A Review on Cost Effective Railway Sleeper

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Abstract— Railways form the backbone of all economies, transporting goods, and passengers alike. Sleepers play a pivotal role in track performance and safety in rail transport. Coal based thermal power plants utilize large quantity of coal for production of electricity. As a result, the fly ash is generated which is considered a by product of thermal power plant and solid waste in nature. Fly ash utilization and its proper disposal are major environmental issues which attracts secondary utilization of fly ash. Still there is tremendous quantity of unused fly ash available every year which calls for its further utilization. Indian railways experimenting with cost effective sleepers for railway tracks. This paper highlights partial replacement of fly ash in sleeper manufacturing without compromising with strength characteristics as per Research Designs and Standards Organization (RDSO) lab studies encouraging its use for sleeper manufacturing which is cost effective.

Key words: Cement, Fly Ash, Concrete, Pre-Stress Concrete Sleeper, Fly Ash Concrete, Environment

I. INTRODUCTION

Railways as a mode of transportation have played a pivotal role in the development of all economies providing means for the transport of goods and passengers. Railways play a significant role in ensuring connectivity to different parts of a country at affordable costs to the common man. With the development of technology, there has been dramatic face-lift from where it all started to the present. In India, the railway track system components have undergone gradual evolution from the timber sleepers of pre-independence days to the pre-stressed concrete sleepers of the modern era being the most noticeable feature of a railway track. There is an ever-growing demand on the part of ordinary man and the industrialists for optimizing the efficiency of the rail operation. Enhancing the load carrying capacity and improving the frequency of trips are essential in developing the rail service and making it viable eventually.

In recent years, there has been a growing challenge in railway engineering research. Railway tracks have been designed based on a consideration to overcome the heavier load-carrying capacity of the roads and trucks either at the moment or in the future. Usually, ballasted railway track which consists of rails, sleepers, ballast formation, and fastening systems is widely constructed for transportation especially in remote area. The railway sleepers play an important role in uniformly transferring and distributing loads from the rail foot to underlying ballast bed to support the rail firmly and evenly, maintain the gauge of the track correctly, to act as an elastic medium between the rail and the ballast and to absorb the vibration of the trains and to align the rail properly.

There are number of sleeper manufacturing units in our country. The demand of sleepers will go on much higher side in time to come. In near future the railways are likely to develop at least 5000 to 8000 kilometer of rail network per year, which is almost 30 to 40% more than in past assuming that kilometer of rail would need 1600 sleepers these plans are likely to results in an annual demand of about 1.3 crore of sleeper. Present manufacturing cost of mono block broad gauge pre-stressed concrete sleeper is in the range of 2200 – 2500/-. The cement which is utilized for manufacture of sleeper is main raw material. In order to make cost effective sleeper the fly ash can be used as supplementary raw material which will result in improving the quality of environment as well.

II. Literature review

Anand Raj et al (2018) highlighted the use of new materials developed recently for the construction of pre-stressed concrete sleepers to improve the performance and life of railway sleepers. Use of geopolymer concrete and steel fibre reinforced concrete, assist in the reduction of flexural cracking, whereas rubber concrete enhances the impact resistance of concrete by three folds. This paper presents a review of state of the art of new materials for railway sleepers.

Gauthaman P (2017) discussed briefly Pre-stressed Concrete Sleepers and observed various parameters governing the same. It is advantageous in rapid making of the material and in terms of high strength requirements.

Afia S. Hameed and A.P. Shashikala (2016) done an experimental investigation by replacing 15% by volume fraction of fine aggregate by crumb rubber was conducted to find the fatigue failure load and impact resistance. The design strength of 50 and 55 MPa was achieved. Test result indicated that there was reduction in compressive strength and modulus values. The fatigue failure and impact resistance were high for rubber concrete when compared with ordinary high strength concrete. The impact strength for railway sleeper with crumb rubber replacement showed increase of about 60%when compared to pre-stressed concrete sleeper.

Vinod Goud (2016) had done the partial replacement of cement with fly ash in concrete and its effect. Fly ash a waste generated by thermal power plants is as such a big environmental concern. In modern decades, the industrialization and urbanization are the two phenomena that are spreading all over the world. Apart from the requirement of these phenomena, there should also be investigation into their negative impacts on the worldwide environment and common life. Most important poor effect of these international processes has been the production of large quantities of industrial wastes. Therefore, the problems related with their safe management and dumping has turned into a major test to environmentalists and scientists. Another problem is the stress on land, materials and resources to sustain the developmental activities, including infrastructure. The thermal power plants produce considerably large quantities of solid byproduct namely fly ash.

B. Deivabalan and B. Tamilamuthan (2015) presented the load-deflection curve of the static four-point loading test. Relationship between hogging moment and gauge rotation is underlined. Criteria of the measure based on the loading capacity are also discussed for determining the failure of railway pre-stressed concrete sleeper. In this study the fly ash based geopolymer concrete mix design was obtained for M50 grade. The fluid to fly ash ratio was fixed as 0.45. The ratio of sodium silicate to sodium hydroxide was 2.5 and the concentration of the solution is 14 molar. The preliminary tests were carried out for the geopolymer concrete and conventional concrete and optimizing the mix design. Two numbers of sleepers were cast in each case one in conventional concrete and other one in geopolymer concrete. All the sleepers were tested under static monotonically loading and the results will be presented. Comparison will be made between conventional concrete and geopolymer concrete.

Swapnil Malipatil (2015) reduced the consumption of energy in curing by adopting ambient (sunlight) curing. In the present study, alkaline liquid to fly ash ratios of 0.35 and 0.4 with 16Molarity and 18Molarity of NaOH solution were used. To determine the compressive strength for geopolymer concrete, specimens of size 15cm x 15cm x 15 cm cubes were prepared. The curing regimes adopted were steam curing at average temperature of 650C for 24 hours and ambient curing at average temperature of 400C for 7days. The compressive strength attained for alkaline liquid to fly ash ratio 0.4 and 0.35 for 18 Molarity were in the range of 36.44N/mm2 to 60.35N/mm2 for ambient curing and 41.9N/mm2 to 72.09N/mm2 for steam curing. The compressive strength attained for alkaline liquid to fly ash ratio 0.35for 16Molarity were in the range of 58.88N/mm2 to 61.33N/mm2 for steam curing and ambient curing.

Manjula (2015) conducted experiments to determine the strength of iron ore tailing (IOT) as a replacement fine aggregate (FA) of river sand (RS) for concrete used for prestressed concrete (PSC) sleepers. The present experimental investigation is aimed to study the static behaviour of a pre-tensioned pre-stressed concrete sleeper using river sand and iron ore tailings. PSC sleeper is used in the experimental studies in accordance with Research Design Standard Organisation (RDSO), IRS; T-39-85. The test programme consists of the static bending test and electrical resistance test to obtain load deflection behaviour, on 4 standard PSC sleepers with regards to different percentage mix of IOT (25%, 50%, 75%, and 100%) proportions for M-55 grade concrete. Replacement of 50% IOT gives maximum compressive strength and for replacement of 100% IOT gives the less compressive strength as compare to 50% IOT, but 100% IOT gives more compressive strength than specified load as per RDSO.

Jabbar Ali Zakeri et al (2014) had done study using slag and limestone to create a slag-containing concrete that was subsequently used to produce sleepers. The results of laboratory tests on slag-containing concrete showed a 46% increase in compressive strength compared with non-slag-containing concrete. The ratio of tensile to compressive strengths of all the slag-containing concrete samples varied between 0.06 and 0.087, which is comparable to the range of 0.1 to 0.15 for non-slag-containing concrete. Negative moment tests performed on sleepers manufactured from slag-containing concrete required a 30% increase in the vertical load to initiate the first crack compared with a sleeper produced from non-slag-containing concrete. These preliminary results suggest that a new generation of high-strength sleepers can be created; the long-term efficiency of this type of sleeper will need to be confirmed by durability tests and practical use.

Angel Palomo (2007) suggested that the tracks that comprise the world railway network are estimated to contain nearly three billion sleepers, over 400 million of which are made of concrete. At the same time, over 50% of the world demand for sleepers (around 20 million units per year) was for the concrete version; and between 2% and 5% of the concrete ties that are laid on tracks every year are to replace or renew worn elements. Concrete durability, however, depends on many factors. And in this context it should be noted that the characteristics of the in-plant industrial process involved in manufacturing precast concrete units differs in a number of ways from in situ construction, vesting these units with properties that distinguish them, in terms of durability, from in situ concrete under the conditions generally prevailing on construction sites. Generally speaking, it is widely admitted that the activation process of fly ashes allows obtaining a material with similar cementing features to those characterising Ordinary Portland Cement. Actually, the alkali activation of fly ashes is a singular procedure by which the powder originated in the power plants is mixed with certain alkaline dissolution and cured under a certain temperature to make solid materials. Contrary to conventional concrete, however, this new type of concrete can attain high strength over a very short time (1 day) and do develop excellent durability properties.

S Matra (2005) collected 4 different varieties of class F fly ashes, from different sources from the state of West Bengal (India) were mixed with lime in 9: 1 wt ratio, followed by compaction of the mixes. The compacts were subjected to steam curing to develop an optimum strength by the reaction between fly ash and lime. The steam cured compacts were heated at different elevated temperatures and free lime content, compressive strength, bulk density and water absorption tendency of these compacts were measured and FTIR spectral changes were studied as a function of the heating temperatures. Kinetics of thermal dehydration of the compacts was also studied from thermogravimetric measurements under non-isothermal condition to ascertain the order of dehydration process and the associated activation energy.

III. STANDARD TESTS FOR RAILWAY SLEEPERS IN INDIA

In the Indian scenario, T-39-85 issued by RDSO (Research Design and Standard Organisation) govern the quality of materials used in the manufacture of pre-tensioned pre-stressed concrete sleepers. It specifies a cement content of 350 kg to 480 kg for M 55 grade concrete mix and 350 kg to 500 kg for M 60 grade concrete mix. The minimum release strength specified is 40 MPa. The manufacturers are also obliged to abide by the testing standards specified for the purchase of sleepers. Every sleeper should be able to withstand a maximum test load of 50 tonnes in the increment of loading at 5 tonnes/min starting from 5 tonnes. The maximum load of 50 tonnes has to be maintained for 5 minutes. A vertical dynamic load range of 39.2 KN to 196.2 KN with a frequency range of 5 Hertz need to be withstood without damage to the sleepers to pass the dynamic load test. The sleepers should also absorb an impact load developed by a 500-kg wheel falling at the height of 750 mm over two drops at two locations. Similar guidelines are available in different parts of the world. The acceptance criteria for the sleepers after subjecting them to static, dynamic and fatigue tests in Britain are guided by EN 13230-2:2009.

IV. Potential Materials That Can Be Used for Sleepers

The primary focus of studies conducted on railway sleepers in recent years has been on the development of new materials that give comparable or better results in comparison with conventional sleepers. Following sections discuss some of the new materials that can be used for the manufacture of sleepers.

A. Polymer Composite Sleepers

Composites made of polymers have superior corrosion and chemical resistance, better durability characteristics and high specific strength. They can be considered eco-friendly as they can be recycled, reducing the dumping of plastics in landfills. They also help to reduce deforestation. Studies on glue laminated sandwich beams indicate that they can be suitable for turnout sleeper due to their strength and stiffness. When these sandwich beams are provided with fibre wraps, there is an increase in shear strength of about 7%. Manalo and Aravinthan reported using their studies that sandwich beams possess properties which are more than comparable with that of fibre composite materials specified by AREMA (The American Railway Engineering and Maintenance-of-Way Association). The Young's modulus and bending strength of the tested laminated panels were about 4.5 times greater than the standard material, and the shear strength possessed was more than twice the requirement in AREMA.

B. Geopolymer Sleepers

Geopolymer has a wide variety of applications in precast industry. The properties of geopolymer concrete mostly depend on the constituents used. However, most of the mechanical properties of geopolymer concrete are at par with the conventional concrete. Shojaei et al. have studied the use of geopolymer concrete in railway sleepers. Ground granulated blast furnace slag was used as the binder, and a mixture of sodium hydroxide and sodium silicate acted as an activator. They reported that 6M solution provided the best results while considering the compressive strength. They concluded that the use of geopolymer concrete satisfies the standards existing in railway codes. Deivabalan and Tamilamuthan conducted static tests on low calcium fly ash based geopolymer railway sleepers and pre-stressed concrete railway sleepers. An insight into the static and flexural tests that were done on sleepers indicates that geopolymer concrete gave better results than conventional concrete.

C. Fibre Reinforced Concrete

Fibres of different types have been used in concrete for decades. Among the fibres most sought after one is steel fibre. Researchers have been pursuing various forms of fibre to improve the properties of ordinary concrete. The addition of steel fibres only marginally increases the compressive strength of concrete, but the split tensile strength can be increased to just a shade under 40%. 8% increase in the modulus of elasticity along with the ability of fibres to bridge the gap when cracks start to develop, lead to enhanced strength properties.

D. Rubber Concrete

The addition of rubber in concrete as replacement of aggregates (both fine and coarse) has been on for 40 years. Rubber has been used as partial replacement of fine aggregate or coarse aggregate. Shredded and crumb form of rubber are the usually used forms of rubber. The workability of fresh concrete is considerably affected by the addition of rubber with higher workability for larger size rubber particles coming under the sizes of fine aggregates.

V. Methodology

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportion with object of producing concrete of certain minimum strength and durability as economically as possible. For the present work a grade of concretem-55 suggested to be used in RDSO specifications.

In our work mix design of M55 grade of concrete will be done according to IS 10262: 2009. The cube shall be surface dry at the time of testing. The rate of loading shall be about 400 KN/min as mentioned in T-39-85 RDSO para 5.3.4 & 5.3.5. After that compressive strength of cubes after steam curing and water curing will be check. However for steam curing 11 &1/2 hour produce strength > 40 N/mm2 and in case of water curing for 15 days cubes will gain strength > 55 N/mm2. In this work three cubes will be casted and tested if it will satisfy RDSO limit then we will go for statical analysis. In case of statical analysis 80 cubes will be casted in which 40 cubes will be steam cured and remaining will be water cured with partial replacement of fly ash. If all goes well we will proceed further for preparing sleepers with partial replacement of fly ash.

VI. Conclusion

Fly ash is a residual of coal based thermal power plants and is generally considered as waste. However it has cement like properties when mixed with lime and water because of pozzolanic characteristics. It will reduce CO2 emissions. Also India produces 150 million ton fly ash every year and by 2012, the production is expected to reach 200 million tons. Mixing 25 to 30 per cent of fly ash gives 20 per cent more durability to the cement structure as the fly ash particles, being smaller in size than the cement particles, settle in the smallest of voids in a cement structure and make the structure more condense. Railway produce around 1.3 crore sleepers every year and if the experiment is successful, it will reduce the cost of production of each sleeper by approximately Rs

30, which will mean an overall cost saving of Rs 30 to 35 crore per annum for India Railways.

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