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Durability and long term performance of geopolymer stabilized reclaimed asphalt pavement base courses

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HIGHLIGHTS

- Promotes the usage of recycled asphalt pavement (RAP) and fly ash in base courses.
- Alkali activation of fly ash increased the reactivity, thus, the strength of mortar.
- Permanency of the base course mixes are studied by durability and leachate tests.
- Strength of mixes continue to increase up to 224 days, though, marginal after 56 days.
- No detrimental affects are noticed due to aged bitumen coat on RAP aggregates.

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ABSTRACT

Utilization of reclaimed asphalt pavement (RAP) materials in pavement base courses has proven to be a viable alternative not only to conserve the natural resources but also to reduce the environmental pollution and landfilling. Recent studies demonstrated that untreated RAP is inefficient to be used as a pavement material unless blended with virgin aggregates (VA) and/or stabilized with additives, because of their inferior gradation and bonding characteristics. Most of the design guidelines limit the amount of RAP in the base course up to 30% by weight of the virgin aggregates, in lieu of the aged bitumen coating present on the RAP aggregates and lack of understanding of the long term performance of the material. Hence, in this study it is proposed to promote a high percentage of RAP in the base course by stabilizing the RAP:VA mixes with a fly ash. However, the presence of the aged bitumen over the RAP aggregates may affect the long term strength and durability of the design mixes. Hence, to attain the desired design strength, the fly ash is activated in an alkali environment to form a geopolymer by triggering the unreacted polymeric compounds present in the fly ash. However, exposure of these mixes to the severe moisture and temperature variations may alter the cementation. This process may lead to strippage of the asphalt coating from the RAP aggregates and leach out the stabilizer from the mixes. Hence, the present study verifies the suitability of these mixes in terms of their initial compressive strength and the corresponding retained strength after exposure to the alternate wet/dry cycles in the severe laboratory environment. The permanency of the stabilizer/activator is also verified through leachate studies. Variation in the hydration products and oxide contents of the mixes are verified at every stage using X-ray diffraction (XRD) and X-ray florescence (XRF) studies. The comprehensive test results indicated that the strength loss of RAP:VA mixes is very minimal and are found suitable for the base course applications.

1. Introduction

In view of the scarcity of natural aggregates and increased demand for sustainable pavements, use of reclaimed asphalt pavement (RAP) materials has gained prominence [1]. RAP is a waste material produced when an existing distressed asphalt pavement is removed or milled. There are in-situ and ex-situ methods available for the production of RAP depending on the site conditions and applications [2,3]. However, the percentage of its production and the utilization has no comparison and it finally ends up in either stock piles or land filling in large quantities. Promoting high RAP contents in pavement construction has become the research interest. Researchers focused on milling the existing underperforming pavements and reusing it with stabilization/modification

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to produce high performance surface and base/subbase courses. The performance of these pavements has been considerably improved in terms of surface characteristics, strength, stiffness and durability [4,5].When RAP is used in the surface course, texture of the pavement is highly important as it governs the friction resistance and overall safety of the driver [6]. RAP is also encouraged to use as a base course material; but RAP alone does not meet the required strength and stiffness criteria [7–11]. In this regard, several researchers have attempted to blend the RAP material with virgin aggregates (VA) and/or lightly stabilize with various cementitious additives to improve their strength and stiffness properties [3,7–11]. These research studies suggest that the VA:RAP mixes stabilized with either lime or cement can be successfully adopted in the base course layers of flexible pavements. Despite of the improvement, several state transportation agencies in the US including Colorado, Texas, Virginia and other states recommend to use a maximum RAP content of about 30% by weight of VA in the pavement layers [12,13]. The limitation is imposed mainly to avoid premature pavement failures when RAP is used in the base courses, as the RAP material contains aged bitumen coating on the surface, which is assumed to hinder the pozzolanic reactions between the binder and the aggregate. Hence, high dosages of stabilizers are required to increase the percentage of RAP in the VA: RAP mix to form RAP:VA mix and to improve the bonding between the virgin and reclaimed aggregates. This solution proves to be uneconomical due to high percentage of conventional stabilizers are involved. In addition, very high dosages of stabilizers will result in shrinkage cracking and subsequent failure of the pavements. Alternatively, low calcium stabilizers such as fly ash, bottom ash, blast furnace slag etc. can be adopted to minimize the costs, energy as well as carbon footprint. In spite of the presence of sufficient calcium, it may happen that the low calcium stabilizers may not impart required strength because of the low reactivity of the binder. This may particularly happen when the pozzolanic binders like fly ash are used for the stabilization. In such cases, the reactivity can be further improved in the presence of alkaline environment. Alkali activation of pozzolanic stabilizers creates highly alkaline medium (pH > 12), which dissolves glassy phases of the fly ash and form products which are semi crystalline to amorphous in nature. This helps in enhancing the polymerization in the mix, thereby increasing the strength. Alkali activation of such mixes has been successfully attempted by various researchers. Past research studies established that the alkali activation triggers the reactivity of fly ash thereby improves the performance of the material in terms of unconfined compressive strength (UCS). Most of the studies discussed fly ash activation by using strong alkalis such as sodium hydroxide or a combination of hydroxide and silicates or aluminates [14–19]. When the silica/alumina content in the mix is not sufficient to form pozzolanic reactions, addition of silicates and/or aluminates improves the bond strength. The influence of Na_2SiO_3/NaOH ratio in developing optimum strength and stiffness is also discussed in the recent studies [14,19]. In the similar lines, several other construction, demolition, industrial and municipal wastes are being stabilized with a motive to conserve natural materials and to reduce waste accumulation [10,19,20].

The above mentioned stabilization techniques on RAP could impart promising strength and stiffness to the RAP:VA mixes. However, the longevity and efficiency of any stabilization/activation technique has to be confirmed by proper durability assessment. It may happen that the stabilizer/activator/cementitious products may leach away or disappear during the service period. This is possible when rain water infiltration takes place or when the reactions get reversed due to several temperature and moisture variations. This may more rigorously happen when secondary materials like RAP are used in the pavement layers. In this regard, durability assessment is a definite prerequisite before adopting any stabilization or activation technique in the field. In this study, fly ash treated RAP:VA mixes at various proportions are tested for their efficiency as base course material in the flexible pavements. An attempt has also been made to activate the fly ash to form a geopolymer in an alkaline environment (NaOH) to enhance the performance of the RAP:VA mixes. The durability studies are performed on the mixes by conducting standard laboratory tests on 28 day cured samples. The sustenance and permanence of the cementation and strength in the respective mixes is also assessed in longevity studies at curing periods up to 224 days. This study is envisaged to help in promoting an innovative and sustainable material like fly ash stabilized RAP in the pavement construction without any premature failures.

2. Background

Stabilized RAP mixes have been on global research for their efficiency in terms of strength and stiffness. However, the durability aspect of these mixes was dealt in very few investigations. The issue with many stabilization techniques is the durability or permanency of the cementation, which may alter its performance over a period of time. Durability in this context may be defined as the ability of the mix to resist severe environmental conditions such as moisture and temperature fluctuations, chemical attack, and abrasion while sustaining its desired engineering properties. Leaching of the chemical stabilizer during seasonal moisture movements in the base layer may affect the durability and sustainability of the pavements. This aspect of durability was studied by Chittoori (2008) in connection with the soil stabilization projects [21]. The durability of the stabilized RAP mixes was studied by Ganne (2009) by subjecting the cement stabilized VA:RAP mixes (containing 50, 75 and 100% RAP) to alternate wet/dry cycles as per ASTM D 559 which measures the resistance of weight loss to 14 cycles of wetting and drying or 14 cycles of freezing and thawing [22]. Ganne (2009) found that the percentage strength loss was around 10–15% on an average for all the mixes studied. Researchers have reported the loss of stabilizers from the base layers after certain service period. It is reported that these problems are not due to abrasion of the pavement but because of the detrimental secondary chemical changes in the stabilization process. In many cases this change is associated with the moisture absorption into the stabilized materials. The study by McCallister (1990) proved that the capillary rise of water in stabilized surface is highly detrimental and can induce some secondary reactions [23]. Due to the metastable nature of many of the mineral phases in chemical stabilization, the water movement makes the alkali and alkali earth metals to leach out and there by decreases the strength of the stabilized layer. Previous studies reported that the infiltration of moisture through the subgrade soils result in variations of pH and Ca/Mg ratios, which can influence the permanency of the chemical modifiers [19]. Leachate studies by Ganne (2009) proved that the effect of leaching on strength of cement treated RAP mixes were minimal. After leaching cycles, the samples have retained about 85–90 percent of their initial UC strengths [22].

In the current study, initially the influence of fly ash stabilization and subsequent NaOH activation on the strength of the RAP: VA mixes is evaluated in terms of UC strength. The durability assessment studies are conducted on 28 day cured specimens by subjecting the samples to alternate wet/dry cycles and pressurized water percolation to replicate the seasonal moisture variations (leachate studies) in the controlled laboratory conditions. Longevity studies are also performed at longer curing periods of 56, 112 and 224 days to verify the sustenance of the UC strength.