International Journal of Advance Research in Science and Engineering
Volume No. 11, Issue No. 06, June 2022
www.ijarse.com
IJARSE
ISSN 2319 - 8354

A Review of Investigation on Use of High Performance Concrete in Pre-stressed Concrete Sleepers by Using Crumb Rubber

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ABSTRACT:

The current scenario in the world is to find new materials at low cost which can guarantee better performance of concretes. Sleepers play an important role in determining the performance of railway tracks. The level of this importance of railway sleepers can be gauged by noting the large number of sleepers on railway tracks. Reducing the life cycle costs of railway sleepers, as a result of decreasing construction, maintenance and operation costs, can have a significant economic effect on the cost of railway track. In this regard, the use of new materials to construct high-strength sleepers is of considerable interest. This paper reviews the study of the use of waste materials like crumb rubber, testing of concrete sleeper by static bending strength test and investigating of sleeper behavior by new impact test.

Keywords–Concrete Sleeper, Crumb Rubber, Impact Test, Railway Sleeper, Static Bending Test

1. Introduction

Railway sleeper are one of the most important elements of railway track system. Theirfunction is to transfer and distribute rail load to ballast and hence secure displacement of gauge,maintaining gauge-width. Sleepers also resist the lateral and the longitudinal movement of therail system. Different kinds of materials are used in sleeper production. Hardwood timber wasthe most widely used sleeper material. Timber sleepers are declining and becoming less capableof meeting performance requirements which has been replaced iron and then with prestressedConcrete sleepers which has been proved to be boon over conventional sleepers used in past.

Railway sleepers have important roles in the complex railway system. Due to different loading condition, poor maintenance of sleeper or bad quality of ballast, a random load distribution along the sleeper-ballast interface may occur. A sleeper design, and also the track system design, which do not considers the random load distribution, could influence the performance of the sleeper and even damage the whole railway system.Railway sleeper is a main component of railway track structure. Its function is to distributeloads from the rail foot to the underlying ballast bed. By passing train wheels the loads appliedby the rail head will be in the form of impact loads. Sleepers are provided to resist repetitive impact stress from dynamic interactions between the train and track infrastructure in services.

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order to maintain the track quality to aspecified service level and ensure a safe trackoperation, damaged and degraded sleepers are beingreplaced with new ones. Strength and durability of thesleepers is one of those ingredients that play animportant role in track system. Failure to adequatelyserve these roles can lead to a derailment endangeringboth lives and property.Beside timber wood, pre-stressed concrete and steelwere widely applied in sleepers but the results were notsatisfactory. This is because concrete and steel sleepers were not economical in comparison to timber sleepers. Steel has a risk of corrosion, high electric conductivity,fatigue cracking, and difficulty of packing it withballast has made it an inferior material to be used insleepers. On the other hand, pre-stressed concretesleeper, which offers a great durability than timber and steel sleepers, suffers due to heavy weight, high initial cost, low impact resistance, susceptibility to chemicalattack consequently; have failed to satisfactorily meetthe demands.[1]

2. Literature Review

The use of rubber product is increasing every year worldwide. India is also one of the largest countries in population exceeds 100cr. So, the use of vehicles also increased, according to that the tyres for the vehicles also very much used and the amount of waste of tyre rubber is increasing. This creates a major problem for the earth and their livings. For this issue, the easiest and cheapest way of decomposing of the rubber is by burning it. This creates smoke pollution and other toxic emission and it create global warming. Currently 75-80% of scrap tyres are buried in landfills. Only 25% or fewer are utilized as a fuel substitute or as raw material for the manufacture of a number of miscellaneous rubber goods. Burying scrap tyres in landfills is not only wasteful, but also costly. Disposal of whole tyre has been banned in the majority of landfill operations because of the bulkiness of the fires and their tendency to float to the surface with time. Thus, tyres must be shredded before they are accepted in most landfills. [2]

Several investigations have been carried out in anattempt to investigate the strongest, durable and costeffective material for replacing traditional sleepers.Hence, the use of composite sleepers has emerged as apotential alternative. Composite sleepers areenvironment friendly, highest in performance incomparison to other sleepers and provide anoutstanding value to its rail customers. Compositesleepers use, decreasesmaintenance cost of track andincreases its lifespan up to 50 years.

2.1 Materials for Railway Sleeper

Timber sleepers are still the most common; however, use of pre-stressed concrete and steel sleepers is also increasing. Timber sleepers have effective and reliable performance in the railway environment. Timbers most commonly used for sleepers in India are Sal(hardwood), Chir and Deodar (softwood). Soft wood sleepers are treated in a creosoting plant before putting them in service, where as hardwood sleepers are generally used untreated. Like the others, it has advantages and disadvantages. The main advantage ofthe timber is their adaptability as it can be fitted with all types of railway track. Timber sleepers are workable,easy to handle, easy to replace and needs no complicated assembly equipment. Their susceptibility to mechanical and biological degradation leading to failure is their major disadvantage. Concrete, because of its natural weakness in tension is not used in sleeper products. Pre-stressed concrete is a method for overcoming this matter. It can be used to produce beams, floors and bridges with longer span.Pre-stressed concrete sleepers have become widely and

successfully accepted for railway sleeper usage especially in high speed lines. Mono-bloc pre-stressed concrete sleepers is the most commonly used.The problem because of heavy weight of concrete sleeper is that it requires specialized machinery and skilled labor during laying and installation. The initial cost of concrete sleeper is almost double than that of hardwood timber sleeper. The main disadvantage of concrete sleeper is, the manufacturing of concrete sleeper, their transport, laying and maintenance requires superior technology, which is not readily available in developing countries like India.

Steel sleepers are moderately used. Steel sleepers canbe intermixed with the existing track but in a fixed intermixing pattern to reduce the variation in the track geometry and prevent the service failure of sleepers. Asteel sleeper is lighter in weight than timber sleeper which makes it easy to handle as well as having a lifespan known to be in excess of 30-50 years. As steel sleepers stronger than wood and cheaper than concrete, they are usually considered as middle way between wooden sleeper and concrete sleeper. Steel sleepers require extra care during installation and tamping due to their inverted through profile which makes them difficult to satisfactorily pack with ballast.

Plastic railway sleeper, also called composite sleeper, mainly refers to the railway sleeper made of the plastic composite. Plastic composite is a total modern material for making rail sleepers. It is the mixtures of plastic or waste rubber or polymer. Plastic sleeper combines the pliability of wood and durability of concrete. Composite material is made from two or more materials to obtain properties which are superior to the individual components.

2.2Use of Rubber in Concrete

The use of rubber product is increasing every year in worldwide. India is also one the largest country in population exceeds 100cr. So the use of vehicles also increased, according to that the tires for the vehicles also very much used and the amount of waste of tyre rubber is increasing. Rubber will take 50-100 years to decay and will emits dangerous gases. This creates a major problem for the earth and their livings. For this issue, the easiest and cheapest way of decomposing of the rubber is by burning it. This creates smoke pollution and other toxic emission and it create global warming. Currently 75-80% of scrap tyres are buried in landfills. Only 25% or fewer are utilized as a fuel substitute or as raw material for the manufacture of a number of miscellaneous rubber goods. Burying scrap tyres in landfills is not only wasteful, but also costly. The use of waste material such as waste tyre rubber as a replacement of fine or course aggregate in construction can reduce the problem of dispose of rubber, hence environment friendly and economically beneficial. Following are some advantages of Crumb Rubber

Advantages

1. Higher resistance to deformation at increased temperature.
2. Improved adhesion and bonding with other materials.
3. Higher elongation and tensile strength
4. Higher Elasticity
5. Resistance to degradation even at high temperature.

2.3 Admixtures for High Performance Concrete

An admixture is a material other than cement, water and aggregates that is used as an ingredient of concrete and is added to the bath immediately before or during mixing. Admixture are also used to modify the properties of concrete so as to make it more suitable for any situation. It is difficult to predict the effect and the result of using admixtures because many a time the change in the brand of cement, aggregate grading, mix proportions and richness of mix sometimes usually alter the properties of concrete. Sometime many admixtures. Affect more, and the effect of more than one admixture is difficult to predict. Carefulness is the watch word in the selection of admixture, and in also predicting the concrete. The commonly used admixture for most Engineering construction are Plasticizer, Super plasticizers, Retarders, Accelerators andAir- Entraining Admixture.

2.4 Cracking of Concrete Sleeper

During the manufacture of concrete sleepers, defects related to the raw materials of the concrete or to the actual fabrication (tensioning and concreting) may arise. The presence of these defects, detected during the inspection phase, may justify the disposal and subsequent destruction of the piece. Among the most frequent defects, which may arise during production and cause sleepers' rejection, are cracks. These, in general, are not related to structural causes, are stable, and therefore do not directly compromise the structural function of the sleeper. On the other hand, if untreated, these same cracks can provide passageways for aggressive agents to enter and, over time, cause prestress loss, compromising the good performance and durability of the piece, including loss of functionality on the track, or making the piece susceptible to the appearance of other pathologies, like rebar corrosion, for example. Therefore, it was concluded that the stable cracks resulting from the manufacturing process of the sleepers did not justify the immediate discarding, and that there is a possibility of recovery and application of these pieces in certain parts of the railroad. However, the criteria for such a procedure should be analyzed, studied and formalized and a practical and effective method for recovering these cracks should be proposed. [3]

2.5 Application Areas of High-Performance Concrete

Major applications of high-performance concrete in the field of Civil Engineering constructions is in the areas of long-span bridges, high-rise buildings or structures, highway pavements, etc. Some of the application areas are discussed in brief below:[4]

1. Bridges- The use of high performance concrete would result in smaller loss in pre-stress and consequently larger permissible stress and smaller cross-section being achieved, i.e. it would enable the standard pre-stressed concrete girders to span longer distances or to carry heavier loads. In addition, enhanced durability allow extended service life of the structure. In case of precast girders due to reduced weight the transportation and handling will be economical. Concrete structures are preferable for railway bridges to eliminate noise and vibration problems and minimize the maintenance cost. [5]

2. High Rise Structures -The reasons for using the high strength concrete in high-rise buildings are to reduce the dead load, the deflection, the vibration and the maintenance cost.

3. Highway Pavements- High Performance concrete is being increasingly used for highway pavements due to the potential economic benefits that can be derived from the early strength gain of high performance concrete,

its reduced permeability, increased wear or abrasion resistance to steel studded tires and improved freeze-thaw durability. A durable concrete known as fast track concrete designed to give high strength at a very early age without using special materials or techniques has been developed. Fast Track Concrete Paving (FTCP) technology can be used for complete pavement reconstruction, partial replacement by an inlay of at least one lane, strengthening of existing bituminous or concrete pavements by a concrete overlay, rapid maintenance and re-construction processes. The benefits of applying FTCP technology in such applications are: (a) a reduced construction period, (b) early opening of the pavement to traffic, and (c) reducing the use of expensive concrete paving plant.[6]

2.6 Method of Testing of Railway Sleeper (As per Indian Railway Standards 2016)

2.6.1 Compressive strength Test

15 cm size cubes shall be cast on a vibrating table conforming to IS:2514 (1963) from random samples spread over the entire lot, out of concrete used for casting sleepers for testing prior to transfer of prestress and 15 days. The cubes shall be surface dry at the time of testing. The rate of loading shall be about 400 KN/minute. These cubes shall be steam cured along with sleepers in the same manner and tested for transfer of prestress to concrete (at least one cube for every steam chamber/3 for each long line but not less than a total of 3 in any case).

2.6.2 Flexural strength test

The test for 15 day modulus of rupture of concrete shall be carried out on concrete beams of 10 x 10 x 50 cm size as specified in IS: 516. One specimen shall be tested daily prior to the stabilization of production technique, and once a week thereafter. If any value falls below 5.2 N/mm^2 for M55 and 5.5 N/mm^2 for M60, the mix design shall be reviewed.

2.6.3 Tests for static bending strength of sleepers

The tests shall be conducted in accordance with the Indian railway standard specification. The sleepers shall be loaded gradually (30-40 KN/min) upto the specified load, which will be retained at this level for three minutes for observing cracks, if any. For the purpose, a crack is defined as one which is barely visible to the naked eye and is at least 15mm long from the tension edge of the sleeper. However, if crack appears at a load smaller than the specified load, that value shall be recorded. In case of 'Moment of Resistance' (MR) test, the sleeper shall be deemed to have passed the test if it sustains the loads specified in Indian railway standard specification or in relevant sleeper drawing without cracking. While loading, load can be applied upto 5KN in excess of specified load. In case of 'Moment of failure' (MF) test, the sleeper shall be deemed to have passed the test if it is able to take load beyond the specified test load. The initial cracking loads shall also be recorded for rail seat bottom, center top or center bottom (as the case be) for further statistical analysis of data during MF test. Sleepers for test shall be selected randomly.[7]

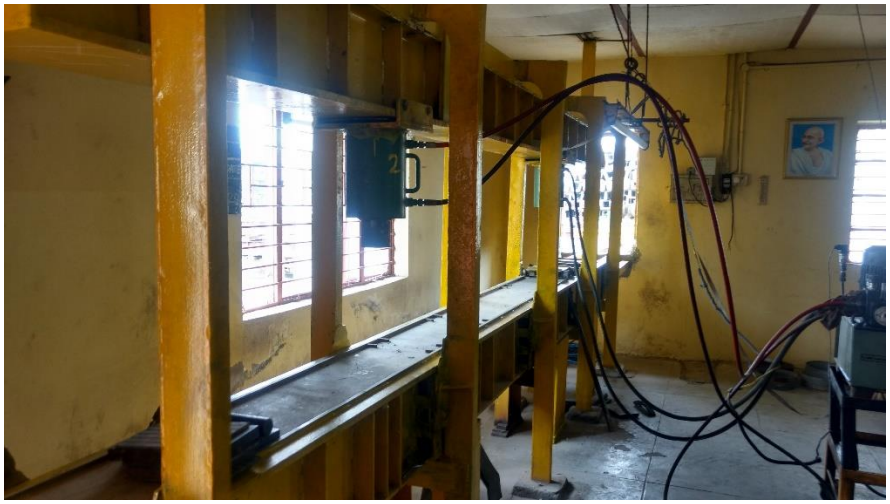

fig.1 static bending strength test of sleepers

2.6.4 Finite Element Method (FEM)

The Finite Element Method (FEM) is a numerical technique to find approximate solutions of partial differential equations. It was originated from the need of solving complex elasticity and structural analysis problems in Civil, Mechanical and Aerospace engineering. In a structural simulation, FEM helps in producing stiffness and strength visualizations. It also helps to minimize material weight and its cost of the structures. FEM allows for detailed visualization and indicates the distribution of stresses and strains inside the body of a structure. Many of FE software are powerful yet complex tool meant for professional engineers with the training and education necessary to properly interpret the results. Several modern FEM packages include specific components such as fluid, thermal, electromagnetic and structural working environments. FEM allows entire designs to be constructed, refined and optimized before the design is manufactured. This powerful design tool has significantly improved both the standard of engineering designs and the methodology of the design process in many industrial applications. The use of FEM has significantly decreased the time to take products from concept to the production line. One must take the advantage of the advent of faster generation of personal computers for the analysis and design of engineering product with precision level of accuracy.

Modeling of the concrete sleeper in FEM

To model the sleeper, initially the geometric model of the sleeper is built in ANSYS and then the finite element model is built. In order to model the rather complicated geometry of the sleeper, key points are input in absolute coordinate form and these key points are created at one end, i.e. rail seat end of the concrete sleeper and also at the center of the sleeper where the cross section varies. Further areas have been created by using key points at rails seat end cross section and also at the center of the sleeper. Adjoining areas have also been created between the two cross sections. These areas have been glued using Boolean operations and then a volume is created using all the six areas. At this stage a half sleeper model is created. The half sleeper volumetric model is then reflected about the centre cross sectional plane to create the other half of the sleeper and both the volumes are added using Boolean operations. In this way, full sleeper volumetric model is built in ANSYS the Line model describing the cross section areas and also the sleeper volumetric model built respectively.[8]

3. Results

Railway sleeper is a composite material in which concrete is used as matrix and powdered waste tyre rubber is used as particulate fiber and it is recommended due to high impact strength and energy absorption. Rubber concrete composite sleepers have some attractive properties like high toughness, high energy absorption capacity, high impact resistance, high damping resistance and low brittleness comparing to conventional concrete sleepers.

Table 1. Compressive Strength of Runner Concrete Cubes

Mix Proportions (% Replacement Crumb rubber)		7 Days Compressive Strength (MPa)	15 Days Compressive Strength (MPa)	28 Days Compressive Strength (MPa)
M50	M50 R0	40.54	50.57	59.29
	M50 R5	38.80	45.34	53.20
	M50 R10	35.51	44.03	51.44
	M50 R15	33.13	43.60	49.70
	M50 R20	29.64	37.49	43.16
M60	M55 R0	43.01	54.06	64.96
	M55 R5	39.67	49.26	58.42
	M55 R10	37.88	47.97	56.70
	M55 R15	35.72	47.08	53.62
	M55 R20	32.26	40.32	47.96

According to table no 1, the results of compressive strength at 7 days, 15 Days and 28 days of experimental samples is shown.There are a lot of positive properties increases but compressive strength of rubber concrete composite little decreases with the percentage increase of the rubber in concrete. So a proper investigation and evaluation should be done for look after the changes in compressive strength. The railway sleeper specimen is prepared and the casting method and process of fabrication is discussed. The waste management and recycling method of scrap tyres are discussed and it should be done for clean environment. The recycled waste tyre rubber can be used in rubber concrete composite, road construction, sports ground and shock absorbing utility like bumpers. So this paper recommends the use of particulate rubber in conventional concrete sleepers for better mechanical properties like high toughness, high impact resistance, high vibration resistance and little transition to ductile for recognizing crack initiation but with some little caution of decreasing compressive strength and flexural strength. M50 and M55 mix ratio is chosen for the current

investigation. Experimental evaluation carried out to study mechanical properties to rubber concrete sleepers for the suitability of rubber concrete in railway sleepers as per Indian railway standards and it is recommended due to high impact strength and energy absorption. [9]

4. Conclusion

Many railway infrastructure companies have using concrete and steel for replacing timber sleepers in existing railway tracks. However, this maintenance strategy has gained limited success. These materials did not prove to be a feasible alternative to timber sleepers. Worldwide most of the maintenance and construction of railway tracks still using timber sleepers despite the increasing reliability and effectiveness of alternatives such as steel and concrete. It is often more financially feasible or convenient in the short term to replace sleepers with new timber sleeper. Concrete sleepers have the ability to provide better line and gauge-holding characteristics than timber sleepers, but they are relatively costly, quite heavy and are often incapable of providing a projected 30-50 year service life. Hence use of waste materials may improve the service life of sleeper and cost effective.

In Current scenario tyres become a major environmental problem and waste management and safe disposal is required. The use of recycled waste tyre rubber which is crumb rubber in concrete is an attractive and beneficial option technically. The crumb rubber is used in production of railway sleeper composite in which crumb rubber is used as reinforcement or particulate fiber. Rubber concrete composite sleepers made from waste tyres are environment friendly and cost effective. This composite can be used as green product and it is eco-friendly because it reuses of the waste material in a productive way. Strength, Rigidity of concrete, train travel noise, Density and vibration smooth running are decreased with increase in rubber aggregate volume content. But the material shows enhanced toughness, a slight progress from brittle to ductile failure mode, light weight, impact resistance, thermal insulation and damping.

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