

# Mechanical and Post Thermal Properties of Concrete with Recycled Asphalt Pavement Aggregate

Jeevan H.<sup>1</sup>, Manjunatha M.<sup>2</sup>, Vadiraj Rao N.R.<sup>3</sup>, Shrikanth H.D.<sup>4</sup>

Assistant Professor, Department of Civil Engineering, National Institute of Engineering, Mysuru, Karnataka, India<sup>1,3</sup>

Assistant Professor, Department of Civil Engineering, NMAM Institute of Technology, Nitte, Karnataka, India<sup>2</sup>

UG Student, Department of Civil Engineering, National Institute of Engineering, Mysuru, Karnataka, India<sup>4</sup>

**ABSTRACT:** These paper describes the behaviour of concrete by partial replacement of coarse aggregate with recycled asphalt pavement (RAP) aggregate. The post thermal compressive strength of cube specimens also studied after subjected to 100°C temperature. The compressive strength of concrete specimen at 0%, 10% 20% and 30% replacement of coarse aggregate with RAP aggregates at room temperature shows beyond the target mean strength. At 40% and 50% replacement level, the compressive strength decreases which is not less than the characteristics strength of concrete. The 28 days split tensile strength of concrete specimen decreases as the percentage of RAP aggregate increases. The residual compressive strength of concrete specimens after subjected to 100°C temperature is 36.30 N/mm<sup>2</sup>, 31.25 N/mm<sup>2</sup> and 28.7 N/mm<sup>2</sup> at 0%, 10% and 20% replacement level which is beyond the target mean strength. At 30%, 40% and 50% replacement of coarse aggregate with RAP aggregates shows the residual strength of 26.05 N/mm<sup>2</sup>, 22.84 N/mm<sup>2</sup> and 20.10 N/mm<sup>2</sup> after exposed to 100°C temperature, indicates it is not less than the characteristics strength of concrete.

**KEYWORDS:** Recycled asphalt pavement aggregate, Compressive strength, Split tensile strength, Workability, Coarse aggregate.

## I. INTRODUCTION

Concrete is the most widely used construction material. It is difficult to point out another material of construction which is versatile as concrete. Concrete has been the most preferred construction material for over five decades. It is being increasingly used day by day all over the world due to its versatility, mouldability, high compressive strength and many more advantages. The main ingredients of concrete are cement, fine aggregate [sand], coarse aggregate [stone] and water. The scarcity and availability at reasonable rates of sand and aggregate are now giving anxiety to the construction industry. Over years, deforestation and extraction of natural aggregates from river beds, lakes and other water bodies have resulted in huge environmental problems. The best way to overcome this problem is to find alternative aggregates for construction in place of conventional natural aggregates. Recycled asphalt pavement (RAP) is the reclaimed and reprocessed pavement material containing asphalt and aggregate. Most RAP is recycled back into pavements, and as a result there is a general lack of data pertaining to the mechanical properties for RAP in other possible applications such as Portland cement concrete.

## II. LITERATURE REVIEW

The compressive and flexural strength of concrete produced with RAP as coarse aggregate were found to be lower than those made from natural aggregate. The strength of RAP concrete is dependent on the bond strength of the asphalt-mortar coating on the aggregate [1]. According to author, it was observed that, incorporation of RAP to the binder course mix resulted in an improvement in all mechanical properties. It was found that the mix containing up to

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30% RAP, displayed improved fatigue resistance relative to the control mix [2]. It was found that the reclaimed aggregates absorbed more water than the natural crushed granite rock. The percentage water absorption values are 3.1, 2.8, and 1.3 for RCA, RAP and CGA respectively [3]. From the authors observation, it can be concluded that the indirect tensile strength test results indicated that the use of RHA as filler contributes more to crack resistance of recycled asphalt pavement than OPC filler [4]. From the investigation, it was observed that the 30% replacement of natural aggregate can be successfully done in base course of flexible pavements, resulting in a savings of around 25- 30% in construction cost [5].

## III. SCOPE OF RESEARCH

These research work has taken up to investigate the strength properties at room temperature and residual compressive strength at 100°C temperature of concrete by partially replacement of coarse aggregate with recycled asphalt pavement aggregate (RAP) and compare the results with referral mix.

The objective of the research work is:

1. To study the physical properties of concrete with various percentage of RAP aggregate.
2. To study the mechanical properties such as compressive strength and split tensile strength with various percentage of RAP aggregates.
3. To study the residual compressive strength of concrete with various percentage of RAP aggregates after subjected to 100°C temperature.

## IV. EXPERIMENTAL PROGRAM

The properties of various materials used in concrete (M20) are discussed in this section:

### A. CEMENT:

The cement is the main ingredient of concrete is used as a binder material, setting starts when cement contacts with water. The cement plays vital role in concrete material to attain required strength and durability. The Ordinary Portland Cement (OPC) is used and it conforms to IS: 12269-1987.

Table 1: Physical Properties of Ordinary Portland Cement (OPC 43 grade)

| Sl.No. | Characteristics   | Unit               | Test results            | Requirement as per IS: 12269- 1987  |
|--------|---|--------------------|-------------------------|-------------------------------------|
| 1      | Fineness<br>(Retained on 90 Micron IS sieve)              | %                  | 2.0                     | Max 10.00%                          |
| 2      | Setting time<br>• Initial Set<br>• Final Set              | Minutes<br>Minutes | 90.00<br>250.00         | Min 30.00<br>Max 600.00             |
| 3      | Compressive Strength<br>• 3 days<br>• 7 days<br>• 28 days | MPa<br>MPa<br>MPa  | 35.00<br>51.00<br>63.50 | Min 27.00<br>Min 37.00<br>Min 43.00 |
| 4      | Standard Consistency                                      | %                  | 35.00                   | -                                   |
| 5      | Specific Gravity  | -                  | 3.15                    | -                                   |

### B. COARSE AGGREGATE:

The crushed stone aggregates of 20mm size obtained from local quarry site were used for the current research work. The specific gravity of the coarse aggregates were found to be 2.65. The water absorption values obtained for the aggregates is 0.5%.

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## C. NATURAL SAND

The natural sand was locally procured and conformed to grading zone II as per IS: 383-1970. The table 2 shows the properties of natural sand.

Table 2: Properties of Natural Sand

| Sl. No. | Characteristics  | Value   |
|---------|------------------|---------|
| 1.      | Type             | Natural |
| 2.      | Specific gravity | 2.53    |
| 3.      | Water absorption | 1.02%   |
| 4.      | Grading zone     | Zone II |

## D. RECYCLED ASPHALT PAVEMENT AGGREGATE:

The figure 1 shows recycled asphalt pavement aggregate was prepared by crushing waste asphalt pavement rubbles obtained from waste dump at a road construction site. The old asphalt pavement was fine graded hot mix asphaltic concrete. The waste asphalt pavement rubbles were crushed, sieved and graded to sizes similar to that of the natural gravel. The RAP coarse aggregate consists of asphalt mortar (Asphalt binder-sand-filler matrix) coated aggregates retained on 4.75mm sieve.



Fig 1: Recycled Asphalt Pavement Aggregate

## E. WATER:

Water is the most important constituent of a concrete mass which enables bonding between cementitious materials and the aggregates and also helps in the hydration of cement which is the most important phenomenon in gaining strength. Potable water which is free from salts and impurities is used for mixing and also curing purposes.

## F. MIX DESIGN:

The concrete mix is designed based on IS: 10262-2009. The mix proportions of M20 grade of concrete is 1:2.28:2.71 with water to cement ratio of 0.55. The table 3 shows the quantity of constituent materials for various percentage of recycled asphalt pavement aggregate.

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Table 3: Mix proportion for M20 grade of concrete for various percentage of RAP

| Percentage of RAP | W/C  | C Kg/m <sup>3</sup> | FA kg/m <sup>3</sup> | CA (20mm) Kg/m <sup>3</sup> | RAP Kg/m <sup>3</sup> | W Kg/m <sup>3</sup> | Slump in mm |
|-------------------|------|---------------------|----------------------|-----------------------------|-----------------------|---------------------|-------------|
| 0%                | 0.55 | 358                 | 818                  | 970                         | 0                     | 197                 | 100         |
| 10%               | 0.55 | 358                 | 818                  | 873                         | 97                    | 197                 | 98          |
| 20%               | 0.55 | 358                 | 818                  | 776                         | 194                   | 197                 | 94          |
| 30%               | 0.55 | 358                 | 818                  | 679                         | 291                   | 197                 | 90          |
| 40%               | 0.55 | 358                 | 818                  | 582                         | 388                   | 197                 | 88          |
| 50%               | 0.55 | 358                 | 818                  | 485                         | 485                   | 197                 | 85          |

NOTE: C-CEMENT, CA-COARSE AGGREGATE, FA-FINE AGGREGATE, W-WATER, RAP- RECYCLED ASPHALT PAVEMENT AGGREGATE

## V. METHODOLOGY AND DISCUSSION

The calculated quantity of ingredient materials of concrete were weighed and mixed thoroughly in concrete mixer till the homogeneous mix was achieved. The cubes of 150 mm size, cylinder of 150 mm. diameter and 300mm length were casted and cured for 7days, 14days and 28days. Total fiftyfour cubes and fifty four cylinders with varying percentage of recycled asphalt pavement aggregate weretested at room temperature. The post thermal compressive strength of other 15 numbers of cubes were measured after subjected to sustained 100°C temperature of 2 hours duration.

### A. COMPRESSIVE STRENGTH TEST:

The compression strength test was carried out on universal testing machine of 200MT capacity as shown in figure 2. Aftercuring periods, thehardened concrete specimens were tested for 7days, 14days and 28days. The results of various percentage of RAP concrete specimen was compared with referral mix.



Fig 2: Compression strengthtest

### B. SPLIT TENSILE STRENGTH:

The cylinder specimen were tested for split tensile strength after curing periods of 7days, 14days and 28days onuniversal testing machine of 200MT capacity as shown in figure 3.

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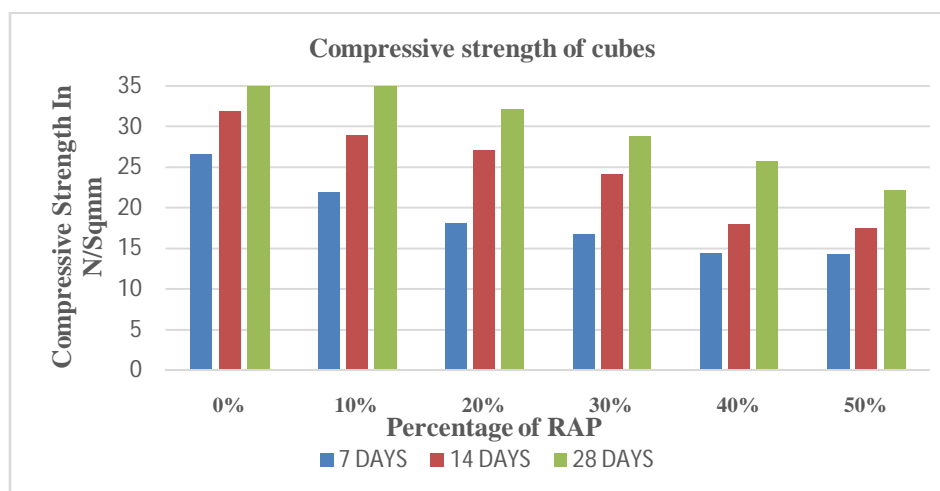
**Fig 3: Split tensile strength test**

## C. OBSERVATION:

The following graphs shows the test results on the hardened concrete for 7days, 14days and 28days:

Table 4: Compressive strength of M20grade concrete for various percentage of RAP

| Sl. No. | % Replacement of RAP | Compressive Strength in N/mm <sup>2</sup> |         |         | % decrease in comp. strength |         |         |
|---------|----------------------|---|---------|---------|------------------------------|---------|---------|
|         |                      | 7 days                                    | 14 days | 28 days | 7 days                       | 14 days | 28 days |
| 1       | 0%                   | 26.60                                     | 32.01   | 41.42   | 0%                           | 0%      | 0%      |
| 2       | 10%                  | 22.01                                     | 29.01   | 36.02   | 17.2%                        | 9.37%   | 13%     |
| 3       | 20%                  | 18.20                                     | 27.16   | 32.12   | 31.5%                        | 15.15%  | 22.45%  |
| 4       | 30%                  | 16.76                                     | 24.16   | 28.95   | 37%                          | 24.5%   | 30.1%   |
| 5       | 40%                  | 14.51                                     | 18.06   | 25.85   | 45.45%                       | 43.5%   | 37.6%   |
| 6       | 50%                  | 14.30                                     | 17.51   | 22.23   | 46.2%                        | 45.3%   | 46.3%   |



**Fig4: Variation of compressive strength of cubes specimenswith various percentage of RAP**

The table 4 and figure 4 shows the compressive strength of concrete with various percentage of RAP aggregates. It clearly indicates that compressive strength decreases as the percentage of RAP aggregates increases up to 50%. The compressive strength at 7days with varying percentage of RAP aggregates 0%, 10%, 20%, 30%, 40%,50% is 26.6,

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22.01, 18.2, 16.67, 14.51, 14.3N/mm<sup>2</sup>. The compressive strength at 14days with varying percentage of RAP aggregates 0%, 10%, 20%, 30%, 40%, 50% is 32.01, 29.01, 27.16, 24.16, 18.06, 17.51N/mm<sup>2</sup>. The compressive strength at 28days with varying percentage of RAP aggregates 0%, 10%, 20%, 30%, 40%, 50% is 41.42, 36.02, 32.12, 28.95, 25.85, 22.23N/mm<sup>2</sup>. The percentage decrease in 7days compressive strength for varying percentage of RAP aggregates 0%, 10%, 20%, 30%, 40%, 50% is 0%, 17.2%, 31.5%, 37%, 45.45%, 46.2%. The percentage decrease in 14days compressive strength for varying percentage of RAP aggregates 0%, 10%, 20%, 30%, 40%, 50% is 0%, 9.37%, 15.15%, 24.5%, 43.5%, 45.3%. The percentage decrease in 28days compressive strength for varying percentage of RAP aggregates 0%, 10%, 20%, 30%, 40%, 50% is 0%, 13%, 22.45%, 30.1%, 37.6%, 46.3%.

Table 5: Split tensile strength of M20 grade concrete with various percentage of RAP

| Sl. No. | % Replacement<br>of RAP | Split tensile Strength in N/mm <sup>2</sup> |         |         |
|---------|-------------------------|---|---------|---------|
|         |                         | 7 days                                      | 14 days | 28 days |
| 1       | 0%                      | 1.908                                       | 3.01    | 3.65    |
| 2       | 10%                     | 1.82  | 2.85    | 3.55    |
| 3       | 20%                     | 1.74  | 2.32    | 3.02    |
| 4       | 30%                     | 1.68  | 2.1     | 2.36    |
| 5       | 40%                     | 1.58  | 1.92    | 2.05    |
| 6       | 50%                     | 1.52  | 1.72    | 1.78    |

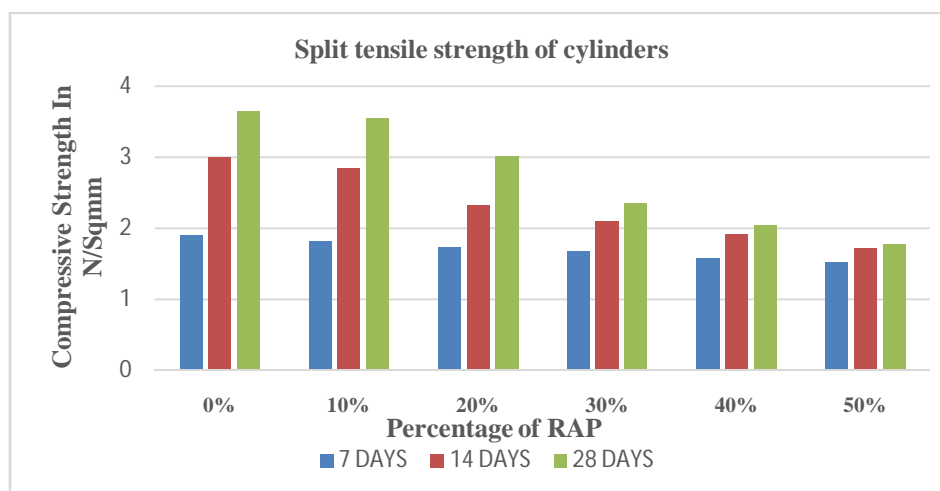


Fig 5: Variation of split tensile strength of cylinder specimen with various percentage of RAP

The table 5 and figure 5 shows the split tensile strength of concrete with various percentage of RAP aggregates. It clearly indicates that the split tensile strength decreases as the percentage of RAP aggregates increases up to 50%. There is slight variation in 7days split tensile strength for all replacement level. At 50% replacement level it shows 1.52N/mm<sup>2</sup>. There is slight variation in 14days split tensile strength up to 30% replacement level. At 40% and 50% replacement level its shows 1.92N/mm<sup>2</sup> and 1.72N/mm<sup>2</sup>. For 28days split tensile strength, there is slight variation up to 20% replacement level. At 30%, 40% and 50% replacement level its shows 2.36N/mm<sup>2</sup>, 2.05N/mm<sup>2</sup> and 1.78N/mm<sup>2</sup>.



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## D. POST THERMAL COMPRESSIVE STRENGTH TEST:

The concrete cubes were made with various percentage replacement of recycled asphalt pavement aggregate (RAP) were exposed to temperature of 100<sup>0</sup> C for a 2 hours duration in an electric furnace of 1000<sup>0</sup> C temperature capacity and tested for compressive strength after cooling to room temperature.

Table 6: Variation of compressive strength of cubes with RAP after exposed to 100<sup>0</sup> C temperature

| SL. No. | % Replacement of RAP | Compressive Strength in N/mm <sup>2</sup> at room temperature | Residual compressive Strength in N/mm <sup>2</sup> after exposed to 100 <sup>0</sup> C temperature | % decrease in compressive strength after exposed to 100 <sup>0</sup> C temperature |
|---------|----------------------|---|--|--|
| 1       | 0%                   | 41.42   | 36.30  | 0%   |
| 2       | 10%                  | 36.02   | 31.25  | 14%  |
| 3       | 20%                  | 32.12   | 28.70  | 21%  |
| 4       | 30%                  | 28.95   | 26.05  | 28.2%  |
| 5       | 40%                  | 25.85   | 22.84  | 37.07%   |
| 6       | 50%                  | 22.23   | 20.10  | 44.62%   |

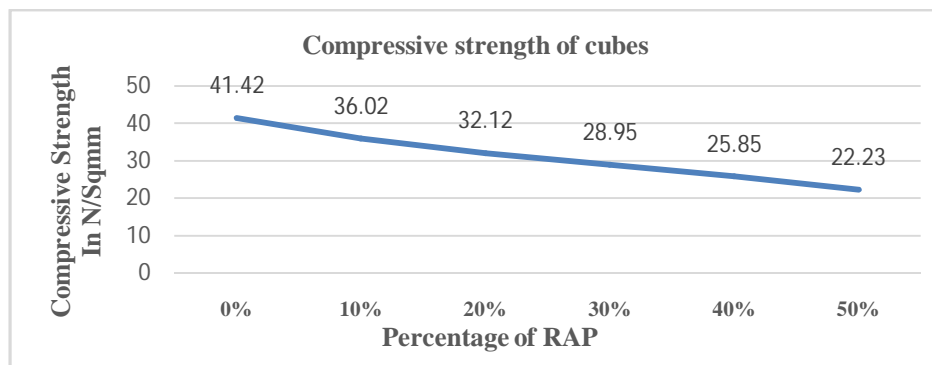


Fig 6: Variation of compressive strength of cubes with various percentage of RAP at room temperature

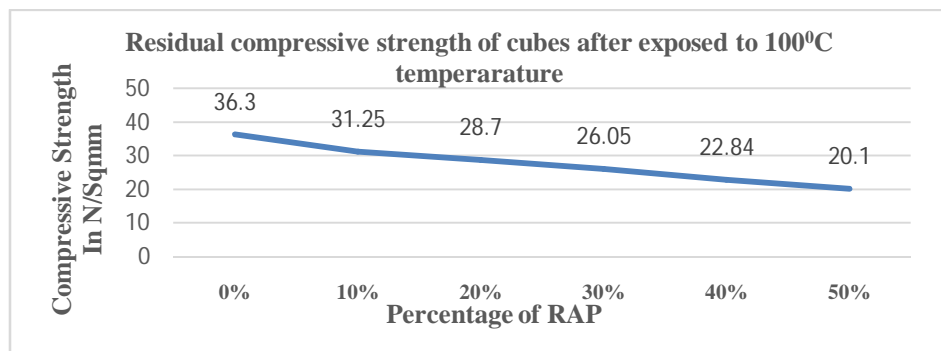


Fig 7: Variation of compressive strength of cubes with various percentage of RAP at 100<sup>0</sup> C temperature

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The table 6 and figure 6-7 shows the variation of compressive strength with RAP aggregates after subjected to 100<sup>0</sup>C temperature. The concrete cubes at 0%, 10% and 20% replacement of coarse aggregate with RAP aggregates shows the residual strength of 36.30N/mm<sup>2</sup>, 31.25N/mm<sup>2</sup> and 28.7N/mm<sup>2</sup>, it indicates beyond the target mean strength of concrete after subjected to sustained 100<sup>0</sup>C temperature for 2 hours duration. At 30%, 40% and 50% replacement of coarse aggregate with RAP aggregates shows the residual strength of 26.05N/mm<sup>2</sup>, 22.84N/mm<sup>2</sup> and 20.10N/mm<sup>2</sup> after exposed to 100<sup>0</sup>C temperature, but it is not less than the characteristics strength of concrete. The percentage decrease in residual compressive strength at 50% replacement level is 44.62%, when compared with referral mix residual compressive strength without RAP aggregate.

### VI. CONCLUSION

Based on the experimental investigation, the following conclusion were drawn:

- 1) The compressive strength of concrete specimen is beyond the target mean strength at 0%, 10% 20% and 30% replacement of coarse aggregate with RAP aggregates at room temperature.
- 2) At higher replacement levels of 40% and 50%, the compressive strength decreases which is not less than the characteristics strength of concrete.
- 3) The split tensile strength at 28 days decreases as the percentage of RAP aggregates increases.
- 4) The post thermal compressive strength of concrete specimens at 100<sup>0</sup>C temperature is 36.30N/mm<sup>2</sup>, 31.25N/mm<sup>2</sup> and 28.7N/mm<sup>2</sup> at 0%, 10% and 20% replacement level which is beyond the target mean strength.
- 5) At 30%, 40% and 50% replacement of coarse aggregate with RAP aggregates shows the residual strength of 26.05N/mm<sup>2</sup>, 22.84N/mm<sup>2</sup> and 20.10N/mm<sup>2</sup> after exposed to 100<sup>0</sup>C temperature, but it is not less than the characteristics strength of concrete.

### REFERENCES

- [1] Fidelis O. OKAFOR "Performance of Recycled Asphalt Pavement as Coarse Aggregate in Concrete", *Leonardo Electronic Journal of Practices and Technologies*, Issue 17, pp.47-48, 2010.
- [2] Amir Tabaković, Amanda Gibney, Ciaran McNally, and Michael D. Gilchrist, "Influence of Recycled Asphalt Pavement on Fatigue Performance of Asphalt Concrete Base Courses", *Journal of Materials in Civil Engineering*, vol.22, No.6, pp.643–650, 2010.
- [3] Obam, Ogah "Comparison of Some Strength Properties of Concrete Made from Reclaimed Aggregates and Crushed Granite Aggregate", *International Journal of Engineering and Science*, vol. 3, Issue 9, pp.01-06, 2014.
- [4] Jaafar Abubakar Sadeeq, Jibrin Mohammed Kaura, Ochebo Joshua and Ahmad Rabilu, "Recycling of Reclaimed Asphalt Pavement (RAP) with Rice Husk Ash (RHA)/Ordinary Portland Cement (OPC) Blend As Filler", *Jordan Journal of Civil Engineering*, vol. 8, No.4, pp.473-48, 2014.
- [5] Brajesh Mishra, "A Study on Use of Reclaimed Asphalt Pavement (RAP) Materials in Flexible Pavements", *International Journal of Innovative Research in Science, Engineering and Technology*, Vol.4, Issue 12, pp.12170-12177, 2015.