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An economical processing technique to improve RAP inclusive concrete properties

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HIGHLIGHTS

- A novel beneficiation method for treatment of RAP is introduced.
- Beneficiation by AB&AT method improved the mechanical properties of aggregates.
- Compressive, flexural, and split tensile strength of concrete increases significantly.
- Incorporations of RAP enhanced the durability properties of concrete.

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ABSTRACT

The presence of asphalt film around Reclaimed Asphalt Pavement (RAP) aggregates has been reported as the main factor lowering the properties of RAP inclusive concrete. A novel Abrasion and Attrition (AB&AT) technique to improve the quality of RAP by removing the contaminant layers of dust and punching the asphalt film adhering to RAP aggregates is introduced in this paper. The effect of incorporating Dirty RAP (DRAP), Washed RAP (WRAP) and AB&AT treated RAP, on the fresh, mechanical and durability properties of concrete are also investigated and compared with each other. The mechanical properties of RAP aggregates were found to be increased significantly on processing with AB&AT method. Beneficiation of RAP by AB&AT method increased the compressive strength of concrete by 9.74% &12.71%, split tensile by 2.66% &12.21% and flexural strength by 6.05% & 8.55% as compared to WRAP and DRAP inclusive concrete. Incorporation of RAP into concrete mix improved workability & cohesiveness. Durability properties of concrete such as water absorption, initial rate of water absorption, total permeable voids and coefficient of water absorption were observed to be reduced for RAP inclusive concrete.

1. Introduction

In the scenario where there is an immense scarcity of natural aggregates and paucity of funds, it is imperative to inculcate a sustainable approach to offset the utilization of natural aggregates and one of the best alternatives is to utilize recycled aggregates. The Ministry of Road Transport and Highways (India) has decided recently to adopt rigid pavement as the default mode of construction across the country due to superiority of rigid pavements over flexible pavements. Considering the necessity to replace flexible pavements by rigid pavements, disposal concerns, and scarcity of natural aggregates paves the way of utilising Reclaimed Asphalt Pavement (RAP) aggregate in concrete pavements. A lot of studies have already been conducted on the use of RAP for partial replacement of Natural Aggregates (NA) in pavement base and subbase courses [1–10] but studies on RAP for concrete pavements is meagre as on today.

RAP is the material freshly milled from a flexible pavement during rehabilitation and construction [11] whereas Fractioned RAP (FRAP) is that RAP resulting from sieving through standard sieves. Thus, the gradation of FRAP is considered to be better than RAP on account of presence of less agglomerations, dust and fines which would eventually affect the properties of concrete in both fresh and hardened states. Screened RAP was observed to reduce some of the dust and binder content adhering to RAP aggregates [12]. Washing of RAP is another valuable method to further remove filler and dust attached to aggregates [13]. Washing of RAP could also remove coated asphalt film around the aggregate to some extent as observed from present study and this enables to create windows imparting stronger bonding between cement mortar and RAP aggregates. It was observed that up to 35% replacement level,

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concrete containing Dirty RAP produced highest compressive and split tensile strength irrespective of days of curing than that of concrete containing sieved dirty RAP and washed RAP [14]. Although proper reason in achieving higher compressive and split tensile strength for concrete containing dirty RAP have not been disclosed in the literature, but it's a common practise to wash the aggregates before use to remove dust adhering to aggregates and removing of the same would affect the durability of concrete considerably [15].

Incorporations of RAP in concrete resulted in reduction in compressive strength [13,14,16–25] flexural strength [13,14,16,17,19,23,24,26] and split tensile strength [13,14,19,22,25,26]. The slump of fresh concrete may increase due to the hydrophobicity of the asphalt layer [13] or decrease due to the high viscosity of asphalt layer [16] and irregular shape of RAP aggregates [27]. Air content of fresh concrete remained almost unchanged [13,19] and unit weight decreased. [13,17,19]. The reduction in properties of RAP inclusive concrete was attributed to the weak bonding between the cement mortar and RAP aggregates due to the coated asphalt film at the interface of aggregates and mortar. On the other hand, coated asphalt film helps in increasing the toughness properties of concrete by arresting the crack propagation [28]. From the available literatures, it was observed that the studies of RAP inclusive concrete conducted so far, were mostly confined to mechanical properties of hardened concrete.

Bonding between cement mortar and RAP aggregates primarily depends upon the roughness of the aggregates and compatibility between the mortar and aggregates [13]. Since the surface of RAP is coated with smooth asphalt film, chances of bonding between cement matrix and aggregates reduces and the bond that develops being weaker in nature causes cracking in mortar even under mild impact loading. In order to achieve firm bonding at the interface of hydrated cement mortar and aggregate, essentially, coated asphalt film needs to be removed partially or completely.

In this context, there are various methods for the removal of asphalt from RAP aggregates such as Abson recovery [29], Ignition [30], and centrifuge [31] method. Few of the aforesaid methods facilitate complete removal of coated asphalt using selective chemical reagents viz., benzene, carbon tetrachloride, toluene, petrol, kerosene etc. but involvement of such solvents has proven very expensive and not desirable for larger sample size.

Available literatures prompt that, RAP in concrete results reduction in properties but seem to be a novel technique to replace some amount of natural aggregates.

In the present study, efforts have been made to device a new technique which has the potential to remove the dust, agglomeration and coated asphalt from the RAP aggregates.

1.1. Research significance

Based on the present comprehensive literature review, researchers have used the RAP either directly in as received condition or simply washed, in partial replacement of NA in cement concrete mix. There were seldom or no attempts before to remove or puncture the asphalt engulfing around the RAP aggregates, hence, the present study is one of its kind, which has attempted to utilize RAP judiciously into cement concrete mix for construction of cement concrete pavements.

2. Experimental investigation

2.1. Materials

RAP was collected from a large stockpile which was obtained through ripping and crushing from distressed old flexible pavement (more than 20 years old) as can be seen in Fig. 1. RAP obtained through this process is being dumped in a stack-yard depicted in Fig. 2. The aforesaid RAP was a mixture of both wearing course and Bituminous Macadam. Bituminous Macadam consists of all-in coarse aggregates (Size > 2.36 mm) and fine aggregates (size 2.36–0.075 mm) mixed in presence of asphalt (3.0%–3.5% by weight of dry aggregates) to produce well stable mixture to be used for bound base course of flexible pavement. Demolition of the same would generate well graded mixture of all in aggregates as found in present study.

Fig. 1. Milling using Ripping & Crushing.

Fig. 2. Stockpiled RAP.

A large amount of dust was present on the surface of the RAP aggregates which can be attributed to the life of stockpiling (1.5 years) during which it was exposed to all seasons. During summer, dust may have created a bond with the soft asphalt layer. Thickness of this dust layer mainly depends upon the layer of pavement to be removed, method of removal, and duration and exposure environment of stockpile. RAP from base layer may contain high amount of dust as compared to RAP removed from wearing course. Removal of RAP by milling creates very less dust impurity in RAP as compared to ripping and crushing [33]. If RAP is stocked in a covered manner then it will protect any foreign matter to enter, which is very rare due to its large quantity. In developing countries like India, RAP is removed in bulk by ripping the entire pavement and then crushing it and stocking in open for long duration. This ensures a thick film of dust around the RAP aggregates in which the dust layer around the asphalt coating is firmly adhered whereas the distant dust layer is loose and can be removed by effective sieving or washing. Moreover, some amount of agglomeration particles may be present on the surface of RAP aggregates depending upon the size of aggregates and type of removal method used. Considering above, RAP is a 4-phase aggregate which consists of aggregate, asphalt film, stiff dust film and loose dust film, making 2 transition phase; one from aggregate to asphalt coating and second from asphalt film to dust layer (Fig. 3-a). Producing concrete with RAP aggregates in dirty form can results in poor bond between mortar and dust film thus impairing the properties of concrete. Removal of this dust film is necessary to improve the bonding. Similarly, removing the asphalt film completely or breaking its continuity, may increase the chances of better bonding (Fig. 3-b). Keeping both in mind one new method which is easy, economical and less time consuming is proposed which resulted in better bonding than the previous studies.