

FACULTY OF CIVIL AND INDUSTRIAL ENGINEERING

Master's degree in Transport Systems Engineering

Reduction of Noise and Vibration

In

Railway infrastructure

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Academic Year: 2018/2019

Be like a train; go in the rain, go in the sun, go in the storm, go in the dark tunnels! Be like a train; concentrate

on your road and go with no hesitation!

Mehmet Murat ildan

ABSTRACT

Rail transport has emerged as one of the most dependable modes of transport in terms of safety. Trains are fast and the least affected by usual weather turbulences like rain or fog, compared to other transport mechanisms. Rail transport is better organised than any other medium of transport. It has fixed routes and schedules. Its services are more certain, uniform and regular compared to other modes of transport. Rail transport originated from human hauled contraptions in ancient Greece. Now it has evolved into a modern, complex and sophisticated system used both in urban and cross-country (and continent) networks over long distances. Rail transport is an enabler of economic progress, used to mobilise goods as well as people. Adaptations include passenger railways, underground (or over ground) urban metro railways and goods carriages.

The Italian railway system is one of the most important parts of the infrastructure of Italy, with a total length of 24,227 km (15,054 mi) of which active lines are 16,723 km. The network has recently grown with the construction of the new high-speed rail network. Italy is a member of the International Union of Railways (UIC). The UIC Country Code for Italy is 83.

As the world is developing day by day with high speed trains and freight trains, there are huge and fast trains creating more noise and vibration. Noise pollution, also known as environmental noise or sound pollution, is the propagation of noise with harmful impact on the activity of human or animal life. Main source of noise are mainly machines, transport and propagation systems. Poor urban planning may give rise to noise pollution, side-by-side industrial and residential buildings can result in noise pollution in the residential areas. Some of the main sources of noise in residential areas include loud music, transportation noise, lawn care maintenance, nearby construction, or young people yelling (sports games).

Noise pollution associated with household electricity generators is an emerging environmental degradation in many developing nations. The average noise level of 97.60 dB obtained exceeded the WHD value of 50 dB allowed for residential areas.

Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. The word vibration comes from the Latin word vibrationem ("shaking, brandishing"). The oscillations may be periodic, such as the motion of a pendulum or random, such as the movement of a tire on a gravel road.

This is what I am discussing about measures need to be taken to reduce Noise and Vibration by which we can give more comfort to traveller and environment.

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Chapter 1

INTRODUCTION OF NOISE AND VIBRATION

Noise is an unwanted sound, its intensity ('loudness') is measured in decibels (dB). The decibel scale is logarithmic, so a three decibel increase in the sound level already represents a doubling of the noise intensity. For example, a normal conversation may be about 65 dB and someone shouting typically can be around 80 dB. The difference is only 15 dB, but the shouting is 30 times as intensive. To consider the fact that the human ear has different sensitivities to different frequencies, the strength or intensity of noise is usually measured in A-weighted decibels(dB(A)). (1)

It is not just the intensity that determines whether noise is hazardous. The duration of exposure is also very important. To take this into account, time-weighted average sound levels are used. For workplace noise, this is usually based on an eight-hour working day.

Other factors that can affect how hazardous noise is include following: -

•Impulsiveness — are there sound 'peaks' (for example, produced by electric arcs)

•Frequency — measured in hertz (Hz). The pitch of a sound is the perception of frequency. For example, 'concert pitch' (the 'A' above middle 'C') is 440 Hz. (2)



Figure-1 Effects of Noise, starting from Exposure (under) to health effects (Top) according to WHO

Noise pollution associated with household electricity generators is an emerging environmental degradation in many developing nations. The average noise level of 97.60 dB obtained exceeded the WHO value of 50 dB allowed for residential areas. Research suggests that noise pollution is the highest in low-income and racial minority neighbourhoods. Documented problems associated with urban environment noise go back as far as ancient Rome. (2)

High noise levels can contribute to cardiovascular effects in humans and an increased incidence of coronary artery disease. In animals, noise can increase the risk of death by altering predator or prey detection and avoidance, interfere with reproduction and navigation, and contribute to permanent hearing loss. While the elderly may have cardiac problems due to noise, according to the World Health Organization, children are especially vulnerable to noise, and the effects that noise has on children may be permanent. Noise poses a serious threat to a child's physical and psychological health and may negatively interfere with a child's learning and behaviour. [2]

Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. The vibration word comes from Latin word *vibrationem* ("shaking, brandishing"). The oscillations may be periodic, such as the motion of a pendulum or random, such as the movement of a tire on a gravel road.

Vibration can be desirable: for example, the motion of a tuning fork, the reed in a woodwind instrument or harmonica, a mobile phone, or the cone of a loud speaker. In many cases, however, vibration is undesirable, wasting energy and creating unwanted sound. For example, the vibrational motions of engines, electric motors, or any mechanical device in operation are typically unwanted. Such vibrations could be caused by imbalances in the rotating parts, uneven friction, or the meshing of gear teeth. Careful designs usually minimize unwanted vibrations. (3)

1.1) Railway Noise

Railway transport is the most sustainable transport mode, as it consumes less energy, it occupies less space and produces less CO2 than any other transport mode. However, noise has long been the main environmental challenge for railway stakeholders.

Rail way noise is largely a problem of freight trains, and trains containing older wagons or engines and is a particularly severe problem during the night. Rolling noise is generally higher from poorly maintained rail vehicles, and from trains running on poorly maintained infrastructure. Aerodynamic noise is particularly relevant for high speed lines where, in most cases, noise limiting measures like noise barriers are implemented; noise barriers reduce the impact of rolling noise but are usually too low to have any effect on noise originating at the pantograph. Engine noise is most relevant at lower speeds up to about 30km/h, rolling noise above 30 km/h and aerodynamic noise dominates above 200 km/h. The most important noise source is rolling noise, which affects all kinds of train. (4)

Whether the sound is unwanted or not, it can damage the hearings of persons subjected to it if the sound level is high enough. Noise radiation is the only environmental effects of the running train. Fast and heavy trains cause vibration in the ground and buildings. (4)

1.2) Railway Vibration: -

Railway-induced vibration was first noticed and labelled an issue in relation to underground train lines. It is only in recent times that the vibration from surface lines is getting more attention. Vibration is usually accompanied by ground-borne noise. The relative significance of these two phenomena depends mainly on the soil type. In some countries with stiff soils, e.g. solid rock, ground-borne noise is generally more important than vibration, and dominant vibration frequencies are higher (i.e. around 50 Hz). With soft soil such as clay or peat, so dominant vibration frequencies are lower (around 5 Hz). This difference in soil type is an important factor affecting the performance and selection of mitigation measures. (5)

For railways, vibration is most often generated by the contact between the train wheel and the railway track. The vibration then travels from the track, through the ground and into the building foundation. Generally, the strength of ground vibration reduces as one moves away from the track. However, the strength of vibration may increase when moving up floors inside the building due to resonances of the building structure (5)

The generation of vibrations is solely a consequence of the vehicle forces passing from the wheel into the track. These forces arise from the weight of the vehicle and irregularities/discontinuities at the wheel/rail interface and then propagate outwards from the track. The vibration level experienced at all other locations within the track, soil or nearby structures is a function of this force, depending on the natural frequency of each component. (6)

Chapter 2

GENERATION MECHANISMS

2.1) Train Noise

Train noise can be a type of environmental noise. When a train is moving, there are several distinct sounds such as the locomotive engine noise and the wheels turning on the railroad track. The air displacement of a train or subway car in a tunnel can create different whooshing sounds.

Subways, Light Rail transit and freight trains can send loud train noise into neighbourhoods. Environmental Protection Agency have set some guidelines for noise level decibel limits for Rapid Transit. [7]

As a train gets closer, it makes a rumbling sound. As it leaves the station, it makes a steadily increasing chugging sound. The whistle sounds like a forlorn call in the night. The brakes hiss and screech when the train slows down to a stop. The air displacement of a train or subway car in a tunnel can create different whooshing sounds. Trains also employ horns, whistles, bells, and other noisemaking devices for both communication and warning. Trains propelled by electric traction motors often produce electromagnetically-excited noise. This high pitch noise depends on the speed and torque level of the machine, as well as on the motor Variable frequency drives use Pulsewidth modulation technique which introduces additional current harmonics, resulting in higher acoustic noise. The switching frequency of the PWM can be asynchronous (independent of the speed), synchronous (proportional to the speed), but always results in acoustic noise varying with Flange Squeal is the sound of the flanges of the metal train wheel set turning on the train track. [7]

2.2) Generation Mechanisms of Noise and Vibration [8]

Noise and vibration phenomena of concern to railways include:

2.2.1) Wheel-Rail Rolling Noise: -

Rolling noise is the main source of noise from railway operations at conventional speeds, and even at 300 km/h, it is at least as important as aerodynamic noise. In the last decade, several large research projects have been carried out across Europe with the aim of reducing wheel/rail rolling noise at source [8]

The primary physical process responsible for the vibrations that radiate as noise is the contact between the train wheel and the rail. The wheel tread rests on the rail head, and the mechanical contact is within a contact patch approximately 10 to 15 mm long and about as wide, when the wheel is rolling on the rail the small unevenness of both wheel and rail cause forces on both. These forces excite vibrations throughout the whole system which in turn radiates sound. This noise generation mechanism is known as rolling noise. [8]

When a wheel rolls on a rail, irregularities on the wheel and rail surfaces excite vibrations which radiate noise. Theoretical models describing the interaction between a railway wheel and the track are used for predicting noise generation, as well as wheel and track vibration, fatigue damage and rail corrugation. Often, especially for noise prediction, a linear model is used, which has the advantage that calculations can be carried out in the frequency domain . In practice, although the wheel can be considered as a linear system, the local elastic deformation of the contact zone has a non-linear stiffness characteristic as do the rail pads and the ballast in the track structure.(12)



Figure: -2 Rolling Noise Generation Mechanism

The major source of noise from railways is due to the rolling of the steel wheel on the steel rail. The sound level, Lp in decibels, of this rolling noise increases approximately according to the formula $Lp = Lp0 + 30 \log 10 (V / V0)$, where Lp0 is the noise level at the speed V0. Rolling noise is caused by very small amplitude undulations of the wheel and rail running surfaces noise. Typically, on both surfaces, there are undulations with amplitudes from less than 1 mm up to tens of mm. The undulations of importance for noise have wavelengths of several centimeters. An irregularity of wavelength l (m) causes vibration with a frequency f = v / l, where v is the speed in m/s.

2.2.2) Squealing as Wheel Radius Curve of Tight Radius: -

Railway curve squeal is a type of mono-tonal, high-pitch noise, which occasionally occurs when the railway vehicle is running along tight curves. It is generally considered to be a type of self-excited vibration instability of the railway wheel, like aerodynamic flutter, rather than a resonance phenomenon.

This high-pitched tonal noise is an acute cause of annoyance to those living adjacent to such a curve. Curve squeal is the intense tonal noise that can set in when a rail vehicle traverses a curve or switch. The process starts with either lateral creeping in the contact patch between rail and wheel or rubbing of the flange of the wheel against the rail.

The main results are a theoretical model that can predict when squeal will occur which together with the measurement rig makes it possible to investigate the effectiveness of measures such as lubrication, wheel damping and rail transverse profile adjustment. [8]

2.2.3) Wheel Vibration and Sound vibration: -

The wheel is a resonant structure with a shape relatively close to that of a (flat) bell. The force from the contact patch will excite vibrations in the wheel much like the force from the clapper in a bell. There are differences though, the wheel is pushed against the rail by a constant preload (the part of the train mass carried by the wheel) and it also rotates around the axle.

For the wheel the contact with the rail be added damping since vibration energy can be transmitted from the wheel into the rail where it propagates away and never comes back. This changes the typical loss factor from 10^{-4} of the freely suspended wheel to 10^{-3} for a wheel preloaded against the rail. [8]

Instead of a single mode or vibration pattern corresponding to one resonance frequency, some modes are broken up into two parts. As opposed to a single frequency related to a certain vibration pattern, there will be two frequencies.

This is due to the different wave propagation speeds for waves travelling from the contact patch and forward or backward, respectively. A wave travelling forward gets a shorter wavelength than a wave travelling backward due to the motion of the wheel. [8]

2.2.4) Rail vibration and sound vibration: -

The rail is an infinite beam-like structure. The forces from the wheel-rail contact patch move along the rail as the wheels move along it, leading to similar effects as for the rotation of the wheel. The rail is fastened to the sleepers via resilient pads, and the sleepers are spaced periodically along the track.(8)

The sleepers are typically placed in ballast, but in some cases the rail might be fastened with or without pads or sleepers directly into a stiff underground. Alternatively, the rails can be mounted on a concrete slab which rests on resilient springs. Most of the tracks are of the rail–pad–sleeper–ballast type, below Rail



Figure: -3 Rail-road connected to sleeper-ballast

At very low frequencies the track is very stiff in the vertical direction. The first resonance corresponds to the mass of the entire track and the stiffness of the ballast. The second resonance is typically slightly higher in frequency and involves the stiffness of the pads and the mass of the rail and the sleepers, where the rail and the sleepers are moving in anti-phase. The resonance frequencies can of course vary a lot depending on the rail mass, pad stiffness and other factors, but typical values for a modern rail on concrete sleepers are around 100 Hz for the first and 500 Hz for the second resonance.

Between those resonances there is anti-resonance where the track acts like a tuned absorber. At frequencies higher than the second resonance the rail is essentially decoupled from the sleepers by the resilient pads. [8]

The bending and longitudinal waves that travel along the length of the rail are filtered by the complex structure of the periodically spaced sleepers. Waves at some frequencies are heavily damped, while others travel along the track relatively unhindered. The important factor for the radiated sound is the damping as an average over a frequency band, often expressed as the damping ratio per meter (dB/m). At low frequencies the rail together with the sleepers are dominating the sound radiation. [8]

2.2.5) Wheel-Rail Roughness: -

The small unevenness or roughness on the wheel and rail surface is the physical structure behind the forces on the contact patch that cause the vibrations and hence the sound radiation. The roughness of both wheels and rails is characterized by micro peaks and troughs, sometimes with a periodic pattern, and with occasional larger areas of damage such as "spalling" of wheels where small sections of material come away, or "head checking" and "shelling" on rails caused by rolling contact fatigue. The roughness of relevance to rolling noise on both wheel and rails will normally be in the wavelength range of 5 - 200mm, with a roughness level ranging from around 0.3 microns peak-to-peak to around 120 microns peak to-peak. (11)



Flowchart 1: -Model for Rolling noise generation

UMRAE is equipped with systems measuring these roughness's:

a measuring system of the rail roughness, using an acceleration sensor interdependent with a mobile support which is manually moved along the rail (trolley);the system can measure amplitude defects inferior to one micrometer at wavelengths from some millimeters up to several meters, a measuring system of the wheel roughness based on a fixed system equipped with several displacement sensors in contact with the wheel which manually rotates; the system can measure amplitude defects inferior to one micrometer at wavelengths starting from several millimeters.(10)

The wheel and the rail are rough not only in the direction along the rail but also in the lateral direction. If the roughness is random in both directions, there is less excitation than if it is correlated in the lateral direction. This is important for braking systems that apply brake pads directly on the wheel tread, which can lead to a correlated roughness profile which is worse than a random profile. The generation of noise for a car tire rolling over a rough asphalt surface is a related research area. One of the differences between the rubber tire and the railway wheel is the adhesion. For car tires a certain roughness is desirable since a very smooth surface can lead to slightly more noise generation due to increased adhesion. For the railway wheel the optimum surface would be perfectly flat, since the adhesion component is less influential in this case. [8]

2.3) **Points and Crossings:** -Point and Crossings are peculiar arrangement used in permanent way (railway track) to guide the vehicle for directional change. Broadly point and crossing assembly consists of three main components namely Point, Lead and Crossing element. A point consists of one pair of tongue rails and Stock Rails with necessary fittings. Crossing is a device in the form of V-piece introduced in the track to permit movement of wheel flange at the inter section of two running lines. It has gap over which the wheel tread jumps. The track portion between point and crossing is called lead. Impact noise generated at discontinuities and severe features on the track or wheel, e.g. points and crossings, rail joints, welds or wheel flats. [8]

2.4) Fellable Low Frequency Ground -borne Vibration: -

Ground-borne vibration can be a serious concern for nearby neighbours of a transit system route or maintenance facility, causing buildings to shake and rumbling sounds to be heard. The effects of ground-borne vibration include fellable movement of the building floors, rattling of windows, shaking of items on shelves or hanging on walls, and rumbling sounds. In extreme cases, the vibration can cause damage to buildings. Building damage is not a factor for normal transportation projects, with the occasional exception of blasting and pile-driving during construction. Annoyance from vibration often occurs when the vibration exceeds the threshold of perception by only a small margin. A vibration level that causes annoyance will be well below the damage threshold for normal buildings. The train wheels rolling on the rails create vibration energy that is transmitted through the track support system into the transit structure. The amount of energy that is transmitted into the transit structure is strongly dependent on factors such as how smooth the wheels and rails are and the resonance frequencies of the vehicle suspension system and the track support system. (8)

These systems, like all mechanical systems, have resonances which result in increased vibration response at certain frequencies, called natural frequencies. The vibration of the transit structure excites the adjacent ground, creating vibration waves that propagate through the various soil and rock strata to the foundations of nearby buildings. The vibration propagates from the foundation throughout the remainder of the building structure. The maximum vibration amplitudes of the floors and walls of a building often will be at the resonance frequencies of various components of the building. the rumbling sound caused by the vibration of room surfaces is called groundborne noise. The annoyance potential of ground-borne noise is usually characterized with the A-weighted sound level. Although the A-weighted level is almost the only metric used to characterize community noise, there are potential problems when characterizing low-frequency noise using A-weighting. This is because of the nonlinearity of human hearing which causes sounds dominated by low-frequency components to seem louder than broadband sounds that have the same A-weighted level. The result is that ground-borne noise with a level of 40 dBA sounds louder than 40 dBA broadband noise. This is accounted for by setting the limits for ground-borne noise lower than would be the case for broadband

Such vibration occurs in locations of soft soil and propagates parallel to the ground surface with a low rate of attenuation with distance. This is of concern for heavy axle freight operations. [8]

2.5) Rumbling Noise from Train in Tunnels (ground-borne noise): - This is generated as vibration of the track is transmitted through the ground and radiated as sound within buildings by vibration of their walls. This has components between about 30 Hz and 200 Hz. It can be particularly annoying as it comes from a source that cannot be seen and no screening is possible. [12]

2.6) Noise Radiated from Bridges: - Concrete viaducts (Bridges) are an important part of urban rail transit systems but they produce considerable noise, thereby affecting the communities living nearby. The vibration generated at the wheel–rail interface is transmitted along the rail and onto the bridge; hence, noise is radiated from both the rail and the bridge. To facilitate noise prediction, it is desirable to develop a model that considers the generation and transmission of vibration in the train–track–bridge system. The vibration and the associated noise of the track–bridge system is computed with a unified vibroacoustic model using a wavenumber domain finite element and boundary element method. An important aspect to note is the frequency-dependent stiffness of a typical rail fastener utilized on bridges due to the resonance of the baseplate between two rubber pads.

To allow for this effect, a multilayer fastener model is proposed. The proposed procedure is applied to a viaduct with a U-shaped section and compared with field measurements during the passage of trains. The elastic modulus and damping of the rubber pads and the equivalent loss factor of the rail are chosen by fitting the calculated track decay rates to those estimated from the measured rail accelerations under train passages. The wheel–rail combined roughness is also derived from the measured rail vibration. A comparison is then made between the simulated and measured bridge vibration to verify the proposed method as well as the parameters used in the track–bridge system. [8]

2.7) Aerodynamic Noise from Train: - For high-speed trains, aerodynamic noise becomes significant when their speeds exceed 300 km/h and can become predominant at higher speeds. At train operation speeds more than 350km/hr., the noise generated rapidly increases as the train speed is increased. This trend is accompanied by the predominance of aerodynamic noise over structure-borne noise Aero- acoustic sources are closely related to airflow around the train and the optimization for a low air resistance. Where the airflow is turbulent, sound will be emitted, and at high speeds (>300 km/h) the contribution can be substantial. The pantograph is a typical problem area, as well as other structures that are protruding from the exterior of the train. [3] Aerodynamic noise is generated at both gradual and abrupt changes in duct area. Gradual transitions and low velocities generate less turbulence than abrupt transitions and high velocities. Noise generated in transition elements such as turns, elbows, junctions, and takeoffs can run 10 to 20 dB higher than the sound power levels generated in straight duct runs.

In the special case with a barrier that shields the wheel-rail source but not the pantograph, aero acoustic sources can be important at lower speeds. Without the barrier the aero acoustic sources are masked by the rolling noise, but the barrier reduces the rolling noise thereby making the aero acoustic noise audible. Secondary sources are noisy machinery on the train such as cooling fans and power transmissions. If poorly designed, they may contribute to the total noise emitted by the vehicle. They may also be very important even if they are not audible on the running vehicle when it is not moving. Then there is no rolling noise or aero acoustic sources that can mask the noise from fans or other auxiliary equipment [8]

what thrills me about trains is not their size or their equipment but the fact that they are moving, that they embody

2.8) Interior Noise in Train: - The noise inside passenger vehicles has a great effect on the level of passenger comfort. It can also be reduced by changing the floor structure of the bogie for example Suspended Floor. (8)

Field experiments were carried out to investigate abnormal interior noise generation in a coach used as a dining car of a high-speed train, including field measurements to investigate the interior noise conditions of another passenger coach under the same operating conditions. Sound quality indexes at each interior noise measuring point were analysed to determine the characteristics of the abnormal interior noise. The differences of vibration and noise in the two coaches were then compared to show the effect of the interior structure of the coach on the abnormal interior noise. In addition, the differences of vibration and noise in the dining coach before and after the wheel re-profiling were compared to examine the effect of the wheel roughness on the abnormal interior noise. (8)

2.9) Rolling Noise Generated by Railway Wheels with Visco-Elastic Layer: -

The noise-generating characteristics are two types of railway wheel design have been studied theoretically. These are "resilient wheels", in which a viscoelastic layer is located between the type and the web, and wheels with constrained layer damping treatments applied to the web. A method of predicting the rolling noise of these wheel types using the TWINS rolling noise model. A finite element model is used to calculate the mode shapes and modal masses. The modal damping is predicted by a complex modal analysis of the finite element model in which a material-specific damping parameter is used. Analyses have been carried out for several resilient wheels with different stiffness's of their resilient layer, including the case where the wheel becomes a conventional one by specifying the resilient element as steel. The sound power radiated by both the wheel and the rail are shown to be dependent on this stiffness. Several configurations of wheels with constrained layer damping treatments have been analysed considering the frequency variation of the properties of real damping materials. (9)

2.10) Vibration Induced by Train: -

The vibration phenomenon caused by train traffic can be described as wave propagation through structures and the ground. For example, the energy created can cause discomfort to people and interference in sensitive machinery. [10]

The generation of vibrations is solely a consequence of the vehicle forces passing from the wheel into the track. These forces arise from the weight of the vehicle and irregularities/discontinuities at the wheel/rail interface and then propagate outwards from the track. The vibration level experienced at all other locations within the track, soil or nearby structures is a function of this force, depending on the natural frequency of each component. Therefore, it is imperative that when simulating railway vibration that the vehicle and resulting forces are modelled in a manner that closely approximates the physical problem. (9)



Figure:-4 Vibration due to Train

Train movement on certain locations causes a response from the surrounding environment. This response depends on the quality of the rail track, type of foundations and type of vehicle. These factors determine the vibration level. In the following tables can be found a detailed description of vibration-related factors: [10]

Life is a train that stops at no stations; you either jump abroad or stand on the platform and watch as it

Factors	Influence
Vehicle suspension	If the suspension is stiff in the vertical direction, the effective vibration forces will be higher. On transit cars, only the primary suspension affects the vibration levels, the secondary suspension that supports the car body has no apparent effect.
Wheels condition	Wheel roughness and flat spots are the major cause of vibration from steel- wheel/steel-rail train systems.
Track surface	Rough track is often the cause of vibration problems. Maintaining a smooth track surface will reduce vibration levels.
Track Support System	On rail systems, the track support system is one of the major components in determining the levels of ground-borne vibration. The highest vibration levels are created by track that is rigidly attached to a concrete trackbed. The vibration levels are much lower when special vibration control track systems such as resilient fasteners, ballast mats, and floating slabs are used.
Speed	As intuitively expected, higher speeds result in higher vibration levels.
Track Structure	The general rule -of-thumb is that the heavier the track structure, the lower the vibration levels.
Depth of vibration source	There are significant differences in the vibration characteristics when the source is underground compared to at the ground surface.

 Table1: - Factors Related to Vibration Source. Adapted from Harris Miller & Hanson Inc. (2005).

Factors	Influence
Soil type	It is generally expected that vibration levels will be higher in stiff clay type soils than in loose sandy soils.
Rock layers	Vibration levels often seem to be high near at-grade track when the depth to bedrock is 30 feet or less. Tunnels founded in rock will result in lower vibration amplitudes close to the tunnel. Because of efficient propagation, the vibration level does not attenuate as rapidly in rock as it does in soil.
Soil Layering	Soil layering will have a substantial, but unpredictable, effect on the vibration levels since each stratum can have significantly different dynamic characteristics.
Depth to water table	The presence of the water table is often expected to have a significant effect on ground-borne vibration, but evidence to date cannot be expressed with a definite relationship.
Frost depth	There is some indication that vibration propagation is less efficient when the ground is frozen.

Table: -2 Factors related to vibration path

Vibrations in soft soils originated the concept of critical speed, because each type of soil has their own wave velocity propagation. With the increase of train traffic speed, that speed is either equalled or higher than it, originating the amplification of the vibration phenomenon. [10]

Chapter 3

REDUCTION AND EMISSION METHODS

3.1) Railway Noise Mitigation Factsheet: Overview of Railway noise sources: -

The major source of noise from railways is due to the rolling of the steel wheel on the steel rail. Rolling noise is caused by very small amplitude undulations of the wheel and rail running surfaces noise. Typically, on both surfaces, there are undulations with amplitudes from less than 1 mm up to tens of mm. The undulations of importance for noise have wavelengths of several centimetres. An irregularity of wavelength l (m) causes vibration with a frequency f = v / l, where v is the speed in m/s. [11]

The TWINS model (Track Wheel Interaction Noise Software) has been developed over several years to provide a theoretical model of rolling noise generation. This modelling process allows the separate components of noise from the wheel, rail and sleeper to be identified. This is broken down into the contributions from the various components. In this case the rail is the dominant source; the wheel is the greatest source at high frequencies and the sleeper is most important at low frequencies.

TWINS provide a tool for detailed design of components, considering their interaction, and allows the total noise to be minimised. Since the contributions to the total noise from the wheel and the track are of similar magnitude, noise reduction of only one part will have limited effect on the total. To make substantial progress in the long term towards a quieter railway, noise reduction measures must be developed for both vehicles and track. (11)

The TWINS model starts with the individual roughness of the wheel and the rail, expressed in terms of the roughness amplitude spectrum (level vs wavelength). These roughness's are then combined and used as the basis of a model of the forces that excite the wheels, the rails and the sleepers. The response of these components to the exciting forces, and their resultant acoustic radiation is then predicted by knowledge of the physical characteristics of the components of the system and the interfaces between them. The reduced surface roughness of

wheels that are not subject to cast-iron tread braking therefore results, both within the mode land, in a rolling noise that is lower than that resulting from cast-iron tread brakes, Options that exist for reducing rolling noise:

- 1. Reduce the amplitude of the irregularities at the wheel and rail running surfaces. for example, using disc brakes instead of cast-iron block brakes acting on the wheel running surface leads to smoother wheels and around 10 dB less noise. Alternatives to cast-iron for the brake block material also allow this effect to be achieved.
- 2. Reduce the vibration response of the wheel, rail and sleeper to a given excitation. This can be achieved by adding damping treatments or redesigning the wheel or rail cross-sectional shape. The rail fastener stiffness is also an important parameter.
- 3. Reduce the sound radiated by the wheel, rail and sleeper for a given vibration level. Smaller wheels or rails lead to reduced sound radiation. Wheels with holes in the web are also under investigation as these allow 'acoustic short-circuiting' to occur between the two sides of the wheel.
- 4. Prevent the noise from reaching the observation position. This can be achieved by using conventional line side barriers. [12]

3.2) Traction Noise :- Traction noise is one of the noise sources of powered by railway vehicles such as locomotives, electric- and diesel-powered multiple unit trains and high-speed trains. Especially at speeds below 60 km/h and at idling, but also at acceleration conditions for a wide range of speeds, traction noise can be dominant. This is relevant for noise in residential areas near stations and shunting yards, but in some cases also along the line. The other relevant are rolling noise. often dominant between 100 and sources 250 km/h, aerodynamic noise, which can be dominant above 300 km/h, braking noise, curve squeal and impact noise. The braking system can often technically be considered part of the overall traction system, although acoustically it will often have separate noise sources.

The level of modelling detail in the many potential traction noise sources has been kept to a minimum, as for rail traffic noise prediction it often suffices to model only the dominant sources. Measurement methods are outlined to determine the noise emission spectra, from which extrapolations are made to obtain estimates for different operating conditions. [13]

Life is like a train station, people come and go all the time, but the ones that wait for the train with you are

3.3) Aerodynamic Noise: -

Aerodynamic noise is a phenomenon associated with high speed operation. This means that when the construction of new high-speed lines is proposed, it often leads to opposition on the grounds of noise, even more than for conventional lines. As speed increases, noise inevitably also increases. Thus, for a high-speed train, aerodynamic sources are important for both interior and exterior noise. Sources include vortex shedding from wheels (particularly around the first bogies) and pantographs, the train nose and tail, and edges/cavities. For high-speed trains, aerodynamic noise becomes significant when their speeds exceed 300 km/h and can become predominant at higher speeds. Since the environmental requirements for railway operations will become tighter in the future, it is necessary to understand the aerodynamic noise generation and radiation mechanism from high-speed trains by studying the flow-induced noise characteristics to reduce such environmental impacts. [14]

Good agreement is achieved between numerical simulations and experimental measurements for the dominant frequency of tonal noise and the shape of the spectra. Vortex shedding around the axle is the main reason for the tonal noise generation with the dominant peak related to the vortex shedding frequency.

The noise directivity shows a typical dipole pattern. Moreover, for both the tandemwheelset and the simplified bogie cases, the unsteady flow developed around them is characterized by the turbulent eddies with various scales and orientations including the coherently alternating shedding vortices generated from the upstream axles. The vortices formed from the upstream geometries are convicted to downstream and impinge on the downstream bodies, generating a turbulent wake behind the objects. (14)

Vortex shedding and flow separation as well as interaction around the bodies are the key factors for the aerodynamic noise generation. The radiated tonal noise corresponds to the dominant frequencies of the oscillating lift and drag forces from the geometries. The directivity exhibits a distinct dipole shape for the noise radiated from the upstream wheelset whereas the noise directivity pattern from the downstream wheelset is multi-directional.

Compared to the wheelsets, the noise contribution from the bogie frame is relatively small. Furthermore, when the bogie is located inside the bogie cavity, the shear layer developed from the cavity leading edge has a strong interaction with the flow separated from the upstream bogie and cavity walls. Thus, a highly irregular and unsteady flow is generated inside the bogie cavity due to the considerably strong flow impingement and interaction occurring there. Unlike the isolated bogie case, noise spectra from the bogie inside the cavity are broadband and a lateral dipole pattern of noise radiation is generated. The noise prediction based on the permeable surface source is formulated and programmed using the convective Ffowcs Williams-Hawking's method. Results show that the bogie fairing is effective in reducing the noise levels is most of the frequency range by mounting a fairing in the bogie area; and for the bogie inside the bogie cavity with the ground underneath, the far-field noise level is increased due to more flow interactions around the geometries and the ground reflection effect. [14]

Other noise sources may also be present, e.g. brake squeal generated by friction brakes at low speeds, wheel rail squeal generated on small radius curves, switches and track equipment



Figure: -5 Exterior Noise source on high speed train

necessary to use models that are capable of taking these different sources into account The noise sources shown in Figure 3 are speed dependent and Figure 4 shows an example of the typical speed dependency. Poisson (2009) reports that traction noise is the dominant noise source at speeds below 80 km/h, rolling noise is the main source from 80-340 km/h (noise levels for this source increase with train speed V at a rate of ~30 log10V) and aerodynamic noise is important at speeds above 340 km/h (noise levels for this noise source type increase with train speed V at a rate between 60-80 log10V).[14]



Graph 1: - Exterior Railway noise and their speed dependency

At the speeds at which HS2 is expected to operate, i.e. 360 km/h for initial technologies and trains, with route alignment designed for 400 km/h (HS2 Ltd, n.d.). [14]

If a train is coming at you, closing your eyes won't save you ... but if you look right at it, you at least have a chance to

3.4) Design of Mitigation Measures: -

Increasing the distance between the track and the receiver is one of the most effective measures of noise and vibration reduction, but only appropriate in cases where the cost of land purchase is less than the estimated cost of the implementation of other mitigation measures. At a distance of 500 m from the rail track people no longer perceive the rail traffic vibrations, while the air borne noise decreases by about 20 dB(A) .(15)

The effect of individual measures for rail traffic noise and vibration mitigation (measures for their reduction at source and reduction of their propagation). Indicate that the measures relating to the application of the appropriate type of track construction, regular track and rail vehicle maintenance, the application of the appropriate type of vehicle and removal of the discontinuities on tracks could certainly greatly contribute to rail traffic noise and vibration reduction. By implementing changes in the noise and vibration propagation path (by constructing barriers and placing tracks in tunnels) the greatest effect of noise and vibration reduction can be achieved. The main problems with such interventions are the high construction costs

	-	
Mitigation measure	Noise reduction	Vibration reduction
P. I. dia da anti-	/ub(A)	/ub
Reduction at source – permanent way		
Resilient rail fastenings	3 ÷ 6	5 ÷ 10 (20)
Embedded rail system	3 ÷ 10	8 ÷ 18
Rail dampers	5 ÷ 6	7 ÷ 9
Wooden sleepers	1 ÷ 2	3 ÷ 5
Under sleeper pads	0 ÷ 3	8 ÷ 15
Ballast bed height increase	3 ÷ 5	0 ÷ 6
Ballast mats	8 ÷ 18	10 ÷ 15
Elimination of the rail running surface discontinuities	6 ÷ 10	0 ÷ 5
Maintaining smooth rail running surface	10 + 15	10 + 20
Reduction at source - rail vehicles		
Wheel re-profiling	5 ÷ 10	5 ÷ 10
Reduction of speed	3 + 7 (10)	3 ÷ 6
Disc brakes	$10 \div 15$	-
Composite brakes	$8 \div 10$	-
Resilient wheels	3 ÷ 20	3 ÷ 4
Propagation reduction		
Barriers	10÷15	0 ÷ 14
Tunnels	0 ÷ 30	10 ÷ 40

Table: -3 Effects of noise and vibration mitigation measures

and lack of space for their positioning is densely built in urban areas. In terms of reducing vibration at the source, a very effective measure is the installation of elastomeric pads under track construction (under sleepers in case of conventional ballast bed track or below the concrete slabs in case of modern slab tracks). When observing noise problem, the most effective mitigation measure would be elastically embedding the rails. Also, great benefit of these measures is that they can rather easily be implemented during regular maintenance or reconstruction of rail tracks. The below Table shows effects of Noise and Vibration mitigation measures. (15)

3.5) MITIGATION MODELS: -

3.5.1) Reducing Railway Noise and Vibration: -

Train noise, known as rolling noise, is the major source of railway noise in Europe. Ground vibration from trains produces a different effect and in extreme cases can damage structures around the track. Both rolling noise and ground vibration can cause considerable disturbance to residents around railway lines, whereas, for rural rail networks, disturbance mainly affects nearby ecosystems and pasture growth/production.

The effectiveness of methods to reduce railway noise and vibration should be balanced with installation and maintenance costs. It is, therefore, important for the railway industry to consider whole-of life costs when implementing measures. Railways can extend for long distances, meaning mitigation methods must also be practicable over many kilometres of track. Rolling noise, measured by using microphones at certain distances from the track, is influenced by train speed and design, track conditions and weather (indirectly: flooding of the track can lead to its oxidation, causing wheel noise; increased damping due to higher moisture could suppress overall sound radiation). [15]

Mitigation measures to reduce rolling noise include reducing track roughness, noise barriers and structural modifications or damping systems. The connection between train wheels and rails is one major source of noise and vibration; for example, deteriorating tracks are often rougher, which increases the sound pressure by up to 20 decibels (dB). Roughness can be reduced by grinding tracks to remove corrugated edges and by lubricating tracks.

Walls and other barriers can reduce noise by between 5 dB and 15 dB, depending on the height, length and distance from the track. The researchers say that making life-cycle comparisons for rolling-noise reduction is difficult, as some interventions comprise annual maintenance (e.g. rail lubrication), whereas others are single investments (e.g. barriers).(15)

Neither a wise man nor a brave man lies down on the tracks of history to wait for the train of the future to run over

Ground conditions, including the materials that provide the base of the railways, are a major source of vibration disturbance. Ground vibration can be in low frequencies on the surface (below 10 hertz (Hz)) or at higher frequencies (30–250 Hz) underground. Sleeper soffits, fixed to sleepers to absorb vibration, and ballast mats, which restrain the movement of the track, can both be used to reduce ground vibration. Ballast mats are much more expensive to install than sleeper soffits due to their size. However, they are better at reducing vibration. Wave-impeding blocks consist of soil that is compacted to reduce vibration. These are used where surrounding buildings or infrastructure prevents the construction of buried walls. [15]

3.5.2) Mitigation of Railway Vibration at the Track through Transmission Path to Soil and Building: -

The principles are different for the mitigation measures at the track, in the soil or at the building. To reduce railway induced low frequency vibration, two mitigation measures - open trenches and buried soft wall barriers, by using coupled finite element-boundary models.(16)



emission primarily via Rayleigh waves

Figure 6: - Vibration due to train on track

These models were developed at KU Leuven and ISVR and have been cross-validated within the EU FP7 project RIVAS (Railway Induced Vibration Abatement Solutions). Variations in the width, depth, location of trench and properties of soft barrier material are considered under various soil conditions. Results show that in all ground conditions, the notional rectangular open trench performs better than the other constructions. The width of an open trench has little influence on its performance, whereas increasing the width of a filled trench reduces the stiffness of the barrier, improving the performance of the trench. (16)

Reduction of noise and vibration at source can also be achieved by:

- increasing the elasticity of the track superstructure
- eliminating the running surface discontinuities,
- regular maintenance of the rail running surface,
- regular wheel re-profiling,
- selecting the appropriate type of rail vehicle.
- reducing the speed of rail vehicles.
- Track Design (special slab tracks, and sleepers)
- Vehicle design (wheel diameter/damping)
- Barriers (Up to 10dB)

3.6) Innovative Noise Mitigation: -

Rail dampers are based on the latest technologies to reduce broadband railway noise at its source. The vibration level within the rail during a train passing by will be damped. Finally, dampers are tuned to reduce emitting noise best possible at corresponding frequency range. The individual tuning of dampers enables application on all kinds of tracks such as ballasted track, ballast less Performance of different rail track and high-speed tracks. [17]



Figure: -7 Rail damper and Laboratory test

To achieve maximum noise reduction, dampers need to be adapted to the individual shape, passing train is simulated by exciting the rail with a special shaker. Finally, dampers are tuned to reduce emitting noise best possible at corresponding frequency range, the individual tuning of dampers enables application on all kinds of tracks such as ballasted track, ballast less track and high-speed tracks. [17]

A story is like a moving train: no matter where you hop onboard, you are bound to reach your destination sooner or

3.7) Mitigation Guidelines for Noise and Vibration: -

□ Retrofitting the existing freight wagon fleet with low noise braking systems especially by replacing the cast iron by composite brake blocks as the most important and effective first step of source related noise reduction measures.

 \Box Establishing funding schemes to cover the retrofitting and additional operating costs of the new noise reduction technologies to avoid a reduction of the rail sector's competitiveness; a substantial part of costs should be covered by the Member States, since quieter trains will reduce the need for, and therefore the cost of, infrastructure noise mitigation measures. (18)

□ Introducing rail track charging systems which differentiate the train charges according to the noise category of a train. The noise classification of a train should be determined by the wagon with the highest noise emission level.

□ Making activities concerning NDTAC or noise limit regulation depending on the same actions in road transport to avoid losses of competitiveness for the rail sector.

□ Making noise limits by TSI Noise ([TSI Noise 2011] also compulsory for existing rolling stock 10 or 12 years after introduction of funding schemes and noise limits for new rolling stock. (18)

□ Adjusting limits of TSI Noise in a phased process for a medium and long-run future to foster the development of new noise reduction technologies.

 \Box Monitoring and maintenance of noise development due to abrasion to assure low noise levels also during operation over long periods. (18)

3.8) Railway Noise Reduction By the Application of CHFC Material on the Rail: -

CHFC is special long-lasting, temperature-proof and environmentally friendly composite material. It contains more than 40% of solid particles and can take over extremely high pressure loads. The material can be applied directly on source of noise, the rail.
For this purpose, CL-E1 top anti-noise application system for rails in curves was developed as a part of revolutionary Wear Out and Noise Reduction on Source (WONROS) technology. The main part of the system is patented and verified dosing borings (φ = 4mm) made into the rail head. They enable expanding of the material CHFC onto the precisely defined point on the rail head. [19]

CHFC material, when applied to the rail, reduce the wear out and noise significantly, especially the high frequency squealing noise, but its friction characteristics would not change the braking properties. The main technical problems with wayside lubricators have been highlighted as blocked applicator openings, leaking holes and poor choice of lubricant. However, with appropriate device, such is CL-E1 top device, and CHFC material all those problems are solved.CL-E1 top anti-noise system with patented boreholes offers reasonable noise reduction despite extremely low consumption of CHFC material. The whole system can be installed also in the middle of the curve and underground. CL-E1 provides also reduction of rails and wheel life cycle cost. CL-E1 reduces environmental pollution with metal filings. [19]



Figure: -8 CL-EI Top anti-noise system

CL-EI Top ant noise application system: -

CL-E1 system has many advantages; -

-the reduction of LCC is high,

-the rail and wheel lifetime are increased and the intervals for grinding are significant prolonged,

-the system reduces corrugation (sinus line) of rails

-maintains low roughness level,

-keeps the rail and the wheel smoother,

-reduce brake screech,

-high percentage of metal particles in the material prevents the rail erosion, GCC and RCF,

-consumption of driving power on serviced segments is reduced,

-system operates at all extreme weather conditions,

-system has ability of supplying both rails with one device,

-the dosing of material can be with borings or with blades,

-the detecting of the wheel is contactless, [19]

-the device detects the driving direction, therefore the applying of material is only in desired

direction (consumption of material is lower),

-own source of power, provided by solar panels or net voltage

-removal of the device is not necessary when maintenance vehicle is passing over, -etc. [19]

However, according to Slovenian Railways by using the CL-E1 device very good results had been achieved in terms of lubricating and in terms of maintenance since the maintenance cost are insignificant. Beside this the usage of CHFC material is controlled and rational and the quality of device meets all requirements. [19]

3.9) Top -of- rail squeal and flanging noise: -

Rail squeal is a screeching train-track friction sound, commonly occurring on sharp curves. Squeal is presumably caused by the lateral sticking and slipping of the wheels across top of the railroad track. This results in vibrations in the wheel that increase until a stable amplitude is reached. Top-of-rail squeal and flanging noise are associated with curves on the railways. On sharp curves (R< 500m) rolling noise is associated generally with tangent track. A large proportion of the squeal noise originating from the top of the rail is associated with stick-slip lateral motion at contact between the wheel tread and rail head. However, the curve squeal originates from the unstable response of a wheel objected to large creep forces in the region of contact, which excite the wheel's axial (and radial) mates and thus the noise generated is strongly tonal in nature in the frequency range 250 Hz to 10 kHz. Flanging noise is the high frequency, broadband or multi-tonal noise which is common on tight curves. The flange contact generates a different form of squeal noise, referred to as flange squeal, which has a considerably higher fundamental frequency and is often intermittent in nature. The lateral creep on the top of the rail is the major culprit in generating the squeal noise, though flange rubbing, and longitudinal slip are also contributing factors to the overall noise radiated while negotiating a curved track. [19]

3.10) NDTA (Noise Differentiated Track Access Charges) SCHEME: -

Noise Differentiated Track Access Charges (NDTAC)scheme is raising more concerns than support towards railway noise reduction. Track access charges are the main price signal affecting the competitiveness of services from railway undertakings as compared to those from other transport modes. One of the main purposes of NDTAC should be to provide incentives for fast retrofitting through mandatory bonuses. In the longer-run, NDTAC might be used to internalise the noise externality through mandatory penalties. Noise in rail transportation has been high on the political Agenda for the major sources for railway noise are freight wagons, high-speed trains European Union and some Member 5tates as it is considered and urban railways. The NDTAC scheme is a charging (bonus/ malus) arrangement between Infrastructure Managers (IMs) and Railway Undertakings (RUs). However, the retrofitting of freight wagons is usually the responsibility of a Wagon Keeper (WK) or rolling stock owner. Therefore, one could see a paradigm where, while a charging scheme is arranged between two parties (IM/RU), a third one is burdened with additional costs without a guarantee for a full or partial return of its investments. Such concerns provoked the need to assess the cost impact of the NDTAC scheme on the investments towards retrofitting and maintenance

When a train goes through a tunnel and it gets dark, you don't throw away the ticket and jump off. You sit still and

of rail freight wagons. (26) An efficient implementation of NDTAC must ensure that the administrative transaction costs are minimised. There is also a strict need to guarantee revenue neutrality for rail infrastructure managers and to avoid a negative impact on rail's competitiveness vis-à-vis the other transport modes. (20)

Three variants of the NDTAC are examined:

- A pure bonus system for quiet freight wagons (NDTAC-bonus);
- A bonus-penalty system in which bonuses are paid for quiet wagons and penalties charged for loud freight wagons, calculated on a wagon-specific base per wagon (NDTAC- bonus-penalty).
- A bonus-penalty system, in which the bonuses are calculated on a wagon specific base, the penalties are only levied indirectly and not for each wagon, but in the form of a general increase of access charges for freight trains (NADTC-TAC-rise).(20)

While the public sector would fund the NDTAC- bonus scheme, the second and third variant is funded by the rail sector itself.

Example case study of Germany NDTAC scheme: -

The German implementation of the NDTAC scheme started on 9 December 2012 and will end on 8 December 2020. Compensation of costs for retrofitting is paid by the national government but limited to \notin 211 per axle. The direct beneficiary is the WK. A challenge is the precondition on the provision of evidence and justification on run mileage data of German infrastructure (DB Netz). Mileage data should be provided from the RU which operates the wagons in its trains, to the WK. However, in practice such data is not readily available in all cases. When not provided the bonus cannot be claimed and thus awarded, leaving the WK with the full costs. It should also be noted that higher operational/maintenance costs (such as wheel wear) caused using composite brake blocks are not considered in the German NDTAC system.(20)

3.11) Rail Dampers: -

The rail dampers can be described as pre-formed or adjustable elements, usually mounted on the lateral sides of the rails by using clips, bolts or glue, while some types have a part under the rail foot, acting to reduce the rolling noise by absorbing the vibrations of the rail. There are discrete rail dampers and continuous rail dampers, in dependence on the manner of placement on the rail. Discrete rail dampers are mounted on the rail, at equal distance, usually half distance between every sleeper bay or the fasteners. The continuous rail damper is located along the rail, but this configuration is hardly used. The rail dampers must be mounted in such way so that they will not affect the normal construction of the track and obstruct the maintenance works. [21]



Figure: -9 mounting of Rail damper

The principle of the rail damper is relatively simple, reduction in the oscillation of the vibrating rail is done by its coupling to a mass (steel elements in the damper) via a damped spring (the rubber between the rail and the steel elements in the damper). The rail vibration energy will be conveyed to the damper, the damper mass will also vibrate, and this energy will be dissipated, due to the damping features in the rubber. The damper effect is similar with the increase of the rail damping level. (21)



Figure: -10 Elements of rail damper

All the track dampers consist in steel elements the oscillation frequency at which the rail vibration energy is transferred to the damper depends on the stiffness and the damping coefficients of the rubber. A change in the type of rubber brings a modification in the range of the damper operating frequency or an improvement in the dissipation of the transferred energy. Similarly, the operating frequency of the rail damper depends on its model. An efficient damper is tuned in a wide range between 500 and 2000 Hz, where the rail vibrations are important sources of rolling noise. Designing such damper is more complex than it seems at first. The issues come from the fact that rubber is a material whose features of stiffness and damping greatly rely on the load, frequency and temperature. The performance of the rail damper is described by track decay rate (TDR); the higher TDR, the lower the noise emission. TDR describes the characteristics of the rail vibration, more precisely the attenuation rate of vibrations along the rail. Consequently, increases of TDR over 10 dB/m are not relevant. Since the rail dampers play the role of mitigating the rail vibrations, which corresponds to an increased TDR, it is important to remember that TDR should be under 10 dB/m in the process of designing the damper.[21]

TDR depends on the track construction parameters and the soil characteristics, which explains the large variations in TDR possible along the track. The high values of TDR at low frequencies, under 400 Hz – for the lateral vibrations, and smaller than 700 Hz for the vertical vibrations, are possible because of the coupling between the rail vibrations and the sleeper bays and soil. TDR also depend on the stiffness of the rail pad; for the stiff pad, the rail vibrations couple themselves with the vibrations in the sleeper bays and TDR is high; for the soft pad, the coupling between the rails and sleeper bays is weak and TDR will be low.



Graph:-2 rolling noise on track without damper

Graph:-3 Rolling noise with rail damper

The reduction of the noise emission largely depends on the characteristics of the track system without dampers. For example, above figure shows the effect of the dampers in reducing the rolling noise emission, due to the rail. Consequently, the overall noise can be considerably reduced by mounting the rail dampers, if the track is the dominant source of noise; in this case, it is about a reduction of circa 4 dB(A). The efficiency of the dampers also depends on train velocity. The rail dampers will therefore be inefficient at speeds lower than 30 km/h, where the traction noise is generally dominant. At high speeds, where the aerodynamic noise becomes significant, a reduced efficiency of the rail dampers is visible, of circa 1 dB(A)[21]

3.11.1) Types of rail dampers: -

The first rail dampers were developed in the 90s by European Rail Research Institute (ERRI) Committee C163 (Railway noise) within the project OFWHAT – Optimized Freight Wheels and Track, and by Société Nationale des Chemins de Fer (SNCF) for the project VONA – Voie Optimisés vis à vis des Nuisances Acoustiques. During the OFTWHAT experiments, tests were done with a rail damper consisting of cylindrical masses contained in an outer cylinder via an elastomeric sleeve that was mounted on the rail foot with stiff pads, on each side of the rail. According to the damper specifications, it was designed for two tuning frequencies, of 800 Hz and 1700 Hz, both vertically and on the lateral side, with damping loss factors ranging from 0.25 to 0.5. [21]

The active mass was 6 kg for each sleeper bay the measurements have shown a reduction of the rail noise component of 2 dB(A) for a train speed of 100 km/h. It is an unfortunate fact that tests were not done for the rail dampers – soft pad



Figure: -11 Rail damper developed in OFWHAT Project

combination for which the use of the rail damper would have brought a considerably bigger benefit in the reduction of the rail noise component Within the VONA project, rail dampers were designed to increase TDR, mainly for the vertical vibrations. They had rectangular steel blocks with the sizes of $200 \times 45 \times 45$ mm, to have an active mass of 3 kg on each side of the rail in each sleeper span. The dampers were glued to the top of the rail foot via an inclined block to give a vertical mounting surface. (21)



Figure:-12 Rail damper developed in VONA Project

The initial design included a clamping arrangement at the edge of the rail foot and this solution proved to be less successful, due to the rail foot flexibility. A mass of 9 kg was added to each sleeper span. To have the tuning frequencies of 1000 Hz and 2000 Hz, different elastomer elements were mounted in alternate sleeper spans. These dampers were estimated to have an effect of reducing the 4-dB noise emitted by rails, whereas the noise could be of 6 dB if combined with the optimized pads. [19]. The rail dampers were steadily developed between 1997 and 2000 for the Silent Track project, aiming to reduce the rolling noise component from the rail by 10 dB. The Silent Track type damper figure below,



Figure: -13 Silent Track rail damper

seen as the most successful solution to increase TDR, includes steel masses incorporated into an elastomer with large damping, thus constituting itself into an adjustable damping two-degree freedom system, continuously attached along the rail on each side. This damper was mounted on a UIC60 type rail track, monobloc sleepers and 10-mm studded rubber pads and tuned for the frequencies of 630 Hz and 1350 Hz, with a damping loss factor higher than 0.35. (21)

3.11.2) Schrey and Viet damper: -

More manufacturers have developed various types of rail dampers, based on different constructive and functional principles. the most used rail dampers, namely the ones made by Schey & Veith, TATA Steel, Vossloh and STRAIL. Schey & Veith have produced diverse types of rail dampers. In general, the damper is made of two or three active elements mounted on the rail by a basic sole plate,



Figure: -14 Schey and veit damping rail

Railway Station is a place where people are going to have their destination journey with full of different emotions

While for the dampers with two active parts, these parts are mounted on each lateral side of the rail, they are under the rail foot for the dampers with three active parts. [22]



Figure: -15 Vicon Amsa damper

Each element consists of a complex of alternate layers of steel elements – elastomer. The steel elements have different masses, which gives efficiency to the damper for an extended frequency range. For this damper, the total mass added to the rail is 70%. (34)

VICON AMSA Advantages: -

• Does not influence common train control systems such as ETCS, ATP EG, ATB NG, PZB, LZB, Crocodile

- Has no impact on existing TSI Infra conformity (no change on the rail itself)?
- Shows no outgassing of polluting substances

• Requires for installation only short track closings due to a reduced number of damper components

• Can also be installed during train operation when train following times are at least 10min

- Is only mechanically fastened without using any type of contact adhesive
- Is free from consumable materials such as liquids
- Causes no fouling of the track
- Complies with REACH standards (Europe)

• Is non-visible from the surrounding sites

• Has no shielding effect on the track neighbouring areas such as noise protection walls

- Is not susceptible to vandalism
- Is combinable with further noise reducing measures

• Shows a significantly increased acoustic noise reduction compared to rail shielding, especially at freight trains [22]

• Is set up as a solid construction for long lifetime, proven by laboratory testing.

3.11.3) Tata Steel silent track damper: -

TATA Steel's Silent Track (the damper developed at CORUS) is the second well know product. TATA Steel has designed the rail damper known as TATA Steel Silent Track, which including three resonant steel masses distributed in such a way to shape into a vertically stacked arrangement incorporated in an elastomer with a high damping factor. The elastomer has two functions – In first function, provides stiffness and mass spring system damping and, on the other hand, protects the steel masses against corrosion. This type of damper is fixed on the lateral sides of the rail by elastic springs and glue. The total mass added to the rail is 30 % [19] The TATA Steel Silent Track damper provides peak track noise levels with 3 - 6 dB and a wide frequency response over the important acoustic range for rail noise. [23]



Figure 16:- TATA steel Damper

The sound pressure level (SPL)without Silent Track damper - blue and with the Silent Track damper-yellow (circa 10 dB/m), which proves that the mounting of dampers seems not to have any effects and it is not the rails but the sleepers that become the dominant noise source at those frequencies. (23)

3.11.4) STRAILastic Rail Damper: -

STRAILastic_A is a rail damper manufactured by STRAIL from a heavy elastomer compound via a specialised vulcanising process. Unlike other rail dampers, this does not contain steel. Based on a large mass, the damper operates like a mass damper and the elastic material raises the general damping effect. The STRAILastic_A damper has two versions. The steel-core STRAILastic_A inox can be fixed with rust-proof stainless-steel clamps. The STRAILastic_A synth damper is made of a natural rubber mixture with a plastic clamp. [23]



Figure 17: - STRAILastic rail damper

- STRAILastic_A absorbers are rail web dampers used to reduce noise and vibration emissions from tracks, which run through residential and/or urban areas. This absorber consists of a steel reinforced heavy elastomer compound and is produced by a special double vulcanizing process. The advantages of this damper,
- Quick and simple handling
- Installation performed in operational conditions
- Less Maintenance and no follow-up costs
- Possible noise reduction up to 7 dB(A)
- Stainless steel clamps, permanent fastening
- No obstruction to standard track maintenance work

3.11.5) Vossloh Rail Damper: -

The Vossloh damper system consists of composite element with a steel core. The damper is clipped to the rail with glue or with steel clamps. (23)



Figure: -18 Vossloh rail damper

3.11.6) Wheel -Vibration Absorber: -

Vibration absorbers are tuned spring-mass mechanical oscillators that produce a high mechanical impedance at the design resonance frequency at the point of attachment to a vibrating surface, thus reducing the response of the vibration system at the absorber's resonance frequency. If the absorber is tuned to match the resonance frequency of the vibrating system, the combined resonance is split into two closely spaced resonance. Damping material is included in the absorber to absorb energy at the tuned resonance frequency of the absorber. The damping material broadens the frequency response at resonance while reducing the amplitude of the response. In this case, the vibration absorber is referred to as a "dynamic absorber. (24)

The vibration absorbers may have multiple masses, thus producing several resonance frequencies and, combined with damping, a "broad-band" damping characteristic. For this demonstration, the selected wheel vibration absorbers are tuned dynamic absorbers, and the rail vibration absorbers are broad-band dynamic absorbers. However, these tuned wheel vibration absorbers were also designed to provide damping over a broad range of frequencies above their fundamental resonance frequency. Tuned wheel vibration absorbers are designed primarily for controlling wheel squeal at curves, where lateral oscillation of the tire in bending is the primary mode of vibration.

Two types of wheel vibration absorbers were considered for testing. One was the ADtranz fin absorber, described as a "broad-band" absorber. The manufacturer indicated that the fin shape of the absorbers makes the absorber act as a damped transmission line, broadening the frequency response of the absorbers. The manufacturer was unable to provide the absorbers within the time frame anticipated for testing. The second type of absorber was the VSG dynamic absorber manufactured by Bochumer Verein, the manufacture of the Bochum resilient wheel. Both the VSG absorber and the ADtranz fin absorber are cantilevered constrained layer plate designs. Both designs are indicated by their respective manufacturers to have broad-band characteristics. (24)

3.11.7) Rail Vibration Absorbers: -

Rail vibration absorbers were obtained from Schrey & Veit, which supplies the absorbers under license from Daimler Chrysler. The selected design consisted of a thick plate clipped to the rail foot, with absorbers clamped to the top of the rail foot and the side of the web. Each absorber thus contained four broad-band dynamic millidegree-of-freedom absorbers. A design requirement was the ability to mount the absorbers on the rail without rising the rail.(24)



Figure: -19-wheel vibration absorber

Earlier designs of rail vibration absorbers had the absorber body clamped to the underside of the rail foot, requiring considerable space between the bottom of the rail and concrete invert or ballast. The configuration employed here required less than 1 in. of clearance between the rail foot and concrete or ballast and was installed easily.

3.11.8) Installation of Rail Damper: -

The dampers will be installed by clamping the dampers to the rail by using a spring or by using a clamp device. The bolts are tightened by a motor driven sleeper screw driver and can easily be dismantled that way (e.g. change of rails). The springs can be easily installed by a leverage tool. Installation of Rail Dampers is easy, even on ballasted and non-ballasted tracks. First need to be checked if a minor quantity of the ballast must be removed or not, at the same time the rail dampers can be distributed on the track and assembly. [25]



Figure: -20 Installation of rail damper

Rail dampers are aligned mechanically. It takes an average manpower of 14 track workers to assemble 300 m/hour (track). By deploying 3 teams of that size an average output of 1,000 meters/hour is possible. In case of a rail replacement the dampers can be dismantled quickly, put aside the track and reinstalled on the new rail. [25]

Based on their components, rail dampers have a long-life cycle and need no maintenance. After the wear limit dampers can be easily dismounted and recycled. Installation process is, to apply Side Mount or Bottom Mount dampers first select location for damper to be installed. Cut out a 3-in. opening in 1 side of duct at selected location. Ensure opening is fully cut from top to bottom of seam, this will allow damper to be inserted without obstruction and then, Slide damper into opening and check for proper alignment. Secure damper using sheet metal screws through clearance holes located on mounting plate. (25)

3.11.8.1) Verify Before Installation of Dampers: -

- Before installing, inspect damper for possible damage caused in shipping.
- If minor damage has occurred to frame corners or flanges, correct by bending or hammering back into position. Ensure correct realignment of repair, as bent or twisted frames might not mate properly with mounting angles, or additional damper sections.
- Do not install damper if damage is more than superficial, if uncertain as to extent of damage.
- Compare items listed on packing list with materials received to ensure all parts of the shipment, including accessories. (26)

3.11.8.2) Installation Considerations: -

1. Place dampers away from areas that may be noise sensitive. It is recommended to install zone dampers near furnace plenum when possible. This may help ease installation as well as dissipate air noise associated with zoning.

2. Install dampers in rectangular or square duct systems only. Any frame misalignment will jam damper blades.

3. Install dampers so actuator is visible for inspection and accessible in the event it would ever need service.

4. Use sheet metal screws to secure damper in ductwork (do not try to weld dampers in any way).

5. To ensure proper fit and operation dampers must be sized according to ductwork. (26)

3.11.9) Tuned Mass Dampers: -

A tuned mass damper (TMD), also known as a harmonic absorber or seismic damper, is a device mounted in structures to reduce the amplitude of mechanical vibrations. Their application can prevent discomfort, damage, or outright structural failure. There are two basic types of TMD; the Horizontal TMD which is normally found in slender buildings, communication towers, spires and the like. The other type is the Vertical TMD, which is usually applied in long span horizontal structures such as bridges, floors and walkways. Both types have similar functions, though there might be slight differences in terms of mechanism. A tuned mass damper (TMD) consists of a mass (m), a spring (k), and a damping device (c), which dissipates the energy created by the motion of the mass. (27)

A new type of tuned mass damper has been developed to reduce rail vibration and noise radiation. The damper comprises multiple masses oscillating along the shear direction of resilient layers forming a multiple mass spring system. It provides effective broadband damping for a frequency range between 300Hz and 2500Hz. The resilient layers are aligned perpendicularly to the rail alignment such that each mass can oscillate in both vertical and lateral directions. The natural frequencies of the oscillating masses are individually tuned to match the rail vibration at multiple frequencies to cover both vertical and lateral pinned resonance frequencies of the rail. (27)

Existing tuned mass dampers are generally providing overall noise reduction in the range of 1 to 3dB(A). while in a field test, an overall noise reduction of approximately 6dB(A) was achieved by using a vehicle fitted with noise-reducing wheels Rail displacement amplitude at the noise radiation frequency is in the order of microns or sub-microns. Coupling between the damper and rail is a critical item affecting damper performance. With traditional mounting method, rail dampers are glued or clamped to the rail without specific technique to enhance coupling effect. Sub-micron movement gaps at the mounting interface are difficult to avoid after severe vibrations induced by repeated train passages, thus hindering vibration absorption in long-term performance. (27)

3.11.9.1) Tuned Mass Damper Design: -

A new type of rail damper has been developed. It comprises multiple oscillating masses sandwiched by resilient layers. The total mass for one damper pair is approximately 20-30kg subject to specific site requirements. For rail vibration in the frequency range of 300-1000Hz, a tuned mass damping mechanism is employed. The shear stiffness and mechanical loss factors of the resilient layers are selected such that each oscillating mass covers a resonance bandwidth of 20-40% depending on frequency. The tuned mass damper incorporates three key features to enhance its performance, the mass oscillates along the shear directions of the resilient layers. Each oscillating mass provides effective vibration absorption along the directions perpendicular to the rail alignment, including both vertical and lateral rail vibration. It provides clear oscillation modes for vibration absorption at designated frequencies. [27]

3.11.10) Quivered Damper: -

Quivered damper (Patent pending) is a new system that eliminates up to 90% of the active and passive vibration. The vibration is absorbed by the supporting stake, which transmits it to the inner springs, varying its frequency. The vibration with the transformed sequence passes subsequently to the central element and to the stake placed in the opposite side of the input direction. The output vibration force is reduced to 10% of the initial value. Quivered damper supports without problems the working stress up to 10 Hz (600 strokes per minute). Beyond this value you ought to contact Euro tools, which will provide special solutions for such working conditions. (28)

QUIVERDAMPER (Patent pending) offers the following advantages:

- Optimal working stability with an oscillation reduction to 0,5 mm, so that the fastening of the machine to the ground is not necessary anymore.

- Optimal working speed and machine efficiency, more working hours even in the night time, without disturbing the neighbourhood. [28]

- Best technical solution existing on the market.

- Protection of technical devices sensible to harmful vibration of other plants, even from outside the factory.

- Decreased machine wear-out and obsolescence, less maintenance costs and improved functioning of the plants.

- Increased efficiency of employees, reduction of stress, tiredness and absence on the workplace.

- Improved productive impact on residential or industrial buildings.

- Decrease injury risks, thanks to the special vibration dampers with a height of only 80 mm.

- Optimal installation practicality, simplicity and easiness, just by placing the system between the plant and the pavement.

- Rapidity of intervention with a minimal interruption of the production. [28]

- Personalized solutions based on the specific characteristics of each machine or on eventual needs and specific requests.

- Best benefit and investment now available on the market.

- Best quality-price rate. [28]

The Restlessness and the longing, like the longing that is in the whistle of a faraway train. Except that the longing isn't really in the whistle – it is in you. Meindert DeJong 46

3.12) Environment and surround protection: -



Figure: -21 Rail Traffic noise and vibration

3.12.1) H-Block Low Noise Barrier System: -

The H-Block low noise barrier system is a pre-cast concrete construction with integrated aerated concrete absorbers. As the most recent development by Hiring in the field of noise protection, the H-Block obtained its approval from the German Federal Railway Organisation in December 2016. (29)

Product description:

1. High sound absorption values.

2 Noise absorption as close as possible to where it emerges (contact to wheels/tracks) 3.Unobstructed view for travellers and residents, to low construction height (up to 76 cm above top of tracks)

4.Fast and simple assembly during short intervals between trains

5.Shallow foundation as heavy-duty wall (no need for pile-driving or drilling)

6. No grounding necessary, to textile fibre reinforcement

7. Components can be walked over when trains are unintentionally stopped Can be displaced during mechanical ballast cleaning.

8.Individual components can be removed or replaced whenever necessary Culverts for small animals can be integrated

9.Escape exits, and surmounting aids can be integrated in the system

10.Durable, low-maintenance and easy to disassemble

11. Appealing design to look at. [29]



Figure 22:- H-block Noise Barrier

3.12.2) Rail Road Sound Barriers: -

A well-designed sound-absorptive barrier can reduce overall sound energy by as much as 15 to 25 decibels depending on the application and environmental factors. The sound walls minimize the nuisance wheel and mechanical noises, reducing hazardous noiserelated health conditions for workers and nearby residents. Horns aren't the only noisy things about trains. The wheel and engine noise generated by trains can generate quite a disturbance for people living near them. One effective way to improve harmony between trains and communities is the use of sound barriers.



Figure 23:- Rail road Noise barriers

While a sound barrier won't do much to lower the blare of a train's horn (which need to be heard for safety reasons), it can definitely help general train noise reduction to more acceptable levels. With advanced LSE Absorptive Sound Barriers from Sound Fighter, much of the offending sound will be absorbed by the patented panel design [29]

3.12.3) Sound Absorbing Panels: -

The noise-absorbing concrete panel is produced by surface coating aggregates having a predetermined particle size with a high strength cement paste and curing the resultant structure, to maintain air gaps among aggregates and to form continuous pores in the cement coated on the surfaces of aggregates. The concrete panels are formed to have a surface with dimples of a special shape to widen the surface area for absorbing noise, and resonance holes for absorbing noise of a specific frequency.

The noise-absorbing railway concrete panels according to the present invention have a significantly high noise reduction coefficient (NRC) of 0.8 or higher and reduces train noises when installed on a railway slab. Further, the noise-absorbing concrete panel of the present invention is made of a concrete material and is thus incombustible and safe in terms of fire. (29)

A new FEM technique has been used to simulate how to allocate the mass to increase the stiffness and the absorptive properties without decreasing the sound-reduction properties. This is accomplished by building a composite panel with a core made of porous, low-density material, a back surface laminated with a non-porous high-module sheet and a front surface made of a micro-perforated but still high-module stiffening sheet.



Figure: -24 Sound walls

Benefits of Our Sound Walls: -

- Non-corrosive
- Customizable for vents, fans, entrance doors, or generators
- Resistant to animal damage
- Effective for any noise reduction application including residential apartments, large warehouse sectors, and loud noise polluters like railways and train stations
- Multiple colour options
- Fits in with the area in appealing ways
- Non-conductive
- Quick delivery
- Lightweight
- Weatherproof
- Rot proof [29]

3.13) Barriers to reduce noise: -

3.13.1) At Rail Vehicle: -

The combination of a rail vehicle and a track represents a complex dynamic system, built up of masses, springs and dampers. Vibration originates mostly from the wheel-rail contact. The response of each element in the system depends on how it is coupled to other elements, damping and its resonant frequency. [30] Any interference in the vehicle track system changes the excitation, but weather this is effective at the receiver point depends on the distance, the frequency and the stiffness of the soil in between. A reliable prediction of the effectiveness of a modification of either the vehicle or the track requires dynamic models combining vehicle, track system and ground (or tunnel + ground). [30]

In soft ground and at low frequencies, the heavy mass of the vehicle vibrating on the bogie often represents the dominant source. But in stiff soils and at higher frequencies (including ground-borne noise), the wheel out of roundness and the unspring mass of a single wheel are often the dominant excitation mechanisms.

3.13.2) Smooth wheels on smooth tracks result in less noise:

Railway rolling noise is the result of roughness on both the wheel and the track in the contact area between the two. Both the wheel and the track vibrate, when the train is in motion, thus creating noise. A significant portion of the noise can be eliminated, if the both wheels and the track are smooth. The use of cast-iron brakes causes rough wheels. On the other hand, wheels remain smooth using composite brake blocks. Therefore, the choice of brake blocks has a large effect on rolling noise levels.

3.14) Reduction of Unsprung Mass: -

For a given combined level of wheel and track irregularities, reducing the unsprung mass leads to a reduction of vertical dynamic wheel/rail contact forces and ground-borne vibration in a wide frequency range.

In a ground vehicle with a suspension, the unsprung mass (or the unsprung weight) is the mass of the suspension, wheels or tracks (as applicable), and other components directly connected to them, rather than supported by the suspension (the mass of the body and other components supported by the suspension is the sprung mass). Unsprung mass includes the mass of components such as the wheel axles, wheel bearings, wheel hubs, tires, and a portion of the weight of driveshafts, springs, shock absorbers, and suspension links. If the vehicle's brakes are mounted outboard (i.e., within the wheel), their mass (weight) is also considered part of the unsprung mass. The unsprung mass of a powered wheelset consists of the wheelset mass and part of the drive system mass.an be achieved, for new locomotives and multiple units, by improving the suspension of the drive system. (30) Lower levels of vibration are associated with vehicles which have secondary suspension or a smaller wheel diameter, although the benefit will be limited to the higher frequency range (above approximately 20 Hz). [30]

3.15) Track Alignment and Singularities: -

Track geometry is three-dimensional geometry of track layouts and associated measurements used in design, construction and maintenance of railroad tracks. Speed limits and other regulations in the areas of track gauge, alignment, elevation, curvature and track surface. Although, the geometry of the tracks is three-dimensional by nature, the standards are usually expressed in two separate layouts for horizontal and vertical. Horizontal layout is the track layout on the horizontal plane. This can be thought of as the plan view which is a view of a 3-dimensional track from the position above the track. In track geometry, the horizontal layout involves the layout of three main track types: tangent track (straight line), curved track, and track transition curve (also called transition spiral or spiral) which connects between a tangent and a curved track. Vertical layout is the track layout on the vertical plane. This can be thought of as the elevation view which is the side view of the track to show track elevation. In track geometry, the vertical layout involves concepts such as cross level, can't and gradient. (31)

3.16) Resilient and Vibration Isolating Rail Fasteners: -

A rail fastening system is a means of fixing rails to railroad or sleepers. The terms rail anchors, tie plates, chairs and track fasteners are used to refer to parts or all a rail fastening system. Various types of fastening have been used over the years. Resilient rail fasteners were proposed a long time ago, in the famous "Cologne Egg". This concept has been improved over the years and is still on the market. However, it is suitable for light rail only. [32]



Figure 25: - Resilient block fitting to the web of the Rail

Design criteria of rail fastening system: -

There are strict criteria on producing rail fastening system:

- **Rail clamping force**: -Clamping forces may be difference according to different kinds of fastening system and customer requirements. Generally, most fastening systems offer a clamping force between 7.5 to 12.5 KN with deflections of the clips toe between 10 and 15mm. According to European standards, for most main line tracks the minimum force to push the rail through the fastening system is 7kN and 9 KN for high speed rail and heavy freight lines.
- Anchor/shoulder: The shoulder/anchor is quite important in fastening system. It must withstand the impact of loads and vibration transmitted to the sleeper under the circumstances of protecting the sleeper from breaking or getting loose. Based on the European standard, all the parts of fastening should be able to withstand a 60KN pull-out force without breaking the sleeper.
- Insulator: To stop the wearing of other fastening components, insulator is necessary, it works as a cushion. So, the materials must be resistant to wear, can attack form chemical and can degrade from ultra violet light. As the change of nature of the signalling and electrical systems, the requirements of insulator are different. (32)

3.17) **Rail pads:** - Sometimes, there is heavy burden in the rail and the bad joints, track irregularities and faults in rolling stock can strength the load. To solve the problem, we can use the rail pads. Usually, the rail pad is made of rubber with 10mm thick and is plastic such as EVA between 5mm and 10mm thick. the typical stiffness of the pad is in the rang 40-450 kN/mm and the 5 mm plastic pad can offer stiffness as high up to 6000 kN/mm.

3.18) Embedded rail system: -

In the embedded rail system, the rail is continuously supported on a longitudinal resilient mat and is embedded in a concrete slab with a wedge on either side to keep the rail in place. (32)



Figure 26: - Embedded Rail system

Life is a Railway station, where love is a train, it will come and go any time, but Friendship is a track it will

The system has been applied in short sections of heavy rail track (mainly for testing) and in operational tracks of light rail and trams. With a proper choice of the stiffness of the supporting mat, it may be effective for ground-borne noise reduction (limited effect for vibration). [32]

3.19) Under Sleeper Pads: -

Under-sleeper pads (USPs), typically made from polyurethane, are used by railways in certain parts of the world to reduce ballast settlement and consequently lengthen the ballast tamping cycle. The rationale behind this relatively new addition to the conventional ballasted track structure is that the pad increases the contact area between the angular ballast particles and the underside of the concrete sleeper, with the effect that ballast breakdown and total track settlement are reduced. They are additionally installed on the bottom surface of the sleepers and increase the degree of vertical elasticity in the track superstructure. The objective is to transmit the loads from the vehicles via the rails, rail fasteners and the sleepers into the superstructure and the subgrade in the smoothest, safest and most well distributed manner possible. Due to the defined degree of elasticity, it is possible to reduce wear on the track system through lower dynamic forces, thereby improving the durability and cost-efficiency of the overall system. (33)

3.19.1) Characteristics of the under-sleeper pads: -

The under-sleeper pad used in the laboratory experiments was made from polyurethane and had elastoplastic properties. The pad had a bending modulus of 0.22 N/mm3 and a static secant stiffness of between 0.01 N/mm2 and 0.10 N/mm2. The pad was 10 mm thick and it was installed directly below the sleeper without a mounting mesh. The pad was manufactured to withstand loads of up to 0.5 N/mm2 and had a smooth and a relatively rough side with an even texture. The pad was placed between the sleeper and the ballast in such a manner that the rough side contacted the ballast.

Targeted use of sleeper pads can help retard this process in the following ways:

- Increasing the contact area between the sleeper and the ballast (5-8% without, 30-35% with sleeper pads at C=0.2 N/mm³)
- Reducing the pressure on the ballast (by 10-25%)
- Adjusting the bending line of the rail
- Stabilising the upper ballast layer
- Reduction of cavitation's
- Lowering the impact force on the ballast bed caused by "hanging" sleepers

Reducing vibrations in the ballast bed and the transmission of such into the surroundings. (34)



Figure 27: -Under sleeper pad

Under-sleeper mats can serve as a simpler and cheaper alternative to the floating slab track, every sleeper is supported by a mat, embedded in the slab. The mat is usually encased, together with the sleeper, in a rubber boot. For a much easier installation, the sleeper is commonly manufactured as two concrete blocks. A Swiss supplier proposes a 30% wider and 50% higher block, mounted onto a resilient mat, with similar or better efficiency than the sleeper mat in ballast. The effectiveness for ground-borne noise is expected to be good, but for vibration the effectiveness is probably limited. [34]

3.20) Trench Barrier: -

A trench can act as a barrier to ground vibration and is a potential mitigation measure for low frequency vibration induced by surface railways. However, to be effective at very low frequencies the depth required becomes impractical. Nevertheless, for soil with a layered structure in the top few meters, if a trench can be arranged to cut through the upper, soft layer of soil, it can be effective in reducing the most important components of vibration from the trains. An open trench is commonly used to attenuate ground vibration from machinery. This can act in a similar way to a noise barrier for airborne sound; vibration is diffracted underneath the barrier and only a fraction of the original vibration reaches the 'shadow zone' behind it. An ideal open trench with vertical sides is not stable so in practice it requires either sloping sides or reinforcing walls.



Figure 28: -Trench Barrier

Alternatively, a trench may be filled with a soft material. This is generally less effective as vibration is transmitted through the fill material as well as being diffracted underneath the trench. The fill material should therefore be much softer than the surrounding soil while being capable of balancing the surrounding earth pressure. Common fill materials considered include bentonite, soil-bentonite mixtures, expanded polystyrene and other geo-foam materials such as polyurethane. (35)



Figure 29: - Open Trench barrier- wave impeding

Trenches and wave impeding blocks have been investigated in computer models and found to be effective. However, since this mitigation measure is very expensive and can be difficult to maintain, only very few cases have been implemented. Trench barriers thus cannot be considered a proven technology. For water ditches, sometimes not deeper than some 2-5 meters, an effectiveness of up to 3 dB. was found. (35)

CHAPTER: -4

MITIGATION COMPARITION

4.1) FLOW CHART: -



4.2) Comparison of flow chart and table

In the above flow chart Noise and Vibration are categorised into three parts (Infrastructure, Vehicle, Noise). Infrastructure deals with Tracks, Rail, Railway Parts. In Mitigation comparison we have seen by using different materials which help us to reduce Noise: for example- Rail Fastening system is about fixing rail to rail road or sleeper. By using proper rail fasting 10db of noise can be reduced, if we see Rail Dampers as they are passive elements that are fixed to the both sides of the rail web to reduce the air born noise occurs due to rail vibration.

So, according to me by there are different parts () there are different methods () but their main goal is to reduce noise. If we use one part and a method, we reduce 10db likewise if the other is selected than 6db these depends on our selection and how much is required to reduce the noise.

Not only in infrastructure but also in vehicle and environment we are using different methods to reduce noise. For example, in environment we use track bed and noise barriers to reduce both noise and vibration.

If we look at the below table, we can see the components that are used to reduce the to noise and vibration occurred in the specific areas of the railway infrastructure.

- By using the rail fasteners rail roughness is reduced and at point crossings also they are used. (10)
- Base pad or Elasto metric pad are used at tracks, sleepers and ballast to lessen the noise and vibration. (27)
- Anti-vibration pads help to lower the frequency and wheel vibration(vehicle).
- FEM module also helps to reduce the rumbling noise (Vehicle) and to lower the vibration
- Barriers and noise enclosures are used to reduce the noise spread area around track. Also track bed absorptions also help in reduction. (23)
- Dampers like silent track, STRAIL are used at tracks, wheels and point crossings in reduction of noise and vibrations. Also, rubber insulators help to reduce vibrations. (18)

4.3) SYSTEMS

COMPONENT	Rail Fasteners	Floating slab	Base plate Pad	Smart Materials	Soft Pad	FEM Model	Reduced Stiffness	Switches Clips,	Barrier					Resilient fasteners	Dampers				Open Trench	Rubber insulators
	[27]	Track [27]	& Elasto metric pad [10,27]		s Anti- vibratio n pads		[10]	Bolts, Glue [10]	N o i s e	Noise Encoenclousure [23]	Near Track	Low Noise [24]	Track Bed Absorption [27]	[10]	Silent Track [19]	STRAIL [18]	Track [19]	Rail [18]	[24]	[27]
INFRASTRACT URE																				
Rail roughness	✓																			
Tracks			✓												✓					
Points crossings	✓							✓								~				
Rail joints								✓												
Wheel rail rolling noise																		~		
Irregular sub surface				1																
Sleeper & Ballast			✓																	
Low frequency ground born vibration					1	1								~						~
VEHICLE																				
Wheel roughness/vibrati on					1		~													
Engine noise																				
Rumbling noise						~														
Vehicle suspension																				
Rough track														~						
Surroundings/e nvironment																				
Barriers									✓	~	~		~							
Buildings									✓	✓										

CHAPTER: -5

CONCLUSION

Noise pollution, also known as environmental noise or sound pollution, is the propagation of noise with harmful impact on the activity of human or animal life. The source of outdoor noise worldwide is mainly caused by machines, transport and propagation systems. Poor urban planning may give rise to noise pollution, side-by-side industrial and residential buildings can result in noise pollution.

Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. The word comes from Latin vibrationem ("shaking, brandishing"). The oscillations may be periodic, such as the motion of a pendulum or random, such as the movement of a tire on a gravel road.

The above is a Concern for the environmental and the quality of life of citizens forces policy-maker to transfer the transportation of goods from the traditional heavy trucks to railways. However, railway companies are subjected to tremendous resistance and objections to build new railway lines until the problem of vibration exposure to citizens is solved. In general, high intensity traffic, wind and other dynamic action generate high noise levels and vibrations on systems and structures. An innovative method is required to notably reduce noise and vibration, at the same time minimizing energy and material use. For these ambitious goals it was necessary to perform some studies on existing old steel structure. Numerous field tests have been performed including the measurements of structural vibration on the one hand and noise radiation on the other hand.

The main causes for the Noise and Vibration are

Wheel Rail Roughness This broad-band noise is caused by vibrations of the wheel and rail which are excited at their contact by irregularities of the running surfaces. This is the dominant source of noise from railway operations.

The small unevenness or roughness on the wheel and rail surface is the physical structure behind the forces on the contact patch that cause the vibrations and hence the sound radiation.

Rumbling noise from train in tunnels (ground-borne noise): - This is generated as vibration of the track is transmitted through the ground and radiated as sound within buildings by vibration of their walls. This has components between about 30 Hz and 200 Hz

Because of which we get Rolling Noise, Traction Noise, Aerodynamic Noise and Ground-Borne Vibration.

Methods of reduction,

In the third chapter we can see how this effect are reduced and what are the important companies manufacturing materials, and the very important part we use to reduce the noise and vibration is Damper.

So, how the dampers are manufactured, the required materials and the areas where they are to be installed are very important points in reduction of our problem.

CHFC material, when applied to the rail, reduce the wear out and noise significantly, especially the high frequency squealing noise, but its friction characteristics would not change the braking properties."

Schrey & Veit specialises in the fields of vibration technology. It has years of experience in shock and vibration isolation, vibration damping, acoustic and production engineering in the railway, aviation / aerospace and automotive industries. VICON RASA wheel dampers are tuned to reduce curve squealing and / or rolling noise.

The TATA Steel Silent Track damper provides peak track noise levels with 3 - 6 dB and a wide frequency response over the important acoustic range for rail noise.

STRAILastic_A is a rail damper manufactured by STRAIL from a heavy elastomer compound via a specialised vulcanising process. Unlike other rail dampers, this one does not contain steel. Based on a large mass, the damper operates like a mass damper. Plus, the elastic material raises the general damping effect.

QUIVERDAMPER (Patent pending) is a new system that eliminates up to 90% of the active and passive vibration.

- Rail fasteners used to reduce the rail roughness
- Smart materials such as ballast, if we put smooth, round pebbles in the ballast, then they might roll or slide over each other when a train passes over the track, therefore they would fail in this job. We need stones of a specific type that won't move around the track. Ballast serves several purposes, it makes sure that the track stays in place when super heavy train roll by on them.
- Base plate provides near sleeper and ballast.
- Anti –vibration pads and rubber insulators used to reduce the low frequency ground borne-vibration.
- Rail Dampers used to reduce the wheel-rail rolling roughness.
- Rumbling noise can reduce by reducing the stiffness of the vehicle.
- Resilient fasteners used to reduce the roughness of the track
- Noise barriers and enclosures used to reduce noise and vibration which should not affect the environment and track surroundings.
- Track Design (pads/sleepers, Embedded rail/special slab tracks)
- Barriers (Up to 10dB but affected by layout of tracks/buildings)
- Vehicle Design (Wheel diameter, Wheel damping)

From the above we see that by using Dampers made of TATA Steel, VOSSOL, STRAIL, SCHREY & VEIT and the additional materials like resilient rail fasteners, floating slab track, noise barriers, anti-vibration pads, lot of reduction of noise and vibration has been done and hopefully in the coming years we may get more better equipment and technology to improve even more in the future.

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Success is to be measured not so much by the position that one has reached in life as but the obstacles which he has

I Like Trains. I Like their Rhythm, And I Like the Freedom of being Suspended between two places, All Anxieties of purpose taken care of: For This moment I know Where

1 am Going.....

Anna Funder, Stasiland

THANK YOU