Application of Flyash Based Geopolymer Coated Aggregates in Bituminous Concrete: A Review

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ABSTRACT: Road Transport is known to be one of the most vital infrastructures in the overall socio–economic development of the country. In India, it enables the transportation sector to contribute 4.7% towards country's gross domestic product. Expanding with road network of over 5,603,293 kilometers, India is the 2nd largest in the World. The funds allotted for highways maintenance being insufficient. This represents the demand and need for innovation in the road materials and technologies, in order to preserve and prolong the life of road infrastructural asset. In general, flexible pavements are bitumen – based macadamisedroads, which consists of 95 percent of aggregate mixture and about 5 percent of bitumen/asphalt binder. But, growing rates of industrialization and infrastructure development activity is expected to impact demand for specific construction aggregates products. Market research has revealed that the global non–renewable resources supply will face permanent shortfall by the year 2030. India's construction sector in particular, is expected to grow at 8% per year for the next decade, which is serious alarm for increasing demand for construction materials. In order to face this, it is quite known that, substantial economic benefit may result if low cost replacements can be found for high quality aggregates. This scenario forces the researches to contribute towards alternative material or promote use of locally available materials. Marginal materials, in their present form do not possess quality levels as defined by current highway standards, sufficient for their use in pavement structural components. If such aggregates are used inappropriately, premature pavement failures may likely occur, leading to increase in maintenance cost. In many cases, these aggregates can be used without negatively affecting pavement life, through enhancing bystabilization, blending, coating etc. So, it is clear that use of marginal or non-specification materials is not new, but in recent years particularly uses of industrial waste/byproduct and waste material disposal, have found focus by the environmentalists and researchers. One such identified byproduct is flyash from coal based thermal power plants.

LITERATURE REVIEW: The road network being

the backbone of country's economy, its development and maintenance consumes a major part of financial budget. The initial investment of road infrastructure can be controlled by using locally available materials thus reducing the cost of transportation. However, this technique often becomes not practicable because of poor quality of materials. Therefore, innovative ideas are required to enhance the properties of theselocally available materials and make them suitable for pavement construction.

Oluyemi-Ayibiowu *et al.* (2016) assessed the engineering characteristics of coarse aggregates used for construction works in Akure Township. Aggregates of different sizes where collected from three different quarry sites in Akure, Ondo State, Nigeria. The engineering characteristics of aggregates were determined using laboratory tests. The tests results of Specific Gravity, Aggregate Impact Value (AIV), Aggregate Crushing Value (ACV), Flakiness Index (FI) and Elongation Index (EI) were used to determine thetoughness indices. It was reported that generally from specifications, if the

Bouchard (1992) carried out research based on the theory that the aggregate water absorption can be used to predict the bonding surface volume available around each particle to improve the performance of mixes under heavy traffic volume. The investigations were carried out on the shearing property of mastic to aggregates under various moisture conditions. The Marshall Stability tests results were compared for the mix types with aggregates having low water absorption values and high water absorption values. The research concluded that the shearing of mastic on the aggregates under load increases with decrease in water absorption value.

Sharif (2001) carried out an attempt to assess the suitability of aggregates from different quarries located in the northern Pakistan in the near province of the project sites for road construction works. High resistance to plastic deformation and high resilient modulus for the aggregate mix was considered as the prime factor of good quality aggregates for road works. The laboratory study was conducted on the locally available aggregates and it was concluded that for the selection of aggregates for the road construction works should be based on resistance to degradation and weathering action and it should be free from plastic fines.

Kamal *et al.* (2006) correlated the results of durability, strength and shape tests on the particular aggregate type from the quarry source and established the relationship between those test values to arrive at the assessment of overall quality of the aggregate. A single factor or index character termed as Toughness Index (TI) was derived using the estimated coefficients from linear relationship between the physical characteristics of the aggregates. The toughness index value was considered to be based on strength and durability characteristic of the aggregate.

Zoorob *et al.* (1997) conducted a laboratory study on bituminousmixtures comprising of ordinary portland cement coated aggregates toinvestigate the effect of surface roughness of aggregate particle given by thick cement coating on adhesion property of bitumen on the aggregate. The analysis was carried out with the results of stability, permanent deformation, creep stiffness and resistance to moisture damage. The tests results indicated that the technique of coating the surface of the aggregate particle with thick film of ordinary portland cement improved the mixture properties and could be used to increase the resistance to moisture damage.

Kim *et al.* (1992) have attempted to evaluate the effect of aggregate type and gradation on the fatigue life and deformation of asphalt concrete. The fatigue tests and static creep tests were carried out under varying temperature, airvoids, asphalt type, asphalt content and applied stress level. The study revealed that the type ofthe aggregate had significant effect on the fatigue resistance and permanent deformation of asphalt concrete. The asphalt concrete mixture comprising of rough surface texture and angular shape could perform better under applied stress. No significant effects of coarse aggregate gradation and medium gradation were reported on permanent deformation characteristics of the mixture. Statistical analysis revealed that there was significant interaction of aggregate and mixture variables and permanent deformation but it was observed that there was no significant interaction of those variables on fatigue values.

Kantha Kumar *et al.* (2008) investigated the influence of aggregate gradation of the bituminous concrete mix on fatigue performance. Gyratory compacted cylindrical specimens were tested for repeated load indirect tension under varying temperatures. Sensitivity analysis was performed to analyse the effect of variation in constraints tested for fatigue life performance. Bituminous concrete mixes were evaluated for its volumetric parameters and resilient modulus and the results concludedthat the bulk specific gravity and voids in mineral aggregate increased with increase in finer particle as the air voids decreased , indirect tension and it was concluded that optimum value for fatigue life was found for bituminous concrete mix comprisedof gradation line of three fourth between mid point and upper limit.

Kavussi & Hicks (1997) studied the characterizing role of fillers in bituminous mixtures.Four types of filler (limestone, quartz, fly ash, and kaolin) with different physical properties were examined. It was reported that the dry compacted filler test proved to be good test method for filler characterization. The four fillers were combined with one type of bitumen at different filler to bitumen ratio levels and regular bitumen tests were carried out. Penetrationindex values were used to study the temperature susceptibility of the various filler-bitumen mixes. Flexural testing was also carried at varied low temperatures to determine the flexural properties of mixes containing different types and amounts of fillers. It was concluded that the performance of dense graded bituminous mix with flyash as filler material resulted in high stability and stiffness values. Kumar *et al.* (2008) studied the effect of using flyash as filler material in the bituminous concrete mixture. It was generally observed that the bituminous concrete mixtures with flyash as filler material resulted in increased indirect tensile strength and fatigue cracking was reported as major observationsin the study. There was also increase in tensile strength ratio and strength properties were observed to be improved for the conditioned samples with flyash filler material. However, it was reported that with increase in the flyash content, the resistance to rutting neither was nor improved.

Vishal Sharma *et al.* (2010) investigated flyash collected from various thermal power plants and studied for their chemical characteristics and investigations were carried out on the bituminous mixtures prepared with flyash as filler. The rheological properties of the mastics prepared with different filler - bitumen ratio were studied. Study concluded that the optimum filler content in the mix was 7% for which better performance was observed than the conventional mix having stone dust as filler. The study also revealed that the higher values of tensile strength ratio, retained stability, better rutting resistance and low permanent strain in the bituminous mixes prepared using flyash with higher amount of calcium oxide.

Tara Sen & Umesh Mishra (2010) reviewed the application of different industrial wastes in the road construction. Fly ash having the hydrophobic properties, effectively acts as anti-stripping agent in the hot mix asphalt and thus increases the durability of the pavement and also the flyash can be used for improving the subgrade conditions and thus reducing the cost of the pavement. Flyash can be effectively used with lime and aggregates to produce good quality stabilizedbase course. Article has also reported the suitable applications of flyash as admixture in the concrete pavements and bridges enhances its performance.

Konstantin Solobev *et al.* (2013) extensively investigated road pavingwith asphalt mix with flyash using standard production and construction technique. The study reported through microstructural investigations that the rheological properties of the asphalt mastics and mixes were improved due to the addition of flyash. The study concluded that the addition of flyash also improvedaging resistance of the mastics, thermal cracking and increase the ability to relieve internal thermal stresses built up in low temperatures. Further, study reported that the techniques were applicable for the asphalt mix with flyash and as flyash couldact as a extender in asphalt binder in the mix, it could reduce the asphalt binder content for the required performance of the pavement.

Rahman & Sobhan (2013) conducted the experimental program to investigate the inclusion of flyash in the filler replacement in the asphalt concrete mixture. From the results of retained stability test it was reported that the lower values were found for mixtures with non conventional fillers butsatisfied the minimum requirement of 75%. The study concluded that the non conventional filler materials required higher optimum binder content compared to the conventional filler materials but the asphalt concrete mixtures with non-conventional fillers proved to be more resistant to permanent deformation and premature failure.

Ivica Androjic *et al.* (2013) performed laboratory investigations onthe asphalt mixtures prepared with different concentration of bitumen - filler which were compared with stone dust and fly ash. showed values lower densities for the mixtures with fly ash as filler when compared to the samples prepared with stonedust as filler material. Filling of voids by bitumen could also not meet theEuropean standards for the samples prepared with bituminous mix having flyash.

Kamal Hussain & Faiz Ullah (2011) attempted to evaluate the effect of lime as modifier in asphalt concrete mix and replacement of conventional stone dust filler. Marshall mix design method was employed to arrive at the optimum binder content of 5.8% for the control mix. The modified asphalt concrete mixes were prepared using hydrated lime in varying percentages. The statistical analysis of the indirect tension tests results revealed that there was significant effect of use of lime as modifier in asphalt mix and replacement of crushed stone filler.

Shivangi Gupta &Veeraragavan (2009) investigated the benefits of SBS polymerwas used to modify conventional binder and its physical and mechanical properties were studied for both Marshall and superpave gyratory compacted specimens. The study concluded that higher density values could be achieved forthe superpave mixes possibly because of higher compaction factor. The tensile strength and marshall stability values werereported as higher by 21% and 25% for the SBS modified mixes than conventional mixes. The resilient modulus increased between 2 to 2.5 times for the polymer modified mixes. It was stated that SBS polymer modified bituminous mixes could be recommended for national highways for its increased fatigue life performance under constant temperature.

Davidovits (1991)demonstrated the technological progress made in the last few years through the development of new materials such as 'geopolymers'. The study reported that with the need for alternate building materials, new state of- the-art materials designed with the help of geopolymerization reactions have new applications and procedures and transforming ideas granted in inorganic chemistry. The study strongly reported that high temperature techniques are no longer necessary to obtain materials which are ceramic-like in their structures and properties. These new invented materials can polycondense just like organic polymers, at even lower temperatures. The article presented the chemical process involved in geopolymerization with chemical reaction of alumino-silicate oxides ($Al3+$ in IV-fold coordination) with alkali polysilicates yielding polymeric Si-O-Al bonds.

Davidovits (1994)attempted with an expectation of possible way to reduce carbon dioxide emissions by 5 t0 10% by reducing the use of fossil fuel and new energy technology. The naturally occurring amino-silicates such as kaolinitewere transformed in low temperature for a short period into three dimensional tecto-aluminosilicates. The thermo setting method was employed for polycondensation of organic resins. The geosynthesis was termed as abilityof the aluminium particle to induce crystallographical and chemical changes in silica structure. The study demonstrated that at low temperature transformation, kaolinite into hydrosodalite tremendous latent energy in the new mineral reaction was observed. The research clearly established the process of formation of geopolymers which reported to be inorganic, hard, stable at temperature upto 1250°C and non flammable.

Hardjito & Rangan (2005) carried out the experimental and analyticalstudy to investigate the application of heat-cured low-calcium flyash based geopolymer concrete in large scale reinforced beams and columns. The structural strength, crack pattern, deflection and ductility were analysed and correlation was done with the ordinary portland cement concrete beams and columns. The crack patterns and failure modes observed for geopolymer concrete columns and reinforced Portland cement concrete columns were reported to be similar. The failure load of test columns were observed to increase as the load-eccentricity decreased, and as the longitudinal reinforcement ratio and concrete compressive strength increased. A good correlation was found between test and calculated failure loads and the study demonstrated the design procedure for Australian standards for its application in concrete industry.

Mustafa *et al.* (2012) highlighted the usage of flyash into a geopolymer binder. It was reported that the compressive strength increases with the optimum NaOH molarity, flyash/ alkaline activator ratio, $Na2SiO3/NaOH$ ratio used, and curing process handled. The study also concluded that fly ash- based geopolymer also provides superior performance giving its better resistance to aggressive environments compared to normal concrete. However, it was reported that different samples of flyash from different sources may result different reactivity due to their varying chemical compositions.

Kong & Sanjayan (2010) **s**tudied on the effect of elevated temperature on geopolymer paste, mortar and concrete made with flyash as a precursor. Various experimental parameters such as specimen sizing, aggregate sizing, aggregate type and superplasticizer type were examined. The study reported that specimen size and aggregate size were found to be two main factorsthat govern geopolymer behavior at elevated temperatures (800°C). It was concluded that aggregate sizes larger than 10 mm resulted in good strength performances in both ambient and elevated temperatures. Strength loss in geopolymer concrete was observed at elevated temperatures as an attribute to the thermal mismatch between the geopolymer matrix and the aggregates.

Dukatz & Anderson (1980) reviewed a research project to study the effect of mineral filler on the properties of asphaltic mixtures. The main objectives were: to determine the gradation and physical properties of typical mineral fillers and to determine the effect of the type and quantity of mineral filler on the mechanical properties of filler-asphalt mixtures; and to the mechanical properties of asphaltic concrete paving mixtures to understand the effect of filler material. Totally eight mineral filler were collected from two different sources and were used in the asphaltic mixtures to evaluate the mixture properties. Modified cone and plate viscometer test were performed at four temperatures for filler mixtures prepared with two filler-asphalt ratios. The studyconcluded that among the samples with flyash used as a filler material resultedin better performance in terms of mechanical properties; however the variation in the chemical composition of the flyash may give varied results.

Samia Saoula *et al.* (2013) carried out the research by considering the aging of bitumen as significant factor in the mechanical behaviour of mixture. This study presented experimental results of the rheological behaviour of a class of bitumen 40/50 to the artificial aging. Three aging temperatures 163˚C, 173˚C and 183˚C were selected for the study. From the experiment results, a study of the risk of deformation of asphalt was performed and correlation between the behaviour of the coated and the binder deducted SHRP specifications was obtained. It was concluded that stiffness of the aged binders increases with aging temperature. There was no risk of rutting and fatigue cracking reported by the study under the varied high temperature.

Christensen & Anderson (1992) attempted to study the Dynamic mechanical analysis, as it was considered that the other methods of rheological testing, which have found many application in the study of asphalt behaviour over many years. However, there was some confusion in the interpretation of dynamic mechanical data on asphalt cements. Study focused on review of articles on appropriate methods of interpreting rheological data on paving grade asphalts, test data for a number of asphalt cements having widely different properties and were analysed in light of rheological theory and appropriatemathematical models.

Bruce W Ramme *et al.* (2016) presented the research work on laboratory and field demonstration work with use of flyash in hot-mix asphalt. It was reported that microstructural investigation (SEM) of the asphalt binderswith fly ash showed crack- arresting behavior induced by the spherical fly ash particles incorporated into the bitumen matrix. It was concluded that the rheological performance of the asphalt binders was performed and confirmed the feasibility of fly ash application for improvement of the performance of asphalt binders. It was reported that incorporating flyash increases the rutting factor $G^*/\sin(\delta)$ and dynamic viscosity η' of plain binders (PG-58-28 and PG-70-22). The authors concluded that the application of fly ash in the bitumen increasedthe shear modulus, and the performance of modified material was superior to the plain bitumen. Also, The best results were demonstrated by Class F fly ash at 15% which improved the grade of the binder from PG-70 to PG-76 and both classes of fly ash when used at 60% increased the grade of bitumen from PG 58 to PG 64. Study reported that fly ash may actually facilitate the mixing and compaction of ASHphalt (The blend of asphalt binder and fly ash) due to predominance of spherical particles giving the “micro-ball-bearing effect” while mixing.

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