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EXPERIMENTAL AND NUMERICAL INVESTIGATION OF ROLL PAVE BLENDED WITH ATACTIC POLYPROPYLENE

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ABSTRACT

In this study asphalt mix is modified by using Atactic Poly Propylene (APP) and made as a roll pave in the form of a prefabricated single unit as 300 mm x 300 mm x 20 mm. A four different roll pave is made by varying the APP content starting from 0 %, 6.5 %, 10 %, and 15 %. This roll pave is tested for density, deflection, and skid resistance for the varying APP contents. The 6.5 % APP content in the roll pave gives optimum. In general addition of APP in asphalt mixes increase the performance of roll pavement rather and it should be tested before it reaches road application. Roll of paving is the best concept for repair works rather than laying the new road. The numerical model created for the roll pave using ABAQUS gives a good agreement with experimental failure patterns.

Keywords: atactic poly propylene, prefabricated roll pave, deflection, skid resistance, finite element analysis, ABAQUS.

1. INTRODUCTION

The Styrene Butadiene Styrene (SBS) in the Asphalt mix increases the pavement performance in terms of lifetime (Li, Y, 2018). The SBS in asphalt mix increases the stress relaxation, and higher resistance to low-temperature cracking, rutting, and fatigue cracking compared to asphalt modified by Ethylene - Vinyl Acetate (EVA) (Diab, A, 2020). The presents of Atactic PolyPropylene (APP) in asphalt mixtures increases the service life of the pavements (Al-Haidri, 2021). To increase the durability of the road pavements steel and plastic are placed below the asphalt mixture, the only challenge in the flexible pavement is laying cost (Jiang, W, 2021). The usage of prefabricated structures in the construction industry leads to quick construction in high-traffic demand places (Jin, Z, 2021 &Stern, S, 2021]. The roll paves concept was first introduced by a consortium with dura Vermeer infrastructure and INTRON and they suggested that this roll pave is useful for motor wave-wearing courses, urban roads, bridge decks, and parking decks. This conclusion is made by testing a prefabricated roll pave of 100 m by 5 m near the highway 2001 and in poor weather conditions four mats of 50m length, 2.5 m width, and thickness of 30 mm were tested (Naus, R, 2004).

The prefabricated rollable asphalt pavement (Roll Pave) modified with SBS is tested for wheel track test, bending test, and immersion marshal test. The results show that roll paving is the best idea to repair damaged pavements due to rainfall and rutting failures (Dong, Y. S, 2017 & Dong, Y. S, 2015).

From the above literature, prefabricated flexible pavement laying is needed for rapidly growing cities and metropolitans. In this project, a small prefabricated roll pave is prepared using APP in the highway engineering laboratory and tested for durability and load-carrying capacity. The varying APP content in the bitumen and bitumen emulsion is started from 6.5 % to 10 % by weight (Jiang, W, 2021).

2. MATERIALS USED AND ITS PROPERTIES

The materials used to produce the roll pave are Bitumen, Coarse aggregate, and Atactic Poly Propylene (APP).

2.1 Bitumen

To make prefabricated roll pave, bitumen is used as a binder. Bitumen is a sticky, black coloured, and highly viscous liquid or semi-solid form of petroleum and its grade is 60/70. The bitumen is procured in the form of an emulsion and its grade is RS-1 for the base preparation of wearing a coat. The tested properties for the bitumen without APP and with APP are shown in Table-1 & Table-2. The APP content of 6.5 % is chosen for the bitumen and emulsion testing.

Table-1. Properties of bitumen and emulsion without APP.

Properties	Tested Results	Test Method
Penetration Test - Grade (60/70)	71 mm	IS 1203 - 1978
Penetration Test - Emulsion RS-1	110 mm	
Softening Point	350˚ C	IS 1205 -1978
Viscosity Test - Grade (60/70)	19 minutes 48 seconds	IS 1206 - 1978
Viscosity Test - Emulsion RS-1	176 seconds	
Ductility Test	450 mm	IS 1208 - 1978

Table-2. Properties of bitumen and emulsion with APP.

Properties	Tested Results	Test Method
Penetration Test - Grade (60/70)	110 mm	IS 1203 - 1978
Penetration Test - Emulsion RS-1	140 mm	
Softening Point	120˚ C	IS 1205 - 1978
Ductility Test	750 mm	IS 1208 - 1978

2.2 Coarse Aggregate

The coarse aggregate in the bitumen pavement is an important role in terms of wear and tear. Before mixing coarse aggregate with bitumen the quality of aggregates has to be examined in a highway engineering laboratory and its average tested properties results are shown in Table-3.

Table-3. Properties of coarse aggregate.

Properties	Tested Results	Test Method
Specific gravity	2.8	IS 2386 - Part - 3
Water absorption Test (%)	2	IS 2386 - Part - 3
Impact Test (%)	3.5	IS 2386 - Part - 4
Loss Angels abrasion Test (%)	14	IS 2386 - Part - 4
Aggregate crushing Test (%)	8.2	IS 2386 - Part - 4
Elongation Index and Flakiness Index (%)	0.68 & 0.10	IS 2386 – Part - 1

2.3 Polymer

The Atactic Poly Propylene (APP) is a grinded solid polymer, which is supplied by prince scientific laboratory suppliers, Tiruchirappalli. Figure-1 shows the APP. The specific gravity of the APP is 0.8 and its softening point is 120˚C and this property is given by the supplier.

Figure 1. The typical view of Atactic Poly Propylene (APP).

2.4 Precast of Roll Pave

The precast of roll pave is done by using an MS container of volume 300 mm x 300 mm x 30 mm. In this mould waste oil is applied. The asphalt mix is placed above the rubber sheet in the mould. The preparation of asphalt mix is made by mixing the heated coarse aggregate up to a temperature of 190˚C and APP polymer at 120˚C using a laboratory oven a small quantity of filler is added while making the asphalt mix. The used filler is fly ash. The asphalt mixing is made in a vessel container, where the coarse aggregates attain a uniform coating made of bitumen. A compaction of 90 blows is given above the bituminous mix after being placed in the mould. This setup is left for 24 hrs before demoulding. After 24 hrs the setup is rolled to form the roll pave. Figure-2 shows the precast unit of roll paves. In this same making procedure, 4 units of roll pave are made by varying APP content 0 %, 6.5 %, 10 % & 15 %.

Figure-2. The typical view of precast roll pave.

2.5 Tests Result on Precast Roll Pave and Discussion

To test the laboratory-made roll pave it has to be laid in a location where it is susceptible to wear and tear. The laying of the roll paves had been done by applying a bitumen emulsion at the bottom of the roll pave for proper bonding. While applying the bitumen emulsion on the bottom of the roll pave heating is required for the emulsion. The emulsion is heated up to 100 ˚C. The following are the tests conducted on roll pave for its performance.

2.5.1 Density test

The density test is calculated after laying in the medium traffic for about 7 to 30 days. After 30 days a small quantity is cut and weighed for its loss of wearing surface. The cut surface was chosen where more failure occurs. The initial weight of the roll pave is taken before laying the roll pave. By using the change of weights in the roll pave the density is calculated. The calculated density for the various APP content in roll pave after 30 days of traffic is shown in Figure-3.

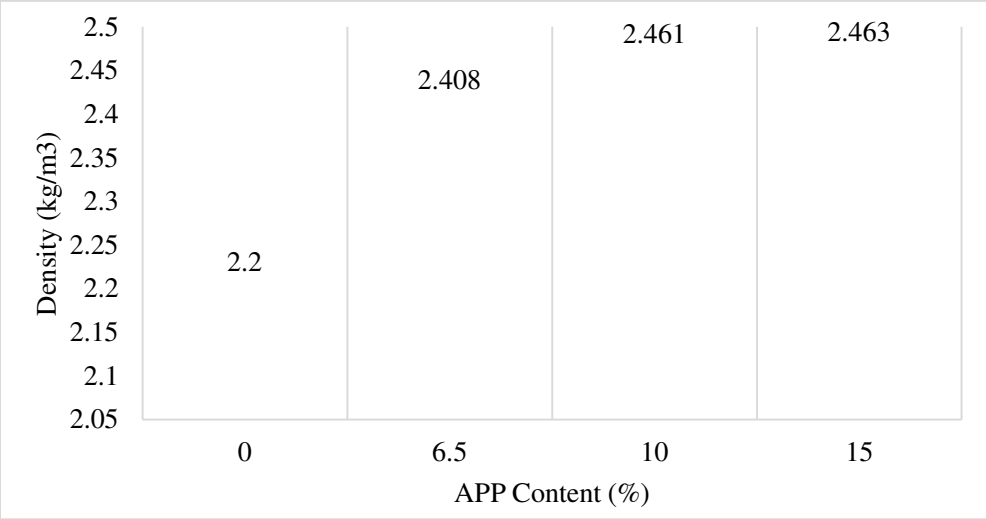

Figure-3. Density Variation for the different APP content.

The density test results show that the addition of APP in roll pave increases the wear and tear failures by up to 10 %. The 15 % of APP in roll pave has the same loss of density as a roll pave has 10 % of APP. This shows that

10 % APP in roll paves gives better wear and tear in terms of loss of density test results.

2.5.2 Deflection test

The surface deflection is measured as a pavement surface's vertical deflected distance as a result of the applied load. The deflection test is done using concrete cubes placed on top of the roll pave by using a simply supported end condition. The load is applied to the various locations to measure the deflection values using a deflectometer. Figure-4 shows the typical view of load–deflection on the roll pave.

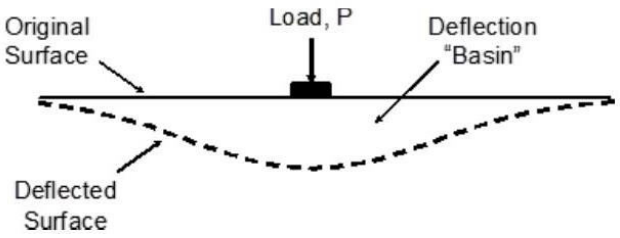

Figure-4. The typical view of precast roll pave subjected to static load.

The roll pave is constantly subjected to a static load of 180 kg by the action of concrete cubes on the top. The roll paves varying APP content and its measured deflection values are shown in Figure-5.

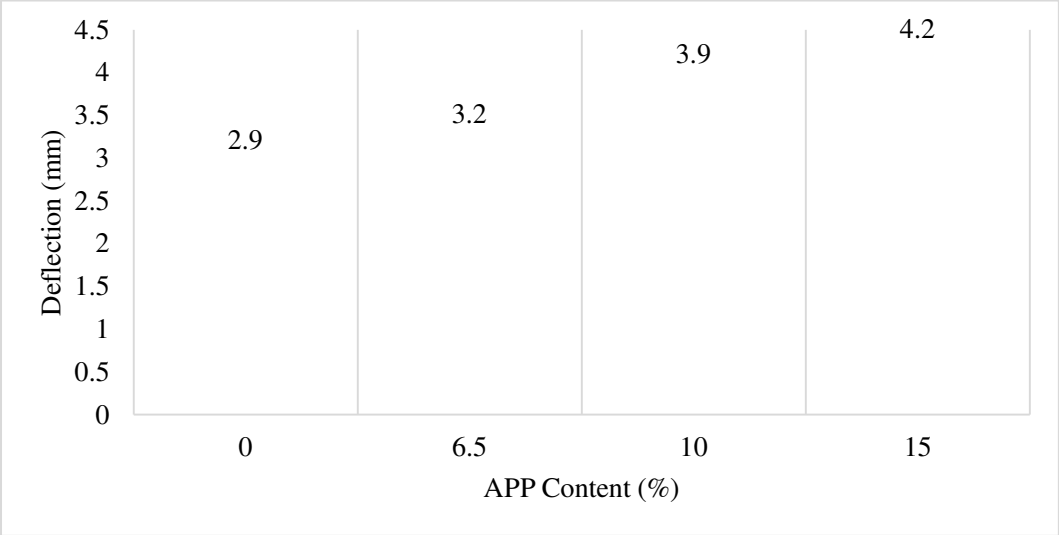

Figure-5. Deflection values for varying APP content.

The deflection values show that an increase in APP content increases the deflection. The increase in deflection purely depended on APP content. To use the APP content in roll pave is based on the field test.

2.5.3 Skid resistance test

The skid resistance was measured using a skid resistance tester with the help of recommendations provided by ASTM E 303 -83. This test is useful to find out the slipping and skidding resistance of a vehicle subjected to a wet and dry state. The roll pave contains 6.5 % APP gives a better skid resistance value and the remaining 10 % and 15 % APP content in roll pave doesn't meet standard values. The skid resistance value for 6.5 % APP content in roll pave is 0.382.

3. FINITE ELEMENT ANALYSIS

The finite element roll paves model was created by using ABAQUS software. The finite element analysis is used for the prediction of experimental results and parametric analysis (Farag Khodary, 2019). The finite element analysis results are highly dependent on the meshing and model calibration (Ahmed Alkaissi, Z, 2018).

Figure-6 shows the created roll pave model in ABAQUS. This model is applied with a boundary condition of pinned end conditions to find out the failure pattern.

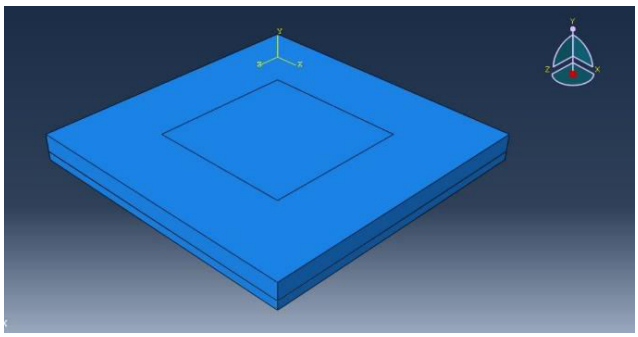

Figure-6. Roll pave model in ABAQUS.

The failure pattern obtained from the ABAQUS software gives the exact failure pattern as in got from experimental failure. The failure patterns for various APP content are shown in Figure-7.

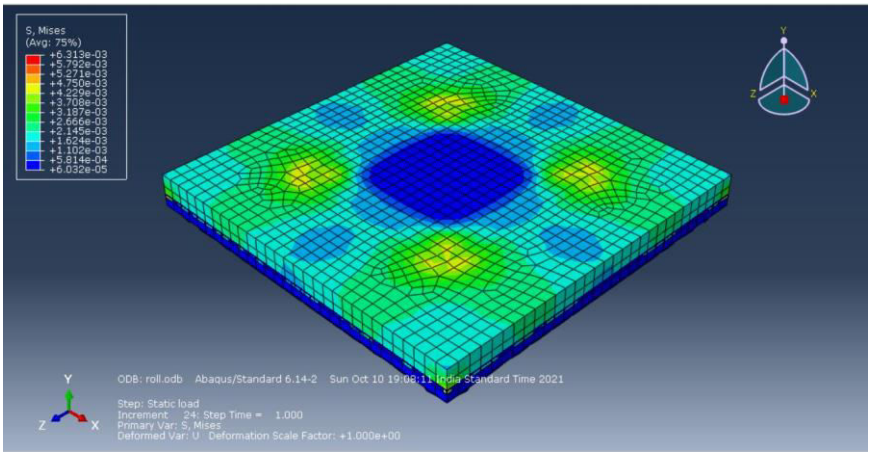

Figure-7. (a) Stress failure for APP content 0 %.

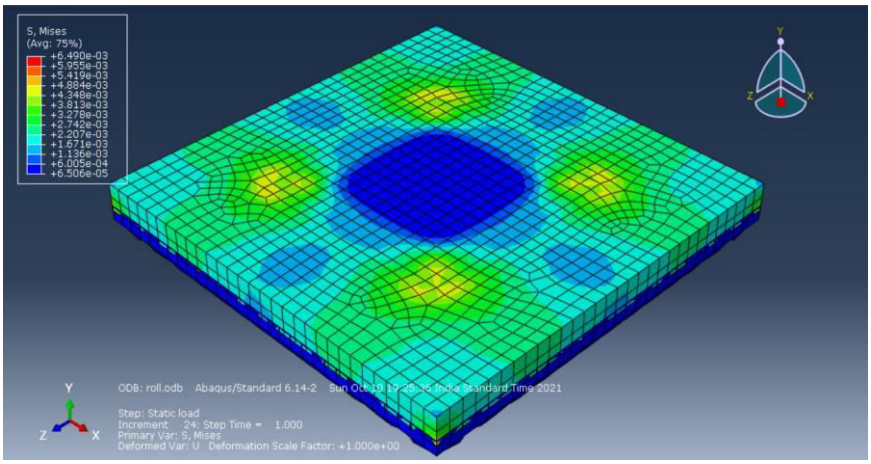

Figure-7. (b) Stress failure for APP content 6.5 %.

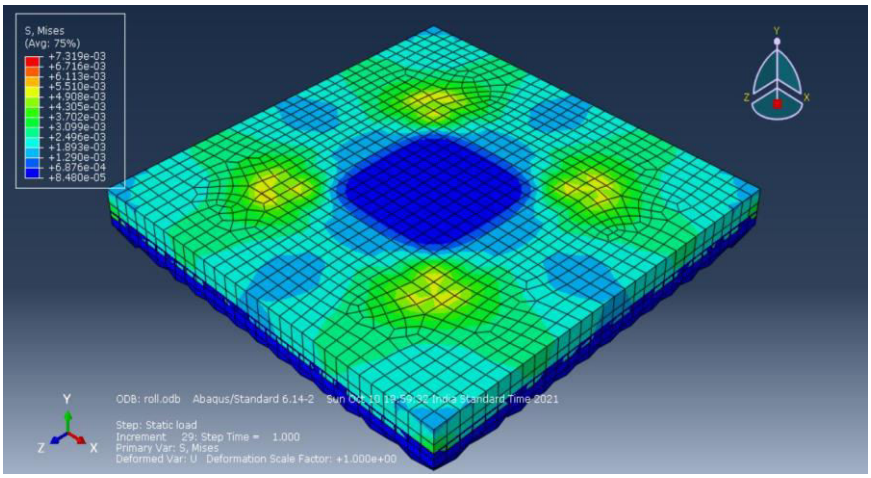

Figure 7. (c) Stress failure for APP content 10 %

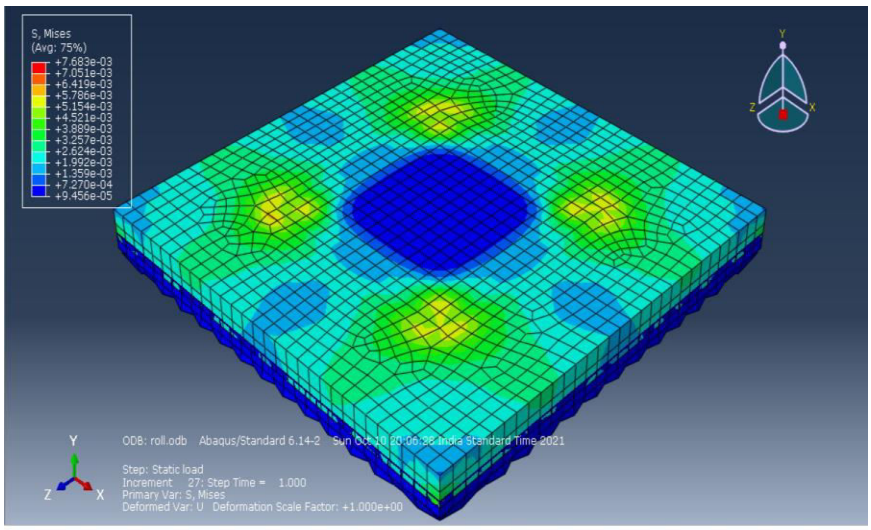

Figure-7. (d) Stress failure for APP content 10 %.

3.1 Finite Element Analysis Results and Discussion

The finite element failure patterns for the varying APP content as shown in Figure-7. The patterns seem to be the same failure mode obtained and the failure is related to the punching effect on the roll pave. The addition of APP in the asphalt mix has a good load-carrying capacity.

4. CONCLUSIONS

The following conclusions and suggestions made for the tested roll pave results

- The loss of density test with respect to Atactic Poly Propylene (APP) content proves that lesser loss was attained.
- The deflection test shows that Atactic Poly Propylene (APP) content increases the flexibility of the roll paves.
- The roll pave is made based on Atactic Poly Propylene (APP) content of 6.5 % gives better skid resistance. This gives an idea about the polymer content in road usage.
- In general, the addition of polymer in asphalt mixes increases the performance of the roll paves but it should test for optimum content before reaches the field application.
- The finite element analysis predicts the failure mode as well as the failure prevention by the rubber sheet.

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