# Comparison of hot mix asphalt (HMA) & warm mix asphalt (WMA) techniques to utilize Reclaimed Asphalt pavement: An Experimental Study

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**Abstract:**

The cost of using of raw materials for roads pavement is too much compared with recycling materials which are used for roads pavement such as reclaimed asphalt pavement (RAP) and also the environmental benefits will be more. In recent years the recycling technology has got attention from the engineers of transportation of civil domain because of its environmental benefits which allow us to consume the used material and renewed without looking for new resource of raw materials in that way we can get more economical and energy, in some cases it will be better for workers health too that's why it is too much desired technology.

In this study we will focus on how can prepare warm asphalt mixture with reclaimed asphalt mixture (RAP) and wax material (propylene) for bituminous concrete that has the same characteristics as a hot asphalt mix using reclaimed asphalt with less emissions that harm the environment with less energy waste and economical savings and compare it with Hot mix asphalt (HMA).

**Keywords:** Hot mix asphalt (HMA), warm mix asphalt (WMA), wax (polypropylene wax), Reclaimed asphalt pavement (RAP).



## Introduction:

Reclaimed asphalt pavement (RAP) is known as a used pavement material consisting of asphalt and aggregates. These materials are found when asphalt pavements are removed from old streets for example when reconstruction of the road, or resurfacing. When properly crushed and screened, we can see that Rap consists of stones and aggregates covered with asphalt cement. Asphalt pavement has been used in America for a very long time because of its environment benefits &saving economic, although most of the RAP which is produced, they waste a large portion of it or downgraded when used in landfills, embankment or base layer.

most of the RAP that is produced is reused and recycled, although not necessary in same year of production. almost of Recycled RAP always reused in the construction of the roadway form, usually mixed into asphalt paving by using hot or cold recycling, but its sometimes used as an aggregate in base or subbase construction.

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## Objectives of the study:

The main objective of this research is to evaluate the effects of partial- and total-replacements of aggregates by RAP on the mechanical response of dense-graded HMA mixtures and WMA mixtures. This study is limited to examine behavior of Bituminous Concrete layer only. Various test to be carried out are as follows: (1) Penetration, (2) Softening point Test for Bitumen, Marshall mix design with virgin aggregate, virgin aggregate + RAP, virgin aggregate + RAP + Wax. Only one type of wax is used (polypropylene wax

## Literature summary:

Using RAP instead of virgin materials has the same characteristics in mixtures, the use of RAP saves the natural resources and have economic benefits, also we can apply warm mix asphalt for preparing asphalt mixtures by using reclaimed asphalt pavement which is the most used materials in recent years due to its environmental qualifications during the work time specially it produces less emissions than hot mix asphalt, even it needs lower temperature during compacted , by adding some new materials to the mixture with ( RAP) we can get new mixtures with enhanced properties wither it is physical and mechanical .

## WMA technology:

The use of RAP with WMA technologies decreases the heat which is required for hot mixtures and by reducing the

amount of virgin material in that way the CO emissions will be less. it is easy. Using RAP with WMA mixtures has the same preparations of hot mix asphalt with some extra additives and less temperature it is slightly more than 100 °C. Due to less temperature of production and application (around 20 – 40 °C lower than an equivalent Hot Mix Asphalt) this WMA has several benefits for asphalt workers: because it is better working conditions for workers and ecofriendly

**Environmental benefits:**

(Less energy used and lower emissions).

Manufacturing and paving benefits: hardening of the bitumen will be less and WMA is fully convenient with the use of RAP. Paving operations benefits: WMA can be used (compacted) at a lower temperature than HMA, producing WMA at the same temperature of HMA will not permit to open for transport and compaction in short time. WMA will cool faster to surrounding temperatures and therefore, the site can be opened for traffic at an earlier time.

The tests for hot mix asphalt:

The Laboratory Experiments for Bitumen Without Additives:

**Penetration test:**

**Table1**: The results of penetration test without additives:

| Trial No | 1 |
|---|---|
| specimen | A |
| Initial reading | 274 |
| Final reading | 358 |
| Result | 84 |
| Trial No | 1 |
| specimen | B |
| Initial reading | 145 |
| Final reading | 224 |
| Result | 79 |
| Trial No | 1 |
| specimen | C |
| Initial reading | 213 |
| Final reading | 284 |
| Result | 71 |

**Softening point:**

The test the results:

•For first ball the temperature of melting bitumen is 44 °C.

•For the second ball the temperature of melting bitumen 46 °C.

**The laboratory experiments of aggregates:**

In this test use three sizes of aggregates (20mm,10mm, 6mm).

**1-Sieve analysis:**

After weighted the sample, put the sample on the first sieve then started the vibration of the vertical sieves for 10 minutes.

weighted the Suspended stones on each sieve in gr unite.

Calculated the collect cumulative pebbles weights on each sieve

**Marshall Mix Design:**

The marshal stability and flow test are used for preparing marshal mix design method to predict the performance of the mixtures.

The stability portion value is to measure the maximum load that can applied on the sample, by test the sample at a loading rate of 50.8 mm/minute, the load is applied on the sample till it fail.

During the loading, an attached dial gauge measures the specimen's plastic flow (deformation)because of the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded. The important steps involved in marshal mix design are summarized next.

**Table 2:** Results of stability and flow

| Bitumen content % | Stability values (KN) | Flow values (mm) |
|---|---|---|
| 3.5% | 16.4 | 2.48 |
| 4.00% | 18.4 | 3.9 |
| 4.5% | 21.5 | 3.7 |
| 5.00% | 25.6 | 4.5 |
| 5.5% | 22.8 | 4.4 |
| 6.00% | 15.6 | 5.1 |

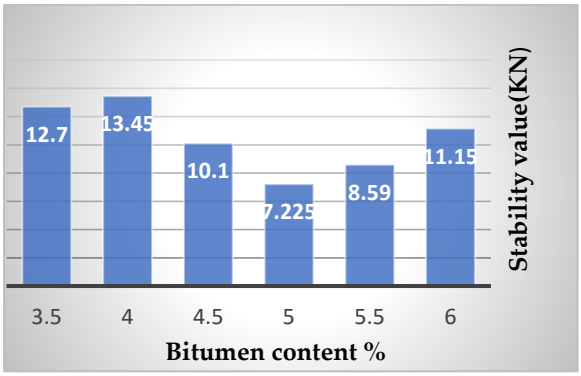



**chart 1: between bitumen &stability**

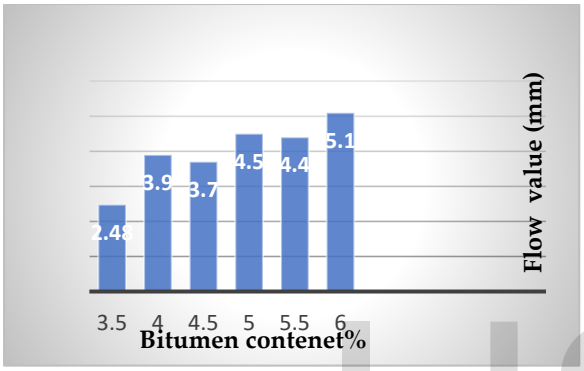


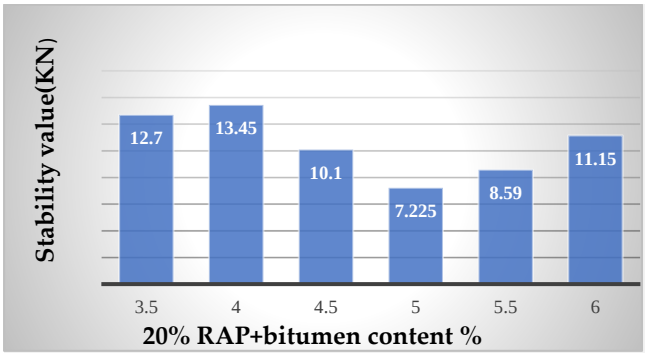

**Chart2: between bitumen &flow**

**The results:**

It is observed that the using of virgin aggregates with 5.00% percentage of bitumen produced the best result of stability &flow.

**Table 3**: results of stability and flow value with 20% of (RAP):

| Bitumen content% | Stability values (KN) | Flow values (mm) |
|---|---|---|
| 3.5% | 12.7 | 4.25 |
| 4.00% | 13.45 | 4.55 |
| 4.5% | 10.1 | 4.65 |
| 5.00% | 7.22 | 4.45 |
| 5.5% | 8.59 | 4.60 |
| 6.00% | 11.15 | 5.20 |




**Chaer3: between bitumen &stability**

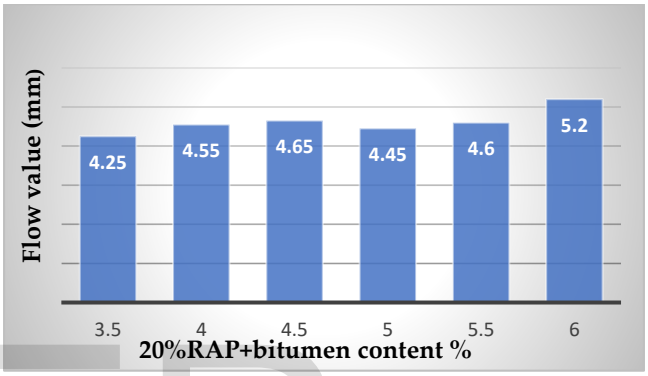



**Chart4: between bitumen &flow**

**The results:**

It is observed from the figure that the best percentage of bitumen content is 4.00% because it has showed the best results for flow and stability.

The results of stability and flow of 4.00%of bitumen content & different percentage of RAP:

**Table 4:** the percentage 4.00% of bitumen content and increase the percentage of RAP (20%,30%,40%,50%,60%).

| Bitumen content% | RAP % | Stability values (KN) | Flow values (mm) |
|---|---|---|---|
| 4.00% | 20% | 38.98 | 3.8 |
| 4.00% | 30% | 40.56 | 4.1 |
| 4.00% | 40% | 42.52 | 4.37 |
| 4.00% | 50% | 46.72 | 4.47 |
| 4.00% | 60% | 40.12 | 4.4 |

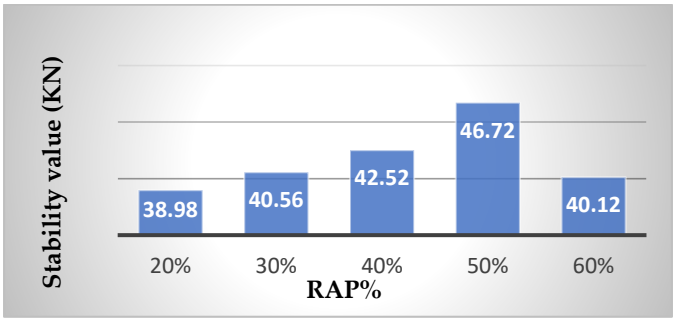



**Chart 5: between RAP& stability**

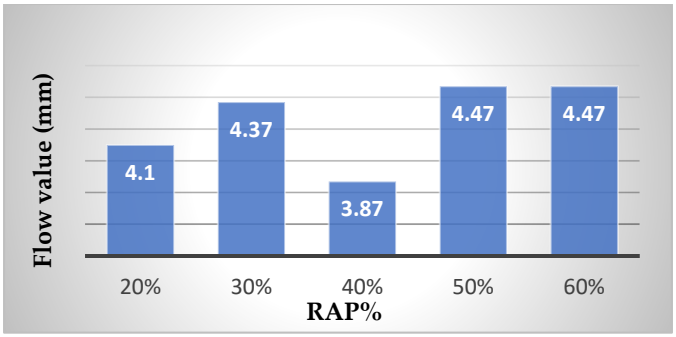



**Chart 6: between RAP& flow**

**The results:**

It is observed from the figure that the best percentage of the RAP for best stability is 50%. For best percentage for best value of flow is 40% of RAP.

**The tests for warm mix asphalt:**

First will do the tests of bitumen with adding different percentage of wax (propylene).

1- **The softening point results:**

take 80 gr of bitumen and heated then we add 5% from the weight of bitumen (wax) Means 80*5%=4 gr of wax and repeat the teste with different percentage of wax (5% ,10% ,15%) mix it together and heat it around 10 minutes. When the mixture is ready, spill it in the mould and keep it in the temperature of 25 °C for 30 minutes, then we start the softening point test.

**Table5:** Softening point test results with wax material

| Bitumen content gr | Wax content Gr | The temperature of first ball | The temperature of second ball |
|---|---|---|---|
| 80 gr | 0% = 0 gr | 44°C | 46°C |
| 80 gr | 5% = 4 gr | 70°C | 75°C |
| 80 gr | 10%= 8 gr | 80°C | 83°C |
| 80 gr | 15% =12 gr | 89°C | 92°C |

It is observed that after the test that the value of temperature of bitumen melting is increasing when we increase the grams of wax.

•It indicates an improvement in bitumen resistance against deformation in high temperatures.

**The results of penetration test with wax:**

**Table 6:** The results of penetration test with (5%, 10%, 15%) of wax:

| Trial No | 1 | 1 | 1 |
|---|---|---|---|
| Wax content | 0% | | |
| Specimen | A1 | B1 | C1 |
| Initial reading | 274 | 145 | 213 |
| Final reading | 358 | 224 | 284 |
| Average value | 84 | 79 | 71 |
| | | | |
| Trial No | 2 | 2 | 2 |
| Specimen | A2 | B2 | C2 |
| Wax content | 5% | | |
| Initial reading | 320 | 320 | 320 |
| Final reading | 343 | 346 | 349 |
| Average value | 23 | 46 | 29 |
| | | | |
| Trial No | 3 | 3 | 3 |
| Specimen | A3 | B3 | C3 |
| Wax content | 10% | | |
| Initial reading | 320 | 340 | 361 |
| Final reading | 348 | 370 | 388 |
| Average value | 28 | 30 | 27 |
| | | | |
| Trial No | 4 | 4 | 4 |
| Specimen | A4 | B4 | C4 |
| Wax content | 15% | | |
| Initial reading | 320 | 320 | 319 |
| Final reading | 365 | 355 | 360 |
| Average value | 45 | 35 | 51 |

**The results of marshal test WMA mixture with 10%of wax with virgin aggregates and different percentage of bitumen**:

**Table7**: values of stability and flows with 10%of wax

| BC% | Wax% | Stability (KN) | Flow value (mm) |
|---|---|---|---|
| 4.00% | 10% | 51.36 | 3.6 |
| 4.50% | 10% | 39.6 | 4.15 |
| 5.00% | 10% | 48.24 | 3.875 |
| 5.50% | 10% | 53.88 | 3.6 |

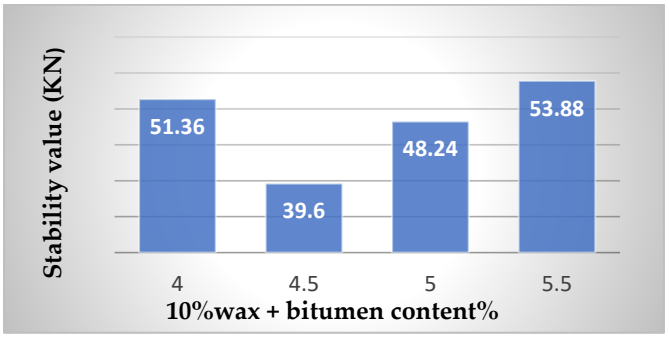



**Chart 7: between bitumen with wax &stability**

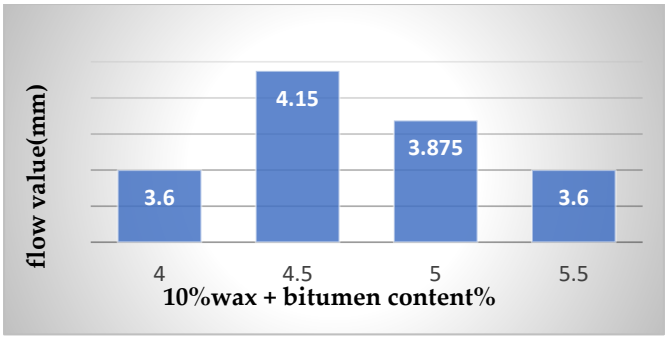



**Chart8: between bitumen with wax & flow**

**The results from the charts:**

It is observed from the figure that the value of stability is the best when the percentage of bitumen is 5.5%. If compare between the value of stability with virgin aggregate with 5.5% of bitumen, can say that the value of stability increases when we add 10% of wax before adding wax it was (22.8 KN) but after adding wax it becomes (48.24 KN). So, the wax improves the stability of the mixture. The flow value decrease in the same percentage of bitumen with adding wax it was (4.5mm) without wax after adding was it becomes(3.87mm).

**Table8:** Marshall stability test with 10% wax and 5.5%bitumen and different percentage of Rap:

| BC% | RAP% | Wax% | Stability (KN) | Flow (mm) |
|---|---|---|---|---|
| 5.5% | 20% | 10% | 48 | 5.375 |
| 5.5% | 30% | 10% | 36.6 | 7.75 |
| 5.5% | 40% | 10% | 51.12 | 8.475 |

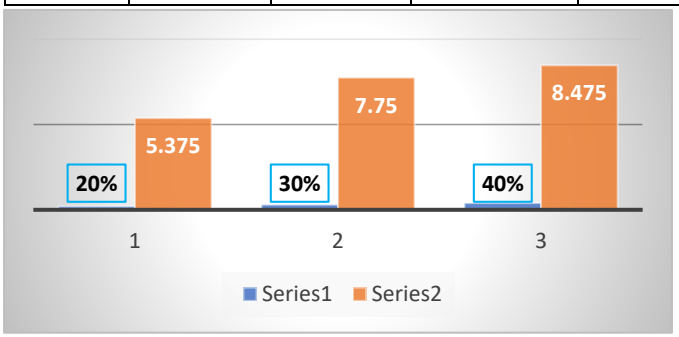



**Chart 9: between RAP &stability**

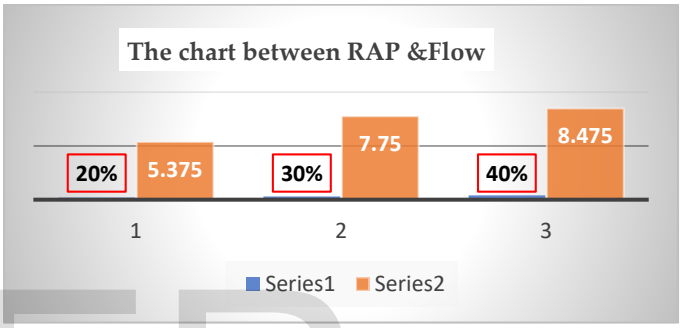



**Chart 10: between RAP &flow**

**The results from the charts:**

1) It is observed from the charts that the best percentage of RAP is 40% with 5.5% of bitumen content &10%of wax due to this mixture we got best results of stability (51.12 KN) and its near to the results of the mixture that content of (5.5%) of bitumen with 10% of wax content and virgin aggregates the value of stability is (53.88 KN).
2) From the flow chart we noticed that the best percentage of RAP is 20% we got the value of flow (5.375mm) without using the RAP the value of flow was (3.6mm) it is near to the value of (5.375mm).

**Table 9:** best percentage of material for (HMA&WMA) mixture:

| *The best results of (HOT MIX ASPHALT)* | | | | |
|---|---|---|---|---|
| BC % | RAP % | Wax % | Stability (KN) | Flow (mm) |
| 5.00 | 0.00 | 0.00 | 25.8 | 4.5 |
| 4.00 | 20.0 | 0.00 | 13.45 | 4.5 |
| 4.00 | 50.0 | 0.00 | 46.72 | 4.7 |
| **The best results of (WARM MIX ASPHALT)** | | | | |
| 5.50 | 0.00 | 10.0 | 53.88 | 3.6 |
| 5.50 | 40.0 | 10.0 | 51.12 | 8.4 |

**After testing different percentages of materials for asphalt mixtures:**

From the table we can see that the best results of stability are (53.88KN) without RAP& (51.12KN) with RAP.

The result is referring to use reclaimed asphalt in warm mix asphalt with these percentages of materials (5.5%of bitumen & 40%of RAP &10%of wax) and

The percentage of material (5.5% of bitumen &0.00%of RAP&10%of wax).

**CONCLUSIONS:**

In this study we experiment the cases of using virgin material & recycling material separately and together the results which we got said it was close to each other.

**In first case by using hot mix asphalt**:

1) We used virgin aggregate with bitumen without adding any material we got best results of stability (22.8KN)
2) When we add 20% of RAP to the virgin aggregate the stability reduce to (11.45KN) but it was the best with 4%of bitumen content.
3) We fixed the percentage 4%of bitumen content and started increasing the percentage of RAP we noticed that the 50% of RAP gave us the best value of stability(46.27KN).

Adding reclaimed asphalt to the mixture improve the properties of the mixture. Means we can use recycling material to save the new

sources of the virgin material with best prosperities.

**In the second case by using warm mix asphalt:**

1) When we use the virgin aggregates and adding 10%of wax to the bitumen with using lower temperature than hot mix asphalt we got better value of stability (53.88 KN).
2) When we used 5.5% of bitumen with 10% of wax with different percentage of RAP, we got the best value of stability (51.12KN) with 40% of rap.

It refers to the using of reclaimed asphalt with wax with little amount of virgin aggregate and preparing the mixture with low temperature we will get the best results.

**The main results of the research:**

1) Using reclaimed asphalt with virgin materials is better than using total virgin material because we got better results.
2) This saves the natural sources of new material and use the material previously used in the paving to be used again so it will cause economic benefits.
3) Using RAP instead of virgin materials has the same characteristics in mixtures.
4) By using warm mix asphalt, it saves energy, and it will be better for the workers' health.

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