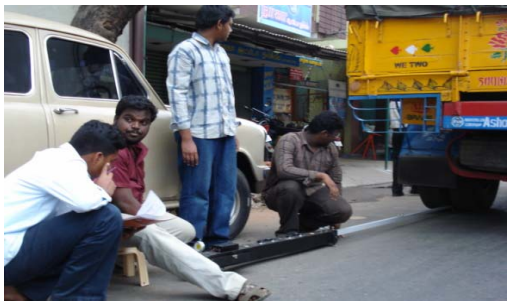
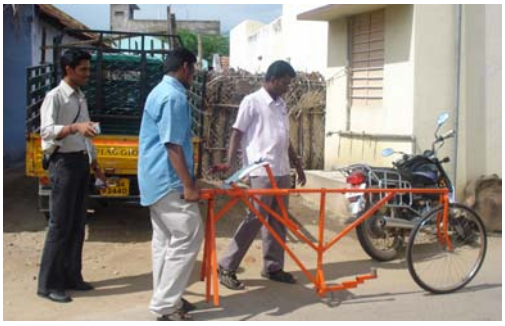
ROGRAMME OBJECTIVE SERIES:
PROBES/122/2008-2009

Performance Evaluation of Polymer Coated Bitumen Built Roads





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Foreword

Plastics wastes consisting of mainly polyolefins from items such as carry bags ,cups, thermocoles and packaging films pose a major problem for their disposal . In this study, the plastics wastes were shredded into small size, i.e 2 mm to 4 mm, molten and thereafter coated over hot aggregate at 160^0C. Several roads have been built in this manner in the State of Tamil Nadu, Puducherry, Maharashtra, Kerala and Andhra Pradesh using polymer-coated–bitumen aggregate. CPCB has sponsored this study in association with Thigarajar College of Engineering, Madurai on "Performance Study of Built Roads" as per the parameters suggested by Central Road Research Institute (CRRI) and Indian Road Congress (IRC). New Delhi. The parameters suggested were roughness survey, skid resistance, sand patch test, Benkelman beam deflection, cracking, raveling, potholes and edge breaks.

I am thankful to Dr. Abhai Kumar, Principal, Thigarajar College of Engineering, Madurai for dynamic support in completing this project. Special thanks are due to Prof R. Vasudevan, Dean, Thigarajar College of Engineering, Madurai for his concerted efforts in successful completion and timely submission of the final Report to CPCB. I am also thankful to Dr. S.K Nigam, Scientist "C", Dr. A.B. Akolkar, Additional Director, Dr. B. Sengupta, Member Secretary and Ms. Neelma Srivastava, Junior Research Fellow for their valued contribution in editing of the Report. I hope the report will be useful for road making agencies such as Municipal Corporations/Councils/Panchayats, Public Works Departments, and National Highways Authorities etc. for using plastics waste in road laying/construction. It will also help IRC for evolving specifications using plastics waste in road construction.

(J.M.Mauskar)

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Chapter – 1

1. Introduction

Plastics waste constitutes a significant portion of the total municipal solid waste (MSW) generated in India. It is estimated that approximately **10 thousand tons per day (TPD)** of plastics waste is generated (i.e 9 % of 1.20 lakh TPD of MSW). Their visibility has been perceived as a serious problem and made plastics a target in the management of solid waste. Plastics are non-biodegradable. They also have very long lifetime and the burning of plastics waste under uncontrolled conditions could also lead to generation of many hazardous air pollutants (HAPs) depending upon the type of polymers and additives used. However, the end-of-life plastics can be recycled into a second life application but after every thermal treatment, degradation of plastics takes place to a certain extent.

To address the plastics waste disposal issue, an attempt has been made to describe the possibilities of reusing the plastics waste (post-consumer plastics waste) in road construction. Central Pollution Control Board (CPCB) Delhi has published "Indicative Operational Guidelines on Construction of Polymer – Bitumen Roads for reuse of waste plastics (PROBES/101/2005-06). The document explains the method of collection, cleaning process, shredding, sieving and then mixing with bitumen for road laying. This studies was carried out by Thiagarajar college of Engineering, Madurai and the report was circulated to all the State Pollution Control Boards / Pollution Control Committees and other road laying agencies for reference.

By using this technology (plastics waste coated aggregate bitumen mix), several roads have been laid in the States of Tamil Nadu, Maharashtra , Puducherry, Kerala ,Andhra Pradesh and Goa. To evaluate the performance of the built roads using plastics waste coated aggregate (PCA) bitumen mix and also to generate data base for evolving Standards by Indian Road Congress (IRC), CPCB has instituted a study on "Performance Studies of Polymer Coated Bitumen Built Roads during 2002-2007" to Thigarajar college of Engineering, Madurai . In this report parameters suggested by Central Road Research Institute (CRRI) and Indian Road Congress (IRC) have been incorporated. Further details of each test and its comparison with the IRC Standards have also been given in this report.

Chapter – 2

2. Present Status of the Plastics Waste Roads.

2.1 Plastics Scenario:

Plastics have become common man's friend. It finds its use in every field. Nearly 50% of the plastic consumed is used for packing. The most used plastic materials for packing are carry bags, cups, thermocoles and foams. These materials are manufactured using polymers like Polyethylene, polypropylene and polystyrene. The tubes and wires are made out of poly vinyl chloride. These materials, once used are either thrown out or littered and ultimately get mixed with Municipal Solid Waste (MSW). As the plastics are non- biodegradable, their disposal is a problem and they cause social problems contributing for environmental pollution.

2.2 Physical Properties:

- Different commercial plastic materials, that are in use were collected and the following tests were carried out
  - (i) Softening Point.
  - (ii) Thickness of the Film.
- Most of plastics get soften below 170^0c except Poly vinyl chloride and Polyethylene terepthalate (Table – I). There is no evolution of any gas during softening. The molten plastics can be used as a binder using proper technique.

Table – I Thermal Behavior of Polymers

Polymer	Solubility		Softening Temp in Deg.C	Products reported	Decom-position Temp Deg.C	Products reported on decompo-sition	Ignition temp. range in Deg. C	Products reported on ignition
	Water	EPT*						
PE Film	Nil	Nil	100-120	No gas	289-335	CH_4, C_2H_6	>700	CO,CO_2
PP	Nil	Nil	140 - 160	No gas	271-329	C_2H_6	>700	CO,CO_2
PS	Nil	Nil	110-140	No gas	300-350	C_6H_6	>700	CO,CO_2

Polymer	Solubility		Softening Temp in Deg.C	Products reported	Decom-position Temp Deg.C	Products reported on decompo-sition	Ignition temp. range in Deg. C	Products reported on ignition
	Water	EPT*						
PE Foam	Nil	Nil	120-125	No gas	309-385	CH_4	>700	CO, CO_2
Tea Cup	Nil	Nil	130-150	No Gas	313-420	C_2H_6	>700	CO, CO_2

2.3. Plastics as a Binder:

Waste plastic is shredded into required size and mixed with hot stone (150 – 170^0c) with uniform mixing. When heated to around 150^0c to 170^0c, they melt and in their molten state they spread over the stone as a thin liquid, which acts as a binder.

2.3.1 Precaution:

It is to be noted here that the plastics cannot be melted separately to use for coating. The stone is heated to 170^0c and the shredded plastic film is sprayed over the hot stone. On contact with the surface of the hot stone the plastic gel softened and coated over the aggregate. It is important to note that the size of the shredded plastic should be in the range of 4.2mm to 1.18mm. The shredded plastics should be less than the surface area of the aggregate to get uniform coating. Otherwise the binding will not be effective.

2.3.2 Coating of Plastic over Granite Stone

It is observed that the stones can also be made to bind with bitumen strongly resulting in better mix for road construction likely;

(i) The coating of plastics over stone reduces the voids in the stone and helps to reduce moisture absorption to a great extent.
(ii) Solid deposition on the pores of stone results in degradation of stones. This is also prevented
(iii) The spreading of bitumen is also made easy

Technology has been developed at Department of Chemistry, Thiagarajar College of Engineering, Madurai for the use of waste plastics for flexible pavement. The process is awarded patent right by the Government of India. Studies on the binding property of waste plastics was carried out

- by varying the percentage of plastic and
- by varying the size of the shredded plastic

The molten plastics waste exhibits **good binding property**. Various raw materials like granite stone, ceramics etc... were coated with plastics and then molded into a stable product. On cooling, it was tested for compression and bending strengths. Moreover, the coated plastics did not leach out by the leaching liquid (5% acetic acid).

Table – II

Binding Property

Percentage of plastics coating over aggregate	Compression Strength (Tonnes)	Bending Strength (Kg)
10	250	325
20	270	335
25	290	350
30	320	390

The increase in the values of the compression strength and bending strength show that the plastics can be used as a binder.

2.4. Road Construction Scenario:

2.4.1 process of construction of flexible pavement

Process: I

The roads were laid using both Mini Hot Mix Plant and central mixing plant. The aggregate mix prepared as per IRC specification, was heated in the cylindrical drum to 170 deg. C. It was then transferred to the puddling compartment where the plastics waste (size between 1.18mm and 4.36mm) was added. As the temperature of the aggregate was around 170 deg. C and the softening temperature of plastics waste was around 135 deg. C the plastics waste got softened and got coated over the aggregate within 30 to 45 seconds. Immediately the hot bitumen 60/70 grade (≈ 160° C) was added and mixed in the puddling chamber. The bitumen got coated over the aggregate. As the plastics and the bitumen were in the liquid state they got mixed. The mixture was transferred to the road and it was spread and compacted using 8 Ton roller.

Process: II

For the construction of long distance roads it is very important that the plastics coated aggregate should be tried with Central Mixing Plant. This was successfully tried at Salem, Tanjore, Mumbai, Trisool and Madurai.

Using a mechanical device the plastics waste was mixed quantitatively with the aggregate at the cylindrical drum before the addition of bitumen. The diagram of the system is with the author. This was done at Trisool, Chennai in the presence of DRDA Engineers.

The material collected at the tipper was uniform and had a temperature of 140 deg. C. This was transported to the spot and the road was laid using 'paver' and 8 Ton roller. The spreading was good and the laying was easy. During the process the materials got mixed at; (1). at the tipper (2). during the transfer from tipper to paver and (3). by the pavers during spreading for road laying . This ensures better distribution of plastics and help better binding.

2.4.2 Road – Laid List (The technique and the process are patented)

Using plastics waste coated aggregate bitumen mix; roads have been laid at different places at Tamil Nadu using different surface area and different composition. The conditions of roads are under observation for the past six years and they are reported to be performing well (List enclosed).

Table-III

List of Roads laid using Dry Process by Different corporations*

Place	Area	Date	Nature of Road
Kovilpatti	600'x12'	4th October-02	WBM road
Madurai	180'x10'	5th October-02	Concrete Road
Salem	1000'x12'	15th October-02	Concrete Road
Komara-palayam	300'x12'	15th October-02	Concrete Road
Chennai	600'x18'	22nd November-02	Concrete Road

Trichy	600'x18'	10th January-03	Concrete Road
Salem	5000'x 18'	17th April-03	WBM
Erode	1500'x 24'	7th May-03	Bitumen road
Theni	300'x18'	10th May-03	WBM
Nagercoil	1500'x18'	16th May-03	WBM
Madurai- Kombadi	1.4 km	13th August -03	WBM
TCE	0.6km	19th January'04	WBM
Vilachery road, Madurai	1km	March 2005	WBM
Vandiyur road Madurai	1 km	October 2005	WBM
TCE Car parking road, Madurai	3500 sq.m	July 2005	WBM
Ettaiapuram, Kovilpatti	0.6 km	August 2006	WBM
Canteen road TCE Madurai	600 m	January 2006	WBM
PSNA College, Dindugal	500m	July 2007	WBM

*Bitumen added = 4.5%; Plastics waste added for coating aggregate = 0.45%:

Table -IV

Plastics Waste Mixed Roads laid by DRDA Tamil Nadu

S.No	Name Of District	Taken Up	
		Length in KM	Cost Rs. In Lakhs
1	Kancheepuram	41.165	120.480

2	Coimbatore	63.250	432.750
3	Cuddalore	43.00	146.410
4	Dharmapuri	34.191	150.660
5	Dindigul	36.670	121.780
6	Kanyakumari	28.021	123.422
7	Karur	30.190	155.060
8	Madurai	54.500	268.460
9	Nagapattinam	31.071	138.857
10	Namakkal	53.780	232.477
11	Perambalur	34.850	220.460
12	Erode	60.110	295.760
13	Pudukkottai	22.930	73.920
14	Ramnad	13.500	54.845
15	Salem	31.685	120.810
16	Sivaganga	22.405	94.800
17	Thanjavur	37.604	199.340
18	The Nilgiris	6.900	34.250
19	Theni	25.000	72.000
20	Thiruvallur	15.000	50.000
21	Thiruvarur	32.705	139.120
22	Trichy	43.000	171.300
23	Tirunelveli	32.890	179.500
24	Tiruvannamalai	39.100	172.000
25	Tuticorin	37.000	205.650

26	Vellore	52.770	211.260
27	Villupuram	54.100	282.940
28	Virudhunagar	25.200	102.800
29	Krisnagiri	28.802	158.72
Total		**1031.389***	**4729.831**

Note: More than 1200Kms of rural roads have been laid by DRDA Tamil Nadu, distributing a minimum of 40Kms for each district and this was extended to all the 29 districts of Tamil Nadu.

2.4.3 Road Laid At Other States :

Table - V

Plastic tar road have also been laid at other states

State	**Place**	**Process**
Pondicherry	Pondicherry	Central Mixing Plant
Maharastra	Mumbai	Central Mixing Plant
Kerala	Cochin Trivandrum Kothamangalam, Vadagara, Calicut	Mini Hot Mix Plant
Andhra Pradesh	Hindpur	Mini Hot Mix Plant

Chapter – 3

3.0 Need for the Present Study

The present study is a continuation of MoU signed between TCE and CPCB on development of " Indicative operational Guidelines on construction of Polymer Bitumen road ". The guidelines on the construction of Polymer coated aggregate bitumen road has been published by the CPCB in the year December 2005 (PROBES/101/2005-2006).

The present study is focused mainly on the Memorandum of Understanding signed between Thiagarajar College of Engineering and Central Pollution Control Board, New Delhi. The MoU is on "Assessing Performance of Built Roads".

3.1. Scope and Objective:

The scope of the study is to evaluate the performance of Plastic tar flexible pavement road constructed using Polymer Coated aggregate bitumen mix at different places at Tamil Nadu during 2002-2007, spreading around 1500Km all over Tamil Nadu. Some of these sites are chosen on the basis of the date of laying as per the requirements of the MoU. They are as follows

1. Jambulingam Street, Chennai- 2002
2. Veerabhadhra Street, Erode- 2003
3. Vandiyur road, Madurai- 2004
4. Vilachery Road, Madurai- 2005
5. Canteen road, situated inside Thiagarajar College of Engineering, Madurai- 2006
6. Bitumen road (without plastics),2002

The Objective of the study is to evaluate the performance of the pavement constructed using waste plastic coated aggregates. Towards realizing this broad objective, the specific tasks of the study are given below;

To measure

1. The roughness of the pavement surface.
2. The resistance offered by the pavement surface against skidding of vehicles.
3. The pavement macro texture for the geometrical deposition.
4. The Field Density of the road

5. To assess the structural evaluation of flexible pavement for the strength of the pavement.
6. To study the Gradation of the laid road.
7. To carry out different tests on recovered bitumen.
8. To examine the condition of the road (cracks, raveling, potholes, rutting, corrugation edge break etc).

The above given tests are carried out as per the IRC specifications.

3.2. Study Area:

Plastic Tar road are being laid since 2002 at different places all over Tamil Nadu. Study areas for carrying out performance studies were chosen as per the requirement of the MoU signed between Thiagarajar College of Engineering and Central Pollution Control Board, New Delhi. The Selected roads are as follows; these roads are open graded premix carpet.

Site – 1

1. Place : Jumbulingam Street , Chennai
2. Road laying authority : Chennai Corporation
3. Date of Laying : 22nd Nov' 2002
4. Road length : 500m length x 7m width
5. Chief guest : Commissioner, Mayor & CE, Corporation, Chennai
6. Plant : Mini hot mix plant
7. Source of waste waste :Municipal waste plastics /Industrial plastics
8. Process : Polymer coated aggregate – bitumen mix
9. Temperature : 33 C
10. Rain Fall : 145mm

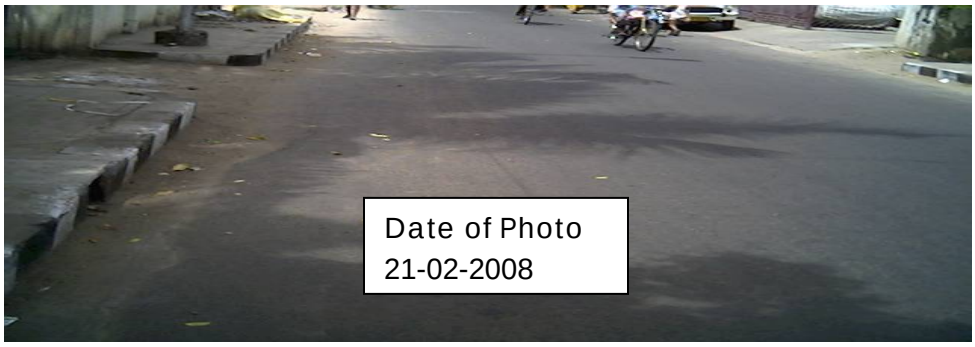

Photo: Jambulingam Street, Chennai- 2002

Site – 2

1. Place : Veerabadhra Street, Erode
2. Road Laying authority : Erode Municipality
3. Date of Laying : 7th May 2003
4. Road Length : 1500'x 24'
5. Plant : Mini Hot Mix Plant
6. Source of Waste : Municipal Solid Waste
7. Process : Polymer coated Aggregate – Bitumen Mix
8. Temperature : 36^0c
9. Rain Fall : 100mm

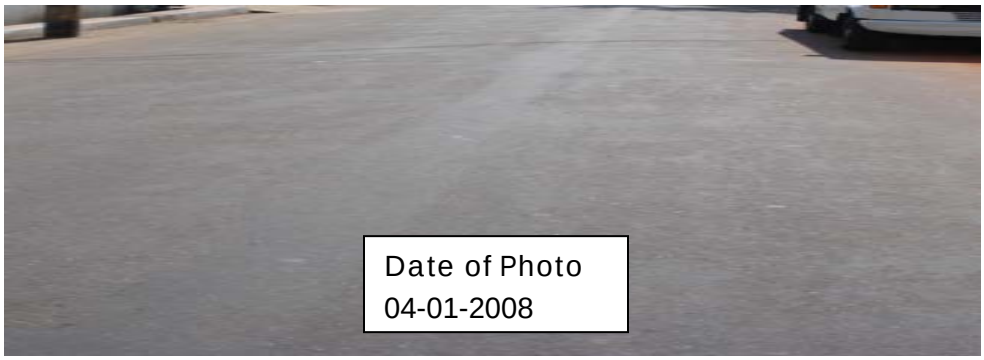

Photo: Veerabhadhra Street, Erode- 2003

Site – 3

1. Place : Vandiyoor Main road, Madurai
2. Road laying authority : Madurai Highways Department
3. Date of Laying :
4. Road length : 1 Km
5. Plant : Mini hot mix plant
6. Source of waste : Municipal waste plastics/Industrial plastics waste
7. Process : Polymer coated aggregate – bitumen mix
8. Temperature : 40^0c
9. Rain Fall : 143mm

Photo: Vandiyur road, Madurai- 2004

Site – 4

1. Place : Vilacherry road, Madurai
2. Road laying authority : Madurai Highways Department
3. Date of Laying : March 2005
4. Road length : 1 Km
5. Plant : Mini hot mix plant
6. Source of waste : Municipal waste plastics /Industrial plastics waste
7. Process : Polymer coated aggregate – bitumen mix
8. Temperature : 40^0c
9. Rain Fall : 143mm

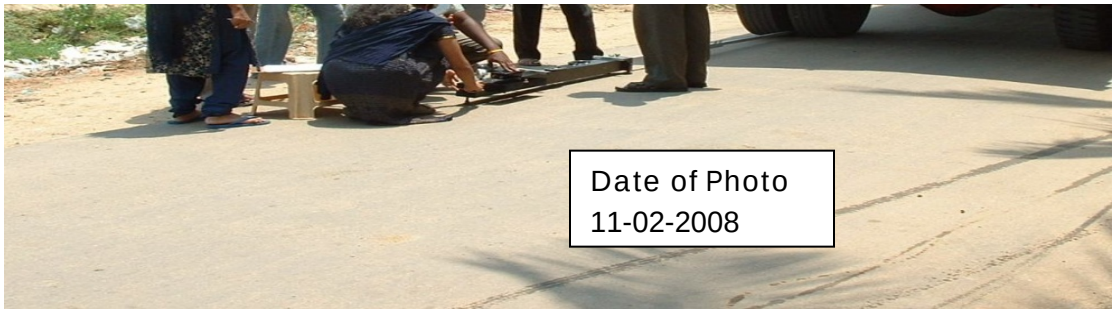

Photo: Vilachery Road, Madurai- 2005

Site-5

. Place : Canteen road, TCE, Madurai

2. Road laying authority : Thiagarajar College of Engineering, Madurai

3. Date of Laying : January 2006

4. Road length : 600M

5. Plant : Central Mixing Plant

6. Source of waste : Municipal waste plastics /Industrial plastics waste

7. Process : Polymer coated aggregate – bitumen mix

8. Temperature : 40^0c

9. Rain Fall : 143mm

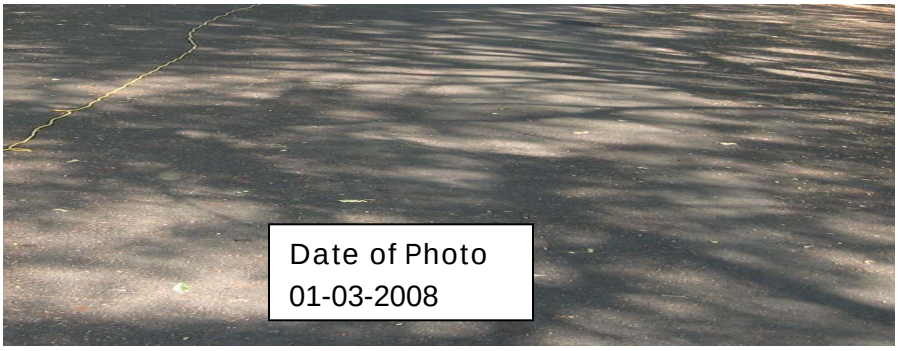

Photo: Canteen road, situated inside Thiagarajar College of Engineering, Madurai-2006

Site – 6

1. Place : Bitumen road, TCE, Madurai

2. Road laying authority : Corporation, Madurai

3. Date of Laying : 2002

4. Road length : 1000M

5. Plant : Mini Hot Mixing Plant

6. Bitumen Used :80/100

Photo: bitumen road (without plastics)

The above sites are chosen taking the parameters variation like,

1. Temperature
2. Position
3. Annual Rainfall
4. Traffic Load
5. Land Base

All these roads are laid or over laid using plastic coated aggregate bitumen mix. The concern government authorities like Municipalities, Corporation and Highways lay these roads. The studies are more pertaining to the plastic coated aggregate bitumen mix layer as the authorities chose the existing base. Anyhow tests needed to study the performance were all carried out as per the standard specifications.

3.3 Choice of Reference Bitumen road:

It is learnt from the local authorities that the Bitumen roads laid during the said period were over laid periodically after the rainy season and the roads were not available for monitoring. The road that we have taken for the testing is situated near Tiruparangundram, Madurai. This road was laid in the year 2002 as per the IRC specification. This road has been taken as a reference road for our performance studies.

Chapter-4

4.0 Methodology

There are two main methods for conducting pavement evaluation viz. (i) structural evaluation and (ii) functional evaluation. The primary objective of pavement evaluation is to asses as to whether and to what extent the pavement fulfils the intended purpose so that the maintenance and strengthening jobs could be planned and budgeted in time. The studies, therefore, investigate the structural adequacy of pavements and other technical requirements for providing safe and comfortable traffic operations. Surface distress is a measure or indicator of the structural and resulting functional state of a pavement section and is generally given the prime importance by highway engineers. Physical distress is identified by the type, severity and extent of various distress modes or types.
The pavements constructed or overlaid with waste plastic coated aggregate was evaluated functionally by conducting (1). The measurement of roughness using bump integrator/ MERLIN, (2). Measurement of skid resistance using portable skid resistance tester and 3. Structural evaluation of the pavement using deflection studies using Benkelman beam instrument.

4.1 Roughness survey

The surface unevenness of highway pavements refers to the regularity of surface finish both in longitudinal and transverse directions. Almost in all major highway works executed, control of surface unevenness has been introduced as a mandatory requirement. The existing standards and tolerances of surface unevenness are prescribed in IRC special publication 16-2004.

Table VI.

Maximum Permissible Values of Roughness (mm/km) for Road Surface

Type of surface	Condition of Road Surface		
	Good	Average	Poor
Surface Dressing	<3500	3500-4500	>4500
Open Graded Premix Carpet	<3000	3000-4000	>4000
Mix Seal Surfacing	<3000	3000-4000	>4000
Semi Dense Bituminous Concrete	<2500	2500-3500	>3500
Bituminous Concrete	<2000	2000-3000	>3000
Cement Concrete	<220	2200-3000	>3000

(Source IRC:SP:16-2004 Table 3)

4.2 Skid Resistance Test

The portable skid resistance tester was designed by R.R.L. U.K, to provide a simple and rapid method for checking the skid resistance in local areas and entails measuring the frictional resistance between a rubber slider (mounted on the end of a pendulum arm) and the wetted road surface. In this case the loss in energy of the pendulum arm, after the slider has traversed the surface, is equated to the work done during the sliding process. The instrument measures directly the coefficient of friction on graduation scale. The measurements are recorded as 100 times the coefficient of friction. When the tester measures the polishing characteristics of road aggregates, the measurement is called the polished stone value (PSV). The test has been standardized in the UK under BS: 812-1967. The specification of skid number is given in Table 2.

Table VII.

Specifications of Skid Number

Guide to interpret Skid Resistance Values. Road Research Laboratory, Great Britain	
Type of site	Min Value of Skid Number (surface wet)
Difficult site such as: Round abouts ,Bends with radius less than 150 m on unrestricted roads, Gradients ,1in 20 or steeper, of lengths greater than 100m, Approaches to traffic lights on unrestricted roads	65 (A)
Motorways ,trunk roads, heavily trafficked roads in urban areas (carrying more than 2000 vehicles per day)	55 (B)
All other sites (city roads with more traffic)	45 (C)

4.3 Sand Patch Test

The ability of bituminous surfacing to provide the required skid resistance is governed by its micro texture and macro texture. The macro texture of the surfacing, as measured by its texture depth, contributes particularly to wet skidding resistance at high speeds by providing drainage routes for water between tyre and road surfaces. The surface condition should include a qualitative assessment of

texture in the wheel paths so that it can be used to trigger quantitative testing if required. The sand patch test is described in detail in BS 598 Part 105 (1990). The method is summarized below.

Table VIII.

Permissible texture depth values

Texture Depth in mm	Surface characteristics of pavement
0-0.4	Smooth
0.4-0.6	Medium
>0.6	Rough

4.4 Benkelman Beam

Benkelman Beam is a device, which can be conveniently used to measure the rebound deflection of a pavement due to a dual wheel load assembly or the design wheel load.

Table IX.

(The limits of BBD data are given based on the rebound deflection)

Rebound Deflection (mm)	Strength of pavement
0.5-1	Reasonably strong
1-2	Moderate
2-3	Weak
>3	Very Weak (permanent Deformation)

4.5 Field Density Analysis:

The field density is studied to find the compactness of the road. The field is an important test to find the nature of the road and also the performance of the road after a prolonged period of open to the atmosphere. The ageing of bitumen and the crushing of aggregates is mainly responsible for the reduction in the field density.

4.6 Surface Condition Survey

Pavement condition surveys are generally conducted by any one of the following methods:

(i) Walk survey- associated with or without actual measurement
(ii) Drive survey

In a walk survey, a team of experienced highway engineers walks along the road and makes visual observations. The actual measurements may also be carried out on a representative and relatively shorter stretch.

In a drive survey, the team travels along the road in a vehicle at a slow speed (say 10 to 15 km/hr) and records the surface condition by visual observations. The data is recorded at convenient interval (unit lengths of the stretch) say 200 m, by noting down distress in each interval. In view of time constraints and large length involved, the visual condition survey method was undertaken by driving in a slow vehicle moving slowly at a speed of about 10-15 km/hour. During the survey, the following items of distress were visually recorded for every 200m in terms of percentage of the pavement surface area.

- Cracking
- Raveling
- Pot holes
- Edge breaks

Chapter- 5

5.0 Performance Studies

5.1 Process Details

Mini Hot Mix Plant

Step. I
Plastics waste (bags, cups , thermocole) made out of PE,PP,and PS cut into a size between 1.18 mm and 4.36mm using shredding machine, (PVC waste should be eliminated)

Step II a:
The aggregate mix is heated to 165^0c (as per the HRS specification) and transferred to mixing chamber.

Step II b
Similarly the bitumen is to be heated up to a maximum of 160^0c(HRS Specification) to have good binding and to prevent weak bonding. (Monitoring the temperature is very important)

Step III:
At the mixing chamber, the shredded plastics waste is to be added over the hot aggregate. It gets coated uniformly over the aggregate within 30 to 45 secs, giving an look of oily coated aggregate.

Step IV:
The plastics waste coated aggregate is mixed with hot bitumen and the resulted mix is used for road construction. The road laying temperature is between 110^0c to 120^0c. The roller used is 8-ton capacity

Central Mixing Plant
The modified process can also be carried out using *central mixing plant*. The shredded plastics are added along the aggregate in the conveyor belt. A special mechanical device is developed which will spray the plastics inside the chamber to coat the plastics effectively. This also can be used as an alternative method
CMP helps to have better control of temperature and better mixing of this material thus helping to have a uniform coating.

A comparative study for 25 mm thickness SDBC-10mm^2 is given in table –X

Table – X

Comparative study for 25 mm thickness SDBC-10mm^2

Material	Plain bitumen process	Plastic-tar road
60/70 Bitumen	30kg	27kg
Plastic waste	-	3kg

5.2 Experimental studies

5.2.1 Plastic Tar Road:

Over the identified road stretches (Table -XIII) various surveys were conducted to find out the values of bumps, skid resistance, texture, and deflection due to loading. The surveys conducted were Unevenness, Skid Resistance, Sand Patch, and Benkelman Beam Deflection Studies to evaluate the conditions of the of existing roads. The roads were chosen to study the effect of types of bitumen namely 60/70 and 80/100 and to study the variation of plastic quantity in accordance to the requirement of MoU (Table-XIII). The sites are as follows.

Table – XI

Road Details

Site No	Site Name	Road Laid Date
Site- I	Plastic Tar road at Jumbulingam Street, Chennai	2002
Site – II	Plastic tar road at Veera Padhra Street, Erode	2003
Site – III	Vandiyur- Melamadai road at Madurai	2004
Site IV	Vilachery Main Road at Maduari	2005
Site V	Plastic tar road at Canteen in Thiagarajar College of Engineering, Madurai	2006
Site VI	Bitumen road at Madurai	2002

Table - XII

Details of the manufacturing

Name of the road	Road Laid Year	Type of Bitumen	Source of Plastics waste	Type of Plastics	Percentage of Plastics
Jambulingam	2002	60/70	Municipal Waste	PE and PP Mix	12
Erode Road	2003	60/70	Municipal Waste	PP Mix	12
Vandiyur road	2004	80/100	Municipal Waste	PE and PP Mix	10
Vandiyur road	2005	80/100	Municipal Waste	PE and PP Mix	12
Canteen road TCE	2006	80/100	Municipal Waste	PE	10
Bitumen Road	2002	80/100	Nil	Nil	Nil

5.2.2 Density Analysis:

Table XIII

Density of the roads

Site No	May 2007	August 2007	November 2007	February 2008
Site I	2.28	2.40	2.45	2.55
Site II	2.62	2.39	2.36	2.33
Site III	2.64	2.70	2.65	2.75
Site IV	2.89	2.30	2.30	2.30
Site V	2.86	2.36	2.35	2.82
Site VI	2.15	2.11	2.09	2.05

The studies on Field Density are normally carried out before laying and after laying to ensure the correct process of laying.

Under the given condition, our study of Density is to find out the change, if any, on the Density of plastic tar road laid at different time interval. It is observed in general that the Densities of the plastic tar are not reducing drastically when compared with the bitumen road. This shows that there is an increase in compaction due to the presence of plastic layer and this result in better binding. The road has not developed any pothole, raveling etc.

5.2.3 Measurement of Surface Roughness

The roughness of pavement surface is commonly designated as unevenness index value and is expressed in surface roughness measured by a bump integrator.

Either towed fifth wheel bump integrator or MERLIN instrument can be used for measuring the road roughness. These are response type road roughness measuring systems and are extensively used in this country for the measurement of roughness.

For long distance road Bump Integrator can be used but for short distance test roads the values may not correlate to the actual value. Under such circumstances it is preferred to use MERLIN instrument and calculate the BI values. The sites being short of length, MERLIN instrument was used and the BI values were calculated.The test roads are Open Graded Premix Carpet and their expected values are given below

Table XIV

Maximum Permissible Values of Roughness (mm/km) for Road Surface

Type of surface	**Condition of Road Surface**		
	Good	**Average**	**Poor**
Surface Dressing	<3500	3500-4500	>4500
Open graded Premix Carpet	<3000	3000-4000	>4000
Mix Seal Surfacing	<3000	3000-4000	>4000
Semi Dense Bituminous Concrete	<2500	2500-3500	>3500
Bituminous Concrete	<2000	2000-3000	>3000
Cement Concrete	<2200	2200-3000	>3000

(Source IRC:SP:16-2004)

The observed data are analyzed and the unevenness of each road is determined. The results of roughness survey for six roads are given in table XV

5.2.4 Roughness Measurement by MERLIN

Table XV

Roughness Survey

Site No	May 2007	August 2007	November 2007	February 2008
Site I	2800	2560	2683	2700
Site II	3950	4000	3982	3785
Site III	3288	3400	3332	3005
Site IV	3500	3900	4307	3891
Site V	3254	3562	3300	3100
Site VI	5200	4700	4900	4753

MERLIN values are the representation of road quality (from the stage of fresh laid road to till date of functioning). The values depends on factors like sub grade level, rolling, traffic load etc. Yet the MERLIN values calculated at different periods correspond to values that represent good quality road, refer Table. From the standard values it is observed that the IRI of Site I to Site V have comparatively **better value**. Again bitumen road shows higher value exhibiting poor quality of road.

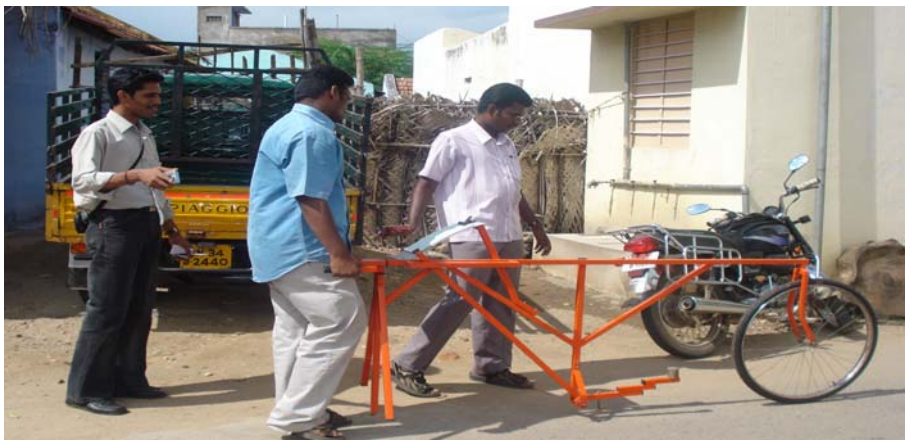

Photo: Testing of Roughness using MERLIN

5.2.5 Sand Patch Test

The ability of bituminous surfacing to provide the required skid resistance is governed by its micro texture and macro texture. The macro texture of the surfacing, as measured by its texture depth, contributes particularly to wet skidding resistance at high speeds by providing drainage routes for water between tyre and road surfaces. The surface condition should include a qualitative assessment of texture in the wheel paths so that it can be used to trigger quantitative testing if required. The sand patch test is described in detail in BS 598 Part 105 (1990). Normally this test is carried out immediately after laying the road. In our case as most of the roads are in good condition the above test was carried out.

Photo: Sand Patch Test

Table- XVI

Permissible texture depth values

Texture Depth in mm	Surface characteristics of pavement
0-0.4	Smooth
0.4-0.6	Medium
>0.6	Rough

Table XVII

Sand Texture Depth

Site No	May 2007	August 2007	November 2007	February 2008
Site I	0.63	0.78	0.78	0.74
Site II	0.65	0.70	0.70	0.70
Site III	0.69	0.73	0.70	0.66
Site IV	0.66	0.62	0.55	0.50
Site V	0.72	0.75	0.75	0.65
Site VI	0.92	0.83	0.85	0.83

The surface texture studies of the Six stretches have been studied. Plastic roads have good surface texture depth, since the values occurs very near to the permissible limit. In the case of bitumen road the change is high which is against the specifications.

5.2.6 Benkelman Beam Deflection Studies

Benkelman Beam Deflection studies are one of the non-destructive techniques for the structural evaluation of flexible pavements. A well compacted pavement section or one which has been well conditioned by traffic deforms elastically under each wheel load application such that when the load moves away, there is an elastic recovery or rebound deflection of the deformed pavement surface. This is the basic principle of deflection method of pavement evaluation.

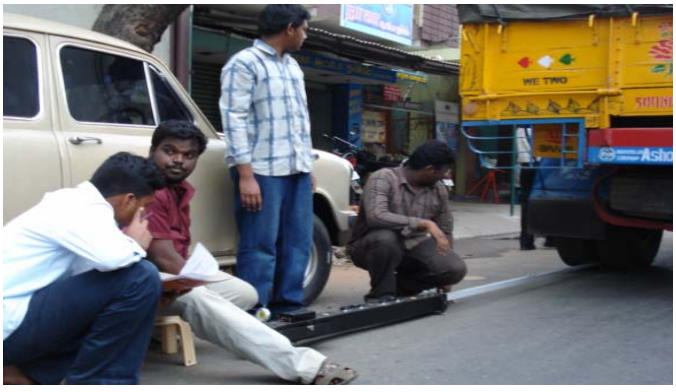

Photo: Testing Of Rebound Deflection Using Benkelman Beam

Table XVIII.

(The limits of BBD data are given based on the rebound deflection.)

Rebound Deflection (mm)	**Strength of pavement**
0.5-1	**Reasonably strong**
1-2	Moderate
2-3	Weak
>3	Very Weak (permanent Deformation)

The BBD test was carried out to determine the rebound deflection of the pavement. The BBD test results for the six roads are given in table (Table XIX)

Table XIX

BBD RESULT

BENKELMAN BEAM DEFLECTION				
Site No	**May 2007**	**August 2007**	**November 2007**	**February 2008**
Site I	0.89	0.91	0.92	0.85
Site II	0.63	0.65	0.69	0.60
Site III	0.88	0.93	0.91	0.84
Site IV	0.92	0.94	0.94	0.86
Site V	0.83	0.83	0.83	0.82
Site VI	1.93	1.63	1.56	1.55

The rebound deflection values of the plastic tar road are less than 1. This shows that these stretches are reasonably strong.

5.2.7 Skid Resistance:

After applying the correction factor, the skid number for wet condition is derived for all roads. The rods being city roads the expected value for skid resistance are up to 45.

Table XX
Specifications of Skid Number

Guide to interpret Skid Resistance Values. Road Research Laboratory, Great Britain	
Type of site	Min Value of Skid Number (surface wet)
Difficult site such as: Round abouts ,Bends with radius less than 150 m on unrestricted roads, Gradients ,1in 20 or steeper, of lengths greater than 100m, Approaches to traffic lights on unrestricted roads	65
Motorways ,trunk roads, heavily trafficked roads in urban areas (carrying more than 2000 vehicles per day)	55
All other sites (city roads with more traffic)	45

Table XXI
(Results of skid resistance)

Site No	May 2007	August 2007	November 2007	February 2008
Site I	42	41	45	41
Site II	47	48	40	42
Site III	43	46	46	41
Site IV	44	48	42	45
Site V	40	41	42	45
Site VI	77	79	70	76

The Skid resistance values of the five stretches of the plastic tar road shows that the roads are good in wet condition.

5.2.8 Pavement Condition Survey:

Detailed surface condition survey was carried out taking a representative section of 1km length from each of the study roads. And these study stretches of 1km length were again permanently marked into blocks of equal length of about 100 or 200mts. The selection of study stretches and their sub divisions into shorter uniform sections were based upon the following:

- Time since construction
- Traffic loading
- Type of road deterioration
- Topography
  Detailed surface condition survey was carried out on the study stretches based on the nature, extend, severity and position of the following defects:
- Surfacing defects like bleeding, fretting, stripping etc.
- Cracking
- Deformation
- Patching and Potholes
- Edge failure

5.3 Physical Status and Surface Conditions of the Roads.

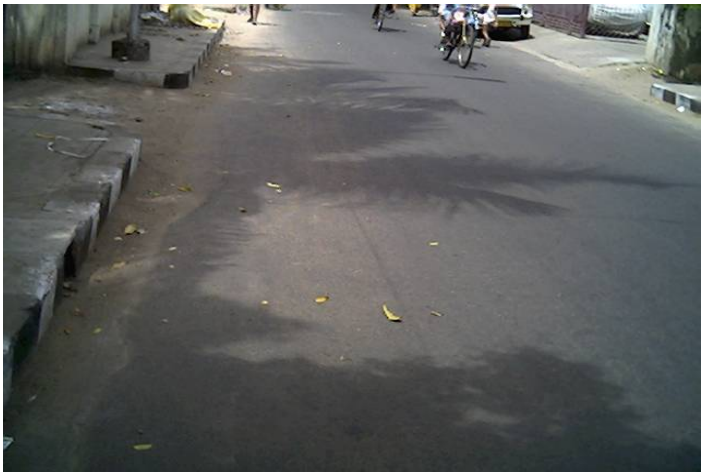

Photo :Jumbulingam road, Chennai

The road condition survey was taken by walking along the road by a team of five members and the result was absorbed as follows

1. No Pot hole
2. No Cracking
3. No Deformation
4. No Edge Flaw

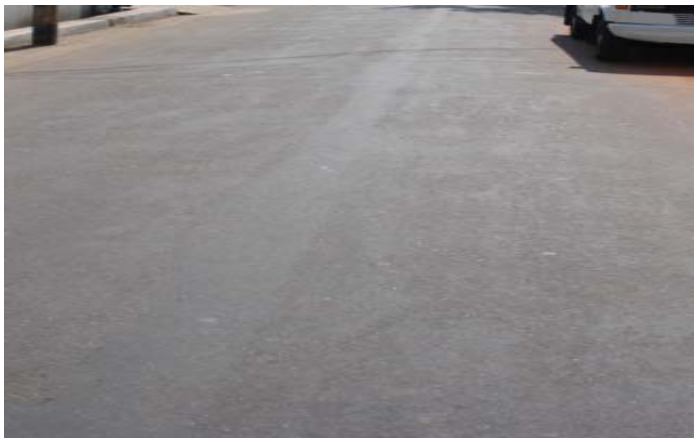

Photo : Veerbadhra Street, Erode

The road condition survey was taken by walking along the road by a team of five members and the result was absorbed as follows

1. No Pot hole
2. No Cracking
3. No Deformation
4. No Edge Flaw

Photo : Vandiyur Main road

The road condition survey was taken by walking along the road by a team of five members and the result was absorbed as follows

1. No Pot hole
2. No Cracking
3. No Deformation
4. No Edge Flaw

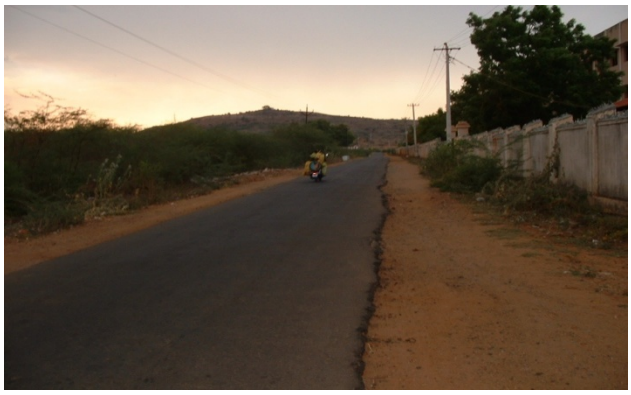

Photo : Vilachery Main road

The road condition survey was taken by walking along the road by a team of five members and the result was absorbed as follows

1. No Pot hole
2. No Cracking
3. No Deformation
4. No Edge Flaw

Photo : Canteen road No Pot hole

The road condition survey was taken by walking along the road by a team of five members and the result was absorbed as follows

1. No pot hole
2. No Cracking
3. No Deformation
4. No Edge Flaw

Photo: Bitumen Road (without plastics)

1. Pot hole found
2. Cracking found
3. Deformation found
4. Edge Flaw found

5.4 Material Analysis (With Plastics/Without Plastics)

Table XXII

Stone Aggregate	Percentage of Plastic	Moisture Absorption	Soundness	Aggregate Impact Value	Aggregate Crushing Test	Los Angel's Abrasion Value	Voids
Without plastic coating	0	4%	5+/- 1 %	25.4	26%	37%	4%
With plastic coating	1%	2%	Nil	21.20	21%	32%	2.2%
	2%	1.1%	Nil	18.50	20%	29%	1%
	3%	traces	Nil	17.00	18%	26%	Nil

5.5 Analysis of polymer coated aggregate with bitumen:

Table XXIII

Site	Gradation Analysis	Binder Content Determination	Marshall Value (Kg)
Jambulingam Street	50%-30%-20%	4.2	1779
Veerabadhra Street	50%-30%-20%	4.2	1760
Vandiyur road,	50%-33%-17%	4.2	1750
Vilachery Road, MDU	50%-30%-20%	4.0	1660
Canteen Road	50%-30%-20%	4.2	1780
Plain Bitumen Road	49%-31%-20%	4.2	1550

Recovered bitumen almost resembles the bitumen used for laying namely 80-100 varieties. The Marshall Stability value also agrees to this.

Chapter-6

6.0 Results

6.1 Individual test results of the roads

The individual results for each site are given below for effective understanding about their quality and performance.

Site – I Jumbulingam Street

Table XXIV

Month of Testing / Tests	May 2007	August 2007	November 2007	February 2008	Tolerance Value*
Field Density	2.28	2.40	2.45	2.55	2.86
Benkelman Beam(mm)	0.89	0.91	0.92	0.85	0.5-1
Roughness (mm/Km)	2800	2560	2683	2700	<4000
Skid Resistance	42	41	45	41	45
Sand Texture Depth (mm)	0.63	0.78	0.78	0.74	>0.6

Site – II Veerabhadra Street, Erode

Table XXV

Month of Testing / Tests	May 2007	August 2007	November 2007	February 2008	Tolerance Value*
Field Density	2.62	2.39	2.36	2.33	2.86
Benkelman Beam(mm)	0.63	0.65	0.69	0.60	0.5-1
Roughness (mm/Km)	3950	4000	3982	3785	<4000
Skid Resistance	47	48	40	45	65
Sand Texture Depth (mm)	0.65	0.70	0.70	0.70	>0.6

Site – III Vandiyoor, Madurai

Table XXVI

Month of Testing / Tests	May 2007	August 2007	November 2007	February 2008	Tolerance Value*
Field Density	2.64	2.70	2.65	2.75	2.86
Benkelman Beam(mm)	0.88	0.93	0.91	0.84	0.5-1
Roughness (mm/Km)	3288	3400	3332	3005	<4000
Skid Resistance	43	46	46	41	65
Sand Texture Depth (mm)	0.69	0.73	0.70	0.66	>0.6

Site – IV Vilacherry Road , Madurai

Table XXVII

Month of Testing / Tests	May 2007	August 2007	November 2007	February 2008	Tolerance Value*
Field Density	2.89	2.30	2.30	2.30	2.86
Benkelman Beam(mm)	0.92	0.94	0.94	0.86	0.5-1
Roughness (mm/Km)	3500	3900	4307	3891	<4000
Skid Resistance	44	48	42	45	65
Sand Texture Depth (mm)	0.66	0.62	0.55	0.50	>0.6

Site – V Canteen Road, T.C.E, Madurai

Table XXVIII

Month of Testing / Tests	May 2007	August 2007	November 2007	February 2008	Tolerance Value*
Field Density	2.86	2.36	2.35	2.82	2.86
Benkelman Beam(mm)	0.83	0.83	0.83	0.82	0.5-1
Roughness (mm/Km)	3254	3562	3300	3100	<4000
Skid Resistance	40	41	42	45	65
Sand Texture Depth (mm)	0.72	0.75	0.75	0.65	>0.6

Site – VI Bitumen Road, Madurai

Table XXIX

Month of Testing / Tests	May 2007	August 2007	November 2007	February 2008	Tolerance Value*
Field Density	2.15	2.11	2.09	2.05	
Benkelman Beam(mm)	1.93	1.63	1.56	1.55	0.5-1
Roughness (mm/Km)	5200	4700	4900	4753	<4000
Skid Resistance	77	79	70	76	65
Sand Texture Depth (mm)	0.92	0.83	0.85	0.83	>0.6

6.2 Consolidated test results of the roads

Monitoring of test roads were carried out using structural evaluation, functional evaluation and conditional evaluation studies. Generally all the roads laid over a period from 2002 to 2006 are performing well. The results obtained for these roads helped to conclude that these roads are performing very well in spite of their age. Under the similar conditions most of the bitumen roads are not performing well at all.

These roads have not developed even small cracking and a pothole. The roads were distributed over the different localities of Tamil Nadu exposed to various environmental conditions like temperature, rainfall, etc., yet the roads are performing well.

Table XXX

Road	Year laid	Unevenness (mm /km)/ Roughness	Skid number / Resistance	Sand Texture Depth (mm)	Field Density	Rebound Deflection (mm)/ Benkelman Beam
Jambulingam Street	2002	2700	41	0.63	2.55	0.85
Veerabadhra Street	2003	3785	45	0.70	2.62	0.60
Vandiyur road,	2004	3005	41	0.66	2.75	0.84
Vilachery Road, MDU	2005	3891	45	0.50	2.89	0.86
Canteen Road, TCE	2006	3100	45	0.65	2.86	0.86
Plain Bitumen Road	2002	5200	76	0.83	2.33	1.55
Tolerance Value*	------	4000	<65	.6-.8	2.86	0.5-1

***** 1. Unevenness / Roughness; Source IRC: SP: 16-2004
2. Skid Resistance/ Skid Number; Standardized in UK under BS: 812-1967
3. Sand Texture Depth; BS 598 part 105 (1990)
4. Rebound Deflection / Benkelman Beam; IRC: 81-1997
5. Field Density; Highway Engineering by S. K. Khanna, C.E.G. Justo; New Chand & Bros, Roorkee (U.A); Eighth edition ; 2001

6.3 Consolidated test results of other sites:

Table XXXI

Road	Year laid	Unevenness (mm/km)	Skid number	Texture Depth (mm)	Field Density	Rebound Deflection (mm)
Kumarapalayam	**2002**	3982	45	0.72	2.53	**Short road**
Trisool Road	**2003**	3000	48	0.71	2.46	0.75
Men's Hostel Road, madurai	**2004**	3569	44	0.60	2.93	0.89

The results shown above also fall with in the tolerance limit as discussed for the first six sites.

- Trisool road at Chennai, has withstood heavy load- Daily 2000 lorry load of gravels are transported through this road
- Men's hostel road at TCE- use of three types , Cup, carry bags and thermocoles.
- The kumarapalaym road which was laid using waste milk pockets is also performing well.

Chapter-7

7.0 Salient Features of Plastic Coated Aggregate Bitumen Road

7.1 Salient Features of the process:

- Plastic is coated over stone
- Coating is easy and the temperature needed is the same as the road laying temperature
- Use of plastics more than 15% is possible
- Flexible films of all types of plastics can be used. Plastics present in municipal waste can also be used including laminated sheets, aluminum coated and plain sheets .
- Bitumen is bonded with the aggregate by means of plastic which acts as a binder
- Bitumen bonding is strong as evidenced from the Extraction of bitumen and higher Marshall value
- Coated plastics acts as binder and the added bitumen binds strongly.
- In situ process. Waste plastic is collected, shredded and can be used in the hot mix plant to lay the roads.
- No new technology is involved. The existing Mini hot mix plant or Central Mix plant can be used without any modification.
- Marshall Stability Value is around 2500kg and the aggregate quality is improved.
- The coated aggregate shows increased strength (Higher LAV, Aggregate crushing and Impact value).
- Bitumen to the extent of 10 to 15% can be saved and thus reducing the cost of the process.
- No pothole formation , rutting or raveling has been observed after 5 to 6 years after construction.
- Dry process can be practiced in all type of climatic conditions. Process can be modified by varying the percentage of plastic with respect to the environmental conditions namely, Temperature, Rain,Snow,load, etc.,
- Dry process with 15-20% of plastics can be used in low temperature areas and water logged areas.

- Pot hole filling can be done using coated plastics aggregate – better strength
- Reclaimed flexible waste can be reused by coating the plastics – better results
- No evolution of any toxic gases like dioxin as the maximum temperature is only 170^0C.
- No granulation or blending is needed

7.2 Salient Features of the road:

- Stronger road with increased Marshall Stability Value
- Better resistance towards rain water and water stagnation
- No stripping and no potholes.
- Increase binding and better bonding of the mix.
- Reduction in pores in aggregate and hence less rutting and raveling.
- No leaching of plastics.
- No effect of radiation like UV.
- The strength of the road is increased by 100%.
- The load withstanding property increases. It helps to satisfy today's need of increased road transport.
- For 1km X 3.75m road, 1 ton of plastic (10 lakh carry bags) is used and 1 ton of bitumen is saved.
- Value addition to the waste plastics (cost per kilogram increases from Rs 4 to Rs 12).
- The cost of road construction is also decreased.
- The maintenance cost of road is almost nil.

8.0 References

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