Use of recycled aggregates from construction and demolition waste in geotechnical applications

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***Abstract-* The reuse of concrete and aggregates (recycled aggregates) in the construction activities leads to a sustainable and a better environment in the society , it is a good step to create market opportunities In last few years there are some cases that emerges the studies of recycled aggregates in the construction and geological works like in the filling purposes and in the unbound pavement layers.This paper is based on the review of some major physical properties of several recycled aggregates (RE) and their comparison with natural aggregates (NA).And how these physical properties affects the behaviour (mechanically and hydrolically) when they are compacted and used in construction works. The analysis of the effects of compaction on respective grading sizes distribution curves and their densities,resilient modulus , CALIFORNIA BEARING RATIO and permeability. It also consists of the influence of recycled aggregates with the performances on unbound road pavements and those which are formed with the normal aggregates with the help of deflection values and International Roughness Index. The data collected shows that the performance of the RA is closer to the NA and can be used in unbound pavement layers .**

***Index Terms-* Recycled aggregates Compacted materials Pavement layers RCA RMA RAP**

I. INTRODUCTION

We all know that wastes have beacome part of our society and so do the constructional waste that is produced when we demolish a structure the concrete that is broken down is a severe cause of consider because it not only affect the environment but also it makes the product totally unusable and we need to throw it .As it causes environmental issues around the world .


In 2010 THE MAJOR sectors that generated the wastes are:-

In European Union - 2.51 billion tonnes (Eurostat, 2014).
The construction and the demolition activities -859 million tonnes that is about 34%of the total.
Quarrying activities -672 million tonnes, 27% of the total.
Mineral wastes and soil -97%as per calculated
.
Mineral waste consist of :-
Excavated earth , road waste , construction and demolition waste ,rocks .
This process of recycling of the constructional waste is just a little practise and it is not used worldwide , it is used in few countries , other countries use this waste in only landfilling practices that spoils the earth.

If these recycled aggregates can be used again other than landfills it creates a new opportunity to us to explore to make the demolished waste useful and hence favourable for our environment too.

In the geographical / construction works we all prefer natural aggregates because of the following reasons:-

-As NA are found nearby while RA have to be transported from other places that can be far from the construction site.
-The NA have good particle properties than RA .
-The composition of RA is much higher than that of asphalt pavement; CBR, California Bearing Ratio; IRI, International Roughness Index.

II. PROPERTIES OF RA

The main RA are - Crushed concrete , crushed masonry , road materials, mixed demolition debris .

After crushing the main types are -

1.Recycled concrete aggregate (90%by mass of portland cement fragments and NA)

2.Recycled masonary aggregates (ceramic blocks , aerated masonary , salg bricks and blocks)
3. Mixed recycled aggregates (crushed and graded concrete and masonary rubble)
4.Reclaimed asphalt pavement (90%asphalt based materials)
5.Construction and demolishion recycled aggregates(as in 2014 glass ,plastic, wood)

TABLE 1

RA type	Average maximum dry unit wt.(KN/m3)	Average optimum water content (%)
NA	21.90	7.3
RCA	19.70	10.9
RAP	19.80	7.1
MRA	19.00	12.3

As the output is a mixed product and not an easily identifiable and uncontaminated one. There are some contaminants, which are unable to be removed with mechanical methods alone as their characteristics are same as of RA, thus we have to include specialized manual separation in the recycling procedure. Different crushers may be used in different conditions and in a different number of crushing stages (Dosho et al., 1998; Gokce et al., 2011; Nagataki et al., 2004; Nagataki and Lida, 2001; Yanagi et al., 1998).

It is useful upto a large proportion that the product coming from a primary crusher should provide particle sizes less than 40 mm. The implementations of several crushing stages decreases the average size of the aggregate and generates more fine particles with diameter (D < 0.074 mm).

To control the RA grading curve, it is recommended to process CDW at least in two consequent crushing stages, but the quantity of fine material needs to be controlled to obtain the grading size distributions required for unbound applications (Kasai, 2004). By controlling the setting of the crusher aperture it is possible to produce good quality coarse aggregates (Hansen, 1992) that meet the specifications necessary for a given purpose (e.g. EN-12620 (2013) and EN-13043 (2013). Still it is not easy to produce good quality fine RA, as it persists a high quantity of old mortar .

Because of using less old mortar, two or more crushing stages therefore lead to rounder and dull particles (Barbudo et al., 2012); if RCA undergoes a crushing process, they will be having higher shape and flakiness indexes than those of NA. (González-Fonteboa and Martínez-Abella, 2008; Ferreira et al., 2011; Fonseca et al., 2011). Still,it is also noted that in few cases NA are flatter and sharper than RA, especially if these are from natural stones with marked cleavage planes. When evaluating the shape of ceramic particles from crushed bricks, (2005) it was found that the RMA consistently have higher shape indexes for larger particles, which goes decreasing with decrease in the size of particle . The properties of RCA strongly depend on the properties of the source concrete (2014). High-strength concrete, with lower w/c ratios, will exhibit greater density values and lower water absorption values, due to the lower amount of water.

TABLE 2
PROPERTIES OF RCA

Process level	Adhered cement paste content (%by mass)	Dry unit wt. (Kg/m3)	Water absorption(%)	Crushing value under 100 KN(%)
1	52.3-55.0	2370-2420	4.88-6.27	3.83-6.30
3	30.2-32.4	2480-2510	3.14-3.76	1.53-2.28

TABLE 3

Aggregate property	Grading size distribution curve	Maximum dry density	Optimum water content	Permeability	freeze and soundness resistance
SIZE	YES	YES	NO	YES	YES
SHAPE AND ROUGHNESS	YES	YES	NO	YES	NO
DENSITY AND POROSITY	NO	YES	YES	YES	NO
CRUSHING STRENGTH AND TOUGHNESS	YES	YES	YES	NO	YES
STIFFNESS	NO	YES	NO	NO	NO
WATER RETENTION PROPERTIES	NO	NO	YES	YES	YES
FREEZE AND SOUNDNESS RESISTANCE	YES	YES	NO	YES	YES

III. MECHANICAL CHARACTERISTICS OF COMPACTED RECYCLED AGGREGATES

The mechanical characteristics of compacted RA of several types collected from the literature are presented in this section.
It contains few studies considering the type of research performed on the use of RA in the unbound pavement layers.
The studies are experimental and were performed to characterize the mechanical properties of different types of aggregates.. The comparison of the properties measured with NA are made in many of these studies, when the research is concentrated on

optimizing the compaction conditions in the field (Saeed, 2008) but there are some field case- studies too (Fernandes et al., 2009; Ho et al., 2008; Lee et al., 2009) which helped in more detailed experimental tests.

These are the common Studies on the mechanical and hydraulic behaviour of mixtures of RAP, RMA,RCA with NA with different proportions .The results consist changes in the grading size distribution curves caused by compaction, dry unit weight and water content achieved for a known compaction effort, strength and stiffness. A few studies are concentrated on quantifying the effects of the stiffness and strength of the aggregate in the same property of the compacted material. These studies hence could help in advanced selection of the aggregates.

Fig. 2b also includes the curves for RCA and NA for comparison with MRA. It can be concluded that vibration has similar effects on all types of aggregates but slightly higher for RA than for NA. Such conclusion cannot be generalized because it depends on the nature of the NA and RA used; however, this is an expected result because aggregates with low crushing strength gives higher breakage (Barata and Cardoso, 2013; Coop, 1990; Lade et al., 1996).

The results obtained after changing the compaction procedure are not evident that maximum dry unit weight and optimum water content, which presents some of the optimum results collected in the literature (Barbudo 2012;; Jiménez , 2011, 2007; , 1998; Park, Chan, 2006b; Saeed, 2008) for different aggregates and compaction practices. The differences between standard and modified efforts are not significant (identified as str comp and comp in the legend of the plot, respectively) and for each type of compaction large variability of data can be seen, and for this reason the average values were obtained using all points (Table 7). In general, optimum water content increases for RCA and MRA and decreases for RAP when compared with NA. This result can be explained by the different porosities and water absorption properties of the various types of recycled aggregates studied. The values of maximum dry unit weight found are higher for NA than for the various RA studied (presented in Table 7). This result is expected because of the lower density and greater porosity of the various RA when compared with NA, and is possible only if particles breakage during compaction occurs in a similar manner for NA and RA (in accordance with Fig.2b).

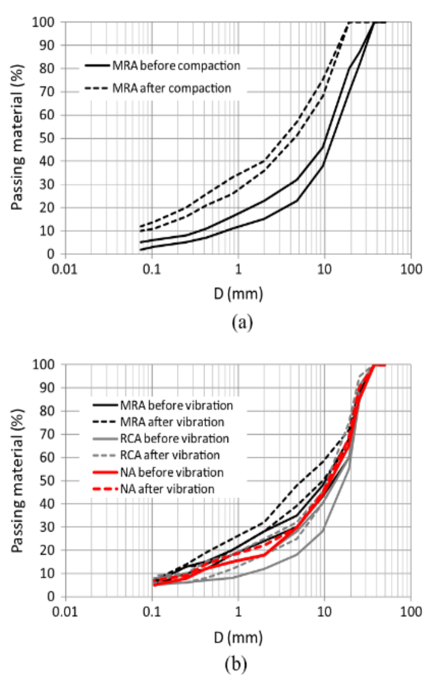

fig 2 -changes in grading distribution due to compaction

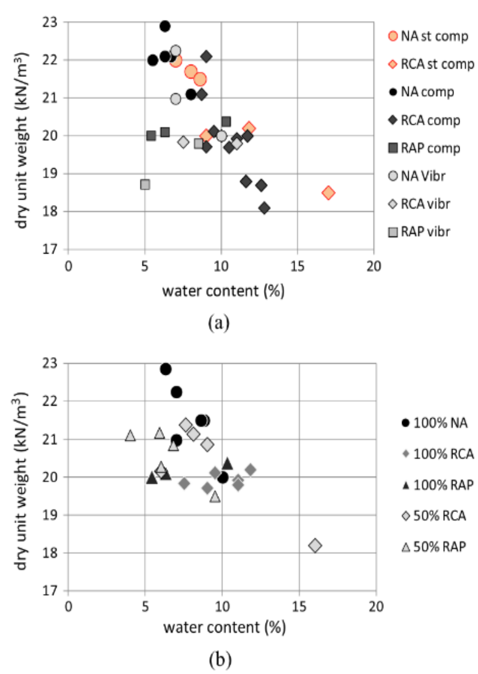

fig 3-relation between dry unit wt and optimum water content

Many other authors studied mixtures of NA and RA with varying proportions, which have intermediate properties to those . Fig.2b presents the optimum points of compaction curves corresponding to specimens prepared with 50% of NA plus 50% of RAP or 50% of RCA, as well as the points found in specimens prepared with 100% NA, 100% RCA and 100% RAP for comparison . The results were obtained via different compaction procedures because variability of results found in these materials does not justify a their approach. The clouds of data found for each case show that the addition of NA mitigates the decline in performance caused by RA, but the mixture still behaves as a RA mixture owing to the physical properties of RA, which influence the compacted material of NA. Different proportions studied by some authors (usually 25% of RA or 75% of RA) confirm this result.

California Bearing Ratio

CBR provides information on the resistance of compacted layers independently of the nature of the particles that are used. It have to be performed on compacted samples under soaking. There are several standards for CBR tests (AASHTO-T193, 2013; ASTM-D1883, 2007; BS-1377-1, 1990; EN-13286-47, 2012).

The review presented showed that the study of RA as material for applications in unbound structures primarily used RCA, RAP and MRA. The Land Transport & Authority (LTA, 2010) established that processed RA from approved CDW recycling processing plants must contain at least 60% of RCA, with no more than 40% of RMA and/or not more than 10% of other foreign materials such as wood, asphalt, glass, plastic and metals. It was also established that the fraction of material which passes through the 20 mm sieve RA type must satisfy the CBR requirements of 30%, for sub-bases (soaked value).

Average maximum dry unit weight (kN/m3) when tested in accordance with BS-1377-1 (1990).In general, the CBR of a RCA sample is lower than that of a NA sample. The study of Bennert and Maher (2008) demonstrated that the use of RAP as material for an unbound application resulted in a very low CBR ratio. These results show that RAP may be unsuitable for sub- base and base application because of their low strength. However, Vegas et al. (2011) found higher CBR value for RAP than for MRA.

IV. CONCLUSION

1- The physical properties of RA depend on the type of recycled material, manufacturing processes when compacted.
2- The compaction done by vibration may be prefferable in considering RA with old adhered morar.
3- The use of higher RCA and RMA can increase optimum water content and decrease max dry density.
4- RAP is responsible for slight decrease the optimum water content .
5- CBR of compacted RCA is sometimes higher than that of NA and sometimes it is lower that NA too .
6- Lower CBR can be observed in the RMA samples that can be further increased by adding RCA .
7- SAmples having RAP have much lower value of CBR than that of required.
8- In terms of exposure to sulphate enriched conditions, the results have shown that RCA have worst performance that of NA.
9- The test result shows that performance of sub bases and bases of RCA may be good or even much better than NA.