International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 08 | Aug 2022 www.irjet.net p-ISSN: 2395-0072

UTILIZATION OF IRON ORE TAILINGS AS SUBSTITUTE TO CONVENTIONAL AGGREGATES IN POTHOLE PATCHING MIXTURES

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Abstract - A pothole is a depression in a road surface, usually asphalt pavement, where traffic has removed broken pieces of the pavement. It is usually the result of water in the underlying soil structure and traffic passing over the affected area. Water first weakens the underlying soil; traffic then fatigues and breaks the poorly supported asphalt surface in the affected area. Continued traffic action ejects both asphalt and the underlying soil material to create a hole in the pavement. Iron ore tailings (IOTs) are a form of solid waste produced during the beneficiation process of iron ore concentrate. Among all kinds of mining solid waste, IOTs are one of the most common solid wastes in the world due to their high output and low utilization ratio.

These iron ore tailings can be used as a complete replacement for conventional aggregates in pothole patching mixtures. Using iron ore tailings in the synthesis of pothole patching mixtures will help in the utilization of these wastes in great volume. The test which has been conducted for the prediction of optimum binder content is the Marshall stability test which includes the preparation of the mold and check the strength of the mold after 24 hours of setting time. The results that were obtained from the tests are that the optimum binder content is about 5 percent of 1200 grams which is the total amount of aggregates taken. The cutback bitumen was made making the mix of kerosene and bitumen in the ratio of 30%-70% respectively.

***Key Words*: Cutback, Iron Ore Tailing, Zycotherm, Optimum Binder Content, Tensile Strength Ratio.**

1. INTRODUCTION

A pothole is a small area of distress in a pavement with an asphalt surface caused by the base course and asphalt surface being worn away. Usually made of asphalt, potholes are depressions in the road's surface where debris has been removed by forcing water into the subsurface soil structure and traffic in the affected area are typically the causes of this. Water initially weakens the underlying soil. The asphalt surface in the affected area is then destroyed as a result of the traffic becoming fatigued

Pothole creation is primarily caused by two factors. Poor craftsmanship and mixed design are two of them. When heavy traffic passes over these areas, the asphalt deteriorates and materials are scraped from the surface, leaving the potholes in its wake. Seepage of water through fractures and freezing conditions are two additional factors that contribute to pothole formation. When water freezes, it forces he top layer of asphalt and the stratum beneath it down, deteriorating the surfaces underneath the road surface that support it and forming a zone of weak strains.

Potholes are created when the surface layer breaks up when the vehicle travels over it. As a result, materials become free and escape the surrounding pavement. Traffic congestion, fuel waste, and longer travel times are all caused by potholes. This ultimately contributes to air pollution, which affects people's health and causes many major issues. In addition, the presence of these potholes contributes to numerous accidents.

The formation of potholes has four main reasons:

1. Insufficient Road tightness to support traffic during snow/melting seasons without local failure

2. Insufficient water flow

3. Failure of operating and simulation channels (holes and drain casings)

4. Faults and cracks in paved roads left unattended and closed to allow moisture and jeopardize the integrity of the pavement structure

When iron ore concentrate is beneficiated, a type of solid waste called iron ore tailings (IOTs) is created. IOTs are among the most widely dispersed solid wastes in the world among all types of mining solid waste because of they produce a lot, but use relatively little. About 5% of the Earth's crust is made up of iron, the fourth most common element. Iron, which is frequently found as ore, has been utilized to make tools and weapons for almost 4,000 years. It is difficult to envision modern life without iron ore because it is a necessary component in the production of steel. South Africa, Australia, Brazil, Canada, India, China, and Europe contain the majority of the world's iron ore reserves.

The formation of iron ore concentrates from the iron ore in raw form and as the result there is the formation of tailing in the form of fines as well as coarse and it accounts of total of 20-40% of total weight of iron ore used in raw form, which is a huge by-product formed and need to be dumped or utilized in some way so that it does not form any kind of pollution and harm to the environment. As if not utilized in any kind of work it needs to be dumped at a place which would results in many things such as polluting the groundwater underneath the dumping area, making the area barren and no more agricultural activity can be done as it makes the soil impervious so making it less fertile.

1.1 PROBLEM OF STATEMENT

- One of the most typical wastes produced worldwide is iron ore tailings. IOTs are a particular category of solid waste produced during the beneficiation of iron ore concentrate.
- In pothole repair combinations, these iron ore tailings can completely substitute traditional aggregates. Iron ore tailings can be utilised in large quantities by creating pothole repair mixtures using them.
- Potholes are prevalent all over the world. To use iron ore tailings as a substitute to other materials used in pothole patching.
- These iron ore tailings can be utilised in pothole filling mixtures in place of traditional aggregates entirely. Utilizing these wastes in significant quantities will be made possible by making pothole-filling solutions out of iron ore tailings.

1.2 OBJECTIVES

- Petrographic examination of iron ore tailings for utilization in pothole patching mixtures.
- Mix design of pothole patching mixtures utilizing iron ore tailings as a substitute to conventional aggregates with antistripping agents.
- Laboratory evaluation of pothole patching mixtures with iron ore tailings and natural aggregate

2. MATERIALS USED

Cutback Bitumen, Coarse Aggregate, Fine Aggregate, Iron Ore tailings and Zycotherm were employed in this experiment

2.1 AGGREGATES

The aggregates were obtained from the L.G BLUE METAL crusher in Tamil Nādu the combined gradation Percentage passing of the Aggregate by Job Mix Formula. The quantity of aggregates was accurately measured to ±0.1 grams in accordance with Indian Standards: 2386(Part 1)-1963

2.2 CUTBACK

The petroleum product known as "cutback bitumen" is made by dilution of bitumen with petroleum hydrocarbon (Kerosene). In order to improve bitumen's penetration into asphalt surfaces, viscosity must be reduced. The cutback bitumen was made making the mix of kerosene and bitumen in the ratio of 30%-70% respectively.

2.3 IRON ORE TAILINGS

IOTs are one of the most prevalent solid wastes in the world among all types of mining solid waste because of their huge output and low usage ratio. Iron Ore Tailings were brought from the Kudremukh. They were sieved accordingly with the sieve sizes of aggregate.

Table -1: Properties of Iron Ore Tailings

Properties of Iron Ore Tailings		
SL NO	**Properties**	**Values**
1	Fines (clay and silt) %	6.5
2	Sand Content	69.50
3	Gravel Content	24.00
4	Specific Gravity	2.65
5	Minimum dry density	1685.00 kg/m3
6	Maximum dry density	1860.00 kg/m3
7	Effective grain size D10	0.13mm
8	D60	2.67mm
9	D30	0.70mm
10	Coefficient of Uniformity, Cu	20.54
11	Coefficient of Curvature, CC	1.41

2.4 ZYCOTHERM

ZycoTherm is a warm mix asphalt-enhanced antistrip additive of the next generation (WMA). It works with every sort of aggregate. It enables increased bitumen adhesion to. An odourless nano organosilane ingredient called Zycotherm is utilised in bituminous mixes. Zycotherm provides improved chemical bonding for longer moisture resistance and guarantees that bitumen is completely coated at low temperatures.

3. Methodology

Various test needs to be performed on the samples and Firstly Marshal stability test need to be conducted to find out the optimum binder content.

3.1 TEST ON AGGREGATES:

The following test need to be conducted on the aggregates.

- Specific Gravity
- Water Absorption
- Abrasion Value
- Crushing Value
- Elongation Index
- Flakiness
- Bulk Density

3.2 TESTS ON CUTBACK

The following are the list of tests conducted on Cutback

- Penetration Test
- Softening Point Specific Gravity
- Ductility Test
- Flash & Fire
- Viscosity test

3.3 TESTS ON MIX SPECIMEN

The following are the list of tests conducted on Mix Specimen

- Marshal Stability Test
- Adhesion Test
- Cohesion Test
- Indirect Tensile Strength Test

3.3.1 MARSHALL MIX DESIGN

The Marshall mix design method consists of 6 basic steps:
1. Selection of aggregates

2. Asphalt binder selection

3. Sample preparation (including compaction)

4. Stability determination using the Marshall Stability test Apparatus

5. Density and voids calculations

6. Optimum asphalt binder content selection

3.3.1.1 MIX DESIGN

Table -2: Marshall Mix Proportions

PROPORTIONS		
Optimum binder content by weight mix	5 % by weight of mix	60 Gms
(9.5mm – 4.75 mm)	40 % by weight of Aggregate	480 Gms
(4.75mm – 2.36 mm)	35 % by weight of Aggregate	420 Gms
(2.36mm – 1.18 mm)	20 % by weight of Aggregate	240 Gms
(1.18mm – 0.075mm)	5% by weight of Aggregate	60 Gms

Table 2 depicts the proportions for marshall specimen preparation based on MORTH table 500-17, as well as the job mix formula restrictions.

Table -3: Combined Gradation of Aggregate

Combined Gradation of Aggregate		
IS Sieve (mm)	Job Mix formula combined gradation Percentage passing	MORTH Specified Limits table 500-10
19	100	100
13.2	99.08	90-100
9.5	85.99	70-88
4.75	58.74	53-71
2.36	46.47	42-58
1.18	38.43	34-48
0.6	31.43	26-38
0.3	22.37	18-28
0.15	15.52	12-20
0.075	6.42	6.42

Table 3 depicts the job mix formula of combined gradation percentage passing as per MORTH (table 500-10) specified limits

In the laboratory, In the process of sample preparation, we should have an idea of the range in which the optimum binder content will fall and make a certain number of samples mix with 3 number of blends and mix the aggregates and the chosen amount of bitumen content thoroughly and place the mix in the oven at 135 C for 24 hours. On the next day, the mix can be taken out and made into the sample with the help of Marshall Hammer with 75 number blows on either side of the mold once placed in the metallic cylindrical mold. Then marshall stability test is performed on the specimen in accordance with ASTM D 1559-76. Then the marshall load & flow values are note downed. Then Bulk Volume, Bulk Specific Gravity, % Air Voids, % VMA, % VFB, are determined using below equations mentioned. Then based on test results graphs are plotted.

- Marshall Stability Load, (KN) = Applied load in Division * Correction Factor * Proving Ring Factor.
- Bulk Volume (cc) = (Mass of Saturated Surface dry Specimen in Air) - (Mass of Specimen in water)
- Bulk Specific Gravity (Gmb) (gm/cc) = (Mass of Specimen in Air) / (Bulk Volume)
- % Air Voids = ((Max SG of loose Mixture)-Bulk SG Specimen)) / (Max SG of Loose Mixture) *100
- % Voids in Mineral Aggregate = 100 - ((Bulk SG of Specimen * Percentage of Aggregates)) / (Bulk SG of Aggregate)
- % Void Filled with Bitumen = 100 * ((% Voids in Mineral Aggregate-% Air Voids)) / (% Voids in Mineral Aggregate)

3.3.2 ADHESION TEST

- Preparation of the sample
- Determination Of Adhesiveness of sample

3.3.2.1 Preparation of the sample

500 grams of lose asphalt mixtures were placed in a 100-mm diameter Marshall mould on top of a 75-mm sample of compacted HMA and compacted with10 blows of a standard Marshall hammer

Fig 1: Mould Prepared for the Adhesion Test

3.3.2.2 Determination of adhesiveness of sample

The compacted sample was extruded and the sample was inverted. The adhesion of the mixture was measured by the amount of time it took for the specimen to drop from the substrate asphalt. Two groups of materials were tested, including the original and oven-aged (608C for 4 h) group. The test was conducted at room temperature (258C).

3.3.3 COHESION TEST

- Preparation of mould
- Determination of the cohesiveness of sample

3.3.3.1 Preparation of the sample

Cohesion test, also named as rolling sieve test, measures the cohesion or the bonding inside the materials. Sealed loose cold mixes and the Marshall mould were placed in a refrigerator at 48C for 12 h. Thousand grams of cold mix were then placed in the mould and compacted five times on each side with the Marshall hammer. The extruded sample was placed in a 30.5-cm diameter full height sieve with 25.4 mm openings.

3.3.3.2 Determination of the cohesiveness of sample

A cover was placed on the sieve and the sieve was rolled back and forth on its side approximately. Then, the material loss was calculated by weighing the material retained on the sieve. The percentage of materials retained on the sieve was calculated as a measure of cohesion of the mixture higher percentage indicates a more cohesive material.

Fig 2: Rolling Sieve Test

3.3.4. INDIRECT TENSILE STRENGTH TEST

Tensile Strength Ratio is used to assess the moisture susceptibility of a cold mix asphalt mixture. The Marshall specimen was subjected to an indirect tensile strength test in order to compute the tensile strength ratio in accordance with MORTH (table500-13) and AASHTO T283.

The indirect tensile strength test has the same mix design as the Marshall mix design. Eight moulds are created for each %. Four of the moulds are kept conditioned, while the remaining four are unconditioned. The dry condition tensile strength of the first set of compacted samples was measured in an environmental chamber at 25 °C for two hours. The second set of compacted samples was placed in a 60-degreeCelsius water bath for 24 hours before conditioning in a 25- degree- Celsius water bath for two hours. The dry and wet specimens were tested for indirect tensile strength at a displacement rate of 50 mm/min at a temperature of 25 °C. Then tensile strength ratio is determined using below mentioned equation,

Indirect TSR = (Average Indirect Tensile Strength Values of Conditioned Specimens) / (Average Indirect Tensile Strength Values of Unconditioned Specimens) *100

ITS of Specimen (2000*P)/(π*D*h)

Where, P = Applied Load @ Failure, (KN).

D = Diameter of Specimen, (CM).

t = Height of the Specimen, (CM).

1 Division = 61.53 Newton's /6.27 Kilograms

Fig 3: Mould kept for testing Fig 4: Moulds kept under water bath

4. RESULTS AND DISCUSSION

Table 4: Results obtained from Marshall Stability test

	AsphaltContent(%)	
Description	**4.5**	**5**
Thickness (mm)	100.5	100.5
Height (mm)	80.50	80.50
Volume (cm^3)	628.00	635.08
Weight in air (g)	1087	1147.5
Weight in water (g)	612.00	644
Dial Reading	113.00	151.50
Flow (mm)	7.25	6.30
Stability Value (kN)	6.20	8.32
Bulk density (kg/m^3)	2288.42	2279.04
Theoretical density (kg/m^3)	2437.98	2421.90
Air voids (%)	6.13	5.9
Volume of Asphalt (%)	16.798	17.633
Void Mineral Aggregates (VMA) (%)	16.798	17.633
Void Filled with Asphalt (VFA) (%)	63.479	66.538

The table shows results obtained in the marshal stability test for the Aggregates with cutback was tested for 4.5% and 5% binder content. According to ASTM D6927-06, the marshall stability value must be more than 8.0 kN to achieve the minimum standard for road pavement. Hence the stability at 4.5% is 6.20 kN and 5% is 8.32 kN and the maximum flow value is 0.2% by weight of bitumen that is 12mm so the value of 4.5% is 7.25 mm and 5% is 6.30mm and hence 5% reached the minimum requirement and it is taken as optimum binder content for the test.

4.1.1 Marshal Properties

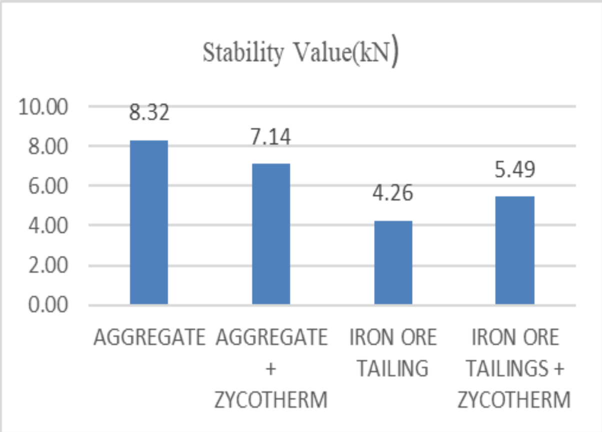

Fig 5: Comparison of stability value of different samples

The graph depicts Marshall Stability value of Aggregate, Aggregate with Zycotherm, Iron ore tailing and zycotherm-treated iron ore The stability value of aggregate sample is 8.32 kN, Aggregate with Zycotherm is 7.14 k N, Iron ore tailing sample is 4.26 k N, Iron ore tailing with Zycotherm sample is 5.49 k N.

4.1.2 Percentage of Air Voids

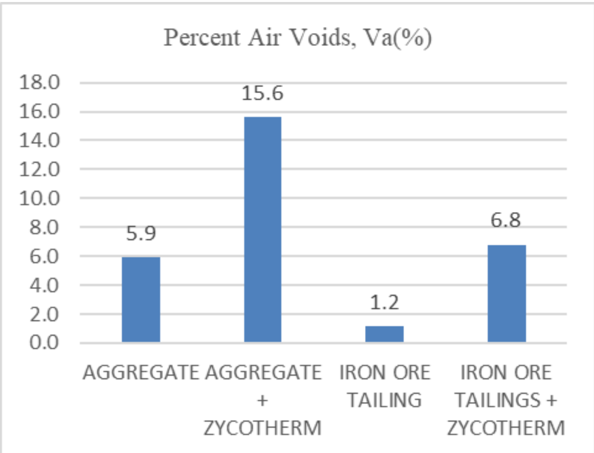

Fig 6: Comparison of Percentage of air voids of different samples

The percentage of aggregate air voids, Aggregate with Zycotherm, Iron ore tailing and Zycotherm-treated iron ore tailing sample. The Percentage of Air Voids value of aggregate sample is 5.9 % Aggregate with Zycotherm is 15.6 %, Iron ore tailing sample is 1.2 %, Zycotherm-treated iron ore tailing sample is 6.8%.

4.1.3 Voids of Asphalt

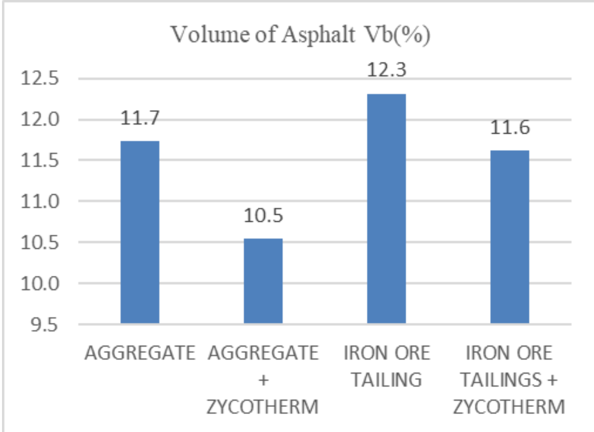

Fig7: Comparison of Voids of Asphalt of different samples

The Voids of Asphalt present in Aggregate, Aggregate with Zycotherm, Iron ore tailing and Zycotherm-treated iron ore tailing sample. The Percentage of Air Voids value of aggregate sample is 11.7 % Aggregate with Zycotherm is 10.5 %, Iron ore tailing sample is 12.3 %, Zycotherm-treated iron ore tailing sample is 11.6%.

4.1.4 Voids in Mineral Aggregate (VMA):

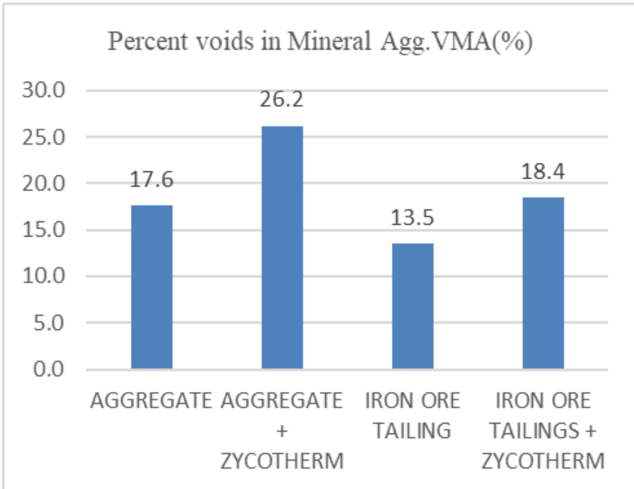

Fig 8: Comparison of Voids in Mineral Aggregate of different samples

The Voids in Aggregate Minerals present in Aggregate, Aggregate with Zycotherm, Iron ore tailing and Zycotherm-treated iron ore tailing. The Voids in Mineral Aggregate value of aggregate sample is 17.6 % Aggregate with Zycotherm is 26.2 %, Iron ore tailing sample is 13.5 %, Zycotherm-treated iron ore tailing sample is 18.4%.

4.1.5 Voids Filled in Asphalt (VFA):

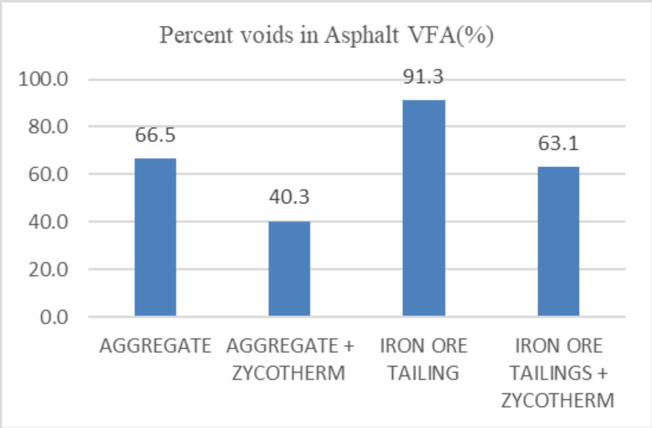

Fig9: Comparison of Voids Filled in Asphalt of different samples

The Voids filled in asphalt present in Aggregate, Aggregate with Zycotherm, Iron ore tailing and Zycotherm-treated iron ore tailing. The Voids filled in asphalt value of aggregate sample is 66.5 % Aggregate with Zycotherm is 40.3 %, Iron ore tailing sample is 91.3%, Zycotherm-treated iron ore tailing sample is 63.1%.

4.1.6 Volumetric Properties

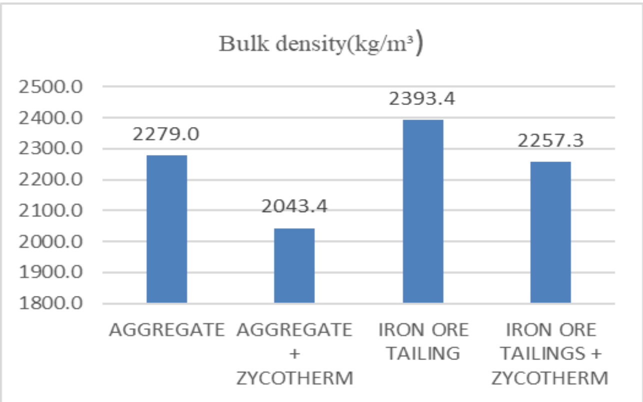

Fig10: Comparison of bulk density of different samples

Volumetric properties such as bulk density for Aggregate, Aggregate with Zycotherm, Iron ore tailing and Zycotherm-treated iron ore tailing are shown in the bar chart. The bulk density of Aggregate is 2279 kg/m3, Aggregate with Zycotherm is 2043.4 kg/m3, Iron ore tailings is 2393.4 kg/m3, Zycotherm-treated iron ore tailing is 2257.3 kg/m3.

4.1.7 Theoretical Density

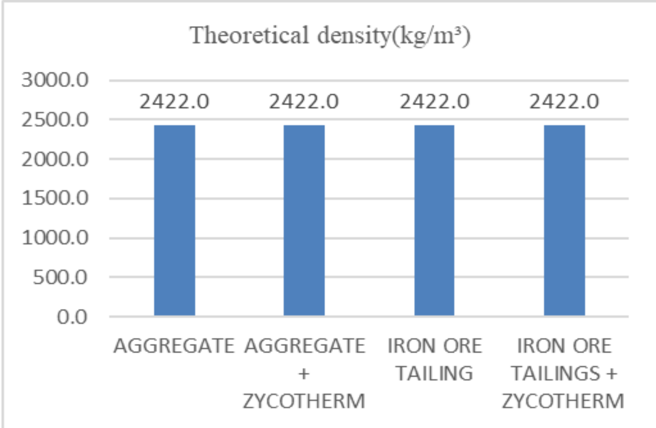

Fig11: Comparison of theoretical density of different samples

Volumetric properties such as theoretical density for Aggregate, Aggregate with Zycotherm, Iron ore tailing and Zycotherm-treated iron ore tailing are shown in the bar chart. The bulk density of Aggregate is 2422 kg/m^3, Aggregate with Zycotherm is 2422 kg/m^3, Iron ore tailings is 2422 kg/m^3, Zycotherm-treated iron ore tailing is 2422 kg/m^3.

4.2 ADHESION

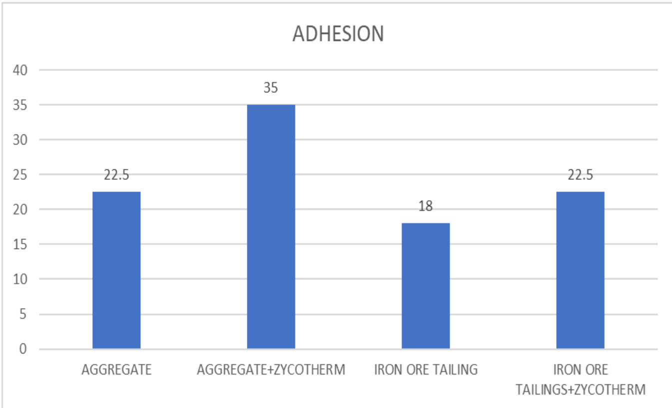

Fig12: Comparison of Adhesion result

Adhesive Properties exhibited by Aggregate, Aggregate with Zycotherm, Iron ore tailing and Zycotherm-treated iron ore tailing are shown in the bar chart. The Adhesiveness of Aggregate is 22.5 seconds, Aggregate with Zycotherm is 35 seconds, Iron ore tailings is 18 seconds, Zycotherm-treated iron ore tailing is 22.5 seconds.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 08 | Aug 2022 www.irjet.net p-ISSN: 2395-0072

4.3 COHESION

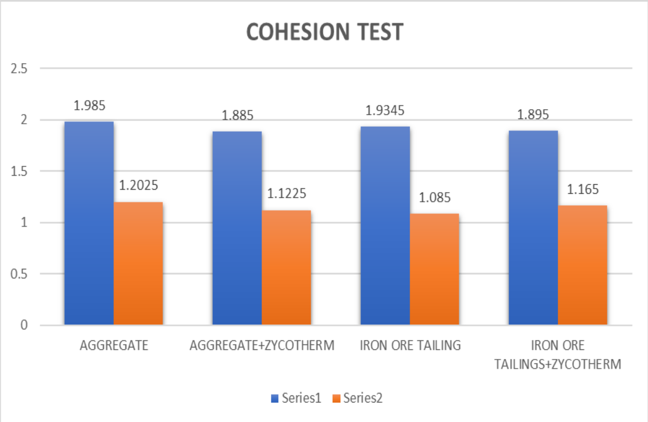

Fig12: Comparison of Cohesion Results

Cohesiveness Properties exhibited by Aggregate, Aggregate with Zycotherm, Iron ore tailing and Zycotherm-treated iron ore tailing are shown in the bar chart. The Weight of Aggregate is 1.985 kg, Aggregate with Zycotherm is 1.885kg, Iron ore tailings is 1.9345kg , Iron ore tailing with Zycotherm is 1.895kg . The Weight retained after rolling of Aggregate is 1.202 kg, Aggregate with Zycotherm is 1.1225kg, Iron ore tailings is 1.08 kg, Zycotherm-treated iron ore tailing is 1.165 kg.

4.4 Indirect tensile strength test

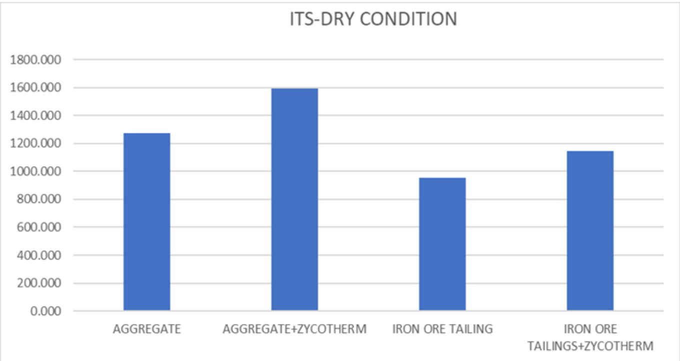

Fig13: Comparison of Indirect Tensile Strength under Dry Condition

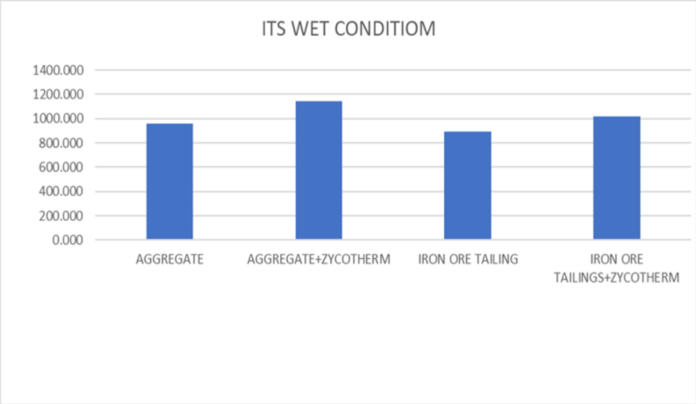

Fig14: Comparison of Indirect Tensile Strength under Dry Condition

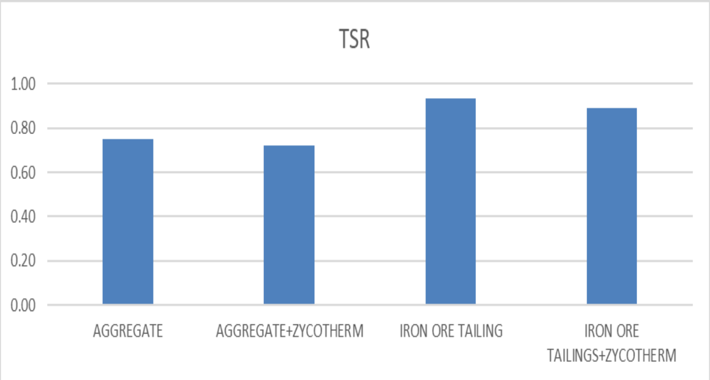

Fig15: Comparison of TSR

The moisture susceptibility may be determined using the tensile strength ratio. When testing moisture resistance, TSR alone was determined to be insufficient. To evaluate the moisture damage resistance of asphalt mixtures, it is recommended to test both TSR and wet ITS strength at the same time. The TSR Value of Aggregate sample and Aggregate with zycotherm, Iron ore tailing and Zycotherm-treated iron ore tailing is shown in the barchart. The value of TSR for the Aggregate is 0.75, Aggregate with Zycotherm is 0.72, Iron Ore Tailing is 0.93 and Zycotherm-treated iron ore tailing is 0.89

Conclusions:

The current study was primarily concerned with the utilization of Iron Ore Tailing as an alternative to conventional aggregate in asphalt mixtures. The following conclusions are reached based on the findings of experimental testing:

- It was investigated to see if iron ore tailings (IOTs) might replace traditional aggregates in pothole patching mixtures. It was discovered that doing so would help to significantly increase the amount of trash that could be used up. You can save 20 to 30 percent on pothole repair costs.

- Since IOTs have a higher moisture content than aggregates, their inclusion reduces the mixture's workability. With the addition of IOTs, the cost strength increase also rises by 20 to 30 percent.

- A small number of samples of cutback bitumen were collected, and both ordinary aggregate and iron ore tailings were used to create the sample. The sample contained 30% kerosene and 70% bitumen. The Marshall Stability test was performed on each of them, and it was discovered that in order to obtain the necessary quantity of flow value and stability, we had to utilise around 5% of the cutback bitumen, or 60g, in the aggregate or iron ore tailings total quantity (i.e., 1200g).

- In a cohesion test, aggregates and iron ore tailings produced roughly the same results at a cutback content of 5%; however, when zycothetrm was added, the cohesiveness value increased.

- The specimens of aggregate, aggregate with Zycotherm, iron ore tailings, and iron ore tailings with Zycotherm underwent an adhesion test. The duration required by aggregate and iron ore tailings using the zycotherm was shown to be 22.5 seconds.

- In both dry and wet conditions, loaded wheel tests were performed on specimens of aggregate, aggregate with zycotherm, iron ore tailings, and zycotherm-treated iron ore tailings. When compared to aggregates, the iron ore tailings will be more resistant to temperature and load.

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