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TO MEASURE THE DEFLECTION AND FIELD DENSITY OF POLYMER MODIFIED FLEXIBLE PAVEMENT

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Abstract - *In recent years due to heavy magnitude of wheel loads, tyre pressure and heavy traffic, the severity of rutting, cracks, raveling and edge drops is increasing on roads. Towards realizing the broad objectives, the specific tasks of this investigation are: Deflection measurement using a Benkelman beam was used to examine the structural assessment of flexible pavement for pavement strength. Using a sand pouring cylinder, estimate the road's field density. Use of polymers in flexible pavement construction is also in progress for the past two decades. Different types of polymers are mixed with bitumen and polymer modified bitumen is being used. Use of PMB has improved the quality of the road to some extent. Yet there are many limitations like the use of higher percentage of polymers, use of different type of polymers etc., In most of the process not much of scientific explanations are available.*

Key Words: *Evaluation of flexible pavement, Benkelman beam test, field density sand replacement method.*

1.INTRODUCTION

Roads act as a communication link in serving millions of people in every part of the World. The roads serve traffic safely, comfortably and efficiently at affordable cost. India being a developing country, the flexible pavement forms the major part of the roads in comparison with the use of other roads like Cement Concrete Road, Water Bound Macadam, Gravel Road, earthen road, etc. The transportation issues that many nations are experiencing have grown significantly, prompting the search for alternatives that provide effective, viable, and quicker modes of transport. Over the past two decades, traffic volumes and the percentage of heavy trucks have increased. Polymers are found to enhance the properties of bitumen and bituminous mixes. Disposed waste polymers like carry bags, cups and thermocol made from polyethylene, polypropylene and polystyrene which do not produce toxic gases up to 250ºC shall be used in the construction of flexible pavements in order to make a stronger bond between the aggregates and the bitumen. Further, the use of waste polymer in the flexible pavement helps reducing voids in it yielding a more durable and stronger flexible pavement. In this work, the scope of using polymer wastes to modify flexible pavements is investigated and established. Polymers, which forms 2% to 3% of the municipal solid waste are durable and degrade very slowly causing polymer waste disposal a great problem. Incineration of polymers releases toxic fumes such as dioxin, methane, ethane, carbon monoxide (CO), and carbon dioxide ($CO2$). Land filling would reduce porosity of the soil and affect soil microbe activity, due to their non-bio degradability. As such, both the process is tedious and unsafe in the case of disposal causing land and air pollution. Disposal of polymer waste in an eco-friendly way is the thrust area of today's research. Situation demands investigation of alternate means of reusing the polymer wastes. As such, a detailed study on waste polymers would address two criteria.

- Strengthening of flexible pavement
- Solid waste disposal

In this process, the polymer is coated over the hot aggregates and the coated aggregate is mixed with hot bitumen. The mixture is used for the construction of flexible pavement. This is an eco-friendly process. The polymer used are only waste polymer materials like carry bags, cups, foams etc., The use of higher percentage of polymer like 10-15% is easily adopted in this process as it involves only coating over aggregate. This process also helps to reduce the consumptions in bitumen to an extent of 10-15% which is being substituted by waste polymers. The coating of polymers over aggregate also helps to improve the characteristics of aggregate. A detailed study has been made in this regard. It has been observed that the coating of polymers over the aggregate has modified the properties of the aggregate.

- by reducing voids
- by reducing moisture absorption
- increasing soundness
- increasing various strength like. Los Angels Abrasion, Aggregate Impact, Crushing Strength etc.

2. LITERATURE REVIEW

Topal A., etal. (2010); González V *etal*., (2010); Pena JJ., etal. (2002); Airey GD., etal. (2003) Performance of bitumen in flexible pavement running on significant research polymer modified bitumen in recent years to improve. Modified bitumen provides the necessary variety of properties for the construction of roads leading to improved performance. Addition of polymer asphalt cement is the most important form of revision due to a wide range of use of its use. Nowadays, polymer technology is considered to be a permanent part of the highway construction. On the other hand, helps to solve environmental problems using crumb rubber scrap tyre, waste plastic, waste and other waste associated with polymers such as asphalt modifiers and help

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to improve pavement performance. **Feng Zhang *etal.*, (2011)** Properties of modified bitumen depend on modifier types that are on the modifier material and bitumen type. The main advantage of such Ilastomrs (SBR) and (SBS) is that they can provide modified bitumen or a high-power mix. Using ABS is a recent research in the field of polymer modified bitumen. ABS are blocked with a tri-section also co-polymer (elastomer), which consists of styrene molecules and nitrile compound on both sides and co-compound compound. The ABS polymer is used to alter the bitumen, and the modified bitumen is put through a set of studies, the outcome of which are presented in this thesis. **Othman. A. et al (2007)** conducted a study to determine the performance like based on physical and mechanical characteristics, polyethylene (PE) improved bitumen mixes. Physical characteristics such as penetration and softening point were assessed. The mechanical characteristics, on the other hand, were assessed using the indirect tensile strength. Polyethylene improves the physical and mechanical characteristics of modified binder and mixes, according to the findings. The paper on "Evaluation of polymer modified chip seal coats" by **Llyod D. Coyne (1987)** describes the evaluation of polymer modified asphalt emulsified chip seal coatings, the Vialit Drop Test and Surface Abrasion Test were adapted. The seal coatings' setting properties were assessed using a modified Vialit Drop Ball test. The seal coatings' durability was assessed using the surface abrasion test. **Gransberg etal. (2006)** Generally, the cationic rapid setting (CRS) type is most commonly used in asphalt for chip sealing on low-volume roads. Due to the low-cost maintenance benefits of chip seals, SHAs seek to expand their use to include roadways with traffic volumes that are greater than those currently used. Because polymer modification decreases the pavement's susceptibility to temperature fluctuations, enhances adhesion to minimise overall damage, and reduces highway friction, PME can be utilised in chip seal design for high-volume roads. Allows for traffic opening; otherwise, it will not be possible. All of these advantages have contributed to the chip seal industry's growing adoption of PME.

2.1 Deflection by use of Benkelman Beam Test

The Benkelman Beam Deflection studies conducted on such affected roads highlights the deteriorated state of the pavement structure.

Table 1: Details of Test Vehicle

Characteristic	Satisfactory range
Rear axle load	6355kg ± 10%
Dual rear wheel load	3170kg ± 10%
Front axle load	2350 to 3350kg
Wheel base	3.85m
Type of size	(8.25 x 20) preferred (7.25 x 20) (9.00 x 20) acceptable
Minimum gap b/w wall of twin rear wheels	Not less than 20-30mm
Gap b/w contact area of twin rear wheels	90 to 140mm
Moving speed	5m in 10±1sec

3. PROCEDURE

The road distance to be examined is split into homogenous parts based on the pavement condition survey. In the case of pavements with a total width greater than 3.5m, the loading points for deflection measurements are positioned along the wheel tracks on a line 0.9m from the pavement edge, and the distance from the edge is decreased to 0.6m for narrower pavements. On each selected section of pavement, a minimum of 10 deflection readings are taken. The lane distances are given in Table.2.

Table 2: Experimental Setup of Lane Distances

Lane width	Distance from kerb or lane edge
3.7m	0.9m
3.4m	0.8m
3.0m	0.6m
2.7m or less	0.4m

The truck was moved gently parallel to the edge and halted such that the left side rear dual wheel was centred above the first deflection measuring point. The Benkelman beam's probe end is placed between the dual wheel's gaps and precisely over the deflection observation point. The initial dial gauge reading Do is noted when the dial gauge reading is stationary. The vehicle is gently driven forward until it reaches a distance of 2.7m from the spot, at which point it comes to a halt. When the rate of pavement recovery is less than 0.025mm per minute, the intermediate dial gauge value Di is recorded. The vehicle is then pushed ahead for another 9.0m, and the final dial gauge reading Df is noted in the same manner as previously. Do, Di, and Df are three deflection dial readings that make up a set of values at one deflection point. The vehicle is then driven to the next deflection point, and the cycle is continued. Throughout the research, the temperature of the pavement surface is measured at one-hour intervals. At appropriate intervals, the moisture content of the subgrade soil must also be measured, and the rebound deflection value D at any point must satisfy one of the following two conditions:

i. If D_i - D_f ≤ 2.5 divisions of the dial gauge or 0.025mm, D = 2 (D_o - D_f) divisions of 0.01mm units = 0.02 (D_o - D_f) mm
ii. If D_i - D_f ≥ 2.5 divisions of the dial gauge or 0.025mm, this indicates that correction is needed for the vertical movement of the front legs.

Therefore D = 2 (D_o - D_f) + 2 K (D_i - D_f) divisions.
The value of K is to be determined for every make of the Benkelman Beam and is given by the relation:

K = (3d – 2e)/f

Where, d = distance between the bearing of the beam and the rear adjusting leg
e = distance between the dial gauge and rear adjusting leg
f = distance between the front and rear legs.
The value of K of Benkelman Beam generally available in India is found to be 2.91. Therefore, the deflection value in case (ii) with leg correction is given by:

D = 0.02 (D_o - D_f) + 0.0582 (D_i - D_f) mm

Table 3: Consolidated Rebound Deflection Values

Study area	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020
SITE I	0.68	0.66	0.70	0.61	0.56
SITE II	Short road	Short road	Short road	Short road	Short road
SITE III	0.76	0.81	0.83	0.79	0.75
SITE IV	0.89	0.92	0.93	0.86	1.5
SITE V	0.93	0.94	0.95	0.87	0.81
SITE VI	0.89	0.93	0.92	0.85	0.81
SITE VII	0.83	0.89	0.90	0.87	0.81
SITE VIII	0.84	0.84	0.84	0.83	0.80
SITE IX	1.94	1.62	1.56	1.56	0.81

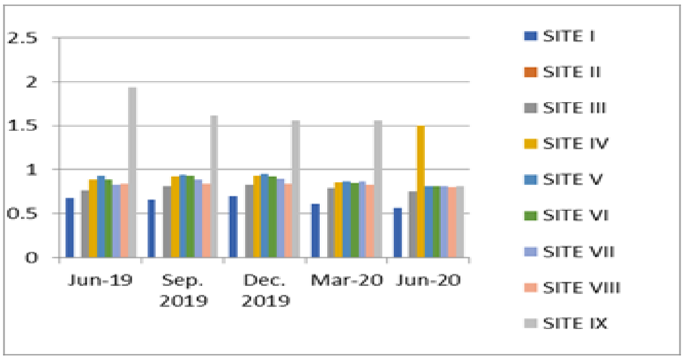

Fig. 1: Consolidated Rebound Deflection Values (mm)

The Benkelman Beam Test was used to assess the pavement's rebound deflection. The plastic tar road's rebound deflection values are less than 1. This demonstrates the strength of these strains.

3.1 Field Density by Sand Replacement Method

These observations are supported by the Field Density data shown in Table 4 and in Fig.2.

Table 4: Consolidated Field Density Values

Study area	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020
SITE I	2.62	2.39	2.36	2.33	2.30
SITE II	2.53	2.46	2.50	2.45	2.40
SITE III	2.46	2.63	2.68	2.33	2.30
SITE IV	2.29	2.40	2.45	2.55	2.50
SITE V	2.90	2.30	2.30	2.30	2.25
SITE VI	2.64	2.70	2.65	2.75	2.80
SITE VII	2.76	2.45	2.40	2.56	2.50
SITE VIII	2.87	2.36	2.36	2.82	2.78
SITE IX	2.15	2.11	2.10	2.05	2.00

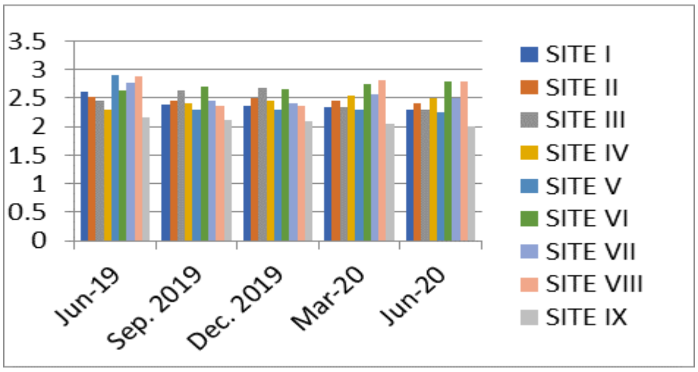

Fig. 2: Consolidated Field Density Values

In general, as compared to bituminous roads, the densities of plastic tar do not appear to be significantly lower. This demonstrates that the presence of a polymer layer increases compaction, resulting in improved binding. There are no potholes, ravelling, or other issues on the road.

3.2 Polymer Coated Aggregate

Table (5 to 8) gives the results obtained with samples collected from various quarries and Fig. (3 to 6) shows the graphical representation of the results.

Table 5: Test results of plain aggregate and polymer coated aggregate of sample collected from SITE I quarry

SN	Details	% of Plain aggregate	% of polymer coated over aggregate		
			0.5 %	1 %	2 %
1	Los Angeles Abarasion Value	37.00	34.00	32.00	29.40
2	Impact Value	25.40	23.00	21.30	18.50
3	Soundness Value	6.00	0.00	0.00	0.00
4	Flakiness Index Value	13.70	13.00	12.90	11.10
5	Elongation Index Value	16.20	16.60	17.10	18.00
6	Crushing Value %	25.90	23.09	21.40	20.00
7	Water Absorption Value	0.53	0.38	0.45	0.36
8	Specific Gravity	2.904	2.789	2.705	2.606

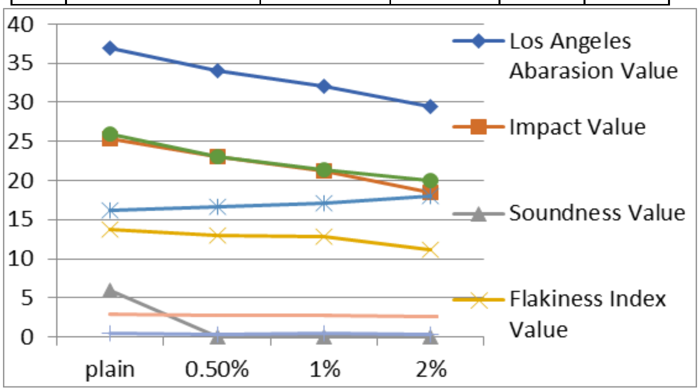

Fig. 3: Laboratory test results of plain aggregate and polymer coated aggregate of sample collected from SITE I quarry

Table 6: Laboratory test results of plain aggregate and polymer coated aggregate of sample collected from SITE II quarry

SN	Details	% of Plain aggregate	% of polymer coated over aggregate		
			0.5 %	1 %	2 %
1	Los Angeles Abrasion Value	27.5	27	26.6	25.4
2	Impact Value	39.3	32	25	22
3	Soundness Value	10.0	3	0.0	0.0
4	Flakiness Index Value	4.2	4.1	4.0	3.95
5	Elongation Index Value	4.7	5.9	6.9	6.4
6	Crushing Value %	29.9	28.2	26.6	23.5
7	Water Absorption Value	0.45	0.4	0.36	0.29
8	Specific Gravity	2.659	2.61	2.585	2.508

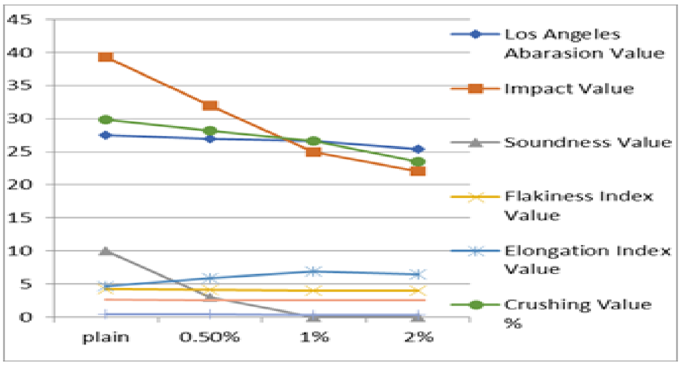

Fig. 4: Test results of plain aggregate and polymer coated aggregate of sample collected from SITE II quarry

Table 7: Laboratory test results of plain aggregate and polymer coated aggregate of sample collected from SITE III quarry

SN	Details	% of Plain aggregate	% of polymer coated over aggregate		
			0.5 %	1 %	2 %
1	Los Angeles Abarasion Value	25	24.2	23.1	20
2	Impact Value	29.25	20.4	14.3	12
3	Soundness Value	7	1	0.0	0.0
4	Flakiness Index Value	7	5.3	3.1	1.6
5	Elongation Index Value	6	5.1	4.2	3.8
6	Crushing Value %	23.4	21.5	20.1	16.
7	Water Absorption Value	0.57	0.5	0.49	0.41
8	Specific Gravity	2.643	2.62	2.583	2.536

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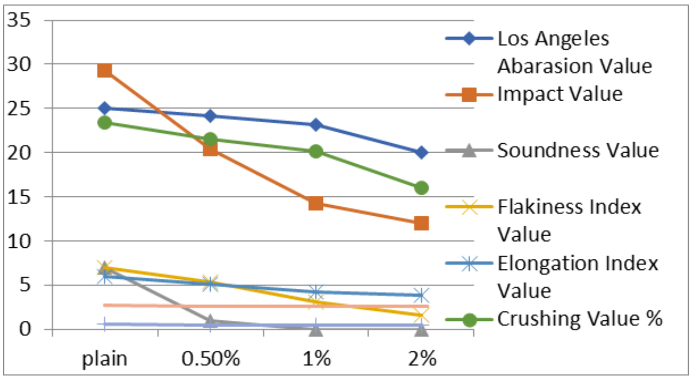

Fig. 5: Test results of plain aggregate and polymer coated aggregate of sample collected from SITE III quarry

Table 8: Laboratory test results of plain aggregate and polymer coated aggregate of sample collected from SITE IV quarry

SN	Details	% of Plain aggregate	% of polymer coated over aggregate		
			0.5 %	1 %	2 %
1	Los Angeles Abarasion Value	44	40.3	37.3	33.8
2	Impact Value	33	29.3	21.3	19
3	Soundness Value	9	2	0.0	0.0
4	Flakiness Index Value	5.64	5.4	5.23	4.92
5	Elongation Index Value	7.5	8.2	9.5	10.3
6	Crushing Value %	29.4	26.2	22.1	19.2
7	Water Absorption Value	0.51	0.45	0.4	0.32
8	Specific Gravity	2.66	2.64	2.623	2.554

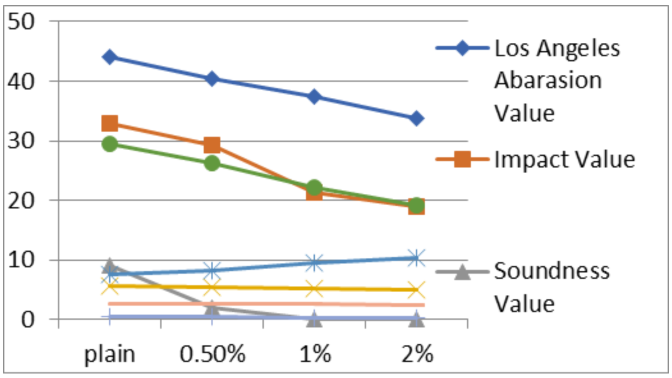

Fig. 6: Test results of plain aggregate and polymer coated aggregate of sample collected from SITE IV quarry

It was found that there is significant increase in the strength properties of the polymer coated aggregates with the addition of 0.5%, 1% and 2% of polymers with respect to the total weight of the aggregates (In all the samples). From the above, it is evident that polymer coated aggregates possess better strength (that is 27.20%), hardness, toughness and durability compared to plain aggregate. Water absorption was found to be less in PCA by 30.80% as compared to plain aggregate indicates a higher degree of water susceptibility. The decrease of specific gravity from 2.904 to 2.606 with addition of polymer does not significantly affect its use in the pavement construction. PCA mix showed no stripping even after 96 hours of water immersion and hence avoids the use of anti-stripping agents in bituminous courses. Further, polymer coated aggregate very well satisfies the MORTH specification (Table 9) for road aggregates.

Table 9: Comparison between Polymer coated aggregate and Plain aggregate with MORTH specification

SN	Property	Plain Aggregate (%)				Polymer Coated Aggregate (Polymer is 10% of Bitumen) (%)				MORTH Specification	Remarks
1	Los Angeles Abarasion Value (B Grade)	37				29.4				30%	Classified as string & suitable for all types of road construction
2	Aggregate impact value	25.4				18.5				30%	As specified
3	Flakiness Index Value and Elongation Index Value	29.9				29				Combined to 30%	As specified
4	Water Absorption Value	0.52				0.36				Less than 2%	As specified
5	Specific Gravity	2.904				2.606				2.5-2.9	As specified
6	Stripping Value	2 hrs	24 hrs	72 hrs	96 hrs	2 hrs	24 Hrs	72 hrs	96 hrs	Less than 5%	As specified
		0	0	2	5	0	0	0	0		
7	Soundness Test	6				Nil				Less than 18%	As specified

Aggregates which are found to be not suitable for road work as per MORTH specification become suitable for road works when coated with polymers. All the above results suggest the improvement in the basic properties of the aggregate. This is due to the fact that by coating polymer over the aggregates, polymer will play significant role in the following basic properties.

Water Absorption of polymer coated aggregate is low due to the reduction in the voids and the porous nature of the aggregate. Due to the voids present in the aggregate, when the aggregate is exposed to rain or water stagnation the water starts to penetrate in to the aggregate and makes it wet resulting in the deterioration of the aggregate. In polymer coated aggregate, the coating of polymers over the aggregate closes the voids and reduces the porosity and thereby not allowing water to penetrate resulting in better strength.

Soundness , the purpose of soundness testing is to see how well the aggregate weathers and how resistant it is to chemicals. When exposed to rainwater, plain aggregate with holes and spaces absorbs the water quickly and allows the water to permeate into the pores of the aggregate. Because rainwater is now impure in nature, including a high concentration of dissolved salts, when it reaches the pores, the salt crystallises and expands, crushing the aggregate. The quantity of voids and porosity of the aggregate directly affect the poor soundness characteristic. There are no voids or porosity in polymer coated aggregate.

Stripping value is the aggregate and bitumen's binding is determined. The bitumen-coated aggregate is submerged in water to test it. The stripping value is the amount of bitumen that peels away from the aggregate. When bitumen covered aggregate is submerged in water, the water seeps between the stone and the bitumen, causing the bitumen to peel. Potholes are formed as a result of the loosening of the aggregate. As a result of the presence of pores and spaces in aggregate, the aggregate's binding to the bitumen is weak. There are no pores in polymer coated aggregates, as previously stated. As a result, it has a low stripping value. Because both the polymer and the bitumen are hydrocarbons, the PCA bonds to the bitumen extremely effectively. As a result, bitumen peeling from the aggregate is quite rare.

In **Los Angeles Abrasion,** the hardness of aggregate is measured. The results for the polymer coated aggregate show better resistance to higher wear and tear load. This is simply due to the fact that covering aggregate with polymers improves adherence to the surface particles. It lowers the roughness of the aggregate, resulting in less abrasion on the aggregate's surface.

Impact value, the main purpose of measuring is to determine the aggregate's brittleness. The use of waste polymers to coat the aggregate lowers the number of voids and air cavities. This assist in the prevention of load cracking. The stones' hardness is also enhanced. As a result, as compared to the plain aggregate test, the impact value of the polymer coated aggregate is lower.

Crushing test is the crushing strength of road aggregate is determined in a roundabout way. The crushing strength of polymer coated aggregate is generally low because the polymer fills gaps and holes when it is coated over aggregate. As we all know, increased pores and spaces cause material to crush underweight, which may be avoided entirely by utilising polymer coated aggregate.

3.3 Performance Studies on Non-Destructive Test

The PCA flexible pavement has been selected for monitoring on the basis of the date of laying, seasonal aspects, and traffic volume. Deflection studies, field density study, roughness evaluation, skid resistance evaluation and sand texture depth were done on study area chosen. Table (10 to 18) gives the observed values on the study area.

Table 10: Study area – I

Month / test	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020	Tolerance value
Benkelman beam	0.63	0.65	0.69	0.60	0.55	0.5-1
Field density	2.62	2.39	2.36	2.33	2.30	2.86

Table 11: Study area – II

Month / test	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020	Tolerance value
Benkelman beam	Short road	Short road	Short road	Short road	Short road	0.5-1
Field density	2.53	2.45	2.50	2.45	2.40	2.86

Table 12: Study area – III

Month / test	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020	Tolerance value
Benkelman beam	0.75	0.8	0.82	0.79	0.75	0.5-1
Field density	2.46	2.63	2.69	2.32	2.30	2.86

Table 13: Study area – IV

Month / test	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020	Tolerance value
Benkelman beam	0.89	0.91	0.92	0.85	0.81	0.5-1
Field density	2.28	2.40	2.45	2.55	2.50	2.86

Table 14: Study area – V

Month / test	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020	Tolerance value
Benkelman beam	0.92	0.94	0.94	0.86	0.81	0.5-1
Field density	2.89	2.30	2.30	2.30	2.25	2.86

Table 15: Study area – VI

Month / test	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020	Tolerance value
Benkelman beam	0.88	0.93	0.91	0.84	0.81	0.5-1
Field density	2.64	2.70	2.65	2.75	2.80	2.86

Table 16: Study area – VII

Month / test	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020	Tolerance value
Benkelman beam	0.82	0.88	0.89	0.86	0.81	0.5-1
Field density	2.75	2.45	2.40	2.56	2.50	2.86

Table 5.17: Study area – VIII

Month / test	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020	Tolerance value
Benkelman beam	0.83	0.83	0.83	0.82	0.80	0.5-1
Field density	2.86	2.36	2.35	2.82	2.79	2.86

Table 5.18: Study area – IX

Month / test	June 2019	Sep. 2019	Dec. 2019	March 2020	June 2020	Tolerance value
Benkelman beam	1.93	1.63	1.56	1.55	1.50	0.5-1
Field density	2.15	2.11	2.09	2.05	2.0	2.86

4. RESULTS AND DISCUSSION

4.1 Benkelman Beam Test:

- The Benkelman Beam Test studies of the entire plastic tar road discussed here are very well. This study is an important property of the performance of the road. The Benkelman Beam Test is the study of the rebound deflection of the road when load is applied or moved over the road. The plastic tar road has an excellent rebound deflection because of its high Marshall Stability value, as previously mentioned. The flow value is rather good, which is mostly responsible for the bituminous mix visco elasticity property. The polymer will assist increase the visco elastic property of the mix by coating it with polymers and combining it with bitumen. Hence the Benkelman Beam Test values of the plastic tar even after performing for so many years is good. But in the case of the plain bituminous road when exposed to atmosphere the road starts losing its visco elastic property and get hardens resulting in the cracking of the road on giving load.

4.2 Field Density:

- This test is done to check the compaction of the road. To test the life of the road this test is indeed important. The field density of the entire plastic tar road discussed above is good. The field density of a road mainly depends upon the ageing of bitumen, i.e. the change in the basic properties of the bitumen after its exposure to the atmospheric air, sun light and rain. In case of polymer coated aggregate bituminous mix the change of properties of bitumen due to the atmospheric factor is very low. Hence there is not much of change in the field density of the plastic tar roads.

5. CONCLUSIONS

A detailed investigation was made on polymer modified flexible pavement and its characterization. The study clearly shows that the property of bitumen is unaltered in this process and rather the strength of the PCA bituminous mix is increased. The following advantages were observed during the structural and functional evaluation of the polymer modified flexible pavement:

- Better binding property as observed in extraction of binder test
- Higher softening point (upto53 ºC) and thereby withstanding high temperature
- Lower penetration value (65mm) and hence higher load carrying capacity
- Water absorption was found to be less in PCA by 30.80 percentages as compared to plain aggregate which indicates a higher degree of water susceptibility.
- The pollution due to burning of waste polymer and the pollution due to disposal by land filling and incineration can be avoided and hence helps to take a step towards controlling global warming
- It is an easy, cost effective and in-situ method as it doesn't involve extra machinery
- This technique is of social benefits as it generate jobs for rag pickers
- Aggregates which are found to be not suitable for road work becomes Suitable for road works when polymer coated.

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