Investigating an Effect of Fly ash and E-waste as Filler on the Performance of Dense Bituminous Macadam Road

Bonny M. Bhut[1] Prof. J.K.Sathawara[2] Dr. H. R. Varia[3]

[1]M.E. Student, Tatva Institute of Technological Studies, Modasa, Gujarat.

[2]Assistant Professor, Civil Engineering Department, Government Engineering College, Modasa, Gujarat,

[3]Professor and Head,CIE, AIIE, Ahmadabad, Gujarat.

ABSTRACT: Bituminous mixes are most commonly used all over the world in flexible pavement construction. It consists of asphalt or bitumen (used as a binder) and mineral aggregate which are mixed together, laid down in layers and then compacted. Under normal circumstances, conventional bituminous pavements if designed and executed properly perform quite satisfactorily. Electronic waste and fly-ash are disposed very casually, which may cause serious health and pollution problems. The disposal of electronic waste is difficult because of non-degradable plastic contents and metals like lithium, copper and aluminium, which may lead to adverse effects on the environment. To deal with this problem, here to study the use of electronic waste and fly-ash as an alternative to conventional material in a DBM (Dense Bituminous Macadam) layer of flexible pavement. In Literatures, there are various tests which have been carried out by replacing coarse aggregates using electronic waste and fine aggregates with fly-ash. The results obtained by laboratory investigation indicate major gain in strength with substantial saving in cost. Marshall Stability Test is a very important test for the bituminous mixes in flexible pavement.

Keywords: Marshall Test, OBC (optimum bitumen content), fly-ash,E-waste, Bituminous Concrete, Marshall Stability, Binder,DBM(Dense Bituminus Macdam)

I. Introduction

Road transport is the second important mode of transport in India. It covers every corner of the country which the railway transport even could not cover. Road transport provides the basic infrastructural facilities to both the agricultural and industrial sector of the country. In India, road transport carries approximately 85% of passenger traffic and 70% of freight transport. But the construction of highways involves huge amount of the investment and mainly sixty percent of the highway project cost is associated with the pavement construction. A highway pavement is a structure consisting of superimposed layers of processed materials above the natural soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. Pavement is a durable surfacing of a road, airstrip, or similar area and the primary function is to transmit loads to the sub-base and underlying soil subgrade. Such a pavement has enough plasticity to absorb shock. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favourable light reflecting characteristics, and low noise pollution. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements. Around ninety percent of the Indian Highways have a covered surface with bituminous layers which are constructed and maintained by using naturally available road aggregates and bitumen, a petroleum product, which being mixed at high temperatures to produce hot mix asphalt. Mix design for the different layers of the pavement can have a major impact on the performance, cost and sustainability of the bituminous surfaces.

2. Literature Review

Rana et al. (2018) presented “Use Non-Conventional Materials on Bituminous Paving as a Fillers” paper, in this paper Bituminous mixes containing fly ash as filler displayed maximum stability at 6% content of bitumen having an increasing trend up to 6% and then gradually decreasing, the unit weight/ bulk density also displayed a similar trend with flow value being satisfactory at 6% content of bitumen. Marshall Stability with bitumen content where it is seen that as usual the stability value increases with bitumen content initially and then decreases. Maximum stability value of 24.23 kN is observed at 6% bitumen content in case of fly ash as a filler.

Tapase Anand et al. (2015) presented "Utilization of E-Waste and Polymer Modified Bitumen in Flexible Pavement" paper and It is concluded that at 5.5% bitumen content in which 7.5% of bitumen replaced by waste Plastic and 7.5% aggregate replaced by e-waste shows increased stability keeping all the Other parameters within limit. From the experimental work, it is clear that the properties of laboratorial designed bituminous mix for bituminous concrete are much more superior to those of the control mixes entirely composed of mineral aggregates and can be effectively used in practical applications.

Kadam Digvijay et al. (2015) presented "Consumption of Electronic Waste In Quality Enhancement of Roads" paper This study indicate that aggregate can be volumetrically replaced by e-waste in DBM layer optimum bitumen content. The e-waste percentage increase more than 7.5% decrease in stability. The outcomes from the laboratory investigation proves the suitability of electronic waste in road construction with substantial cost saving. So, disposal of hazardous electronic waste in the pavement can prove to be one of the alternatives to make the earth greener and pavements more durable.

Katara S.D. et al (2014) present "Influence of Modify bituminous Mix with Fly Ash "Study of fly ash in this paper indicate that marshal stability of bituminous increased by about 25% by adding of fly ash. Also density of mix increase in compare to grade of 60/70 bitumen. The serviceability and resistance to moisture will also improve when compared to ordinary method of mix. This study also help to utilize fly as in effective and eco-friendly way as compared to ordinary method of land filling.

3.MATERIAL SPECIFICATIONS FOR BITUMINOUS MIX

3.1 Bitumen

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. The bitumen shall be viscosity graded paving bitumen complying with Indian Standard Specification for paving bitumen, IS: 73 or as specified in the Contract.

Table 1 Selection Criteria for Viscosity –Graded (VG) Paving Bitumen Based on Climatic Conditions

Lowest Daily Mean Air Temperature °C	Highest Daily Mean Air Temperature °C		
	Less Than 20°C	**20 to 30°C**	**More than 30°C**
More than -10°C	VG-10	VG-20	VG-30
-10°C or lower	VG-10	VG-10	VG-20

3.2 Coarse Aggregates

The Coarse aggregates shall consist of crushed rock, crushed gravel or other hard material. It shall be clean, hard, durable and cubical shape, free from dust and soft organic and other deleterious substances. The aggregate shall satisfy the physical requirements of [MORTH, Clause 507.2.2]

Table 2: Physical Requirements of Coarse Aggregate for Bituminous Concrete [MORTH, Clause 507.2.2]

Property	Test	Requirements	Test Method
Cleanliness	Grain size Analysis	Max. 5% passing 0.075 micron	IS:2386 Part I
Water Absorption	Water Absorption	Max 2%	IS:2386 Part III
Strength	Los Angeles Abrasion Value Aggregate Impact Value	Max 35% Max 27%	IS: 2386 Part IV IS: 2386 Part IV
Specific Gravity	Specific Gravity	2 – 3	IS:2386 Part III

3.3 Fine Aggregate

Fine aggregates shall consist of crushed or naturally occurring material, or a combination of the two, passing 2.36 mm sieve and retained on the 75 micron sieve. They shall be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious matter.

3.4 Aggregate Grading and Binder Content

When tested in accordance with IS: 2386 Part 1, the combined grading of the coarse and fine aggregates and added filler for the particular mixture should fall within the limits shown in Table, for Dense Bituminous Macadam grading 1 or 2. The type and quantity of bitumen, and appropriate thickness, are also indicated for each mixture type according to [MORTH, Table 500-10]

Table .3 Gradation of Dense Bituminous Macadam [MORTH, Table 500-10]

Grading	1	2
Nominal Aggregate Size	37.5 mm	26.5 mm
Layer thickness	75-100 mm	50-75 mm
IS Sieve (mm)	Cumulative % by Weight of total aggregate passing	
45	100	
37.5	95-100	100
26.5	63-93	90-100
19	-	71-95
13.2	55-75	56-80
9.5	-	-
4.75	38-54	38-54
2.36	28-42	28-42
1.18	-	-
0.6	-	-
0.3	7-21	7-21
0.15	-	-
0.075	2-8	2-8
Bitumen context % by mass of total mix	Min 4.0˟	Min 4.5˟*

4.ADDITIVE IN BITUMINOUS MIX

In this experiment work i used e-waste and fly ash ash additive material. Stone dust is replaced by Fly-ash and coarse aggregate is replaced by e-waste.

4.1 E-WASTE

Electronic waste or e-waste describes discarded electrical or electronic devices. Used electronics which are destined for reuse, resale, recycling, or disposal are also considered e-waste. Informal processing of e-waste in developing countries can lead to adverse human health effects and environmental pollution. With more than 1.8 million tonnes a year, the majority of it from the unorganized sector. India is the fifth largest e-waste producing country in the world 2017.

4.2 Fly-ash

Fly ash is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the gases. This ash is divided in to two part. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys.

4. Methodology

4.1 Tests on Bitumen

4.1.1 Penetration Test

Penetration value test on bitumen is a measure of hardness or consistency of bituminous material. A 80/100 grade bitumen indicates that its penetration value lies between 80 & 100.

4.1.2 Ductility Test

Ductility of bitumen is its property to elongate under traffic load without getting cracked in road construction works. Ductility test on bitumen measures the distance in centimetres to which it elongates before breaking.

4.1.3 Softening point test

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. Ring and ball test is used to determine the softening point of bitumen, asphalt and coal tar.

4.1.4 Viscosity Test

Viscosity denotes the fluid property of bituminous material and it is a measure of resistance to flow. A rotational viscometer gathers data on a material's viscosity behaviour under different conditions.

4.2Aggregate Test

4.2.1 Impact value Test

The property of a material to resist impact is known as toughness. Due to the movement of vehicles on the road, the aggregates are subjected to impact the aggregates should have sufficient toughness to resist their disintegration due to the impact. This distinctive property is measured by impact value test.

4.2.2 Specific Gravity and Water Absorption Test

Specific gravity test of aggregate is done to measure the quality of the aggregate. Water absorption test determine the water holding capacity of aggregate.

4.2.3 Los Angeles Abrasion Value Test

The aggregate used in surface course of the highway pavements are subjected to wearing due to movement of traffic. When vehicles move on the road, the soil particles present between the pneumatic tyres and road surface cause abrasion of road aggregates. Resistance to abrasion of aggregate is determined in laboratory by Los Angeles test machine.

4.3 Modified Marshall Test

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically at a deformation rate 53 of 50 mm per minute. There are two major features of the Marshall method of mix design. (i) density-voids analysis and (ii) stability-flow tests. The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. The flow value is the deformation that the test specimen undergoes during loading up to the maximum load. Flow is measured in 0.25 mm units. In this test, an attempt is made to obtain optimum binder content for the type of aggregate mix used and the expected traffic intensity.

5. TEST RESULTS

5.1 Aggregate Testing

Property		Results	Specifications
Aggregate Impact Value, %		11.05	24% maximum
Water Absorption, %	20mm	1	2% maximum
	10mm	1.23	
	6mm	1.34	
	Stone Dust	1.40	
Specific Gravity	20mm	2.83	2 – 3
	10mm	2.79	
	6mm	2.69	
	Stone Dust	2.62	
Apparent Specific Gravity	20mm	2.91	-
	10mm	2.89	-
	6mm	2.79	-
	Stone Dust	2.71	-
Abrasion value%		16.34	Maximum 35

5.2 Bitumen Testing

Property	Test Results	Specified Limits as per IS
Penetration at 25ºC/100 gm /5 sec, mm	66	60-70
Ductility, cm	90	75 cm minimum
Softening Point	48’	40 ºc to 55 ºc
Viscosity at 60ºC, Poise	1057	1000±200
Specific Gravity	0.999	-

5.3 Fly ash Testing

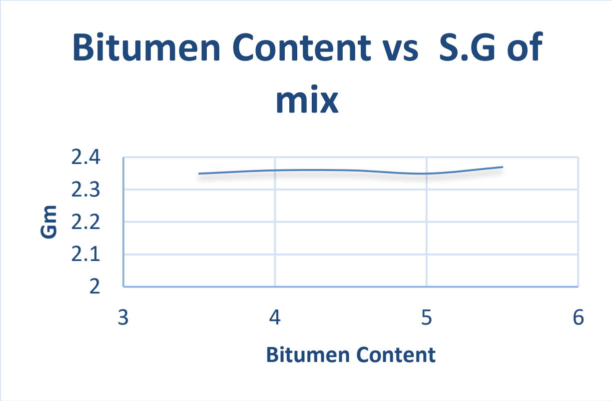
Sr.No.	Test Details	Test Method	Test Results	Requirements as per IS 3812 (Part-1)
1	Consistency	I.S 1727-1967	30.5 %	-
2	Specific Gravity	I.S 1727-1967	2.30	-
3	Soundness by Le-chatlier Method	I.S 1727-1967	1.0 mm	-
4	Fineness – By Blain’s air Permeability Method	I.S 1727-1967	350m2/kg	Shall not less than 320 m2/kg

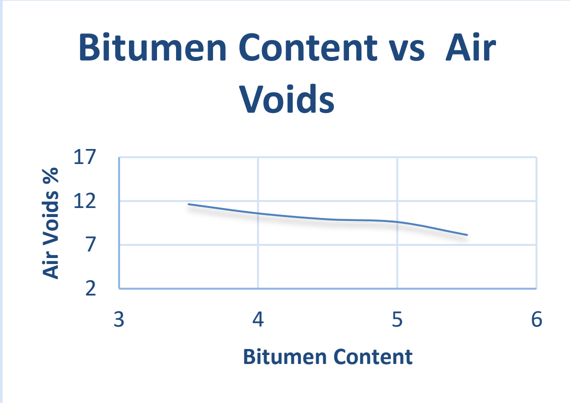
5.4 Gradation of Combined Aggregate

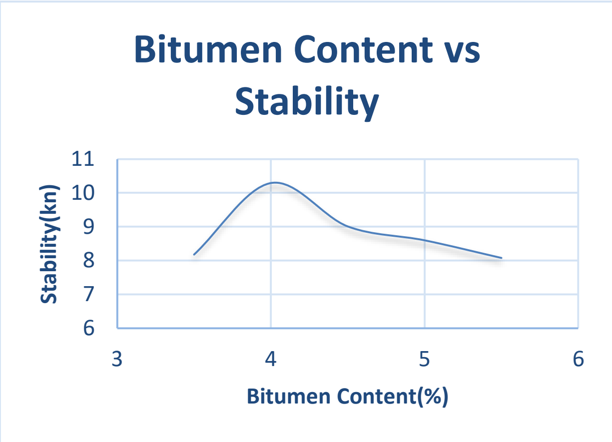
IS Sieve	% Passing				Graded % Passing	Requirement
	20mm	10mm	6mm	Stone Dust		
	40%	10%	23%	27%		
37.5mm	40	10	23	27	100	100
26.5mm	40	10	23	27	100	90-100
19mm	33	10	23	27	93	71-95
13.2mm	5.7	9.6	23	27	65.2	56-80
9.5mm	1.1	7.2	23	27	58.3	-
4.75mm	0.3	0.4	16.2	27	43.9	38-54
2.36mm	0.0	0.0	7.6	26.9	34.4	28-42
1.18mm	0.0	0.0	2.6	20.8	23.4	-
0.600mm	0.0	0.0	1.1	16.3	17.4	-
0.300mm	0.0	0.0	0.8	8.1	8.9	7-21
0.150mm	0.0	0.0	0.6	4.8	5.4	-
0.075mm	0.0	0.0	0.0	2.9	2.9	2-8

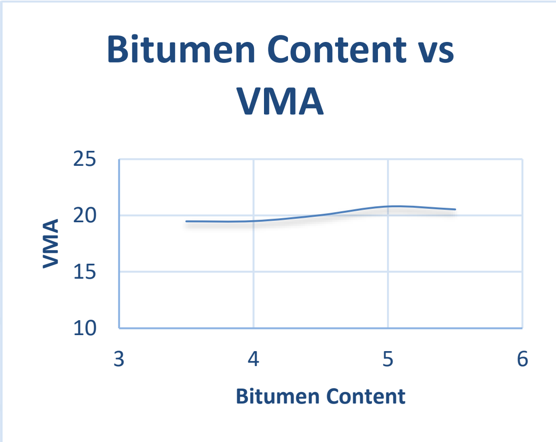
5.5 DBM Mix Parameters at Different Binder Content

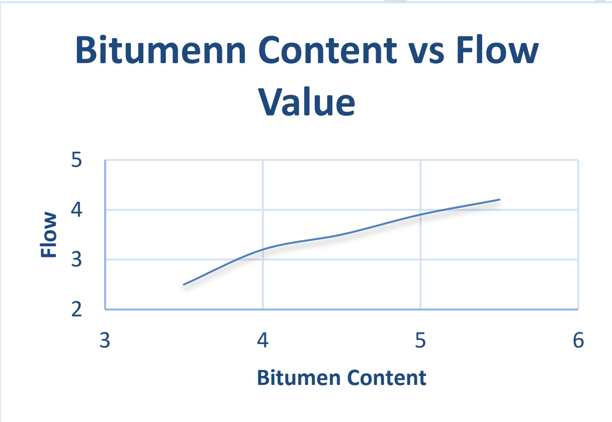
Sample No	% Bitumen by total Wt. of mix	Gm	% Air Voids	% VMA	% VFB	Stability (Kn)	Flow (mm)
1	3.5	2.49	6.4	14.7	56.5	8.18	2.5
2	4.0	2.52	4.5	14.1	68	10.29	3.2
3	4.5	2.51	4.2	14.9	71.8	9.01	3.5
4	5.0	2.51	3.5	15.4	77.3	8.60	3.9
5	5.5	2.52	2.4	15.6	84.6	8.08	4.2

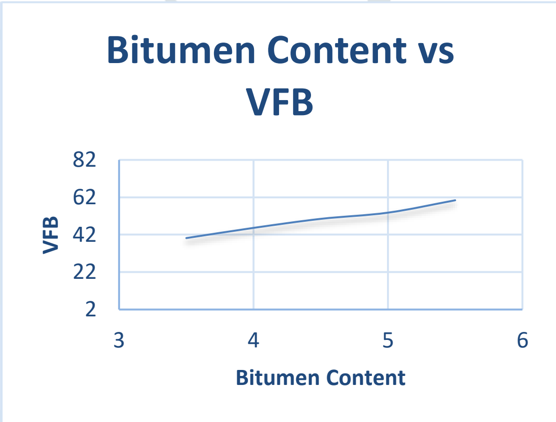






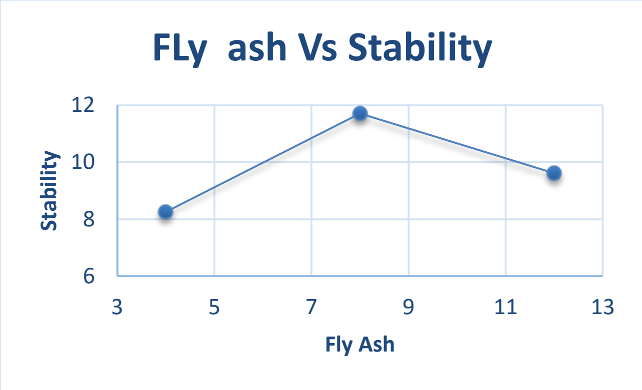


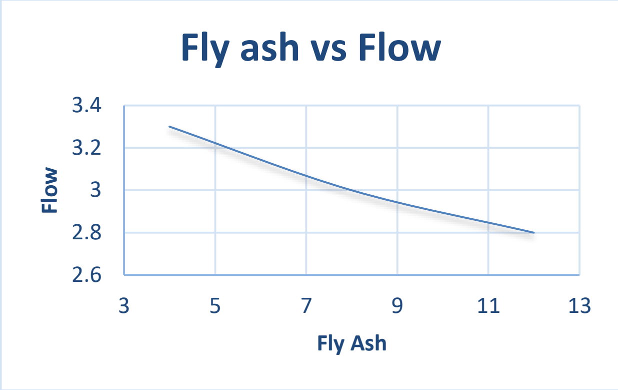




5.6 DBM Mix Parameters at 4% Binder Content and Different Fly ash Content

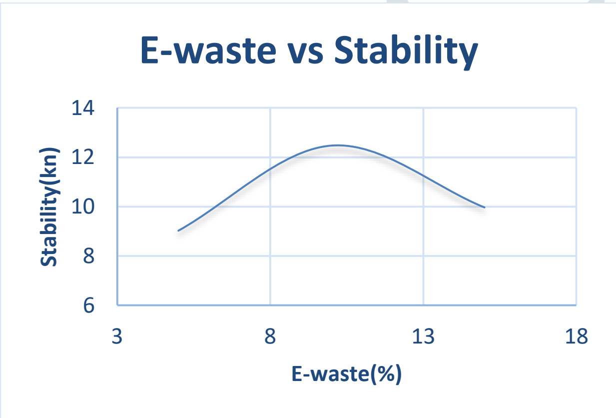
Sample No	% Bitumen by total Wt. of mix	% fly-ash by Total wt. Of stone dust	Stability (KN)	Flow (mm)
1	4	4.00	8.26	3.3
2		8.00	11.70	3.0
3		12.00	9.61	2.8

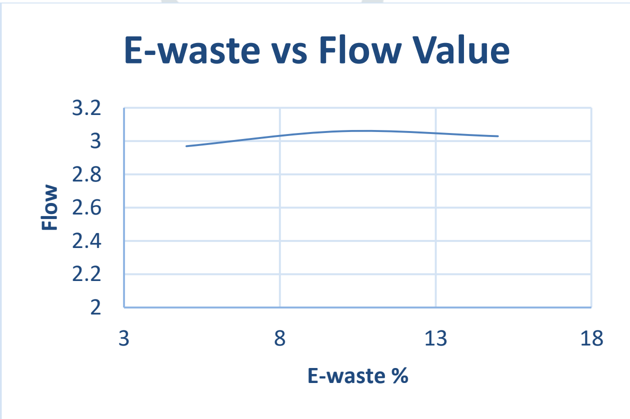




5.7 DBM Mix Parameters at 4% Binder Content and Different E-waste Content

Sample No	% Bitumen by total Wt. of mix	% E-waste by Total wt. Of Aggregate	Stability (KN)	Flow (mm)
1	4	5	9.03	2.97
2		10	12.47	3.06
3		15	9.97	3.03





5. CONCLUSION

- Table-5.7 shows the variation of stability and flow of bituminous concrete mix with percentage replacement of coarse aggregates by electronic waste with 5%, 10% and 15% e-waste. The stability value increased by 4.0% bitumen and 10% e-waste replacement and decreased by 15% e-waste replacement.
- From the experimental study, it is observed that the 10 % of coarse aggregate can be volumetrically replaced by e-waste in DBM layer having 4.0 % optimum bitumen content gives the best stability value.
- As, the e-waste percentage goes on increasing beyond 10% decrease in stability is observed clearly indicating negative results from excess use of e-waste.
- Table-5.6 shows the variation of stability and flow of bituminous concrete mix with percentage replacement of fine aggregates by Fly-ash with 4%, 8% and 12% Fly-ash. The stability value increased by 4.0% Bitumen and 8% Fly-ash replacement and decreased by 12% fly-ash replacement.
- In this experimental work, it is observed that the 8% of stone dust can be volumetrically replaced by Fly-ash in DBM layer having 4.0 % optimum bitumen content gives the best stability value.
- When the Fly-ash percentage goes on increasing beyond 8% decrease in stability is observed clearly indicating negative results from excess use of fly-ash.
- The outcomes from the laboratory investigation proves the suitability of electronic waste and fly-ash in road construction with substantial cost saving. So, disposal of hazardous electronic waste and fly-ash in the pavement can prove to be one of the alternatives to make the earth greener and pavements more durable.

5. REFRENCES

- Rana, C., Chandrakar, V.K.S., Tomar, P.S., (2018) "Use Non-Conventional Materials on Bituminous Paving as a Fillers" IJSRD - International Journal for Scientific Research & Development| Vol. 6, Issue 03, 2018
- Tapase, A., Kadam, D., Mujawar, S., (2015) "Utilization of E-Waste and Polymer Modified Bitumen in Flexible Pavement" Journal of Environmental Research and Development Vol. 9 No. 3A, January-March 2015.
- Tapase, R., Kadam, D., Tapase, A., (2015) "Consumption of Electronic Waste in Quality Enhancement of Roads" Journal of Environmental Research and Development Vol. 9 No. 3A, January-March 2015.
- Randive, M.S., Shinde M.K., (2012) "Performance Evaluation of E-Waste in Flexible Pavement- An Experimental Approach" International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD) ISSN 2249-6866 Vol.2, Issue 3, Sep 2012.
- Katara, S.D., Modhiya, C.S., Raval, N.G., (2014) "Influence of Modify Bituminous Mix with Fly Ash "International Journal of Engineeringand Technical Research (IJETR) ISSN: 2321-0869, Volume-2, Issue-April 2014.
- Durga, B.P., AJAY, P.V.K., Dedeepya, K., Shabuddin, A., Rao, K.S., (2015) "Use of fly-ash as a mineral filler for bituminous paving" IJRET: International Journal of Research in Engineeringand Technology eISSN: 2319-1163 | pISSN: 2321-7308.
- Debashish, K., Panda, M., Giri, J.P., (2014) "Influence of fly-ash as a filler in bituminous mixes" VOL. 9, NO. 6, JUNE 2014 ISSN 1819-6608 ARPN Journal of Engineering and Applied Sciences ©2006-2014 Asian Research Publishing Network (ARPN).
- Lunagaria, M.H., and Gatesi Jean De Dieu (2015) "Utilization of High Calcium Fly Ash as Filler Materials in Concrete Bituminous Mixes for Flexible Pavement " IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 11, 2015 | ISSN (online): 2321-0613.
- M.C.Vats,S.K.Singh(2014)"E-waste Characteristic and its disposal "International Journal of Ecological Science and Environmental Engineering.
- IS 2386: (Part 1-6) "Methods for test on aggregates".
- IRC 37 "Guidelines for the Design of Flexible Pavement"
- IS: 1201-1220.1978 "Methods for Testing Tar and Bituminous Materials(First Revision)"
- MORTH 5th edition