APPLICATION OF RECYCLED MATERIALS IN ROAD CONSTRUCTION

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INTRODUCTION

- As the world population grows, so do the amount and type of waste being generated. Many of the wastes produced today will remain in the environment.
- According to NITI Aayog(2021), urban India generates between 1.3L to 1.5L metric tonne of municipal solid waste every day except biodegradable waste. Which is 50 million MT per year.
- If the proper utilization of these wastes can be done it can substitute natural construction materials and drastically reduce the quantity of waste.
- Some of the widely used recycled materials in road construction are **reclaimed asphalt , plastic wastes , glass wastes, recycled concrete aggregate, mine waste, coal powder, fly ash, steel slag** etc.

https://www.niti.gov.in/sites/default/files/2021-12/Waste-Wise-Cities.pdf

OBJECTIVE

- Investigation of waste materials or byproduct or recycled materials.
- To test various properties of materials in the lab to be used for road construction.
- Analysis of the test results to evaluate suitability of recycled materials for road construction.

METHODOLOGY

Materials Collection

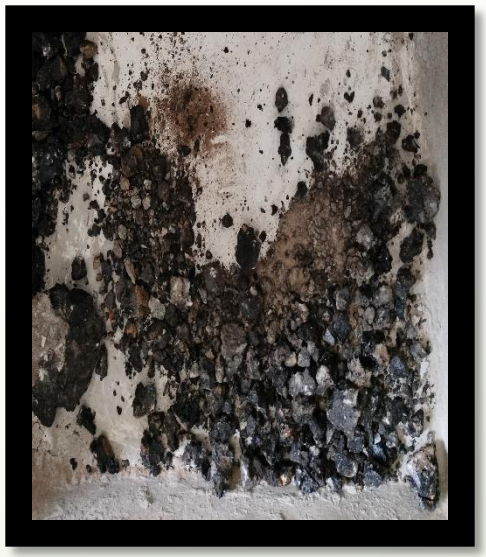
1. **Normal Aggregates**
2. **Quarry waste(Fine Aggregates)**
3. **Waste glass**
4. **Concrete waste**
5. **Reclaimed asphalt**
6. **Iron slag**
7. **Bitumen**
8. **Waste Plastic**

Tests to be performed

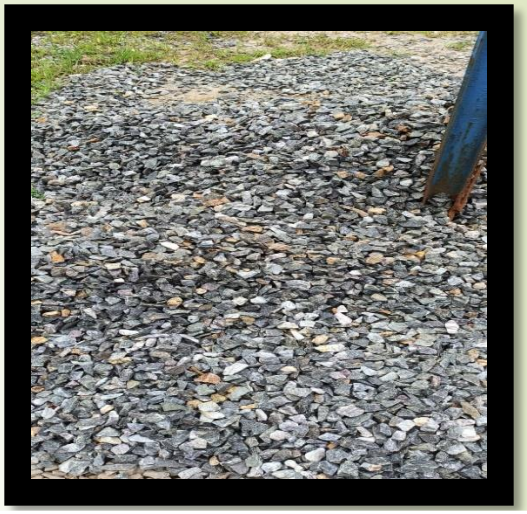
1. **Specific Gravity Test**
2. **Impact Value test**
3. **Los Angeles Abrasion value test**
4. **Water absorption test**
5. Marshall stability test
6. **Softening Point**

Materials Collection:-

Waste Glass



Reclaimed Asphalt



Normal Aggregates

Recycled Concrete Aggregate

Stone Crusher Waste

Iron Slag

Bituminous

Waste Plastic

Tests Performed On Aggregates

1.Specific gravity Test :(Using Pycnometer)

- The specific gravity of an aggregate is considered to be a measure of **strength** or quality of the material.
- The specific gravity is defined as the ratio of the mass of a given volume of the aggregate to the mass of an equal volume of water.
- Aggregates having low specific gravity are generally weaker than those with high specific gravity.
- The specific gravity of aggregates normally used in construction ranges from about **2.5 to 3.0**. (As per IS 2386-3 (1963))

Result of Specific Gravity

Sample No	W1 (gm)	W2 (gm)	W3 (gm)	W4 (gm)	SPECIFIC GRAVITY
1	510	1504	1100	1882	2.783
2	510	1508	1064	1854	2.666
3	510	1506	1070	1860	2.718

Average = 2.722

Sample size : 20mm sieve passed and 12.5mm sieve retained

W1 : Mass of clean dried pycnometer
W2 : Mass of pycnometer filled with distilled water
W3 : Mass of pycnometer with aggregate (1/3rd)
W4 : Mass of pycnometer with aggregate & distilled water

2. Aggregate Impact Value

- It is the ability of aggregate that resist sudden impact or shock load on it.
- The characteristics of any material to resist sudden impact is toughness.
- The impact load can break aggregate into smaller pieces which results in the failure of roads and pavements.
- The need of impact test is used to measure the **toughness** of aggregate which is nothing but the ability of aggregate to resist the **sudden loading** or impact loading.
- The quality of aggregate in impact test is based upon IS2386 Part 4.

Result of Impact Value Test

Sample No	Weight of measuring cylinder (A)	Wt. of measuring cylinder + aggregate(B)	Weight of aggregate (W1) (B-A)	Wt. of aggregate passed 2.36 mm sieve(W2)	Impact value (%) W2/W1 *100
1.	880	1226	346	50	14.45
2.	880	1214	334	56	16.76
3.	880	1218	337	54	16.02

Average = 15.74%

All units are in gm.

Sample 1 & 2 : 12.5mm sieve passed and 10mm sieve retained

Aggregate Impact value	Classification
<10%	Exceptionally Strong
10-20%	Strong
20-30%	Satisfactory for road surfacing
>30%	Weak for road surfacing

3. Los Angeles Abrasion value of aggregates

- Abrasion is a measure of resistance to hardness and abrasion resistance such as crushing.
- When vehicles travel on the road, the soil particles present between the tires of the vehicle & the road surface creates abrasion effect on aggregates.
- Aggregates used in road construction must be hard enough to resist abrasion.
- The working principle of Los Angeles abrasion test is to find the percentage wear due to the relative rubbing action between the aggregate and steel balls used as abrasive charge.

Los Angeles Abrasion Machine

The suitability of aggregates for different road constructions can be judged as per IRC specifications as given below.

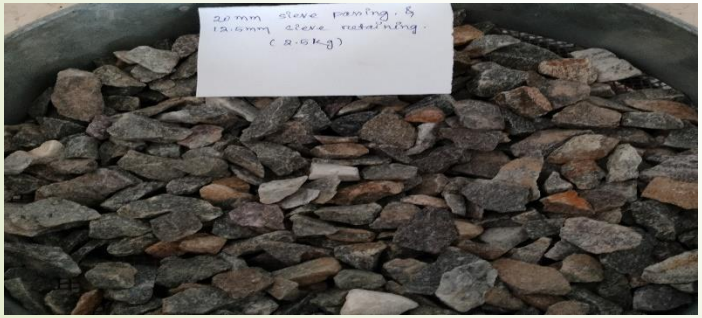
Sl No.	Types of Pavement	Max. permissible abrasion value In %
1.	WBM sub base course	60
2.	WBM with bituminous surfacing	50
3.	Bituminous bound macadam	50
4.	WBM surfacing course	40
5.	Bituminous penetration macadam	40
6.	Bituminous surface dressing, cement concrete surface course	35
7.	Bituminous concrete surface course	30

Result of Abrasion Test

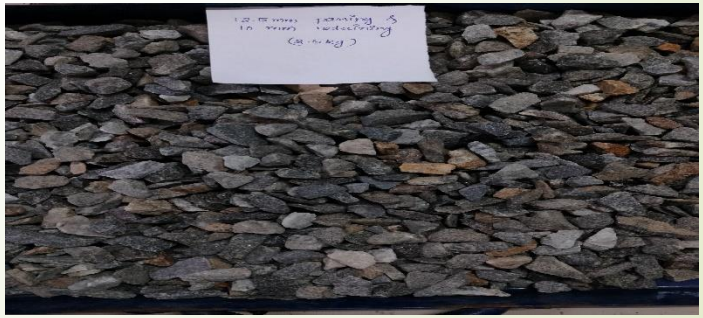
Wt. of sample (W1 gm)	5000	5000	5000
Wt. of sample after abrasion & passed 1.7mm sieve (W2 gm)	3550	3568	3562
% wear (W1-W2)/W1 * 100	29%	28.64%	28.76%

Average = 28.8%

- The value we got was 28.8% which indicate that it was only suitable for Bituminous concrete surface course .(IS 2386-5)



20mm passed 12.5mm retained



12.5mm passed 10mm retained

4. Water Absorption Test :-

- Water absorption gives an idea on the internal structure of aggregate.
- Aggregates having more absorption are more porous in nature and are generally considered unsuitable.
- The water absorption of aggregate ranges from **0.1 to 2%** and not more than that. (IS 2386 Part 3)

Materials kept in oven

Result of water absorption test

Sample No	Wt. of oven dried sample W1	Wt. of saturated sample W2	Wt. of water absorbed (W3=W2-W1)	% of Water Absorption (W3/W1*100)
1	200	201.3	1.3	0.65%
2	200	200.9	0.9	0.45%
3	200	201	1	0.5%

Average = 0.53%

- All units are in gram.
- Sample 1 & 2 : Passed through 10mm sieve.
- The value obtained of both the sample is greater than 0.1 & less than 2%

5.Flakiness Index test of aggregate

- It is the percentage by particles whose least thickness is less than 0.6 times of their mean thickness.
- The Flakiness test is not applicable to sizes smaller than 6.3mm.

Passing through I.S Sieve (mm)	Retained on I.S Sieve (mm)	Wt. of fraction consisting of at least 200 pieces (gm)	Wt. of aggregate in each fraction passing on thickness gauge (gm)
25	20	3160	746
20	16	2010	312
16	12.5	1030	233
12.5	10	554	134
		W = 6754gm	**W** = 1425gm

Flakiness Index = (w/W)*100 = 21.09%

The value we got was 21.09% which indicate that it was only suitable for Bituminous penetration macadam, Bituminous surface dressing. (IS 2386-5)

6.Elongation Index test of Aggregate

- The elongation index of an aggregate is the percentage by weight of particles whose greatest length is greater than 1.8 times their mean length.
- The elongation test is not applicable to sizes smaller than 6.3mm.

Passing through I.S Sieve (mm)	Retained on I.S Sieve (mm)	Wt. of fraction consisting of at least 200 pieces (gm)	Wt. of aggregate in each fraction retained on length gauge (gm)
25	20	3160	627
20	16	2010	120
16	12.5	1030	336
12.5	10	554	55
	Total =	6754 gm	1138 gm

Elongation Index = (w/W)*100 = 16.84%

The combined value of flaky & elongation index is

16.84+21.09= 37.94%

7.Specific Gravity Test: (Sand) Using Density Bottle

Sample	W1(gm)	W2(gm)	W3(gm)	W4(gm)	Specific Gravity
1	47	149	113	190	2.64
2	45	148	89	176	2.75
3	47	149	111	191	2.90

Average = 2.76

W1 : Mass of clean dried density bottle
W2 : Mass of density bottle filled with distilled water
W3 : Mass of density bottle with Sand (1/3rd)
W4 : Mass of density bottle with Sand & distilled water

*The size of sand is retained on 1.5 mm sieve.

Sand

Test Performed On Quarry Waste

1.Specific Gravity Test (Pycnometer)

- The specific gravity is defined as the ratio of the mass of a given volume of the aggregate to the mass of an equal volume of water.
- The specific gravity of all the crusher samples is lies in between **2.5 to 3** which fulfill the sand requirement.(IS 2386 part 3)

Materials retaining on 1.7 mm sieve

Materials retaining on 150 micron sieve

Result of Specific Gravity

Sample No	W1 (gm)	W2 (gm)	W3 (gm)	W4 (gm)	SPECIFIC GRAVITY
1	588	1559	1066	1871	2.87
2	588	1565	1068	1873	2.79
3	588	1566	1064	1869	2.75

Average = 2.80

- W1 : Mass of clean dried pycnometer
- W2 : Mass of pycnometer filled with distilled water
- W3 : Mass of pycnometer with quarry waste ($1/3^{rd}$)
- W4 : Mass of pycnometer with quarry waste & distilled water

Using Density Bottle :-

- For the material size i.e. retained on 150 micron sieve, we performed the specific gravity test using density bottle.
- We use this material as a substitute of filler material.

Sample Number	W1 (gm)	W2 (gm)	W3 (gm)	W4 (gm)	Specific Gravity
1	44	148	110	190	2.75
2	44	148	109	189	2.70
3	44	146	112	190	2.83

Avg.=2.76

W1 : Mass of clean dried pycnometer
W2 : Mass of pycnometer filled with distilled water
W3 : Mass of pycnometer with quarry waste (1/3rd)
W4 : Mass of pycnometer with quarry waste & distilled water

2. Water Absorption Test :-

- Water absorption gives an idea on the internal structure of aggregate.
- Aggregates having more absorption are more porous in nature and are generally considered unsuitable.
- The water absorption of aggregate ranges from 0.1 to 2% and not more than that. (IS 2386 Part 3)

Sample Size :Retained on 1.7 mm sieve

Observation & Calculation :-

Sample No	Wt. of oven dried sample (W1)	Wt. of saturated sample (W2)	Wt. of water absorbed (W3=W2-W1)	% of Water Absorption (W3/W1*100)
1	200gm	205gm	5gm	2.5%
2	200gm	203.5gm	3.5gm	1.75%

Average= 2.13%

Test Performed on Waste Materials

A. Specific Gravity Test :

1.Crushed Glass (Density Bottle)

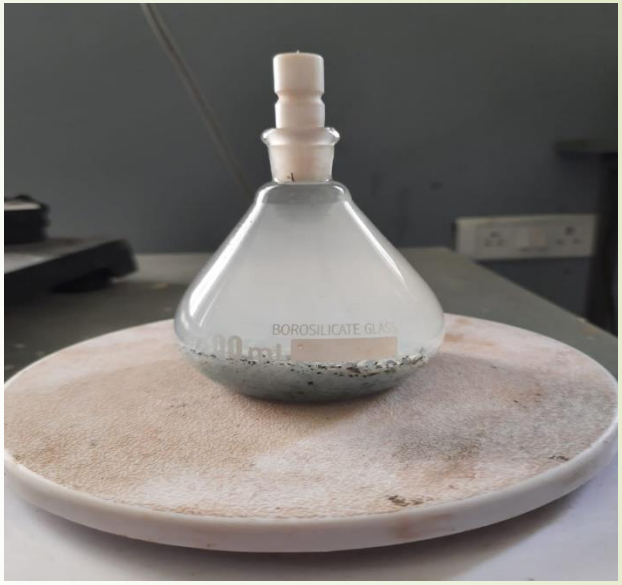
Sample	W1(gm)	W2(gm)	W3(gm)	W4(gm)	Specific Gravity
1	45	148	88	175	2.68
2	45	148	87	174	2.62
3	45	148	89	176	2.75

Average= 2.68

Sample Size : Retained on 1.7mm sieve

W1 : Weight of clean dried density bottle
W2 : Weight of density bottle filled with distilled water
W3 : Weight of pycnometer with crushed glass(1/3rd)
W4 : Weight of pycnometer with crushed glass & distilled water

Crushed Glass retained on 1.5mm sieve



Crushed Glass & Density Bottle

Specific Gravity Test:

2. **Reclaimed Asphalt** (Pycnometer)

Sample	W1 (gm)	W2 (gm)	W3 (gm)	W4 (gm)	Specific Gravity
1	587	1583	988	1821	2.46
2	587	1584	985	1820	2.47
3	587	1583	987	1823	2.57

Average = 2.5

Sample size : 20 mm passed and 12.5 retained

W1 : Mass of clean dried pycnometer
W2 : Mass of pycnometer filled with distilled water
W3 : Mass of pycnometer with bitumen waste (1/3rd)
W4 : Mass of pycnometer with bitumen waste & distilled water

Reclaimed Asphalt

Specific Gravity Test :

3. **Waste Concrete** (Using Pycnometer)

Sample	W1 (gm)	W2 (gm)	W3 (gm)	W4 (gm)	Specific Gravity
1	508	1544	889	1579	1.01
2	508	1543	894	1578	1.09
3	508	1546	891	1581	1.10

Average=1.06

Sample size : 20 mm passed and 12.5 retained

W1 : Mass of clean dried Pycnometer
W2 : Mass of Pycnometer filled with distilled water
W3 : Mass of Pycnometer with waste concrete (1/3rd)
W4 : Mass of Pycnometer with waste concrete & distilled water

Specific Gravity Test :

4. Iron Slag : (Using Pycnometer)

Sample	W1 (gm)	W2 (gm)	W3 (gm)	W4 (gm)	Specific Gravity
1	587	1582	1103	1946	3.39
2	587	1580	1100	1945	3.46
3	587	1581	1101	1944	3.40

Average=3.41

Sample size : 20 mm passed and 12.5 retained

W1 : Mass of clean dried Pycnometer
W2 : Mass of Pycnometer filled with distilled water
W3 : Mass of Pycnometer with iron slag (1/3rd)
W4 : Mass of Pycnometer with iron slag & distilled water

(B). Impact Value test

1.Waste Concrete :-

Sample Size : 12.5 mm passed & 10mm retained

Sample	Weight of measuring cylinder (A)	Wt. of measuring cylinder + aggregate (B)	Weight of aggregate (W1) (B-A)	Wt. of aggregate passed 2.36mm sieve (W2)	Impact value (%) W2/W1 *100
1	880	1157	277	84	30.32
2	880	1158	278	79	28.41
3	880	1156	276	82	29.71

Average = 29.48%

- The impact value of above sample was satisfactory for road surfacing .

Wt. of waste concrete in cylindrical measure

Wt. of concrete passed by 2.36mm sieve

Sieve of waste Concrete

Impact Value test :

2. Reclaimed Asphalt :-

Sample Size : 12.5 passed & 10mm retained

Sample	Weight of measuring cylinder (A)	Wt. of measuring cylinder + aggregate (B)	Weight of aggregate (W1) (B-A)	Wt. of aggregate passed 2.36mm sieve (W2)	Impact value (%) W2/W1 *100
1	880	1193	313	44	14.06
2	880	1176	296	50	16.91
3	880	1187	307	43	14.00

Average = 15.01%

- So the above aggregate had strong impact value.

Impact Value Test :

3. Iron Slag :-

- Sample Size : 12.5 mm sieve passed & 10 mm sieve retained

Sample	Weight of measuring cylinder (A)	Wt. of measuring cylinder + aggregate (B)	Weight of aggregate (W1) (B-A)	Wt. of aggregate passed 2.36mm sieve (W2)	Impact value (%) W2/W1 *100
1	880	1264	384	35	9.11
2	880	1257	377	31	8.22
3	880	1266	386	37	9.58

Average = 8.97

- So the above aggregate had exceptionally strong impact value.

(C). Los Angeles Abrasion Test :-

1. Waste Concrete :-

- Abrasion is a measure of resistance to hardness and abrasion resistance such as crushing.
- The suitability of aggregates for different road constructions can be judged as per IRC specifications as given below.

Sl No.	Types of Pavement	Max. permissible abrasion value In %
1.	WBM sub base course	60
2.	WBM with bituminous surfacing	50
3.	Bituminous bound macadam	50
4.	WBM surfacing course	40
5.	Bituminous penetration macadam	40
6.	Bituminous surface dressing, cement concrete surface course	35
7.	Bituminous concrete surface course	30

Results of Abrasion Test :-

Wt. of sample (W1 gm)	5000	5000	5000
Wt. of sample after abrasion & passed 1.7mm sieve (W2 gm)	1460	1465	1461
% wear (W1-W2)/W1 * 100	29.2	29.3	29.2

Average =29.23%

The value we got was 29.23% which indicate that it was only suitable for Bituminous concrete surface course .(IS 2386-5)

(D). Water Absorption Test :-

1. Waste Concrete :-

- Water absorption gives an idea on the internal structure of aggregate.
- Aggregates having more absorption are more porous in nature and are generally considered unsuitable.
- The water absorption of aggregate ranges from **0.1 to 2%** and not more than that. (IS 2386 Part 3)

Calculation & Observation :-

Sample No	Wt. of oven dried sample W1(gm)	Wt. of saturated sample W2(gm)	Wt. of water absorbed (W3=W2-W1) (gm)	% of Water Absorption (W3/W1*100)
1	196	204	8	4.08%
2	199	203	4	2.01%
3	198	204	6	3.03%

Average = 3.04%

- The value obtained of both the sample is greater than 2% & is not in the permissible limit.

Tests Performed on Bituminous :-

(A). Specific Gravity Test :-

- The specific gravity is defined by **ISI** as the ratio of the mass of a given volume of the bituminous material to the mass of an equal volume of water, the temperature of both being specified at 27°C±0.1°C.
- The specific gravity is greatly influenced by the chemical composition of binder.
- Increased amount of aromatic type compounds cause an increase in the specific gravity.

Sample	W1 (gm)	W2 (gm)	W3 (gm)	W4 (gm)	Specific Gravity
1	46	146	104	148	1.03
2	46	144	105	149	1.09
3	46	145	103	148	1.05

Average=1.05

- W_1 = Mass of clean and dried density bottle
- W_2 = Mass of density bottle with distilled water
- W_3= Mass of density bottle with Bituminous material
- W_4 = Mass of density bottle with Bituminous material and distilled water

(B). Softening Point Test :-

- Bitumen does not suddenly change from solid to liquid state, but as the temp increase, it gradually becomes soften until it flows rapidly.
- The softening point of bitumen is the temp at which the substance attains particular degree of softening under specified condition of test.

Observation & Calculation :-

Test Property	Trial-1
Temperature (in °celsious) at which **I** ball touches the bottom plate	53.4
Temperature (in °celsious) at which **II** ball touches the bottom plate	53.7
Final Softening Point Temp.	53.5

The Softening Value of a given bitumen sample is 53.5° celsious.

Summary Table :-

Tests Performed	Materials Used						
	Normal aggregate	Quarry wastes	Waste glass	Concret waste	Reclaimed asphalt	Iron slag	Bituminous
1. Specific Gravity Test	2.72	2.80	2.68	1.06	2.5	3.41	1.05
2. Impact Value Test	15.74%			29.48%	15.01%	8.97 %	
3. Los Angeles Abrasion Test	28.8%			29.23%			
4. Water Absorption Test	0.53%	2.13%		3.04%			
5. Softening Point Test	_						53.5°c

Findings :-

- From the table we found that, we can use quarry wastes and crushed glass as a replacement of sand and use them as fillers.
- We can use the reclaimed asphalt in the road construction as it has strong impact value.
- We can use the waste concrete in the bituminous concrete surface course.
- We can use the iron slags in the road construction as it has exceptionally strong impact value.
- We can mix the waste plastic bottles with bituminous and use it in a replacement of bituminous in road construction.

C/S of Flexible Pavement

Road Map

Application Of Recycled Materials In Road Construction

Materials Collection

Tests Performed

Mix Design & Marshall Stability test to be perfomed

Comparison

Conclusion & Future Scope

THANK YOU