CONSTRUCTION WASTE IN HOT MIX ASPHALT

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Abstract

This paper analyzes the effect of water on the durability of hot asphalt mixtures made with recycled aggregates from construction and demolition waste. To design the asphalt mixtures Marshall tests were carried out. Indirect Tensile tests were carried out to evaluate stripping behavior. The mixtures tested were fabricated with 0%, 20%, 40% and 60% recycled aggregates. The hot asphalt mixture specimens made with different percentages of recycled aggregates from construction and demolition waste and of natural quarry aggregates showed poor stripping behaviour. This poor stripping behaviour has a negative effect on the durability of hot asphalt mixtures containing this type of recycled aggregates

1. Introduction

Waste is one of the most serious environmental problems facing modern societies. This situation is worsening because of the increasing amount of waste that is being generated and the close relationship between income levels and quality of life and the sheer volume of waste produced. In this regard, since road building projects are public works that use large quantities of materials, which generally come from the quarrying industry, it is necessary to carry out an in-depth study on all the possible uses of wastes in road building (1-6). Therefore, this article examines the possibility of using aggregates from construction and demolition waste in hot mix asphalt for low-volume traffic roads.

2. Characterization of the materials

2.1. Natural quarry aggregates

Two different types of natural aggregates (NA) were used. First of all the mixtures were designed with an aggregate supplied by a quarry located in the municipality of Carral in the area surrounding A Coruña (Spain), in fractions of 0/6, 6/12 and 12/25. This aggregate was Feldspar Schist whose principal components are quartz (35%), sodium feldspar (30%), colourless or muscovite mica (20%) and chlorite (15%). Also used as a natural aggregate was a dolomitic calcite from a quarry in the municipality of Baralla in the province of Lugo. Both aggregates meet the PG-3 specifications (from 2002) (7), since all of their sides are of the fracture type. They have a flakiness index of ≤20% in all the fractions of coarse aggregate tested. The Los Angeles fragmentation coefficient ranges between 25% and 30% and the sand equivalent is greater than 50%.

2.2. Recycled aggregates.

The recycled aggregates (RA) from Construction and Demolition Waste (CDW) were supplied by the plant owned by the company TEC REC, located in Crtra. Valdemingómez PK 0+700 (Madrid) (Figure 1). These aggregates present the granulometry required for fillers in fraction 0/40. Their approximate composition in weight is as follows: Concrete (72%); Stone (20%); Ceramic (3%); Plaster and other impurities (1%) and Bituminous materials (4%). The flakiness index and sand equivalent values meet the requirements stipulated in the Spanish specifications PG-3

(2002). The Los Angeles fragmentation coefficient is 30%. This value does not meet the requirements for heavy traffic laid down in PG-3 (2002) (7) for heavy traffic flows T00 and T0 on base courses (8). Moreover, the absorption coefficient of RA (coarse) is 4.86%, which is a much higher value than those presented by the NA.

2.3. Bitumen

A bitumen with 60/70 penetration and a value of 48.5 on the ring and ball softening point test was used. The penetration index was equal to -0.8 and density, 1.03 g/cm^3. The bitumen complied with all PG-3 specifications (7).

3. Results

3.1. Mix design

Mixture type AC 22 base G (formerly G-20) was selected for use in base course layers. A total of 9 asphalt mixtures with the same granulometric composition, but different percentages of RA were designed. The Marshall Method (NLT-159) (9) was used to elaborate the mix designs in accordance with the PG-3 of 2002 (7). Figure 2 shows the granulometry selected for all of the mixtures. In all of the mixes 4.75% cement was used as filler. Table 1 presents the four mixes that used feldspar schist (S) as a natural aggregate. The RA percentages of these mixes were as follows: 0%, 20%, 40% and 60%. These RA percentages were used in the coarser fractions of the granulometric curves. Later, two asphalt mixtures were prepared with 20% and 40% of RA material after being tested on the Los Angeles Abrasion Machine to eliminate the mortar adhering to the recycled aggregates. These two mixes are specified in table 1 under the nomenclature AC22-20A-S; and AC22-40A-S. Finally three asphalt mixtures were elaborated using natural calcite aggregate (C), with RA percentages of 0%, 20% and 40%.

Table 1 presents the values of the Marshall parameters: Voids in the mineral aggregates (VMA); Voids in the mixture (Va); Flow (F); Stability (S) and Unit Weight (UW), in addition to the optimum bitumen percentage (Bo). On the basis of the results shown in this table, it may be inferred that all the mixtures can, in principle, be used in base courses for low volume roads (T3 traffic category), pursuant to the requirements specified in PG-3 of 2002 (7). Traffic category T3 refers to the following interval of Annual Average Daily Heavy Traffic: 50≤ AADTH<200.

The results provided in table 1 show that the specimens made with RA from CDW have a higher percentage of voids in the aggregates. This table clearly shows that as the percentage of RA in the mixtures increases, the percentage of voids in the aggregates also rises. Hence, mixtures made with RA require a higher optimum bitumen percentage than those elaborated only with NA. This behavior occurs in the mixtures fabricated with RA and aggregates from schist, as well as in the mixes made with RA and calcite aggregates. It is also interesting to note that the densities of the mixtures diminish as the RA percentage increases. The densities of the mixtures containing calcite aggregates are greater due to the higher bulk specific gravity of these aggregates. This is evidenced by the fact that the mixtures containing calcite aggregates have a lower percentage of voids in the aggregates than the mixtures with schist, and therefore a lower optimum bitumen percentage is required.

However, table 1 shows that mixtures AC22-20A –S and AC22-40A-S, which do not contain any mortar adhering to the RA or impurities, behave differently. Thus, the percentage of voids does not increase with the percentage of RA. Nor do they require a greater amount of bitumen to fill the voids in the aggregates. It is interesting to note that with these two mixtures, practically the same Marshall parameter values are obtained. On the basis of these results, it may be inferred that the mixtures elaborated with RA have more voids than the mixtures designed only wih NA. The higher void percentage may be attributed to both the mortar adhering to the RA from the demolition of structural elements fabricated with concrete and the various impurities: plaster, bricks, etc., found in CDW. All of this translates to a greater absorption of water. Moreover table 1 shows a rising tendency in the Marshall stability of the mixtures as their RA percentage increases.

3.2. Mixture Stiffness

Figure 3 presents the values of the stability/flow ratio (Marshall Modulus) in terms of the percentage of bitumen for the two types of mixtures fabricated with feldspar schist. It can be seen that the mixtures without the mortar adhered to the recycled aggregate are not as stiff. Hence, in figure 3a, mixture AC22-40A-S is located below mixture AC22-40-S. The same thing happens in figure 3b; mixture AC22-20A-S is located below mixture AC22-20-S. These results show that when the mortar is removed from the cement containing RA, the stiffness of the mixtures decreases.

3.3 Resistance to moisture damage

The resistance of these mixtures to water action was evaluated by means of the immersion-stripping test according to standard UNE-EN- 12697-12 (10). Six specimens of each mixture type designed under the conditions indicated in the test standard were tested. Table 2 shows the results of the Indirect Tensile Strength Test (ITS) in specimens in both the moisture and dry state. The tensile strength ratios (TSR) are also given.

In mixtures using 100% feldspar schist as the natural aggregate (AC22-0-S), the value generated on the tensile strength ratios was 79%, which did not reach the 80% threshold required in the PG-3 (year 2008) (11) for hot asphalt mixes used in base courses. Mixture AC22-20-S, which is designed with 20% RA from CDW, has a tensile strength ratio value of 64%, and did not reach the above threshold. Mixture AC22-40-E, which uses 40% RA, does not meet this criterion, either. Mixture AC22-60-E is the exception, with a TSR of 87%. Mixtures AC22-20A–S and AC22-40A-S, which are fabricated with RA subjected to the abrasion process in the Los Angeles Machine, exceeded the 80% threshold, offering tensile strength ratios of 85% and 83%, respectively. Both mixture AC22-0-C and mixture AC22-20-C, which used a natural calcite aggregate and 0% and 20% RA, offered excellent tensile strength ratio values of 85% and 92%, respectively. The tensile strength ratio of mixture AC22-40-C was only 72%.

Table 2 shows the broad variability of the results of the indirect tensile tests. It is surprising to see that mixture AC22-0-S yields a result of 79% tensile strength ratio, which does not reach the 80% minimum threshold for base courses. Mixtures AC22-20-S and AC22-40-S do not achieve this threshold, either. In contrast, mixture AC22-60-S, which contains the highest RA percentage, shows a tensile strength ratio of 87%, above the required threshold. At the present time, there is no explanation for these results, since the tensile strength ratio should be lower, given the greater percentage of RA, unless the adhesive quality improves with the decrease in natural silicon aggregates. Clearly, more specimens must be studied to be able to obtain conclusive results. On the other hand, mixtures AC22-20A-S and AC22-40A-S yielded good tensile strength ratio results which were similar in value; 85% and 83% respectively. These two mixtures could have been influenced by the heterogeneous nature of the RA. RA from CDW includes plaster and other undesirable particles that crumble and break down during the process of mixing and specimen fabrication, which has a negative effect on their granulometry. Moreover, these plaster particles are detrimental from the standpoint of adhesiveness. Any amount of these undesirable particles, however small, can negatively affect the mechanical resistance of a specimen after being immersed in water. Therefore, by subjecting the RA to abrasion on the Los Angeles Abrasion Machine, all of the impurities and plaster fragments they contain are eliminated. The mortar adhering to the RA is also eliminated. This could explain the substantial improvement on the TSR.

On the other hand, the tensile strength ratio of mixture AC22-0-C was 85% and mixture AC22-20-C had a value of 92%. These results would seem logical since the calcite aggregate is expected to improve the adhesive capacity of asphalt mixtures. Mixture AC22-40-C, however, yielded poor results, with a tensile strength ratio of only 72%. The latter value also appears to be coherent, since higher percentages of RA are expected to lead to a decrease in adhesive capacity.

4. Conclusions

The following conclusions have been drawn from this research work:

- Hot asphalt mixes fabricated with different percentages of coarse RA and cement used as a mineral powder have a poor adhesive capacity. This poor adhesive capacity increases in silicon aggregates. When RA and calcite aggregates are used, the adhesive capacity of the mixtures is considerably improved.
- The mortar adhering to RA, as well as different types of impurities, have a negative effect on the adhesive capacity and mechanical resistance after immersion in water.
- Asphalt mixtures fabricated with RA appear to be stiffer than those that do not contain this type of aggregate.

Finally, it is important to note that further research is needed on the possibility of using these RA in hot and cold mix asphalts. In this regard, following is a suggestion of possible future studies:

- Chemical, Mineralogical and microstructural characterization of natural and recycled aggregates.
- A study of the possible use of activated bitumens that will improve the adhesive capacity of these mixtures.
- A study of the compatability with other fillers and additives.

5. References

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Mixture	RA (%)	Bo (%)	VMA (%)	Va (%)	F (mm)	S (KN)	UW (g/cm^3)
AC22-0-S	0	4.5	14.5	5.0	2.3	10.5	2.36
AC22-20-S	20	5.0	15.5	5.0	2.4	11.0	2.33
AC22-40-S	40	5.5	17.0	5.0	2.4	11.0	2.27
AC22-60-S	60	5.5	17.0	5.5	2.6	12.2	2.26
AC22-20A-S	20	4.5	15.5	5.0	2.3	10.0	2.32
AC22-40A-S	40	4.5	15.0	5.5	2.5	10.0	2.33
AC22-0-C	0	4.0	14.0	5.0	2.3	10.2	2.45
AC22-20-C	20	4.3	15.0	5.0	2.4	11.2	2.39
AC22-40-C	40	4.5	16.5	7.0	2.7	11.2	2.30

Tabla 1. Optimum bitumen percentage and Marshall parameters.

Mixture	ITS MPa		TSR
	Wet	Dry	
AC22-0-S	0.863	1.094	79
AC22-20-S	0.783	1.220	64
AC22-40-S	0.857	1.084	79
AC22-60-S	0.832	0.950	87
AC22-20A-S	0.788	0.927	85
AC22-40A-S	0.804	0.968	83
AC22-0-C.	0.789	0.927	85
AC22-20-C.	0.934	1.018	92
AC22-40-C.	0.799	1.118	72

Tabla 2. Results of the immersion-stripping test

Figure 1. Recycled aggregates

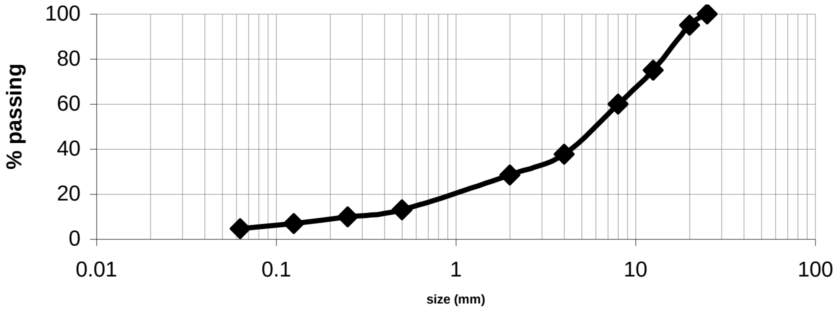

Figure 2 Granulometric curve

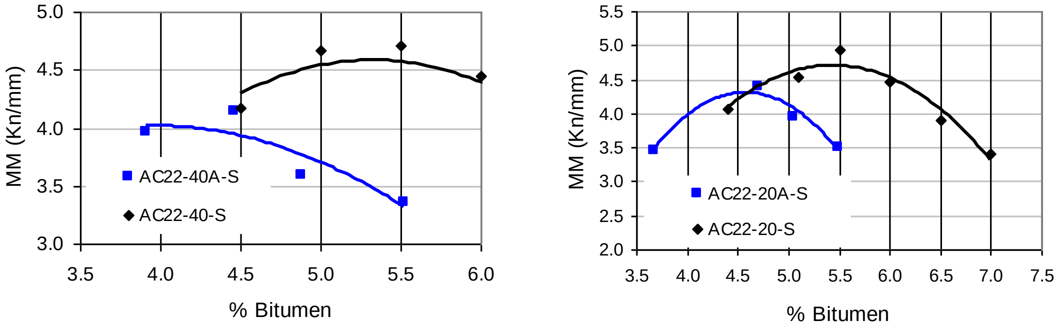

Figure 3. Marshall Modulus of the mixtures. a) 40% RA, b) 20% RA.