surface impedance measurement generally effected. The method is based upon a set up in which a PU probe is placed at a certain distance in front of a spherical loudspeaker. In a fast two step approach measurements are done. First the probe is calibrated against air. In a second step, a relative measurement is done by pointing the set up to the material to be tested. The method was believed to contribute to industry standardization and better modelling. The reflection coefficient R of an acoustic material was delineated by the proportion of the incoming sound wave and reflected one [25-29]. If sound waves are plane the phase shift of between the sound pressure and particle velocity is zero or 180 degrees depending on the direction of the sound wave. The sound pressure (p) is scalar and the particle velocity (u) is a vector value. It was demonstrated that if the plane sound wave in one direction was given by the signal $p+u\rho c$, the sound wave in the opposing direction is given by $p-u\rho c$. The reflection coefficient is then given by: where ρ the density, c the speed of sound and α is the absorption coefficient. Plane waves are found in a standing wave tube below the cut off frequency $f_c=c/2d$ with d the inner cross section of the (square) tube. Measurements in the free field are more complex because plane waves are practically impossible to create.

If a source is relatively close to the sample under test, spherical waves may be expected. If a special (monopole) source is chosen, the sound wave is exact spherical, and this gets a model to estimate the reflection coefficient possible. Several methods are possible to estimate the reflection coefficient from the measured impedance [30-33]. Another problem with free field measurements is that a monopole sound source generates a sound pressure which is directly proportional to the frequency. Apart from difficult measurement, the models to calculate the reflection coefficient from the measurement become more difficult for lower frequencies. The measurement set up consists on a spherical shaped loudspeaker. The radiation impedance of the loudspeaker. The radiation impedance in front of the loudspeaker is quite similar to a monopole. The loudspeaker mounted, mechanically decoupled to a grip. On the grip is a structure is mounted that holds the PU match probe. A Pavement Performance Model (PPM), according to the World Road Association, was understood a mathematical expression which help out to envisage the future state of roads, created at present state, corrosion aspects like road traffic and environment, effects consequential from maintenance and restoration works. A Computer based software, named KENLAYER was used to catch on the damage ratio with the help of various distress models. Generally, in this software, cracking and rutting are two basic distress models. They were supposed to be the most critical essentials for bituminous pavements. At the bottom of the bituminous layer, the horizontal tensile strain (E_t) creates fatigue cracking. While the vertical compressive strain (E_c) on the outward of the pavement caused long lasting distortion and rutting. (Gedafa, 2006). The performance of the roads was projected using pavement deterioration models in HDM -4. [34-36].

L. Sedyowati et. al., 2017 [37] studied the outcomes of 4-types model based on the CBPs (concrete block pavements), impeding the runoff speed of vehicles on pavement surface. CBP properties based 3-design parameters were proposed that affect the movement retardation significantly. The following three parameters were considered in this work, straight channel ratio (S_r), opening ratio (O_r), and void ratio (V_r). In order to analyse the effect of rainwater intensity and surface gradient to flow on numerous CBPs, an inclined plot equipped with rainfall simulator was casted-off. An improved dye tracing process was implemented to check the surface flow speed of vehicles. Flow retardation coefficient (F_r) was determined on the basis of speed on flat roads calculated at the identical rainfall intensity and surface gradient. The outcomes presented that flow reduction coefficient enhanced with an upsurge in rainfall intensity, openings ratio and surface gradient. The authors also presented a simple relationship on linear regression function among flow retardation coefficient. Still more research is required to enhance the accuracy and reliability of the model with the help of upgrading the regression function and increasing thee design parameters.

P.K. Jain 2013 [38] studied an efficient evaluation of pavement by identified design and prompting factors. His evaluation strategies practiced performance monitoring with the assistance of test site and field evaluation. Though the ground estimation can be taken away by observing working roads as well as smaller replicate test strips by using an "Accelerated Pavement Testing Tools". The rain substantially effected the quality of pavements with extra rate of augmentation in rutting of the test. To accelerate the impairment, the tyre pressure and wheel weight was enlarged which obvious after 4.32 msa of traffic where substantial rutting had happened.

G. Liao et. al., 2014 [39] analysed the effects of pavement surface characteristics on tire/pavement noise levels. From the time span of August 2009 to August 2011, noise levels and pavement surface characteristics were determined quarterly on impervious and open-graded asphalt pavements at 2009 NCAT test track. The linear regression analysis method and dominance analysis method was used to determine the effects of single and multiple pavement surface characteristics on noise levels, respectively. The results showed that the surface texture increases noise levels at lower frequencies (below 1600 Hz) particularly on impervious asphalt pavements. Porosity mitigates the noise levels at every single frequency (except at 2500 Hz) on open-graded asphalt pavements. The outcomes will assist to design future low-noise asphalt pavements.

F. Irali et. al., 2014 [40] evaluated the acoustic and surface characteristics of different Canadian pavement types was carried out in 2013 at the test track of the Centre for Pavement and Transportation Technology at the University of Waterloo. Noise testing was performed to determine the coefficient of noise absorption on cored samples and noise emissions in the field using the close proximity and the on-board sound intensity methods. Wearing course characteristics were evaluated with field testing, including visual condition surveys, evaluation of frictional properties with the British Pendulum tester, mean texture depth measurements, and surface profile and roughness evaluation with a walking profiler. As of the time of testing, the noise testing results indicate comparable acoustic properties in both flexible and rigid pavement sections, despite differences in the

initial pavement materials, mixes, and surface finishing. With increasing pavement age, the amount of noise emissions increases as the pavement surface is worn down. Comparable friction values are also observed in all pavement sections, in line with the noise testing results. However, this is largely based on the initial construction values. Surface distresses are also not uniformly distributed: they are more severe in the oldest sections and more frequent in the loaded lane, which carries the heaviest traffic loads.

A. Vaitkus et. al., 2018 [41] have presented the study of age effects on tyre/road noise levels. There are various types of age and surface type pavements (conventional AC and SMA pavements, low noise SMA TM, TMOA and PA) were evaluated and compared in terms of acoustical performance. Analysis of CPX noise level measurement results were obtainable followed with the conclusions and recommendations of low noise pavement application for severe climate regions. Investigation of acoustical behaviour of developed low noise asphalt mixtures (SMA 5 TM, SMA 8 TM, TMOA 5) for Lithuanian and regional climate conditions is relevant to gain understanding how developed mixtures react to real traffic and harsh climate conditions. Such knowledge is important when preparing low noise asphalt layers' implementation guidelines.

V.F. Vázquez et. al., 2018 [42] presents the geo-referenced acoustical results obtained throughout the close proximity noise (CPX) technique carried out on different urban sections included within the 2017 strategic noise mapping (Directive 2002/49/CE) in Ciudad Real, a Spanish medium-sized city. The employed methodology quantifies the tire/pavement noise generated in the contact between the tire and the surface of the studied sections. Measurements were carried out in different research campaigns between 2008 and 2015 (medium-term evolution). They give valuable information about the pavement-aging effect on its surface characteristics. Throughout these years, the acoustic situation of these sections has worsened mainly due to surface damage and higher mean profile depth (MPD) values, although the performance does not follow the same pattern in every section. The relationships between measured tire/pavement noise and theoretical environmental noise, just due to the geometric spreading of sound energy, is also studied in order to elaborate a simple rolling noise mapping and to assess the environmental noise evolution. Traffic noise plays the main role in the noise registered within the assessed sections, therefore, CPX assessment could be used by local authorities to take decisions regarding urban planning and traffic management, with the aim of reducing noise exposure from traffic.

O. Sirin et. al., 2018 [43] investigated the changes of acoustical performances of DGA pavement over time in the State of Qatar by using the OBSI method. Three similar DGA pavements with different age were selected to evaluate the effect of pavement age on tire-pavement noise. The following conclusions can be made based on the experimental results obtained from this study: The acoustical performance of DGA pavement deteriorates with pavement age. Therefore, this deterioration of acoustical performance should be considered for selecting 'quieter pavements' in order to devise sustainable policies for noise abatement. One-third frequency analysis showed that when there are no visible distresses on the pavement, noise increasing with pavement age due to increase of high frequency noise (frequency in between 800 Hz to 3150 Hz) which resulted due to further densification of pavement materials under heavy and repeated traffic. In the presence of distresses such as fatigue cracking or ravelling, increase of noise with aging is mainly contributed by low frequency noise (noise below 1000 Hz) due to changes in surface texture of pavements.

E. Hammer et. al., 2018 [44] evaluated the noise reduction coefficient of common market tyres on the most frequently used road surfaces in Switzerland and elsewhere in Europe. It revealed that the simplified measurement procedure with a modified CPX trailer is suitable for predicting coast-by rolling noise emissions according to UN/ECE. They determined the noise reduction coefficient of "silent tyres" on road surfaces in Switzerland as well as Europe. Noise productions were assessed approx. 14 selected tyres with diverse dimension, profile and noise label on a set of 12 dissimilar pavements. The assessments were carried out with the help of a modified CPX trailer. It further permitted the modifications of the tyre load with respect to the UN/ECE 117 standard's requirements. This research discovered the narrowest tyre of the sample was about 5 dB quieter than the widest assessed tyre. The noise reduction coefficient was recorded up to 4 dB within the same dimensions. The obtained noise reductions are similarly high for all assessed road surfaces. However, many studies have shown that a tyre's noise reduction coefficients do not weakened with tyre age, that's why, it is suggested for policy makers to offer more resources to the proliferation of "silent tyres" (e.g. by improving label relevance and understanding) as this may contribute on the way to lower down the traffic noise levels on a large scale.

The development of traffic noise emission on different pavement types used on highways has been analysed by the H. Bendtsen et. al., 2010 [45] on the background of long-time measurement series carried out in California and in Denmark. The key focus was on the progress of noise over time. Other factors relevant for the description of the development of the physical structure of the pavement surface like texture, porosity, visual signs of wear and tear etc. have not been taken into account. The pavements included in this project were grouped in the following main types:

- DGAC Dense Graded Asphalt Concrete
- OGAC Open Graded Asphalt Concrete
- PAC Porous Asphalt Concrete
- Thin Open Asphalt Layers

K. Kimura et. al., 2017 [46] proposed a technique for determining an oblique incidence absorption coefficient for optimum Aoshima's time-stretched pulse (OATSP). This technique can be applied in in-situ measurement of absorption coefficient for sound absorbing materials attached to structures such as noise barriers and ceilings of double deck viaducts. Using this

method, field measurements were taken away at the four unsimilar locations where absorptive panels were kept to the underside of upper decks of elevated roads. It was revealed that oblique incidence absorption coefficient measured in the field shows good agreement with the results in the laboratory. The measurement in-situ was the same method as in a semianechoic room. The assessments of pavements were taken away in four different sites of the underside of the upper decks of elevated roads. In this case, oblique incidence absorption coefficient measured has revealed a better agreement with outcomes from the offsite.

E. Freitas et. al., 2016 [47] observed the objectivity of road noise annoyance by ignoring vehicle mechanical noises and generating virtual stimuli with tyre/road noise. A very basic sound propagation algorithm was developed by integrating the some crucial effects like absorption and reflection. Moreover, the engine noise, from electrical or traditional vehicles, and other noises, the masking effect of traffic annoyance could be better studied and understood. The experimental testing with the help of real sounds for assessing annoyance was pretty complex and could impede study interactions with a wide set of variables. They had described, discussed and presented the outcomes of a straightforward method to assess tyre/road noise and related annoyance, based on the virtual sounds made by vehicles, with no interferences.

In [48], the authors presented some experimental results show that application of the solid element with additional spherical refraction surface can be helpful for acoustic investigation of small samples with high sound velocity. It provides enhanced transmission of the sound into the sample and gives the possibility to evaluate the sound velocities both for longitudinal and shear waves. Such angle transformer could be interesting for crystalloacoustic experiments where a source of shear wave beam with radial polarization is needed. the acoustic energy of the wide collinear beam from the transducer can be concentrated by large aperture lens and spherical surface into the narrow beam incident normally on the specimen face. The steel element serves also as impedance transformer between coupled liquid and the object.

3. CONCLUSION

More studies and researches are required to understand the processes, their causes and to optimise the maintenance methods in a better way to get hard-wearing low noise pavements. Knowledge and experiences should be exchanged so as to allow the innovation. From the various literatures, we have met requirement for the standardisation of assessment for pavement noise efficiency and noise labelling. It can simplify the distribution of knowledge on low noise pavement. This can further make assistance to the road builder choosing the appropriate products. The actual fact may suggest the chance of considering in future, various projects, the mitigation of noise, air pollution and many other environmental related issues. Specifically, the road surface features, rolling resistance along with shear resistance and also the combined study of noise shall be of an important practical value.

4. REFERENCES

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