SuPerPave® Recycled Asphalt Mix-Design Guidelines

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Superpave® recycled asphalt mix-design guidelines are a reference for engineers and researchers concerned with reusing RAP (Reclaymed Asphalt Pavement) in asphalt concrete mixtures designed according to the Superpave® system.

Keywords: mix-design ; recycled asphalt ; RAP (reclaimed asphalt pavement) ; RAP binder ; virgin binder ; RAM (reclaimed aggregate material) ; SuPerPave®

1. Introduction

From 1987 through 1993, the Strategic Highway Research Program (SHRP) carried out several major research projects to develop the Superpave® method for performance based HMA (Hot Mix Asphalt) design. One limitation of the Superpave® method is that it makes no specific provision for the use of RAP in the mixture design process. To remedy this situation, the Federal Highway Administration's Superpave Mixtures Expert Task Group used past experience to develop interim guidelines for the use of RAP in the Superpave® method [1][2].

These guidelines reflect the fact that the effect of aged binder from RAP on the performance properties of the virgin binder depends upon the level of RAP in the HMA. When the level is low, the effect is minimal, and the RAP is likened to a "*black rock*" that influences the mix volumetrics and performance through its aggregate gradation and properties. As the level of RAP in the HMA increases, the black rock analogy breaks down, the aged binder blends with the virgin material in sufficient quantity to significantly affect its performance properties [2].

2. RAP as a sustainable resource for the production of Recycled Asphalt mixtures

In the perspective of sustainable development, road construction field offers several solutions, among which the recycling of damaged road pavements is the most important. During their life, flexible road pavements are subject to asphalt layers degradation. To restore the structural and/or functional pavements integrity, it is necessary to perform maintenance work that, most often, involves the damaged layers replacement, with consequent accumulation of waste material commonly called RAP. In the European context RAP is called RA (Reclaimed Asphalt) and it is defined as "*the processed material in the form of milled or the ripped-up slabs from existing bituminous road layers and the asphalt mixtures from surplus, rejected or failed productions*" [3][4].

In Europe in 2018, approximately 300 million tons of asphalt concrete were produced and, today, on the continent more than 90% of the 5.5 million kilometers of roads are made with this material [3]. The option of landfilling RAP is generally rejected in favor of alternatives that involve recycling it within the road pavements themselves. This issue is of extreme importance, as reflected in the considerable amount of recent studies available in literature [5][6][7][8][9][10][11][12][13][14][15]. These studies investigated short and long-term mechanical performance of recycled asphalt mixtures [5][7][8][10][11][12], the outlook and benefits of their use [4][9], mix-design issues [6][13][14], and RAP use in road embankment construction [15].

3. Comments on the use of guidelines in Europe

Among the most widely international recycled asphalt concrete mix-design references are the guidelines developed by the SuPerPave® Mixtures Expert Task Group [1]. These guidelines highlight that, influence of RAP binder on performance properties of blended binder (RAP binder + virgin binder) depends of RAP percentage in asphalt concrete mixture. When RAP percentage is low, its influence is minimal and RAP is compared to a "*black rock*" (pure inert aggregate) that only influences volumetric properties of asphalt concrete mixture through its grading and physical/mechanical properties. As RAP percentage increases, RAP binder binds to the virgin binder in such a way that it significantly influences performance properties of blended binder [2].

The characteristics of a recycled asphalt mixture depend not only on the amount of recycled materials, but also on their nature. In the USA, RAP and RAS (Recycled Asphalt Shingles) are increasingly being recycled simultaneously [16]. More than 99% of RAP and about 1 million tons of RAS are used to make recycled asphalt concrete [17]. To take into account the simultaneous presence of different nature materials (RAP and RAS) the same NCHRP 452 report [2] has been updated several times [17][18][19]. Initially, the NCHRP specifications set limits for the use of RAP and RAS in asphalt

mixtures, referring to their percentage by weight of total aggregate weight. However, this approach does not properly evaluate either the aged binder content in RAP and RAS or the overall performance characteristics of blended binder [20]. To overcome these limitations, updates to NCHRP Report 452 adopted the concept of Reclaimed Binder Ratio (RBR), which was previously introduced by AASHTO M323 [21].

Specifically, many USA agencies consider RAP and RAS Binder Ratios to be mutually equivalent and additive quantities. Today, this approach is no longer considered reliable because, as already pointed out, these amounts are not additive. In fact, RAS contributes an amount of aged binder in blended binder that is about twice as much as that contributed by an equal amount of RAP [20][22]. Therefore, it can be said that there is no widely recognized method to evaluate the performance characteristics of blended binder [20]. The problem is obviously related to the correct interpretation of effects produced by shingles in recycled asphalt mixture.

Authors believe that this problem is a "*false problem*" if one takes into account that, the use of RAS in pavement recycling is still subject to severe limitations. For example, in the USA, although shingles are present in large quantities, their recycling has been considered only in recent years. In Europe, the use of RAS in road pavements is even more limited [16]. Based on these considerations, authors believe that it is permissible to neglect (especially in the European context) the use of RAS, therefore, it is reasonable to refer to the SuPerPave® mix design guidelines defined in NCHRP Report 452 [23][2].

4. A mix-design experience of Recycled Asphalt Concrete in the European Standards Context

The recycling of degraded road pavements requires extensive experimental investigations, especially when RAP percentages to be reused are high (>30%). The guidelines developed by the SuPerPave® Mixtures Expert Task Group allow for the mix design of recycled asphalt concrete to be approached in a rational way. This rational approach was applied to studying the mix design of recycled asphalt concrete mixtures for wearing course layers with high RAP percentage (30%, 40%, and 50% by weight). Then, it was evaluated the compatibility and reliability of the above guidelines with respect to the requirements imposed by European standard EN 13108-1.

The authors first studied the rheological performance characteristics' determination of the bituminous binder blend consisting of a RAP binder and virgin binder addition. In the blending strategy phase, unlike SuPerPave® guidelines, neither the "*blending at know RAP percentage*" nor the "*blending at a known binder grade*" method was applied. Instead, an original "*hybrid procedure*" was adopted, which involves the use of a single virgin binder of known characteristics, and requires the choice of RAP percentages and requires that the analytical calculation of critical blend temperatures (T_{blend}) be carried out with reference to SuPerPave® specifications. The results obtained in this way were experimentally verified by operating on specially prepared blends of the RAP binder and virgin binder (blended binder). This verification allowed to highlight their remarkable convergence to the estimated critical temperatures calculated with the SuPerPave® approach.

The next phase of recycled asphalt mixtures mix-design involved the study of dry aggregates mixtures' particle size gradation. This was performed according to EN 13108-1, and it was necessary to integrate aggregate gradation with limestone of good mechanical properties and to replace 3% of the natural filler with monohydrated lime.

Finally, a basic mechanical characterization of the designed mixtures was carried out in order to express a preliminary judgement on the effectiveness of their performance characteristics, which turned out to be fully satisfying the minimum European standards.

The authors remark that the research may have future developments in different areas such as, for example, the study of the effects produced by the use of FCA (Functional Chemical Activant), the mixture's mechanical characterization in relation to the fatigue phenomena (FC-Fatigue Cracking), permanent deformation (rutting), durability, etc.

Based on the abovementioned limitations, the results confirmed the full reliability of SuPerPave® rational mix-design methodology. The experimental results also showed that the basic mechanical performance was fully satisfactory with respect to European requirements/standards, thus confirming the effectiveness of the rational approach to the road pavements recycling in the European Standards Context.

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