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Valuation of Using Recycled Scraped Asphalt in Concrete Mixture

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Abstract— *Recycled Asphalt Pavement (RAP) is a recyclable product of old asphalt. RAP consists of well graded gravel covered with asphalt cement. This research Examines the properties of concrete using RAP directly without bitumen separation, and then we use RAP after separating the bitumen from the aggregate. RAP coarse fraction was used to replace coarse aggregates at 25, 50, 75 and 100% for both mixtures. In addition to the control mixture (0%), RAP-containing mixtures were evaluated for slump, compressive strength, flexural strength, and modulus of elasticity. Durability was evaluated using the surface absorption test. After laboratory tests and observing the results of different proportions of concrete mixtures (clean aggregate and RAP), We've got that in the case of using RAP with clean aggregate at a rate of (0% to 50%) in each of them (mix 30) MPa and (mix 50) MPa, the results are satisfactory and within permissible limits. After performing the process of separating the aggregates from the bitumen, concrete mixtures were made with different ratios between the washed aggregates and the clean aggregates., it was found that in the case of using washed aggregate (recycled asphalt) with clean aggregate in a ratio of (0% to 75%) the results are satisfactory and within the permissible limits. It is preferable to use the scraped aggregate (RAP) directly without separation to avoid environmental pollution and high costs.*

Keywords— *Reclaimed asphalt pavement (RAP), Compressive strength, Elastic modulus, concrete mixtures.*

I. Introduction

Total or partial replacement of natural aggregates with recycled aggregates in concrete mixes is a potential path to producing more environmentally friendly materials in the future [1,2]. A viable solution includes the use of modified asphalt pavement (RAP) for use as recycled aggregate in concrete mixes. RAP is solid waste from demolition and scraping of existing asphalt pavements during utility access under roads or during maintenance of destroyed roads [3], and thus falls under the construction and demolition waste (CDW) group. RAP is a material consisting of natural aggregates covered with a layer of bitumen and a layer of fine dust due to the method used in crushing and storing asphalt [3].

High-quality aggregates are used so much that they are not stocked for future generations in most regions of the world, or it may be costly to transport them to the construction site. Existing OPC and asphalt concrete pavements provide a source of high quality aggregate that can be recycled. Recycling can contribute to the disposal of waste and the preservation of spent natural resources [2]. The study used either fine aggregate replacement, coarse aggregate replacement, or both. The replacement percentages were 25, 50, 75 and 100% of the total. The study recommended limiting the amount of recycled aggregate to 75% and 50% for coarse aggregate and fine aggregate, respectively. A decrease in compressive strength has been reported with the increase in the replacement of recycled aggregates. The study found that the tensile and compressive strength relationships of natural concrete can be used for recycled concrete. [3,4].

Morshed et al. 1997, studied the use of course compositions and RAP fine aggregates in ordinary concrete mixes and compared the results of compressive strength with conventional mixes with ratios of 0.4 and 0.5 water cement. Compressive strength values were found to decrease with increasing RAP content. The study concluded that RAP-containing concrete admixtures can be qualified for concrete applications such as sidewalks, driveways, sidewalks, and gutters [5].

Yankovic, 2002, in his study, compared the effect of 0, 4, and 8% polymer mixtures on concrete made from a mixture of recycled bricks and river sand. The study concluded that there is no effect of the polymer on compressive strength and flexural strength. However, the polymer provided some improvement in water resistance and frost resistance. The study recommended the use of concrete made of recycled blocks for thermal insulation and in the load-bearing walls of buildings [6].

Limbachia et al. 2000, recycled concrete is used as an aggregate in high-strength concrete. The results indicated that up to 30% recycled concrete aggregate had no effect on strength. At higher percentages, there was a gradual decrease in strength. The study presented a method for adjusting the water-cement ratio to overcome this decrease in strength. The study concluded that high-strength concrete made from recycled concrete aggregates can have equivalent engineering performance and durability to unfilled high-strength concrete [7].

In the past, RAP was mainly reused in asphalt mixtures after abrasiveness or as coarse aggregate after bituminous layer extraction; However, a limited amount of RFP has been applied in this practice [8]. High proportions of RAP in asphalt mixtures may cause obstacles in cracking and hardening, due to the high degree of hardening RAP that is characterized by it and its brittleness [9,10]. Currently, RAP can be successfully added to asphalt mixtures at up to 30 wt% of the total aggregate [11]. Scientific research has also focused on improving the properties of asphalt mixtures containing up to 60 wt% of RAP as a natural alternative to aggregates, with interest in adding a soft binder or a property-preserving regenerator of the old binder [12–15]. In addition, the percentage of RAP can be successfully increased by considering RAP from the first layers, as they are less involved in the natural aging of bituminous materials [16,17].

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RAP has only recently been applied as a substitute for natural aggregates in cement mortars and concretes. In several research studies [18–24], it has been observed that mixing RAP into concrete significantly reduces mechanical performance as a function of the amount of RAP added in the mixture. This change is also confirmed

Through other recent studies aiming to use high concentrations of RAP (up to 100% of the weight of the concrete mix) [25–30]. To date, RAP as recycled aggregate in concrete is typically recommended for non-structural applications [7, 21, 23] and some authors have recommended a maximum 50 wt% of RAP content over total aggregate in concrete [31,32]. Moreover, the addition of RAP as a natural substitute for aggregates was found to negatively affect some properties of concrete in the fresh condition such as workability which was measured by slump test [19, 26].

Similarly as before, studies on cement mortar containing RAP also indicated a significant decrease in mechanical properties with increasing amount of RAP used [32,33]. The adhesion problem between the cement matrix and the RAP, due to the presence of a layer of bitumen, has been cited as a primary reason for the reduction in strength [34,35]. Moreover, because RAP consists of high concentrations of agglomerated particles, its optimal particle size distribution exhibits fewer fine-graded fractions and a higher amount of coarse-graded fractions than normal aggregates typically applied for concrete production [7,19,31,36]. . Even if RAP agglomerated particles can disintegrate easily when subjected to external pressure [18], some recent studies have focused on improving the bond between the cement matrix and RAP by applying a surface treatment on RAP, thus obtaining better performance in terms of mechanical properties, durability and workability [4, 27,35]. At the same time, the use of RAP in concrete has been shown to enhance some properties, such as toughness due to the presence of a bituminous layer that prevents the propagation of faults [18,19] and cold resistance due to larger open pores in hardened samples compared to conventional concrete [33,37].

This paper presents the results of a study conducted to evaluate the use of RAP in concrete mixes directly, where two mixing grades were designed. The coarse aggregate is replaced by the coarse fraction of the RAP aggregate at various percentages including 0, 25, 50 and 75%. Then we separated the bitumen from the RAP using a solvent of petroleum derivatives (kerosene), and the properties of the mixture were shown including: (slump, compressive and flexural strength, modulus of elasticity and surface absorption).

II. MATERIALS AND METHODS

- Asphalt abrasion (RAP) of fast and slow maintained roads of different grades.
- Natural aggregates of different grades (fine and coarse) that were tested in the college laboratories.
- Ordinary Portland cement grade 42.5.
- Graded sand (fine - coarse).
- Fresh water.

Table 1 presents the aggregate gradings used in mix design.

TABLE 1. Gradation of aggregate used

Sieve size inch	Design gradation	Specification limits
1	100	100
3/4	87.5	80-100
1/2	75.4	--
3/8	73.2	60-80
No.4	48.9	48-65
No.8	41.6	35-50
No.16	36.3	--
No.30	28.7	19-30
No.50	16.8	13-23
No.100	11.4	7-15
No.200	7.3	3-8

III. EXPERIMENTAL PROGRAM

The aggregate we use in the concrete mix consists of 20mm coarse aggregate (CA), fine aggregate (FA) and recycled asphalt concrete pavement (RAP). As a result of the crushing process, the RAP is in the form of separate granules covered with a layer of old bitumen. RAP was separated by sieving on a 5 mm sieve size into coarse and fine RAP. Ordinary Portland cement was used. The aggregate and RAP gradation are shown in Figure 1. The physical properties of aggregate and RAP are shown in Table 2. Two normal Portland cement concrete control mixes (with no RAP aggregate) were designed with ratios of 1: 1.9: 2.9: 0.5 and 1: 1.7: 2.5: 0.45 for cement to fine aggregate to coarse aggregate to water. The cube compressive strength after 28 days of water curing resulted in 33 and 50 MPa for the two mixes, respectively. The mixes were referred to as Mix 30 and Mix 50. The coarse aggregate was selected to be replaced with coarse RAP aggregate as it constitutes a higher percentage in the mix. The percentages of replacement were 0 (control), 25, 50, 75, and 100 %, by weight of the coarse aggregate.

TABLE 2. Aggregate and RAP physical properties

Aggregate	Coarse Agg.	Fine Agg.	Coarse RAP	Fine RAP
Bulk SG	2.78	2.57	2.35	2.40
Bulk SG (SSD)	2.81	2.65	2.40	2.45
Apparent SG	2.84	2.78	2.5	2.5
Absorption (%)	1.8	1.5	1.8	1.6
Abrasion lA (%)	19.5	-	26.4	-

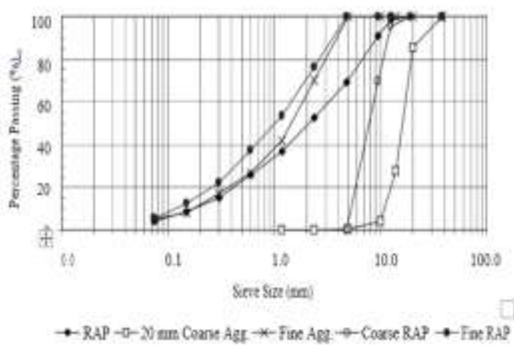

Figure 1. Grain size distribution for aggregate and RAP

Table 3. Shows mixing quantities. Aggregate weights depend on the state of the saturated surface dry (SSD). Fresh concrete mixes have been tested for slump measurement (ASTM c143-98) and unit weight (ASTM c138). Twelve 100

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cubes, three 150 mm cubes, three 150 x 300 mm cylinders and three 100 x 100 x 500 mm prisms were cast for each concrete mix. All samples were treated with water. A test was carried out on 100 mm cube samples in order to determine the compressive strength after 7 days, 14 days, 28 days and 90 days of water treatment. The cylinders were then tested for both modulus of elasticity (ASTM c469-94) and compressive strength (ASTM c873) after 28 days of water curing. The flexural strength of the leaflets (ASTM c78) was tested after 28 days of water curing. Cubes with a size of 150 mm were used to determine the strength value of the concrete mixtures according to the surface. After that, the bitumen attached around the rap was separated and included in the concrete mixtures, and the percentage allowed to be used in the concrete mixtures was determined.

TABLE 3. Mix quantities

MIX	RAP (%)	Cement (Quantity (kg/m ^{3})	Fine Agg. (Quantity (kg/m ^{3})	Coarse Agg. (Quantity (kg/m^3)	Coarse RAP (Quantity (kg/m ^{3})	Water
30	0	380.0	730.0	1100.0	0.0	190.0
	25	380.0	730.0	825.0	275.0	190.0
	50	380.0	730.0	550.0	550.0	190.0
	75	380.0	730.0	275.0	825.0	190.0
	100	380.0	730.0	0.0	1100.0	190.0
50	0	425.0	714.3	1070.0	0.0	191.4
	25	425.0	714.3	802.9	267.1	191.4
	50	425.0	714.3	535.7	534.3	191.4
	75	425.0	714.3	267.1	802.9	191.4
	100	425.0	714.3	0.0	1070.0	191.4

IV. RESULTS AND DISSCUSSION

Fresh Concrete Properties

Table 4 It shows the slump and unit weight of the two concrete mixes with different proportions of RAP substitution. The table indicates a significant decrease in the slump value from 163 to 20 mm for Mix 30 and from 55 to 5 mm for Mix 50 with an increase in the percentage of RAP replacement from 0 to 100%. We note that the unit weight showed the same trend for both mixtures, as it decreases with increasing percentage of RAP content. Figure 2 shows the results of the slamp [38].

TABLE 4. Slump and unit weight for different RAP content mixes.

Mix	Parameter	0%	25%	50%	75%	100%
30	Slump, mm	163	95	90	85	20
	Unit Weight, kg/m^3	2458	2405	2392	2357	2323
50	Slump, mm	55	43	20	12	5
	Unit Weight, kg/m^3	2442	2458	2453	2389	2377

Figure 2. Slump testing of fresh concrete

Compressive Strength

Figure 3 shows the results of the cube compressive strength (fcu) test after 7, 14, 28, and 90 days of curing for the different percentages of RAP replacement for Mix 30. The figure indicates the expected gain in strength with age. The figure also shows a marked decrease in strength with an increase in RAP content. Figure 4 shows the cube compressive strength (fcu) results for Mix 50. The previous figure also shows an increase in strength with water curing and a decrease in strength with the addition of RAP to all blends.

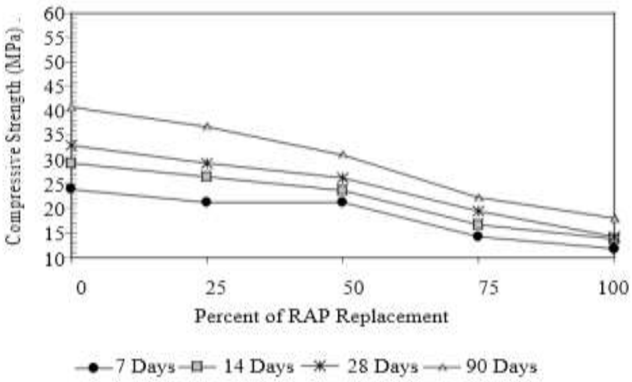

Figure 3. Compressive strength for Mix 30

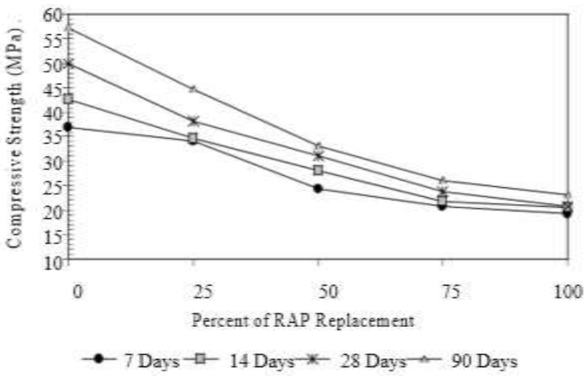

Figure 4. Compressive strength for Mix 50

For the 28 days compressive strength, the reduction in strength is indicated in Figure 5 for both mixes. The figure indicates approximately 10% higher reduction in strength for Mix 50 compared with Mix 30. At 100% RAP replacement, the reduction is approximately 58 % for both mixes Figures 6 and 7 It shows an increase in the compressive strength of the cube at different times of water curing for each of the concrete admixtures and different RAP ratio. The readings show the ratio of compressive strength at different periods of hydrotherapy to compressive strength at day 28 of hydrotherapy (development ratio). The strength development was the same for the two concrete mixes. The results are similar to typical results reported for strength gain for normal concrete. Table 5 shows the compressive strength of the cylinders (fcy) after 28 days of water curing as well as the fcu to fcu ratio. The results indicate a decrease in strength with an increase in the proportion of RAP content, which is consistent with a decrease in the case of cube samples. The fcy to fcu ratio ranged from 0.77 to 0.89 for all samples tested.

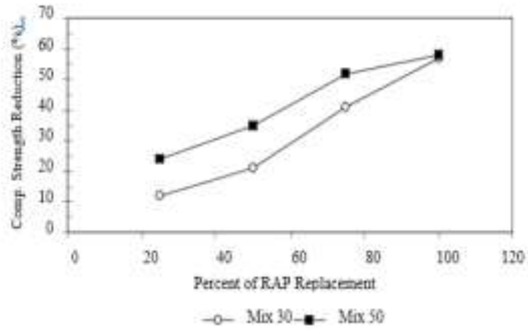

Figure 5. Percentage reduction in compressive strength

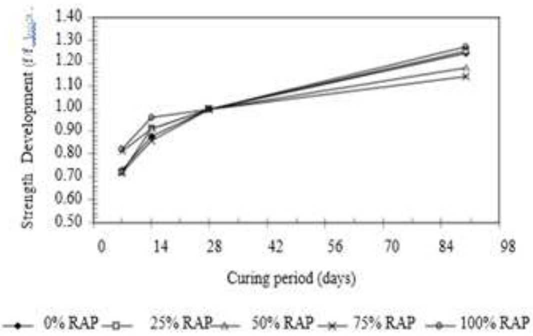

Figure 6. Strength development ratio for cube compressive strength (Mix 30)

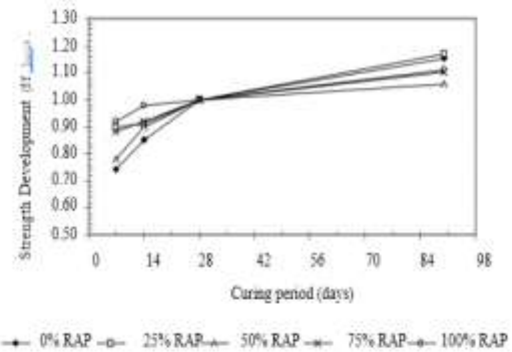

Figure 7. Strength development ratio for cube compressive strength (Mix 50)

TABLE 5. Cylinder compressive strength

Mix	Parameter	0% RAP	25% RAP	50% RAP	75% RAP	100% RAP
30	f_{cy}[a]	29.4	23.8	20.9	15.9	12.4
	f_{cy}/f_{cu}[b]	0.89	0.81	0.80	0.81	0.87
50	f_{cy}[a]	39.5	30.3	24.0	19.8	16.9
	f_{cy}/f_{cu}[b]	0.79	0.79	0.77	0.83	0.81

[a]f_{cy} = cylinder compressive strength in MPa,
[b]f_{cy}/f_{cu} = ratio of cube to cylinder compressive strength

Flexural Strength

Table 6 Shows the results of flexural strength (modulus of tear) (fr) after 28 days of water curing. Expected results based on the values in the ACI code. And the compressive strength of the cylinder (fcy) is also shown, as well as the ratio (fr/fcy). A general trend of decreased strength can be seen with increasing RAP content. The modulus of rupture decreased from 4.0 to 2.72 MPa for an increase in RAP replacement by 100% for Blend 30, and strength decreased by approximately 33.1%. For the higher strength blend (50 blend), the rupture model decreased from 5.53 to 3.91 MPa for 100% replacement of RAP, which corresponds to a reduction of 29%.

The results of the modulus of tear of concrete obtained from laboratory rhetorical tests are consistent with the permitted equations in the ACI code. For this reason, the ratio (fr/fci) for both mixtures and for the different percentages of RAP substitution are consistent with the correct values desired from normal concrete.

Modulus of Elasticity

Modulus of elasticity [39]. Determined according to ASTM c469-94 on cylinder samples prior to testing and crushing. As we can see the results in Figures 8 and 9 for Mix30 and mix50, respectively. For comparison, the following is an expression for the constant modulus of normal weight concrete.

TABLE 6. Prism bending strength (modulus of tear)

Mix	Modulus of Rupture (fr), MP	0% RAP	25% RAP	50% RAP	75% RAP	100% RAP
30	laboratory	4.0	4.30	3.3	3.1	2.7
	ACI Code[a]	3.6	3.2	3.0	2.6	2.3
	ACI Code[b]	5.4	4.9	4.6	4.0	3.5
	ACI Code[c]	3.4	3.0	2.8	2.5	2.2
	fr/fcy	12	15	13	16	19
50	laboratory	5.5	4.5	3.8	4.5	3.9
	ACI Code[a]	4.1	3.6	3.2	2.9	2.7
	ACI Code[b]	6.3	5.5	4.9	4.4	4.1
	ACI Code[c]	3.9	3.4	3.0	2.8	2.5
	fr/fcy	11	12	12	19	19

[a]lower range = $0.66\sqrt{f_{cyl}}$, [b]upper range = $1.0\sqrt{f_{cyl}}$, and [c]recommended value = $0.62\sqrt{f_{cyl}}$

$$E_c = 4.70\sqrt{f_{cy}} \quad (1)$$

where, E_c = the modulus of elasticityin GPa and f_{cy} = the 28 days cylinder strength in MPa. values of the static modulus of elasticity based on the 28 days cube strength. as follows:

$$E_c = 9.1\, f_{cu}^{0.33} \quad (2)$$

where, E_c = the modulus of elasticityin GPa and f_{cu} = the 28 days cube strength in MPa.

Both expressions 1 and 2 were used as shown in Figures 7 and 8. The results indicate a decrease in the modulus as RAP percentage is increased. The results also indicate that the obtained results fall between the values predicted from both equations up to 50% RAP replacement. For higher percentages of RAP, the modulus is lower than that given by both equations. A regression analysis was per-formed on the ten mixes to obtain equations similar to Eqs. 1 and 2, the resulting equations were as follows:

$$E_c = 0.65\, f_{cyl}^{1.1} \; (R^2 = 0.85,\ R^2_{adj} = 0.87) \quad (3)$$

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$E_c = 0.61 f_{cu}^{1.05}$ ($R^2 = 0.85$, $R^2_{adj} = 0.87$)   (4)

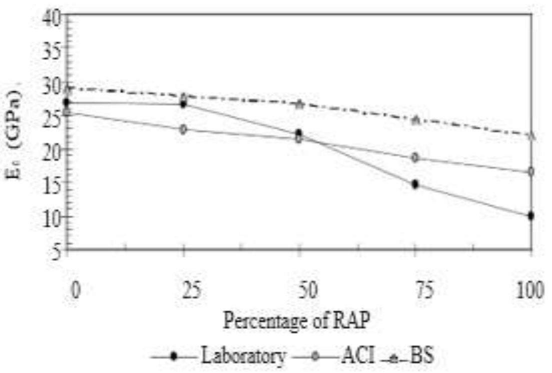

Figure 8. Modulus of elasticity for Mix 30

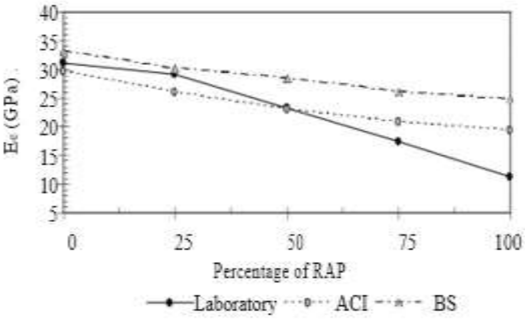

Figure 9. Modulus of elasticity for Mix 50

where, Ec, fcy and fcu are as defined before; and R2 R2 adj are the coefficient and adjusted coefficient of determination, respectively.

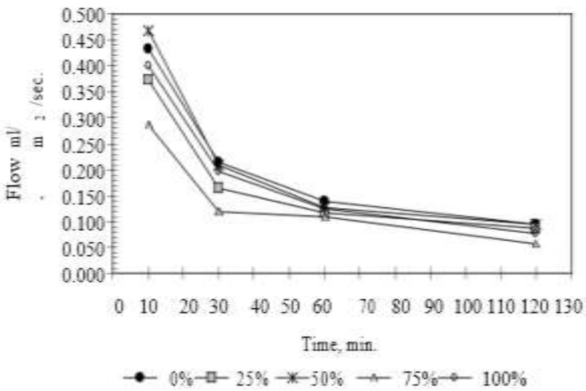

Figure 10. Initial surface absorption for Mix 30

Durability

The absorption test was carried out on the surfaces as an indicator of the durability of the concrete mixtures. The test gives a water flow (in mm/m2/sec) to the surface of a completely dry cube sample subject to a 200 mm header. The water is allowed to permeate at intervals of 10, 30, 60 and 120 minutes. At the end of each period, flow measurements were performed. appearance. Figure 10 shows the results for Mix 30. The figure indicates a decrease in the surface absorption results with time. The same notes apply to Figure 11 (Mix 50). The flow at 120 minutes for Mix 30 was in the range of 0.057 to 0.093 ml/m2/sec. Lower flow values were obtained for mix 50 with values in the range of 0.043 to 0.063 ml/m2/sec. The results did not indicate a significant difference in the absorption result with increasing RAP content for both mixtures. However, a lower flow value was obtained for the stronger concrete mix (Mix 50) than was expected.

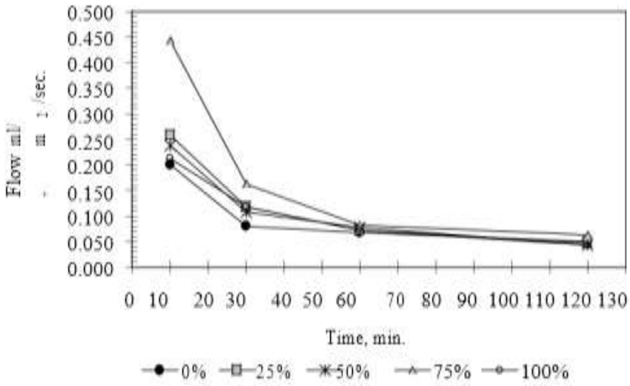

Figure 11. Initial surface absorption for Mix 50

The Results (1)

After laboratory tests and observing the results of different proportions of concrete mixtures (natural aggregate and RAP), it was found that in the case of using RAP (recycled asphalt) with clean aggregate at a ratio of (0% to 50%), the results are satisfactory and within the permissible limits, and when the ratio is increased from (50%) to 100%), we find a gradual change in the results until the occurrence of collapse, in both mixtures (mix30) and (mix50).

Study of the behavior of concrete after the process of separating bitumen from aggregates

After the process of separating was performed the aggregate from the bitumen from Figure 12 to Figure 17, concrete mixtures was made in different proportions between the washed aggregate and the clean aggregate (25% & 50% & 75% & 100%).

Fig. 12 weigh the sample and the pot

Fig. 13. Adding petroleum derivatives as a solvent

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Fig. 14 Extractor shape


Fig. 15 Extractor shape


Fig. 16. Bitumen produced by centrifugal force


Fig. 17 Filter paper on the extraction device

Table 7 shows the mixes quantities (washed aggregate and the clean aggregate).

TABLE 7. Mix quantities (washed aggregate and the clean aggregate)

MIX	RAP (%)	Cement (Quantity (kg/m ^{3})	Fine Agg. (Quantity (kg/m^3)	Coarse Agg. (Quantity (kg/m^3)	Coarse RAP washed (Quantity (kg/m^3)	Water
30	0	380.0	730.0	1100.0	0.0	190.0
	25	380.0	730.0	825.0	275.0	190.0
	50	380.0	730.0	550.0	550.0	190.0
	75	380.0	730.0	275.0	825.0	190.0
	100	380.0	730.0	0.0	1100.0	190.0

Figures 18, 19 and 20 Shows the results in different percentages of the compressive strength test of concrete (fcu) after 7 days, 14 days, 28 days and 90 days of treatment with water to replace the washed RAP. The figure indicates the expected increase in strength with age. The figure also shows the decrease in strength with an increase of washed RAP by more than 75%.

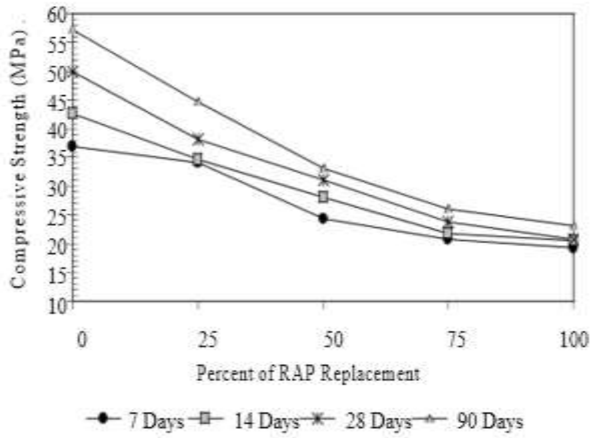

Fig. 18 Compressive strength for washed aggregate


Fig. 19. Crushed sample


Fig. 20 Compression Testing Machine

The Results (2)

After laboratory tests and observing the results of different proportions of concrete mixtures (clean aggregate and washed aggregate), it was found that in the case of using washed aggregate (recycled asphalt) with clean aggregate in a ratio of (0% to 75%) The results are satisfactory and within the permissible limits, and when the percentage is increased from (75% to 100%) we notice a noticeable change in the results gradually until the occurrence of a collapse. And we found that the extraction process (separating bitumen from rubble) is very expensive and produces waste that is harmful to the environment, which makes us prefer to use abrasive aggregate (recycled) in its direct form without resorting to expensive separation processes.

V. Conclusions

Based on the tests carried out, the following conclusions were reached regarding the use of RAP aggregates in concrete mixes instead of natural aggregates.

1- Reclaimed asphalt paving has been used as a substitute for coarse aggregate in two types Different ordinary concrete mixes have concrete compressive strength after 28 days of 33 MPa and 50 MPa. RAP was used with 25, 50, 75, 100% coarse-gradient aggregate replacement. Stagnation decreased as RAP content increased. pressure and Bending strength also decreased with the increase of RAP content. And we note direction of force development, as well as the relationships between bending force, The modulus of elasticity and compressive strength of RAP mixes are in excellent agreement with that of ordinary concrete mixes.

2- The mechanical and physical properties of RAP aggregates were slightly lower
from natural aggregates. Especially in the case of sieve analysis where it is coarse
RAP was finer than coarse aggregate and fine RAP was coarser than fine gathering. This was expected due to the fracturing process of the RAP and RAP aggregates agglomerate due to the presence of asphalt slurries. The specific gravity of the RAP groups was found to be lower compared to natural aggregates.

3- The higher the amount of RAP, the lower the slump value of concrete when working Compared to concrete made from natural aggregates. This was due to the surface The texture and shape of the RAP aggregates and also due to the presence of more dirt Particles in RAP. When we observe the shape of RAP aggregates, they are of Mostly irregular and tapered in shape which leads to poor workability. And when A comparative study of stagnation between coarse and soft RAP was performed Practically, it was found that the concrete containing RAP coarse only is the best performance between the two mixtures containing fine aggregate and coarse aggregate.

4- It was suggested that the water-treated RAP aggregates had better performance than the Unprocessed RAP groups. For example, unprocessed water absorption
RAP was higher than the RAP-treated groups.

5- When performing the comprehensive RAP concrete compressive strength analysis, it is done It was determined that the strength of the samples decreases with an increase in RAP aggregates. This was due to the poor bonding between bitumen around the asphalt, RAP and cement paste. But as a solution to this, RAP dealt Dirt-free aggregate has better performance. But they are expensive It has a negative impact on the surrounding environment.

6- Similar to compressive strength, flexural and cleavage tensile strength of Concrete samples including RAP aggregates followed the same trend. But it was Evaluating that due to the presence of bitumen around RAP aggregates. The load absorption of concrete samples increased compared to concrete Made from natural aggregate. This was due to its low modulus of elasticity tangible with an increase in RAP content.

7- The hardness coefficient was given for concrete containing RAP aggregates
Good result compared to concrete containing natural aggregates. This proved that RAP universal concrete can be used where the loads are cyclical and its influence on nature.

8- The permeability of concrete containing RAP is higher, which means that
The chance of reinforcement corrosion will be high when used. This was because
RAP totals and RAP chroma coefficient are included gathering. As a solution to this problem, fly ash can be used to improve Permeability of concrete when using RAP aggregates.

9- Based on the results of this study, we can use RAP in concrete mixtures directly By up to 50% without any damage to the properties of concrete and we Washed RAP can also be used in concrete mixes up to 75% Without any negative effect on the properties of concrete.

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