Equipment Noise Attenuation for Pavement Layers

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Abstract

Elevated noise levels deteriorate the quality of construction environment by affecting the human safety, health and machine productivity. These noise levels are mainly influenced by the type of equipment, maintenance condition, operation, land use, terrain and materials used in road construction. The noise generation and attenuation for different equipment and pavement layers are important for mitigation measures. Although the ambient noise levels for various land uses have been specified, noise generation by different equipment during construction of road pavement layers is scarcely studied. This paper examines the influence of noise generated by different equipment during the construction of subgrade and granular subbase pavement layer on the noise attenuation distance. The ambient noise attenuation distance for granular crushed aggregate layer (Subbase) was found to be twice as that of soil layer (Subgrade). The attenuation distances for dozer, excavator, grader and compactor were 25.6, 11.5, 31 and 25.4 m respectively for subgrade layer and the corresponding distances for granular subbase were 27.8, 24.3, 37.5 and 91.5 m.

Keywords: *Equipment noise attenuation, subgrade, subbase, attenuation distance*

1.0 Introduction

Noise is undesirable as it deteriorates the quality of environment with short or long term impact. While temporary impacts are those generated by construction activities and traffic, long term impacts are due to the surrounding utilization of land. Ambient noise levels must not exceed the permissible limits as it leads to health issues such as hearing impairment, sleeping disorders, cardiovascular issues, communicating troubles and adverse effect on the wildlife [1]. Equipment play significant role in construction of roads. Better quality and speedy construction are the benefits of inducting equipment resource in road construction projects.

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However, cost of equipment and the noise generated by them during their operations are some of the concerns. Construction equipment is a major noise generator during execution of road projects. The noise levels of equipment are mainly influenced by the equipment type, model, condition and type of operation. The main source of noise in construction equipment is engine exhaust. However, in construction works such as pile driving and pavement breaking, the noise produced by the work is dominant. Equipment noise levels are also influenced by land use, terrain and materials handled during road construction.

Several researchers reported effect of noise levels of construction equipment [2] and analysed noise levels of heavy earth moving machineries adopted at chromite mining complex, Odisha, India. The authors indicated that the equivalent noise level is different with reference to time of monitoring and types of machineries at 1% level of significance. William Bowlby et al. [3] developed models for prediction of noise level based on usage of equipment, distance at which the noise levels are measured and time of response. A computer program was used to validate the data of over fifty types of construction equipment and operations.

Cynthia S Y et al. [4] developed a manual for measurement of highway-related noise to reflect improvements and changes in noise measurement technologies evolved since the FHWA, 1981 and procedures for measuring highway noise. WSDOT Biological Assessment Guidance (2015) [5] provides guidelines to biologists engaged in preparing biological assessment (BA) reports for transportation projects. This manual takes into account the recommendations by FWHA, 2010 and NCHRP, 2012. The NCHRP [6] recommends permissible noise levels for road construction activities for various types of land use viz., residential (75 dB), commercial (80 dB) and industrial (85 dB). Mathematical models were proposed to arrive at noise attenuation dynamics for different land use types and heavy construction equipment. These models were developed considering several contributing factors such as topography, vegetation, temperature, baseline (existing) noise level and construction activities. The distance traversed by noise before it attenuates to ambient levels both due to traffic and construction was calculated as per equation (1).

$$D = Do \times 10^{\frac{\text{Construction Noise – Ambient Sound Level in dB)}}{\alpha}} \tag{1}$$

where, D is the distance from the noise source, Do is the reference measurement distance (10 feet in this case), α = 25 for soft ground and 20 for hard ground. For point source noise, a spherical spreading loss model is used. Values of α assume 7.5 dB reduction per doubling distance over soft ground and 6.0 dB reduction per doubling distance over hard ground.

Noise generation and attenuation with distance for different equipment and types of road pavement layers are important for mitigation measures [7]. Although the ambient noise levels for various land uses have been specified, noise generation by the different equipment during construction of different types of road pavement layers are least explored. The present study focusses on analyzing the behavior of noise by different road construction equipment with respect to construction of subgrade (layer constructed using good soil) and granular subbase (layer constructed using graded crushed stone aggregates) pavement layer and determination of distance for noise attenuation.

2.0Field Study

2.1 Noise levels - Different types of Equipment and Loaders

The study was carried out along State Highway-73 connecting Hubli and Dharwad in Karnataka, India when construction activities for sub grade, sub base, lean cement concrete sub base (unbound aggregate) and paving quality concrete layers of road pavement were in progress. Dry lean concrete is a plain cement concrete with compressive strength in the range of 10 to 15 MPa. Paving quality concrete is a cement concrete top layer with compressive strength 40 to 4 5 MPa. DIGI noise meter, a mobile phone application was used to record the noise generated by the construction equipment. Minimum and maximum values of noise around the equipment were recorded at a radial distance of 3 and 6 m. Before measurement of noise in the field with DIGI noise meter, the mobile phone application was calibrated with sound level meter. The maximum and minimum noise levels recorded by different equipment during road construction activities including the average noise levels are presented in Table 1. The noise levels generated by the loader are shown in Table 2.

Table 1. Noise levels recorded for different equipment during road construction

Sl. No.	Type of equip-ment	Operations	Age of the Equip-ment (years)	Average Noise Level (dB)		Min. Noise Level (dB)	Max. Noise Level (dB)
				3m	6m		
1	Dozer	Dozing	4	89.3	87.2	62	100.4
2	Backhoe	Excavating	3	80.7	76.4	62.4	96.9
3	Loader	Loading	4	80.7	76.5	60.3	100.1
4	Dumper	Moving	2	74.2	70	53.8	86.1
5	Grader	Grading	6	89.4	86.1	58.1	94.8
6	Concrete Slip form Paver	Paving	3	81.8	78.6	64.8	98.8
7	Roller	Rolling	4	100.1	95.8	55.3	106.5
8	Drilling Machine	Breaking of concrete blocks	3	100.1	93.6	70	106.5
9	Diesel generator	When engine on	5	85	81.8	66.7	98

Table 2. Noise levels Generated by Loader

Sl. No	Equip-ment	Type of opera-tions	Noise Level (dB) measured at a distance of 3 m and 6 m					
			Subgrade		Reduc-tion in noise, dB	Granular sub base		Redu-ction in noise, dB
			3 m	6 m		3 m	6 m	
1	Loader	Forwarding	78.6	76.5	2.1	--	--	--
		Loading	76.5	72.1	4.4	--	--	--
		Dumping	77.5	74.3	3.2	--	--	--
		Idling	68.9	66.6	2.3	--	--	--
		Noise range	62.4 to 100.1			--		
2	Grader	Forwarding	81.5	77.5	4	88.3	84	4.3
		Reversing	89.3	85	4.3	89.4	86.1	3.3
		Idling	73.2	71	2.2	77.5	73.2	4.3
		Rising	78.6	75.4	3.2	78.6	75.4	3.2
		Noise range	58.1 to 92.6			61.3 to 94.8		
3	Roller	Forwarding	82.9	78.5	4.4	85	80.7	4.3
		Reversing	84	80.7	3.3	92.5	89.4	3.1
		Idling	74.3	70	4.3	82.9	77.5	5.4
		Vibration	87.2	82.9	4.3	100.1	95.8	4.3
		Noise range	55.3 to 91.4			66.7 to 106.5		
4	Back	Forwardi	86.1	83.9	2.2	-	-	

	Hoe	ng						
		Loading	-	-		87.2	85	2.2
		Dumping	-	-		89.3	87.2	2.1
		Excavating	88.3	85	3.3	-	-	
		Idling	69.9	67.8	2.1	69.9	67.8	2.1
		Noise range	66.3 to 97.6			62 to 100.4		

2.2 Traffic noise along study stretch

The noise levels generated by vehicles moving on road were measured and are presented in Table 3. The noise measurements were recorded along shoulders of pavement

Table 3. Typical Traffic Noise Levels

Sl. No.	Type of vehicle	Noise in (dB)
1	Tractor	72.1
2	Car	64.6
3	Bike	61.3
4	LCV	66.7
5	Truck	68.9
6	Bus	68.9
7	Auto	62.4

3.0Results and Discussion

The noise attenuation distances have been calculated for equipments, subgrade and subbase layers based on equation (1) described in the earlier section. The reductions in noise levels with varying distances for various equipment and land are as presented in Table 4. The attenuation distance for sub grade layer and GSB layer construction are as presented in Table 5. The attenuation distance for different equipments are as indicated in Table 6.

Table 4. Percentage noise reduction for various land use along the road

Sl. No	**Name of Equipment**	**Distance (m)**	**Percent noise reduction**		
			Residential	**Commercial**	**Industrial**
1	Loader	3	--	--	--
		6	7.6	7.2	6.9
		9	13.8	11.5	11.1
		12	15.3	14.5	13.9
		15	17.7	16.9	16.1
		18	19.7	18.8	17.9
		21	21.4	20.4	19.5
		24	--	21.8	20.8
2	Excavator	3	--	--	--
		6	8.4	7.9	7.5
		9	15.3	12.6	11.9
		12	16.8	15.9	15.1
		15	19.5	18.4	17.5
		18	21.7	20.5	19.5
		21	23.5	22.3	21.2
		24	--	23.8	22.6
3	Grader	3	--	--	--
		6	7.5	7.1	6.8
		9	13.4	11.3	10.8
		12	15.0	14.2	13.6
		15	17.4	16.5	15.8
		18	19.3	18.4	17.6
		21	21.0	20.0	19.1
		24	--	21.4	20.4
4	Compactor	3	--	--	--
		6	7.6	7.2	6.9
		9	13.8	11.6	11.0
		12	15.3	14.5	13.9
		15	17.8	16.9	16.1
		18	19.8	18.8	17.9
		21	21.5	20.4	19.5
		24	--	21.8	20.8

It could be inferred that the reduction in noise varies between 2.1 to 4.4 dB for subgrade and 2.1 to 5.4 for granular subbase layer. However, biological assessment manual [5] has suggested the levels at 7.5 dB for soft ground and 6.0 dB for hard ground. Hence the values suggested in the biological assessment manual may not be specifically applied for subgrade and granular subbase layers.

Table 5. Attenuation distance for different layers

Construction activity	Ambient noise level Attenuation distance (m)
Sub grade	79.6
Granular Sub Base	164.8

As shown in Table 5, the noise attenuation distance for subgrade layer was found to be about 67.4% less as compared to unbound granular layer. The change in noise levels with distance from the point source of its generation was quantified for varying land use during the construction of subgrade and GSB layers. The extent of noise reduction is as presented in Table 6.

Table 6. Attenuation distance for different equipments

Construction Equipment	Attenuation distance, (m)	
	Sub grade	GSB
Dozer	25.6	27.8
Excavator	11.5	24.3
Grader	31	37.5
Compactor	25.4	91.5

4.0Conclusion

The present study focusses on the assessing the effect of noise by different road construction equipments with respect to construction of subgrade and granular subbase pavement layer and determination of distance for noise attenuation. The roller generated highest noise level of about 106.5 dB amongst other equipments considered for measurement of noise. It was also observed that when the distance doubled from the source of generation, the noise level reduced by 2.1 to 5.4 dB. The distance point source construction noise traveled 80 m before it attenuated to the ambient sound level and 150 m during sub grade construction for unbound granular subbase layer. The noise attenuation distance for dozer, excavator, grader and compactor was found to be 25.6 m, 11.5 m, 31 m and 25.4 m respectively during construction of subgrade layer. The same was found to be 27.8 m, 24.3 m, 37.5 m and 91.5 m for dozer, excavator, grader and compactor respectively during construction of unbound granular subbase layer. The reduction of noise on subgrade and granular layer were found to be around 3.5 and 4.3 dB respectively when the distance got doubled.

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