

**PARTIAL REPLACEMENT OF AGGREGATE BY CRUMB
RUBBER AND QUARRY DUST AS A FILLER MATERIAL IN
ASPHALT CONCRETE PAVEMENTS**

A RESEARCH REPORT

Submitted by

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11617748

RC1612A15

In partial fulfillment for the award of the degree of

MASTERS OF TECHNOLOGY

IN

TRANSPORTATION ENGINEERING



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CERTIFICATE

Certified that this dissertation report file entitled “PARTIAL REPLACEMENT OF AGGREGATE BY CRUMB RUBBER AND QUARRY DUST AS A FILLER MATERIAL IN ASPHALT CONCRETE PAVEMENTS” submitted by “Farhat Hussain”, under Registration no. 11617748 student of Lovely Professional University Punjab in partial fulfillment of the requirement for the award of degree M.Tech. in Transportation Engineering is an authentic record of the candidates own work carried out by him under proper supervision. The content written in this dissertation report is original and has not been submitted anywhere for the award of any other degree.

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ACKNOWLEDGEMENT

I acknowledge with high gratitude and great regards to my supervisor (Mr. Waseem Bhat) for his kind and helpful supervision during the entire course of this dissertation work. His blessings, support and direction carried me an extensive in expedition of life on which I am about to work in my life ahead.

I appreciate all the faculty members and students of the Lovely Professional University for the cherished information provided in respective fields. I am highly grateful for their assistance during the period of this report.

At last but not the least I am very much thankful to the Almighty and my parents who supported and encouraged me at the every step to put forward for the completion of this report.

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ABSTRACT

With steep increase in road traffic the number of waste tyres is hence increasing day by day and their disposal is major environmental problem and matter of concern. Furthermore there is need to increase the performance and life of pavement due to increased wheel loads from the vehicles. The waste tyres rubber or crumb can be used as a coarse aggregate in the asphalt pavements, which proves to be an efficient way of disposal of these waste tyre hence the environmental pollution can be reduced, also there is improvement in the overall performance of pavement against the wheel loads and environmental condition. Besides this, the use of natural aggregate can be preserved for the future generations. IN this paper different tests like Marshall stability test, Indirect tensile strength test, Rutting test are done to find the optimum content of crumb rubber as a coarse aggregate which gives better results as compared to normal asphalt concrete pavements.

Keywords: crumb rubber, marshal test, rutting, tensile strength, asphalt pavement

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1. INTRODUCTION

With every day there has been steep increase in number of vehicles in India during recent years so the demand of tyres has increased with same pace even huge number of waste tyres go for recycling or re-treading process still the discarded waste tyres is going to increase significantly . About 1.5 billion waste tyres are generated in the world annually. Only in India about 0.6 million Tons of tyre wastes is generated which means on an average about one tyre is discarded per person per year. If the tyres are improperly handles they can be threat to the environment as they can become the breeding house for the mosquitos and other animals, they burning can cause the air pollution and since they are almost non degradable ,if they are dumped in the soil ,they can make soil barren. Aggregate crushers produce huge quantities of quarry dust, a waste product, which is produced during crushing of Gravel and rock. Disposal of these large quantities of quarry dust poses serious threat environment and health. Quarry dust can be used as a filler material in the asphalt pavements to reduce the voids in bituminous pavement and prevents the cracking of pavement hence increase the stability of the same.

Pavement is a structure that is above the natural soil subgrade and consist of superimposed layers .it should be able to withstand the applied wheel loads and the transmitted stresses by wheel loads should not exceed bearing capacity of below subgrade. There pavement must provide good riding quality, low noise pollution and sufficient skid resistance. Mainly there are two types of pavements, flexible pavements and rigid pavements; each is different from one another in terms of their structure, design life, construction period, etc. Flexible pavements are also called asphalt pavements/bituminous pavements the load transfer in this pavement is from grain to grain. While on case of rigid pavements load transfer is. Rigid pavement is used when the wheel loads are high and environment condition is not favorable. The material used in flexible pavements is bitumen, aggregates and fillers. The overall life of road depends on quality of aggregates use, bitumen and also the filler material.

1.1 Bituminous mix design

The aim of mix design is to decide the proportion of coarse aggregate, filler, and fine Aggregates and bitumen to produce a mix, which is strong and economical as well. Dry mix design and wet mix design are the two main bituminous mix designs.

Requirements of bituminous mixes:

1. The mix design should possess good stability
2. It should be durable
4. It should provide a good skid resistance
5. It should possess good Workability.

2. Scope of study

Most of the roads in India are affected due to the overloading of trucks and significant variations in daily and seasonal temperature, which has led to the distress conditions like undulations, raveling, cracking, rutting, bleeding etc. on bituminous surface use of crumb rubber in asphalt concrete offer solution to these problems furthermore the waste rubber can be disposed properly without affecting our environment. This study is aimed at to find the viability of the waste rubber and quarry dust in bituminous concrete pavements, detailed laboratory investigation will be done to check its suitability, economic and environmental aspect of the study.

- Overall life and performance of pavement increases by increasing its stability, rutting resistance and cracking also the asphalt concrete becomes resistant to the moisture.
- Proper disposal of waste tyre rubber and quarry dust can be achieved without affecting the environment.
- Use of natural aggregate which is decreasing at very fast rate can be reduced

3. Objectives of study

- To evaluate the effect of using crumb rubber as coarse aggregate and quarry dust as a filler material on Marshall Stability.
- To compare the rutting, indirect tensile strength between the conventional asphalt pavements and crumb rubber modified asphalt pavements.

4. Literature Review

Thomas U. Ganiron JR (2014) [1] conducted experimental research on waste rubber as asphalt cement modifier for road pavements use of asphalt cement. Waste tyre was used which passed through the 9.5 mm sieve and retain at 4.47 sieve. Waste tyre is used as 2%, 4%, 6%, by the weight of aggregate. Marshall stability test and immersion compression test is done on all samples as per the procedure. Marshall stability values were less as compared to conventional bituminous mix. But result from immersion compression test showed that crumb rubber there is increase in water resistance and further he concluded it mitigates road noise due to wheel loads moving on it.

Sharma pawan kumar et al (2013) [2] conducted study on the possible use of waste tyre rubber in flexible pavements, varying percentages of rubber 8%, 10%, 12%, 14% by the weight of bitumen was used in the bituminous mix. VG-30 grade bitumen is used for the study. Different properties of bitumen like penetration value, ductility and softening point was determined besides this the marshall test was employed on each sample. The penetration value decreases with increase in crumb rubber and at 14 % crumb rubber the penetration value is 45. Similarly softening point and elastic recovery increased and their values were 65 and 63 respectively. Marshall Stability increase with increase in crumb rubber at 12% crumb rubber it was maximum equal to 1230.78 kg, then after start decreasing with the increase in crumb rubber content. Maximum values of stability are 18% higher than the conventional bituminous mix.

Samuel B Cooper Jr (2008) [3] Studied the characterization HMA mixture with crumb rubber additives. The fatigue cracking, moisture susceptibility, and rutting was analyzed conducted to determine the effect of water on HMA mixture utilizing freezing thaw cycle. Dissipated creep strain energy test was conducted to determine fatigue cracking in the pavement. And to calculate the rutting Hamburg loaded wheel tracking device is used. Lott man test showed that tensile strength ratio for crumb rubber modified HMA is more than the conventional pavement meaning that they have better resistance to water and freezing. Values from DCSET were higher meaning they are less prone to cracking.

Nuha salim mashaan(2014)[4] Studied the fatigue life of crumb rubber modified SMA and its relationship to stiffness. Crumb rubber by the weight bitumen of 6%, 8%, 10% and 12% are used in the study. The various tests comprises of dynamic stiffness, dynamic creep test and fatigue test at 25 degree. The indirect tensile test is done at three different stress levels i.e 200, 300, and

400 kPa. Indirect tensile strength test is used to measure the stiffness modulus of bitumen mix. Asphalt concrete produced by the modified bitumen improved the stiffness hence load bearing capacity is increased. Dynamic creep test showed that binder become more elastic hence improvement in the resistance to elastic deformation. Thus, the modified binder became more elastic and thus improved its resistance to elastic deformation. Indirect test fatigue results showed resistance to cracks and propagation of micro cracks.

Dipu Sutradhar(2015)[5] conducted experimental research on the effect of waste filler material on the bituminous mix. Three different filler i.e. stone dust, waste concrete dust and brick power dust is used .The filler material passing through 75 micron was used in the Limits. Marshall Stability test is conducted which showed marshal Stability of the mixture increased. Mixes containing brick dust showed maximum stability of 11.3 KN at 5.5 % bitumen content. And in case of mixes containing waste concrete dust and fine sand with stone dust as filler were 11.1KN and 9.8 KN.

Kshitish Jaiswal(2016)[6] Studies the strength and rutting behavior of flexible pavement with modified bitumen. Crumb rubber was used as a modifier in the bitumen with different percentages as 5%, 10%, and 15% by the weight of bitumen. Tests where first done on the modified bitumen, following results were obtained

Table 1: Physical properties of CR modified bitumen

Properties	0 % CR	5 % CR	10 % CR	15 % CR
Penetration value	65	59	65	45
Softening point	57	62	72	77
Ductility test	75	82	87	95
Viscosity test	0.5	1.5	2.24	4.75

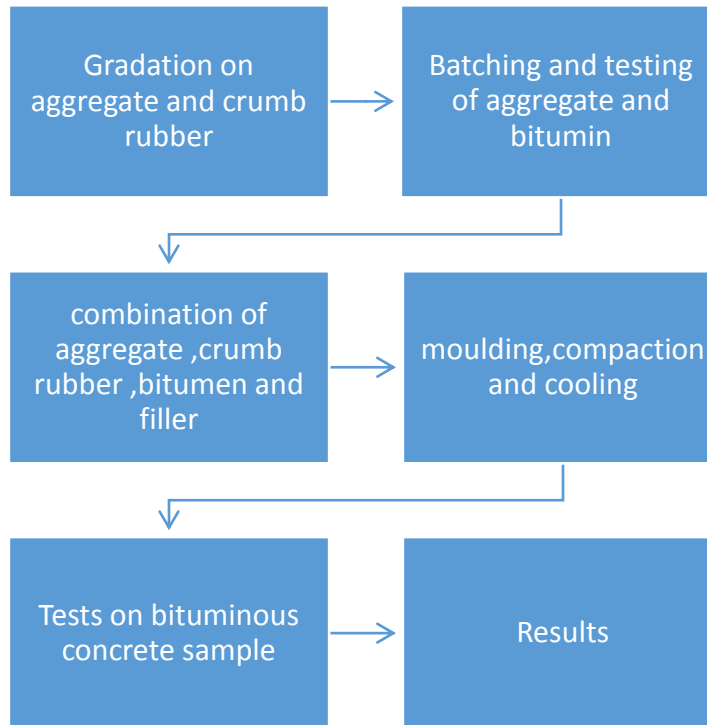
Marshall test was conducted on the specimen, maximum stability was achieved at 15 % CR which is equal to 1698 kg to that of 1469 kg at 0% crumb rubber. There is also significant increase to the rutting resistance by the addition of crumb rubber, rutting depth was minimum at 15% CR.

Table 2: Rut depth in mm

Mix type	VG 30	5 CR	10CR	15 CR
Rutt depth	6.71	4.49	2.45	2.01

5. RESEARCH METHODOLOGY

The methodology employed in the study is as follow:



5.1 Materials used in study

The materials that are used in the study to make asphalt bitumen concrete are:

1. Aggregates used in the study are brought from ACC ready-mix plant near LPU. Size of aggregates used in the study is as per MORTH code for bituminous concrete.
2. Bitumen of VG-30 grade is used in the study
3. Crumb rubber passing through 4.75 mm sieve and retained at 1.80 mm sieve are used in the study
4. Filler material is used which passes through the 75 micron sieve is used in the study.

5.2 Gradation on aggregate and crumb rubber

The gradation of aggregate is the particle distribution of the aggregate. Sieve analysis is conducted to find the particle distribution of aggregate. Proper gradation results in presence of all types of

aggregate sizes. A well graded sample has fewer voids as compared to poorly graded aggregate. Gradation of aggregate is done as per MORTH code (fifth revision) Composition of bituminous concrete layer for nominal size of 13.2mm.

5.3 Batching of aggregate

Batching is done in such a way that the mixture of aggregate, crumb rubber, filler and bitumen should have weight equal to 1200 grams. Crumb rubber percentage is varied as 2%,4%,6%,8%,& 10% by the weight of aggregate while filler material is kept constant as 2% by the weight of aggregate . Similarly bitumen percentage is varied as 4.5%, 5%, 5.5% & 5% by the weight of aggregate. And total samples equal to 15 are prepared for one test.

5.4 Tests on aggregate

The various tests done on the aggregate are Impact test, Crushing test, Loss abrasion test, elongation and flakiness test

a. *Impact test:*

It is done to find the resistance of aggregates to the impact loads. First aggregate passing through 12.5 mm sieve and retained at 10 mm sieve after that it is filled in cylinder of impact testing machine in 3 layer and each layer is compacted by 25 blows, then hammer of weight about 13.5 to 14 kg is made to drop in free fall from 38 cm and 15 blows are given to the sample in mould. The crushed aggregate is passed through 2.36 mm IS sieve. Impact value is calculated as material passing through that sieve to the total weight of sample. As per IRC for wearing coarse impact value should be less than 30%.

b. *Crushing test:*

It is done as per IS 2386 part 4 ,it is used to find out the resistance to crushing by gradual load. Aggregates are dried and aggregates passing through 12.5 mm sieve and retained on 10 mm sieve are used for the experiment. Aggregates are filled in the cylinder with dimension of 11.5 mm diameter and 18 cm height and compacted in 3 layers. After that load on the mould is applied at rate of 4 ton per minute for 10 minutes such that total load applied is 40 ton. Crushed aggregates are then sieved through 2.36 mm sieve. Crushing value is calculated which is equal to loss in weight

to that of total weight of aggregates.as per IRC the crushing value should be below 35% for wearing coarse.

c. *Abrasion test:*

This test is used to determine the hardness property of the aggregates or the abrasion value of the aggregates. IN this study Los angles abrasion test is done to find the abrasion value as per IS 2386 part 4.it consists of drum having diameter 70 cm and length equal to cm.spherical balls are used whose weight is about 350 grams. No of balls vary according to grading.500 revolutions are given to the sample with steel balls @33 rpm .After that the sample is sieved through the 1.7 mm sieve. Abrasion value is calculated as the weight of material passing through the mentioned sieve to that of total weight of sample. Abrasion value according to IRC should be less than 35 % for wearing coarse.

d. *Shape test:*

Shape of aggregate is determined by the flakiness and elongation index. When the least dimension of aggregate are less than 0.6 times the mean dimension it is called as flaky and if the greatest dimension of aggregate is greater than 1.8 times the average dimension it is called as elongated. Flakiness gauge is used to test for flakiness and elongation gauge is used for the calculation of elongation index. The procedure in the test is followed as per IS: 2386 part 1.The total value of elongation & flakiness index should be less than 35%.

5.5 Tests on Bitumen

The various test to be done on Bitumen before using it in Bituminous mix are :

A.**Penetration test:** This test is used to measure the hardness or softness of bitumen It measures the depth in tenths of millimetre when the penetration needle of standard penetrates for 5 seconds. The needle has a weight of 100 grams. A grade of bitumen 70/80 means penetration value is in range of 70-80.the test shall be conducted at the temperature of 25 degree.

B. **Softening point test:** Softening point denotes temperature at which bitumen attains a particular degree of softness. Ring and ball apparatus is used to conduct this experiment. A steel ball is kept on bitumen and it is heated @ 5 degree per minute. The temperature at which bitumen touches the metal place below it is taken as its softening point. Higher softening point indicates the bitumen is less susceptible to temperature.

C. **Ductility test:** Ductility can be defined as the distance in CM up to which a standard sample can be elongated without breaking. The sample is kept in bath tub of ductility machine before the pull is

applied on the sample According to BIS the min ductility of standard sample should not be less than 75 cm.

D. Viscosity test: Viscosity test measures the resistance to flow of bitumen. The bitumen sample should neither have high viscosity nor have low viscosity as both reduce the stability of bitumen. Orifice type viscometers are used to find the viscosity indirectly. It is expressed in terms of the time taken in seconds by the 50 ml bitumen to pass through the orifice of viscometer.

The other tests to be done on bitumen are flash and fire point test, specific gravity test, Elastic recovery test, float test etc.

5.6 Preparation of specimen

- The coarse aggregate, fine aggregate and filler is proportioned as per dry mix design, such that compacted specimen should be having thickness about 63.5 cm, which approximately equals to 1200 grams.
- Aggregate, crumb rubber and filler material are heated in temperature of range 150-170 degrees. Also the mould and rammer are heated for temperature above 100 degrees.
- Bitumen is heated in range from 150 to 165 degrees and then required percentage of bitumen is mixed properly with aggregates.
- The mix is placed in the Marshall mould having standard size 10.16 cm diameter and 6.35 cm height.
- Mix is compacted by rammer having weight of 4.54 kg and rammed by giving 25 blows on each side.
- If the compacted specimen has height other than 63.5 cm then necessary corrections are applied.
- After the sample is extracted from mould by sample extractor after curing.

5.7 Tests on bituminous mix

Marshall Stability test: before carrying out test specimen is kept in water bath at 60 degree temperature for 30 to 40 minutes. After that specimen is taken and placed on breaking head and the breaking head is put on Marshall testing machine. Load is applied on breaking head @5 cm per

minute. Stability values are the load at the time of failure is noted while flow value is deformation to the specimen in centimetres. Also the correction is applied if the specimen do not have height of 63.5 cm.

Density void analysis is carried out and following quantities are determined.

- Specific gravity of specimen
- Average specific gravity of aggregate
- Theoretical maximum specific gravity of aggregates
- per cent air voids in mix
- Per cent air voids in mineral aggregate (VMA)
- per cent aggregate voids filled with bitumen (VFB)

Following graphs are plotted to find out the optimum binder content:

- Marshall stability and bitumen content
- Flow values and bitumen
- Specific gravity and Bitumen
- Percentage voids in bitumen mix and bitumen content
- Percentage aggregate filled with bitumen and bitumen content

Optimum bitumen content is the average of bitumen content when stability is maximum, bitumen content when bulk density is maximum and bitumen content when air voids are 4%.

Split Tensile test

This test is done to find the tensile strength of bituminous mixtures, the tensile strength can be related to the cracking properties of bitumen. If the tensile strength is high it means the bituminous mixture has higher resistance to cracking or we can say the resistance to fatigue cracking is related to tensile properties. Specimen is prepared in same way as in Marshall test. The specimen is loaded along the diametric plane and compressive load is developed along this plane. Procedure as per ASTM D 6931 is employed to calculate the tensile strength of specimen. Rate of loading is 51 mm/minute and plywood is used so load is applied uniformly along the length. The maximum load is noted which is just before the failure of specimen.

$$S_t = (2000P)/\pi t D$$

Where, S_t = indirect tensile strength, kPa

P = maximum load, N

t = height of specimen

D=dia.off specimen

Tensile strength ratio: It is used to determine the moisture susceptibility of mix. It is the ratio of tensile strength of water conditioned specimen to that of unconditioned specimen. A high value of tensile strength ratio means it is having good resistance to moisture.

Rutting test

Rutting is defined as the permanent deformations in the pavement due to the wheel loads applied on it. It is one of the major causes of failures in the pavement. Wheel tracking test is done to evaluate the performance of pavement against rutting. A loaded wheel tracks the specimen under the standard condition of temperature and speed of wheels and development of rut is monitored in the test. It is determined in terms of rut depth, more the rut depth means less resistance to the pavement deformation. The bitumen mix specimen is having dimensions of 300*300*50 mm. The void ratio is kept constant for all samples. The sample before the testing are conditioned in air at 50 degree C. Force of 750 N is applied with 42 oscillations per minutes and total 10000 passes are done. Final rut depth is measured after 10 thousand passes.

6. EXPECTED OUTCOMES

Following outcomes are expected from the study:

- Increase in the Marshall stability of asphalt concrete
- Optimum binder content is reduced
- Increase in the Tensile strength of concrete
- Increase in the Rutting resistance of asphalt concrete
- Reduction in the cracking of asphalt concrete
- Proper disposal of waste tyres
- Reduction in the usage of natural aggregates

Chapter 7

7. PROPOSED WORK PLAN WITH TIMELINES

Till date experiments have been done on the aggregate to check if they can be used in the bituminous mix, their values are in the acceptable limits .further study will be carried as per following work plan.

Work plan	Time
January	Tests on bitumen
Feb	Preparation of sample
March	Tests on bituminous mix
April	Dissertation 2 file preparation

8. RESULTS AND DISCUSSION

Sieve size	Aggregate passing (%)	Aggregate retained(%)	Mean agg. Passing(%)	Cumulative mean agg.pass%	Aggregate passing per sample(1200g)
19	100	0	0	0	0
13.2	90-100	0-10	5	5	60
9.5	70-88	12-30	21	16	192
4.75	53-71	29-47	38	17	204
2.36	42-58	42-58	50	12	144
1.18	34-48	62-52	59	14	168
0.60	26-38	62-74	68	4	48
0.30	18-28	72-82	77	9	108
0.15	12-20	80-88	84	7	84
0.075	4-10	90-96	93	9	108
<0.075	0-4	96-100	98	7	84

Table 3: GRADATION FOR ASPHALT CONCRETE

Total weight of aggregate (g)	Weight retained (2.36 mm)sieve	Loss in weight	Impact value%
650	586	64	9.846
650	592	58	8.920
650	580	70	10.769

Table 4: RESULTS OF AGGREGATE IMPACT TEST

Total weight of aggregates kg	Weight retained (4.75 mm) sieve	Loss in weight (kg)	Crushing value (%)
3.70	3.055	0.645	17.42
3.70	3.110	0.590	15.94
3.70	3.102	0.598	16.16

Table 5: RESULTS FOR AGGREGATE CRUSHING TEST

Gradation type	Total weight of aggregate(kg)	Weight retained on 1.7 mm sieve	Loss in weight (kg)	Abrasion valu(%)
D type(6balls ,500 revolutions) & (4.75-2.36 sieve)	5.00	4.160	0.84	16.8
C type(8 balls) (6.3-4.75) (10-6.3)mm sieve	2.50 2.50	4.210	0.79	15.8

Table 6: Results of aggregate Abrasion test

Aggregate size	weight of all aggregate (Gm)	Weight of elongated agg.(gm)	Elongation index
12.5	620	48	7.741
12.5-10	385	46	11.948
10-6.3	135	22	16.296
total	1140	116	Mean=10.17

Table 7:: Results for elongation Index

Aggregate size	weight of all aggregate (Gm)	Weight of flanky aggregate(Gm)	Flakiness index
12.5	620	65	10.48
12.5-10	385	42	10.90
10-6.3	135	13	9.63
total	1140	120	Mean =10.53

Table 8: RESULTS OF FLANKINESS INDEX

The gradation of aggregates for asphalt bitumen concrete is done as per the MORTH code revision 5, maximum sieve size used is 20 mm sieve and nominal size of aggregates 13.3 mm. All the value for aggregate test like impact test, crushing test, shape test, abrasion test are within the limits as specified in IS codes.

CHAPTER 9

9. CONCLUSION

Replacement of crumb rubber as aggregate in concrete asphalt has resulted in the increase in the various properties of asphalt pavement. From the studies it is concluded that optimum binder content to achieve the same stability is reduced. The tensile strength of the mix is also increased which in turn results in the prevention of cracking in the asphalt concrete pavements. The rutting of the pavement i.e. the permanent deformation is considerably reduced, therefore life of pavement increases and its maintenance cost is reduced. Furthermore the rubber has sound absorbing properties, so the sound produced by moving e vehicle is reduced preventing the noise pollution by vehicles. The waste rubber can also be disposed properly which will result in decrease in pollution also our natural aggregate which is depleting at fast rate can be conserved for the future use.

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