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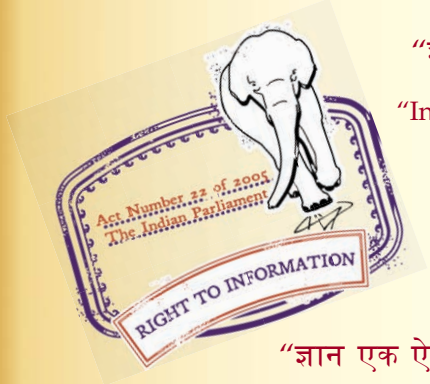

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Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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Indian Standard

RECOMMENDATIONS FOR NOISE ABATEMENT IN TOWN PLANNING

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RECOMMENDATIONS FOR NOISE ABATEMENT IN TOWN PLANNING

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Indian Standard

RECOMMENDATIONS FOR NOISE ABATEMENT IN TOWN PLANNING

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 12 December 1968, after the draft finalized by the Functional Requirements in Building Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 To prevent human life from the harmful effects of noise which continues to increase day by day, man shall continue his efforts to find ways and means for the abatement of noises which may be a cause of nuisance to an individual in particular or public in general. An individual may find himself helpless against the nuisance of noise, but with regard to the effect of noise as nuisance to the public, a planner assisted by an acoustical expert may really do a lot by reducing effectively the effect of noises on the community. There are certain noises which may be prevented by law and ordinances, like Motor Vehicles Acts and Factory Acts in force from place to place. For noises which fall outside the control of the above legislations, a town planner has to exercise his ingenuity to create conditions within the scope and means of his project to effectively meet the requirements of abatement of noises.

0.3 Good town planning practices segregate the major types of urban uses by designating appropriate locations for each of them, at the same time inter-relating these to each other to produce orderliness and smooth functioning. The residential areas are separated from the industrial and commercial zones by means of physical barriers, roads, railway lines, parks or green belts. It is difficult for a particular zone to function independently of the other and it is this aspect which necessitates the need to think of methods by which the noisy zones may be located in the neighbourhood of the zones which need quiet, at the same time overcoming the hazards which the noise from one zone produces in the adjoining zone.

0.4 In residential areas, the occupants of dwellings are constantly exposed to noise. The most common sources of noise are due to various types of traffics, such as heavy vehicles, trains and automobiles. Even noise from air and sea transport may be a source of great nuisance and inconvenience. With the increase in industrial development, noise from the industry is ever on the increase. In case of localities where there are no zonal regulations, the location of industrial buildings anywhere and everywhere in the community area may be a source of great nuisance from the noise point of view. It is with this object in view that this code is being prepared to lay down

general principles for town planning schemes in order that a reasonable degree of quiet is achieved for work and living in the neighbourhood.

0.5 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

0.7 In the preparation of this standard assistance has been drawn from the following publication:

SURI (R L). Acoustics, design and practice (Volume I). 1966. Asia Publishing House, Bombay.

1. SCOPE

1.1 This standard lays down basic principles to achieve optimum conditions of noise abatement in town planning schemes.

2. SOURCES OF NOISE

2.1 Common sources of outdoor noise are the following:

a) Traffic:
   i) Air traffic,
   ii) Rail traffic,
   iii) Road traffic, and
   iv) Sea shore and inland water traffic;

b) Industries; and

c) Other activities.

2.1.1 *Traffic Noise* —Noise produced by traffic has always been a nuisance to the society. The intensity and nature of the traffic noise depends on various factors. The disturbance due to aircraft noise depends very much on the type of aircraft. A jet aircraft at take-off produces more noise than a propeller type and a heavy truck carrying loose luggage may have a greater nuisance value than a private car. In case of automobile traffic the condition of the road and the maintenance of the vehicles play an important part.

*Rules for rounding off numerical values (*revised*).

The noise produced by trains also depends upon the type of train (*see* Appendix A) for typical values of train noise, the rails and their bending. As in the case of road, rail, and air traffic the noise produced by sea traffic is more at the harbour where the loading and unloading takes place.

2.2 Industries — Noise is one of the by-products of industry. The nature and intensity of the noises depend on the type of industry. These noises are generally produced by rotating, reciprocating or any other machinery, or by high pressure, high velocity gases liquids or vapours involved in the processes of industry.

2.3 Noises Due to Other Activities — These noises are periodical, continuous or intermittent, such as from temple and church bells, sirens, blaring or loudspeakers, hawkers and children playing, as a result of local community life and activity. Noise levels of some noisy sources are given in Table 1.

TABLE 1 NOISE LEVELS OF SOME NOISY SOURCES

Sl No.	Noisy Sources/Areas	Noise Level dB
i)	Air traffic:	
	a) Jet, take-off, at about 300 m	100-110
	b) Propeller type, take-off, at 300 m	90-100
ii)	Rail traffic (at about 30 m)	90-110
iii)	Heavy road traffic (highways)	80-90
iv)	Medium road traffic (main streets)	70-80
v)	Light road traffic (side streets)	60-70
vi)	Industries	60-95

3. CONSIDERATIONS FOR LAYOUT AND LOCATIONS OF VARIOUS ZONES

3.1 General Considerations — Usually, the town planning architect is primarily interested in the best utilization of land. But in this process, there are a number of factors (smoke, odour, noise, etc), which he may take into account. All these factors collectively help him to determine the zones which should be earmarked for residential, commercial and industrial purposes. Most important of all these factors is the extent of annoyance and disturbance caused to the community from various sources of noise. In detailed town planning, care is therefore required to be taken to segregate noisy sources (industries, railways, aerodromes, highway road traffic, etc). Also, in order to ensure the requisite degree of quietness in certain specific buildings, suitable areas/locations need to be allocated for the purpose.

These aspects need careful consideration in the initial stages of planning a town. In this connection reference is invited to Table 2 giving acceptable noise levels that are required.

TABLE 2 ACCEPTABLE NOISE LEVELS

Acceptable Outdoor Noise Levels in Residential Areas			Acceptable Indoor Noise Levels for Various Types of Buildings		
Sl No.	Location	Noise level dB (A)	Sl No.	Location	Noise level dB (A)
i)	Rural	25-35	i)	Radio & TV studio	25-30
ii)	Suburban	30-40	ii)	Music room	30-35
iii)	Residential (urban)	35-45	iii)	Hospitals, class room, auditoria	35-40
iv)	Urban (residential and business)	40-50	iv)	Apartments, hotels, homes	35-40
v)	City	45-55		Conference rooms, small offices	
vi)	Industrial area	50-60	v)	Court rooms, private offices, libraries	40-45
			vi)	Large public offices, banks, stores, etc	45-50
			vii)	Restaurants	50-55

3.1.1 The comparative study of Tables 1 and 2 emphasizes the fact that while planning a new township, care has to be taken to see that the various zones are conveniently located from the noise point of view. As a general classification, the following zones may be visualized:

Zone	*Noise level*
a) Quiet	$\leqslant$60 dBs
b) Zones of concentrated noise sources quite at times	60-70 dBs
c) Zones of concentrated average noise sources	70-80 dBs
d) Zones of high noise sources	80-90 dBs
e) Zones of extremely high noise sources	$>$90 dBs

3.2 Based on the above considerations, the locations of the various types of buildings are to be considered in detail as follows:

a) Location of aerodromes and air routes;

b) Location of railway stations, routing of railway track and arterial roads;

c) Industrial areas;

d) Residential areas; and

e) Community areas containing the following:

1) Office buildings, courts and council chambers;
2) Shopping centres;
3) Hospitals and broadcast studios;
4) Educational institutions, such as universities, colleges, and schools, libraries, national laboratories;
5) Entertainment centres, such as cinemas, theatres, clubs, stadiums, swimming pools, restaurants and parks; and
6) Places of worship, such as temples, mosques, churches.

4. BROAD RECOMMENDATIONS

4.1 The question of boundary areas for different purposes is not so simple to tackle. Indeed, the problem is complex and involved. As a result the matter needs careful thought and study by the authorities concerned in consultations with the acoustical experts at the appropriate stage of urban and regional planning. However, broad outlines for the guidance of the town planners are given in **4.1.1** to **4.1.11.8.**

4.1.1 *Location of Aerodromes and Air Routes*

4.1.1.1 *New aerodromes* — New aerodromes should be located sufficiently away from the city and adequate boundary area should be allocated for the purpose such that residential construction may come up only beyond that area. Considering the present day requirements of the angle of glide of jet aeroplanes, an area of 6 to 8 km square should be adequate. But to be on the safe side and to accommodate any future expansion programmes, it would be better to earmark an area of about 6 to 8 km square. It may not be forgotten that a city located even at a distance of say 16 km away from the aerodrome is also exposed to noise. The noise level at such a distance may be lower than at locations nearer the airport but there will be disturbance in any case, especially in the night. When establishing the routes for flying into and out of an airport, it is necessary to avoid flying over towns of thick population.

4.1.1.2 *Existing aerodromes expansion* — One cannot do much where an existing small aerodrome located in the outskirts of the city had to be expanded to cater to the bigger and noisier aircraft. A township has automatically grown around it. At the same time the development of the city had of necessity to be pushed in that direction too. But this should be avoided in future and as far as possible, the planners should disallow residential areas, hospitals and schools to be laid out within a certain area of the aerodrome. In case a township has grown and is well-established around an aerodrome, and if the noise levels due to the air traffic exceed the recommended maximum noise levels in the area, it is even worthwhile considering an alternative more distant location for the airfield.

4.1.2 *Location of Railway Stations, Rail Tracks, Highways and Arterial Roads* — A comprehensive development plan of a city must take into account the lay-out of rail and road traffic. The location of the railway station, shunting yards, loco-sheds and the routing of rails have to be carefully worked out so that the noise produced in these areas cause least disturbance to the residential community and other similar areas requiring day and night quiet conditions. For the same reason, due attention should be paid to the location of bus and truck depots, as also freight transfer points. These are very important in minimizing transport activity and consequent reduction in noise in the community area. The rail tracks, highways and arterial roads should preferably be routed away from the residential and commercial areas. If the highway is to be connected to the residential areas, it is better to provide a ' link road ' and rout the highway through a ' by-pass '. However, if due to other considerations a rail head or line has to be located in or near a residential area or community centre, certain precautionary measures to abate the noise shall have to be taken. Three of the methods which may be adopted without much difficulty and expense are given in **4.1.2.1** to **4.1.2.3**. Any or all of these methods may be used, depending upon the severity of the conditions.

4.1.2.1 *Laying rails-roads in deep cut track* — One method for reducing the noise from a track is to keep the track below the ground level. A typical arrangement is given in Fig. 4 in Appendix A. The track shown has a depth of 3·5 m and walls sloping at 45° to the vertical. Results of measurements made in this track are shown in Fig. 1. It was noticed that the attenuation effect of the cutting is much more at the higher frequencies than that at the lower ones. Also, the attenuation effect is much less in the case of engine noise and whistle, because these sources are at a higher level than the track.

4.1.2.2 *Inter-position of a solid barrier* — Use of solid barrier is another method (*see* Fig. 1). This may be in the form of walls of different heights placed between the source and the community. Even the existence of buildings (not used for human occupation) between the rail track and the residential or commercial area in question would help in the attenuation of noise.

The amount of noise reduction obtained depends on the distances betwee the source and the barrier, and between the receiving position and theu barrier, the height of the barrier and on the wavelength of the sound.

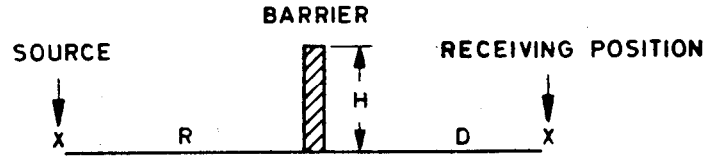


FIG. 1 USE OF SOLID BARRIER

If $D \gg R$ and if $R \gg H$, the noise reduction may be calculated from the formula, reduction (dB) $= 10 \log_{10} (20 H^2 / \lambda R)$

where

λ = wavelength of sound,

R = distance between noise source and the barrier, and

D = distance between barrier and the receiving position.

In practice, the reduction achieved by such walls is never as much as predicted from the above formula. For guidance, a typical set of curves are given in Fig. 2 in Appendix A indicating the sound level reduction at 100 c/s for various wall heights and distances from the source.

4.1.2.3 *Planting of trees and hedges on either side of the track or road* — Belts of trees or shrubs may also be used as barriers of sound. It has been found that in dense evergreen woods (average visibility 20 m), the attenuation of sound is about 18 dB per 300 m at 500 c/s. This is due to absorption by the foliage on the one hand and multiple scattering on the other. Obviously, denser the barrier, greater is the attenuation. This method of noise reduction is comparatively less expensive and may be used with success, if there is not much of limitation of open land in the vicinity of the noise source.

NOTE — In addition to the above remedial measures, noise reduction at the source also may be adopted. Resilient mountings of the tracks and welded track for rail lines and smooth asphalted roads for the roadways, and better silencers for the engines help in the reduction of noise at the source.

4.1.3 *Location of Industrial Areas*

4.1.3.1 Normally, planners have, in the past, followed the practice of segregation in industrial zoning and to restrict certain areas for various types of manufacturing units. These areas have been arranged to be at different distances from the residential and commercial areas. This segregation may have been justified some years ago when the factories were put up in ugly ramshackle structures and caused nuisance in the form of smoke, odours, etc, and, of course, noise too. As a result, the planners allocated only such of the areas for industrial units which were not required

for other purposes. This concept has since changed. Industry is now a part of community life and is an asset to the city because it not only gives employment to the citizens, but also the industrial development helps to provide all the public services required by the community. As a result, modern industrial colonies with well-planned layouts and buildings are seen in many cities. It would not be correct to classify the industries only in terms of the usual ' light ' and ' heavy ' industries, as such a classification does not indicate the performance characteristics from the noise point of view. An industrial unit classified as 'light' may be as noisy or noisier than another unit classified as ' heavy '. The classification may be based on the noise vibration produced by them. Their performance standard in this respect alone, should decide their zoning. The boundary noise level need to be specified and the boundary earmarked accordingly.

4.1.3.2 *Cases where noise level exceeds the limits* — In cases where the noise level exceeds the permissible limit, the planner has the following possible alternatives to consider:

a) To re-allocate the area for a zone where higher noise levels are permissible. This would mean that from the noise point of view, the residential areas are down-graded to commercial areas, which in turn are earmarked as industrial areas.

or

b) To devalue the residential land which may lie within a certain boundary (from the noise source) where it reaches the permissible noise level.

4.1.3.3 *Location of heavy and noisy industries* — It is likely that some industrial units are either located much farther from the residential areas or another industrial property intervenes between the two. In such a case, the particular industrial unit could obviously be permitted to emit more noise. In any case, really heavy and noisy industries, like ship-building, locomotive workshops, structural steel and coach factories, etc, shall be located in specially reserved areas, as far away from the residential areas as possible. This should be done even if such location has some consequential adverse effect on the economy of the town. We have to remember that the constant impulsive sounds emanating from these industries may prove extremely harmful to human life by causing nervous breakdowns and insomnia.

4.1.3.4 *Wind direction* — Another salient factor which needs to be borne in mind for zoning various areas is the direction of wind. The noises travel in the direction of wind and if residential buildings are situated in that direction, the uncomfortable effect on the community is obvious, particularly when in modern times, the industries work continuously in shifts around the clock. This experience is quite common in coastal towns where some industries are located between the coast and the residential areas.

4.1.4 *Control of Industrial Noise in the Existing Cities* — The control of industrial noise in the existing layout of the cities is undoubtedly difficult, as it would mean shifting of the various noise producing industrial/non-industrial units to another area away from the residential and commercial community. But the question does need to be studied in order to plan their shift in stages, and for future, necessary restrictions should be imposed, by means of local regulations/legislations in order to prevent location of further industrial buildings and/or noise producing equipment in the residential/commercial areas.

4.1.5 *Location of Residential Areas* — However, in addition to the general precaution to earmark a silent zone for locating the residential area in a new township, certain other fundamental principles also shall have to be observed in working out the detailed plans of buildings inside the residential locality.

4.1.6 *Layout in Proximity of Rail and Road Traffic* — When residential/commercial buildings have to be provided in proximity of the railway track or the main road, running along flat ground, it is necessary to set back the buildings by a suitable distance of at least 50-75 m. This distance shall need to be increased where the rail track is a part of the marshalling yard or is used for shunting day and night. In case the rail track or road is in a cutting, this distance could be reduced (*see* Appendix A). Similar would be the case if other buildings or wall barriers intervene in between and help to screen the noise source.

4.1.7 *Location of Noisy, and Quiet Buildings* — Here we have to realise the practical conditions in the present-day busy life of a city or town. It would be well-nigh impossible to prevent some heavy automobile vehicles from passing through certain parts of the town, because they transport goods which are essential for the life of the local community. But if the layout of the roads and the freight transport points are suitably arranged, the adverse effect of such traffic could be minimized. Again, there are some buildings which may be called noisy because of their function and the essential human activity conducted therein. For example, buildings, such as stock exchanges, restaurants and mercantile offices should fall in this category. Buildings of this kind could be located on the main streets while hospitals, schools, dwellings, etc, could be laid out along the side streets.

4.1.8 *Suitable Set Back of Buildings from Roads* — Noise levels on the side streets, which are not frequented by heavy traffic, would no doubt be less than that of the main streets but may still be within the objectionable limit. A certain amount of improvement may be effected by arranging to set back the buildings from the road by a suitable distance. The farther it is from the road, the better it will be, because the intensity of noise gets reduced with the increase in distance. For the same reason, the accommodation should be laid out in a manner so as to be concentrated in the central part of the site rather than on the outer sides/edges of the site.

4.1.9 *Trees, Shrubs and Hedges* — Trees, shrubs and hedges help in screening the noise from the buildings.

4.1.10 *Surfacing of Roads/Streets* — The type of surfacing used affects the extent of noise emanating from the roads/streets. Hard metalled roads should be discouraged where animal drawn or conventional type of vehicles with hard wheels are still in use. Asphalted road surfaces being soft are less conducive to impact noises. Even if the volume of traffic does not justify the provision of separate graded routes, on the main roads, for fast moving traffic, slow traffic and for cycles, the facility does have more than a safety significance. The noise sources being spread out, the build up of noises is minimized.

4.1.11 *Location of Community Facilities* — The community facilities need to be located nearer to the residential areas. But the individual units and their locations have to be examined on the basis of their particular requirements. Some of these units need day and night quiet conditions of a high degree and do not produce any noise of their own. Others need noise quieting for certain periods only while during certain periods they act as noise sources. Based on the above requirements they may be classified as given in **4.1.11.1** to **4.1.11.8**.

4.1.11.1 *Broadcasting television/film studios* — The standards of noise protection for such buildings and areas need to be very high. Broadcasting studios need unusually quiet surroundings. It is very necessary that a quiet locality is earmarked for the studio premises. Other precautions, such as off setting the building away from the road, confining the studio proper in the core of the building complex by arranging the technical areas and offices in the outer periphery, by adopting double wall constructions, isolating foundations and floating floors as required shall be adopted to in the planning stages itself.

4.1.11.2 *Commercial buildings* — These buildings include offices, hostels, courts and council chambers, etc. The degree of quiet required for these buildings is not very high. But for maximum efficiency and minimum interference from external noise sources, a suitable locality shall be chosen to accommodate the above types of buildings. Whatever be the location, here again, the main source of noise in urban areas is due to road traffic. The modern buildings of the above type now consist of multi-storeys and are arranged along the roads with a continuous facade. The rooms which face the roads and are on the lower floors are subjected to maximum noise level. Of course, comparatively less noise will reach similar rooms on the upper floors. One method of reducing this noise is to off-set the building by a suitable distance from the road. The noise conditions would need further improvement and the occupants could be given some relief by screening off the noise coming from the windows. A better method would be to arrange the layout so that all rooms requiring quiet conditions are placed on the

quieter side of the site/building. In the worst conditions of noise, artificial ventilation may have to be resorted to and/or double doors and windows utilized to provide necessary sound insulation.

4.1.11.3 *Educational institutions* — Universities, colleges, schools, libraries, national laboratories, etc, come under this category. It may be mentioned that these are buildings which require average quiet conditions but are also at the same time noise sources at certain times. In the first instance, efforts should be made to find a site which is situated in comparatively quiet environments at least the site should be away from the noisy roads, rail tracks, aerodromes etc, where there is no choice and these must be located in relatively noisy environment, due attention shall need to be paid to the layout of the rooms and facilities. Adequate open space should be left between the building and the roads/noise source. The rooms, shall be arranged to be farther away from the noise source, while other unimportant rooms, like gymnasium may be laid out closer to it and in a manner so as to provide a noise shield to the class-rooms.

4.1.11.4 *Entertainment centres* — Buildings, like cinemas, theatres, clubs, swimming pools, etc, present very exacting demands of noise reduction. But it may also be mentioned that these areas are inherently noise producing in nature during certain periods and hence may be planned away from the residential localities. Other precautions as suggested in **4.1.6** to **4.1.10** shall be observed in the detailed layout of these buildings.

4.1.11.5 *Hotels/restaurants/parks* — These buildings present problems similar in principle to those of residential flats but it is generally assumed that these buildings are quieter than residential flats as the occupants or users produce much lesser noise; only the occupancy is more. However, the considerations in the location and siting of the residential areas shall be applicable here also.

4.1.11.6 *Places of worship and religious buildings* — These are also to be located in a quiet place. The quiet conditions required are similar to those required for libraries and laboratories. In order to obviate the possibility of church bells or temple noises disturbing the neighbourhood, it is preferable that these buildings are located a little away from the residential areas.

4.1.11.7 *Shopping centres and stadiums* — Shopping centre is a noise area. So also the stadium. Hence these are required to be segregated from the quieter areas.

4.1.11.8 *Parks and playfields* — Parks and playfields are essential for the society and are indispensable to neighbourhood units. Care should, therefore, be taken that the noise due to parks and playfields does not prove a source of inconvenience to the units which need quiet conditions.

APPENDIX A
(*Clauses* 2.1.1 *and* 4.1.6)

A-1. GENERAL REDUCTION MEASURES FOR NOISES AT SOURCE

A-1.1 The above noise levels are extremely high for community areas and it is advisable to consider their reduction. Suggested methods are given below:

a) *Inter-position of Solid Barrier* — This may be in the form of walls of different heights placed between the source and the community as shown in Fig. 2. Even the existence of buildings (not, of course, used for human occupation) between the rail track and the residential/commercial area in question would help in the attenuation of noise.

b) *Planting of Trees and Hedges on Either Side of the Track/Road* — In dense evergreen woods (average visibility 20 m), the attenuation of sound is about 18 dB per 300 m at 500 c/s. This is due to absorption by the foliage on the one hand and multiple scattering on the other, obviously, the denser such a barrier is, the greater will be the attenuation effected.

A-2. TRAIN NOISE LEVELS

A-2.1 Typical noise levels are shown in Fig. 3.

A-2.1.1 *Track Noise Level* — The following are given:

a) Freight trains (900 to 1 200 m long) running at 25 to 40 km/h	90 dB at 6 m 77 dB at 150 m
b) Freight trains (900 to 1200 m long) running at 65 km/h	96 dB at 7·5 m

A-2.2 Engine Noise Level — The noise level under all operating conditions will be 97-105 dB at 15 m.

A-2.3 Whistle Noise Level — The noise level will be 110 dB at 15 m.

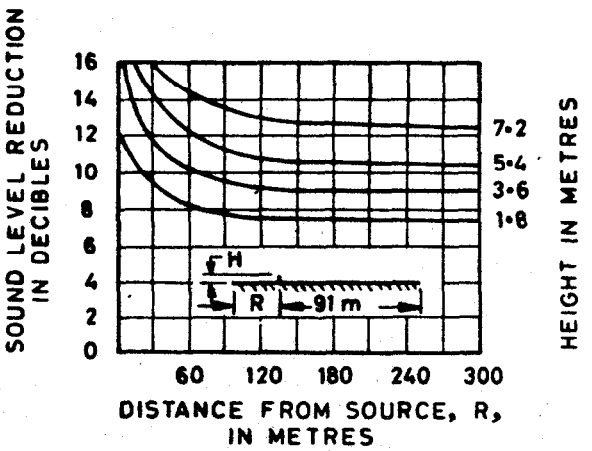
NOTE 1 — It has been noted by the investigators that while track noise increased by 6 dB for every doubling of speed, it decreased by 3 dB for every doubling of the distance.

NOTE 2 — Similarly, engine noise decreased by 3 dB for every doubling of the distance, except within a distance of 15 m where this rate was 6 dB.

NOTE 3 — In the case of whistle noise, the attenuation was 6 dB for every doubling of the distance.

NOTE 4 — Attenuation rate in the case of train and engine noise is attributed to line source of noise, as distinct from point source in the case of whistle noise.

A-2.4 Reduction of Train Noise Levels by Laying Rails in Deep-Cut Track — A typical track with a depth of 3·5 m and walls sloping at 45° to the vertical is shown in Fig. 4. It was also noticed that the attenuation effect



NOTE — It will be observed that noise reduction increases with the height of the barrier. In most of the cases, even with economical wall or barrier construction, a noise level reduction of 10 to 15 dBs is achieved. This is true as long as the source remains on the ground, typical cases being railway trains and automobiles.

FIG. 2 SOUND LEVEL REDUCTION AT 100 c/s FOR VARIOUS WALL HEIGHTS AND DISTANCES FROM SOURCE

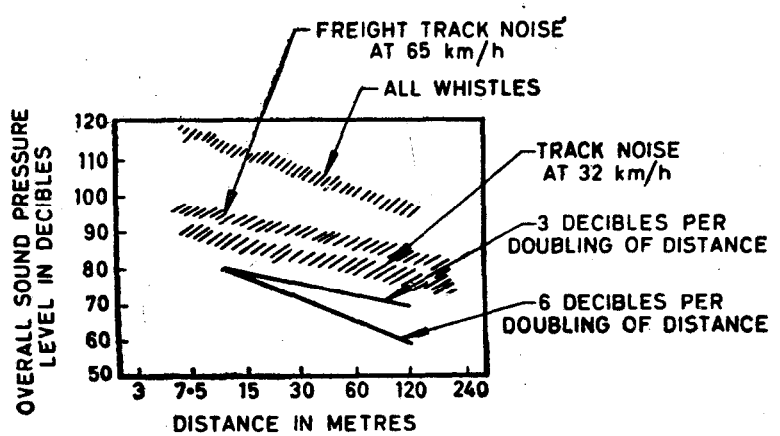
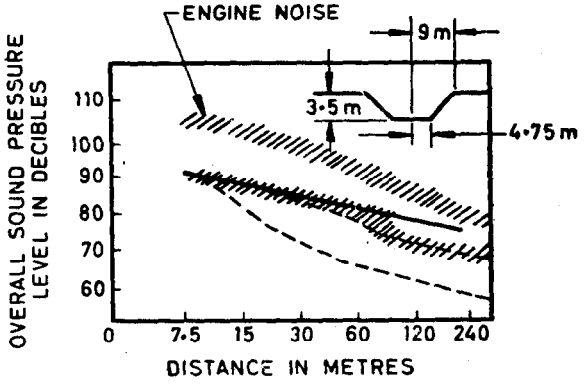


FIG. 3 TRAIN NOISE LEVELS OVERALL SOUND PRESSURE LEVELS AS A FUNCTION OF DISTANCE FROM THE TRACK

of the cutting is much more at the higher frequencies than at the lower ones. Also, the attenuation effect of the cutting is much less in the case of whistles and engine noise, because of these sources being located at a higher level and the track being visible above the 6 m cutting. As a result, the cutting is almost ineffective in these cases.



NOTE — The above figure shows measured overall sound pressure levels vs distance for track and engine noise in a cutting having the dimensions as shown. This track noise is compared with the calculated values of attenuation : (i) as would be read by the sound level meter (dotted line), and (ii) as would be heard by the ear (dashed line). Solid line shows the expected curve if there was no cut.

FIG. 4 REDUCTION OF TRAIN NOISE LEVELS BY LAYING RAILS IN DEEP CUT TRACK

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