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# Use of ceramic Waste as Filler and in replacement of coarse aggregate in Dense Bituminous Macadam

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**ABSTRACT**

Most commonly used and costly flexible pavement layer is the Dense – Bituminous – Macadam. Adding filler to the DBM mix ensures the strength and stability of the pavement by filling up the gaps between the aggregates. Traditional fillers (cement and lime) are inexpensive, but their cost has an effect on the overall construction cost. To meet this demand and keep the environment clean, ceramic waste material can be used. We're talking about tones of ceramic waste (CW) being produced and dumped every month all over the world as buildings made of ceramic materials go up. As a result, using recycled waste ceramic in DBM reduces pollution.

**Keywords**: Ceramic waste, Concrete, Tests, Macadam, pavement.

## I. INTRODUCTION

Due to the ease with which it may be constructed, semi-dense bituminous concrete is the kind of pavement that is used most often. The ever-increasing economic costs and the lack of availability of natural material have opened the door for the possibility of exploring waste material that is accessible in the local area. It's possible that pollution and disposal issues may be alleviated to some degree if materials from industrial waste could be utilised appropriately in road building. According to what has been reported, the Indian ceramics sector, which includes products such as wall and floor tiles, sanitary ware, bricks and roof tiles, refractory materials, and ceramic materials for home use and other applications, generates between 15 to 30 MT per year of trash. The Indian state of Gujarat is responsible for around 70 percent of the nation's entire ceramic output. However, out of the nation's total production of ceramics, 30 percent is considered trash and is dumped in open places [1]. The use of ceramic waste dust in road construction as mineral filler has a number of benefits, including the following: I the ceramic dust can be obtained at no economic cost; (ii) the chemical and mechanical properties will be consistent; (iii) the activity of road construction moves closer to being environmentally friendly; and (iv) the material is long-lasting, hard, and highly resistant to the biological, chemical, and physical forces that cause degradation [2].

The Indian Road Congress had previously established the very first requirements for bituminous macadam back in the beginning of 1967. During this time, on February 10th, 2001, the EPC-Pavement committee held a meeting where they discussed and decided to adopt changes to the provision in order to keep up with the variations in technology and developments in the ever-changing construction processes, as well as the quality assurance and control outcomes.

Dense Bituminous Macadam, also known as DBM, is a binder course that is used for payment construction (including road) with a large number of transport vehicles (commercial heavy vehicles) and a nearby reviewed pre-mix material that has a void content that falls somewhere between 5 percent and 10 percent. This content ranges from 5 percent to 10 percent. The qualities and requirements that regulate the stability and durability of DBM mixes under specified predicted traffic, climatic circumstances, and natural conditions are calculated, established, and planned for in the laboratory. This is done to severely meet these properties and necessities. Mineral aggregate and the suitable binder are to be the components of DBM, which must then be thoroughly combined in a hot mix plant before being paved over by a mechanised paver. It is a blend that has good open grades and is appropriate for use as a foundation course. Layers of DBM may be laid down in a single layer or in numerous layers, with the

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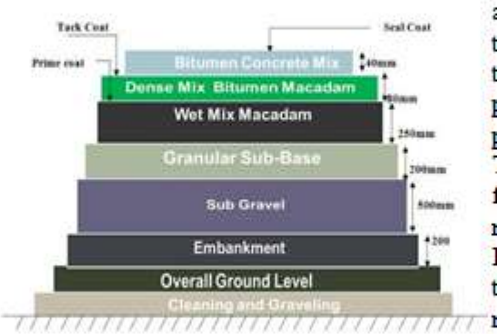
thickness of each layer ranging anywhere from 0.050 m to 0.100 m. Since the thick bituminous macadam is a combination that is open-graded, there is a possibility that it may trap water or moisture vapour inside the planned pavement system. In the meanwhile, there is a possibility that it may trap water. Therefore, in this kind of scenario, a genuine drainage opening to the BM layer has to be established in order to prevent moisture from **Figure 1: General flow diagram for the construction of roads**

causing damage to the BM layer as well as surrounding or adjacent bituminous layers.




Because of the many methods that may be used to produce it, bituminous concrete is the kind of paving material that is used the most widely.

The consistently increasing financial cost and nonattendance of accessibility of normal material have opened the door for the possibility of researching locally accessible waste material. The

problems of contamination and removal may be alleviated to some degree, provided that the materials that make up mechanical waste can be used in the construction of roads in an acceptable manner. According to what has been uncovered, the Indian earthenware production industry, which includes the manufacturing of divider and floor tiles, clean items, blocks and housetop tiles, hard-headed materials, and artistic materials for use by both locals and others, generates approximately 15 to 30 MT for each year's worth of waste. The state of Gujarat is responsible for around 70 percent of India's total terminated production, and out of the total terminated production, 30 percent is considered garbage and is deposited in open places.

It is more prudent to use an impenetrable DBM rather than the BM in order to ensure more desirable performance. DBM will also have higher fundamental power in comparison to openly evaluated BM (in far off nations the primary strength of BM type open reviewed mix is considered about portion of DBM type thick mix). In addition to this, it is argued that the BM that is now on open review is against the enactment of reflection breaks. While

This is true, and the amount of moisture that may get trapped in the BM has the potential to do a significant amount of damage. Because this is such a critical topic about the arrangement, we need to have a chat with an expert about it. We are unable to state unequivocally that BM has performed brilliantly in the past without first investigating and then addressing the problem with the waste exit. It's possible that back in the day, when motorised hot mix machines weren't as readily available, making mix was a straightforward process. In any case, it seems to be difficult to remove it at this point due to the anticipated interference from customers. The very least that should be done is to warn the customers about the possible dangers that are associated with the use of the product.

The most common use for dense bituminous macadam is as a fastening course for roads that are utilised by a significant number of sizable company high load commercial vehicles. In DBM blend, there is a broad range of room for adjusting the degree in order to get an outstanding mix without negatively affecting the asphalt's tensile strength. It is very necessary for the production of adaptable asphalt to achieve an acceptable level of bituminous mix compaction. In most cases, the Marshall Mix design technique is used when it comes to the process of designing mixes for dense graded bituminous macadam (DBM). Additionally, DBM is being considered for usage as a material for the foundation of roads. The general flow for the construction of the roads is as shown in the below figure,

The DBM road construction follows the following procedure showed in the below figure,


**Figure 2: DBM road construction steps.**

A. Base preparation to road

The DBM base will be premeasured. The surface will be dust-free. If the base is unbalanced and wavy, a corresponding course with suitable thickness is offered. After applying a heavy layer.

B. Mixing

Hot Mix Asphalt (HMA) plant mix readiness is acceptable. Group or continuous type plant.

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3. Spreading of the mix on the ground
Tipper trucks will transport and disseminate the mix. It should be dispersed such that after compacting a consistent cover course is established.

C. Compaction
After spreading, the mix is compressed by rollers moving at 5 km/h or less.
D. Allowing the vehicles to run on constructed road: The rollers are run on the road to make the road even and introduce a pressure on it. Once it is completed then the vehicles are allowed to pass on it.

## II. LITERATURE SURVEY

Art wastes and basaltic pumice cements were beneficial in tests. Scraped area cement blockage was affected by its compressive characteristics. As chloride intrusion deepened, ceramic expansion slowed. The evaluation showed CC and CBP may be utilised to make low-scraped spot and high-strength cements.[3]
Replacing 20% of concrete with ceramic residue increases centre compressive strength from 3.9% to 5.6%. No essential difference in flexural strength and split-unbending nature was detected compared to normal concrete. This exploratory study compared solids of various ages for mechanical characteristics.[4]
The X-beam test reveals CWA overall isn't pozzolanic, therefore it may be used to reduce natural contamination. Earthenware concrete is less porous than regular cement. Fractional replacement of ordinary total with CWA total in solid ideal at 55%. 50 chambers total. [5]
5-10-15-20% of bituminous macadam asphalt is replaced with ceramic waste. Ceramic totals regulated marshal soundness and stream esteem. They found that replacing 5%, 10%, 15% of typical totals with ceramic waste didn't reduce strength.[6]

## III. EXPERIMENTS CARRIED OUT AND MATERIALS

The materials employed for carrying out the experiment are as follows,

- Crushedquartziteaggregate
- Normalcoarseaggregate
- Bitumen
- Cement
- Ceramicwastedust

Crushed quartzite aggregate
The ceramic waste of around ten to twenty mm is crushed to obtain the base for the experiment and the instance of it is as shown in the below figure,

**Figure 3: Crushing the ceramic waste.**

Normal coarse aggregate: a 20 mm of coarse aggregate is employed in the experiment
Bitumen and ceramic waste as shown in the figure 3.

**Figure 4: Crushed quartzite aggregate**

**Figure 5: Ceramic dust from cutting and shaping of granite.**

A. Experimental analysis
The preparation of the DBM cement is as shown in the below figure, The Marshall Test is a renowned test that measures the load and flow rate of asphalt specimens by compaction into moulds using human or automated Marshall Compactors and adaptation in a Water Bath at a present temperature. Marshall Test agrees to identify the best folio content for filler elements (cement and ceramic waste). Each 2.5inch (height) by 4inch

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(diameter) example is made using 4-7 percent bitumen and 3-5% filler.

**Figure 6: DBM preparation.**

The prepared mould of the sample prepared is as shown in the below figure,

**Figure 7: Sample moulds prepared.**

The equipment employed for testing the samples is as shown in the below figure,

**Figure 8: DBM sample testing equipment.**

Each sample's stability (kN), unit weight (gm/cc), percentage of air voids, flow value (mm), percentage of bitumen-filled voids, and mineral aggregate voids were assessed. Tables 1 & 2 provide all the characteristics for ceramic wastes and lime with 3% and 5% filler.

**Chemical Composition of Ceramic Waste:**

The quantities of $SiO_2$ (Silicon dioxide) and $Al_2O_3$ (Aluminium oxide) present in large amount in the form of dust can cause hazardous problems inhaling these chemicals. Ceramic waste also consist of Sodium oxide ($Na_2O$), Calcium oxide($CaO$), Ferrous Oxide($Fe_2O_3$), Magnesium oxide($MgO$) and Potassium oxide($K_2O$).

**Table 1: The Physical properties of ceramic aggregates**

| SlNo | Descriptionof Test | Test MethodISStandards | Test resultsobserved | Specification as perMOR T&H |
|---|---|---|---|---|
| 1 | Aggregate impactvalue (%) | IS-2386(P-4) | 16.61% | Max24% |
| 2 | Aggregate crushingvalue(%) | IS-2386(P-4) | 21.6% | Max10-25% |
| 3 | Los Angle abrasionvalue (%) | IS-2386(P-4) | 20.8% | Max30% |
| 4 | Flakiness andelongationindex(%) | IS-2386(P-1) | 27.3% | Max30% |
| 5 | Water absorption(%) | IS-2386(P-3) | 0.9% | Max2% |
| 6 | Specificgravity | IS-2386(P-3) | 2.56 | NA |

**Table 2:The Physical properties of ceramicaggregates**

| SlNo | Descriptionof Test | Test MethodISStandards | Test resultsobserved | Specification as perMORT&H |
|---|---|---|---|---|
| 1 | Aggregate impactvalue (%) | IS-2386(P-4) | 10.23% | Max24% |
| 2 | Aggregate crushingvalue (%) | IS-2386(P-4) | 16.6% | Max10-25% |
| 3 | Los Angle abrasionvalue (%) | IS-2386(P-4) | 18.56% | Max30% |
| 4 | Flakiness andelongationindex(%) | IS-2386(P-1) | 23.45% | Max30% |
| 5 | Water absorption(%) | IS-2386(P-3) | 0.79% | Max2% |
| 6 | Specificgravity | IS-2386(P-3) | 2.86 | NA |
| 7 | Stripping (%) | IS-6241-1971 | 99.6% | Min95% |

**Table 3: Bitumen properties**

| Slno | Descriptionoftest | Test method ISstandards | Testresults | Specification as perMORT&H |
|---|---|---|---|---|
| 1 | Specificgravity | IS-1202 | 1.03 | 0.99min |
| 2 | Penetration | IS-1203 | 65 | 50-70 |
| 3 | Ductility | IS-1208 | 84 | Min40cm |
| 4 | Softeningpoint | IS-1205 | 52 | Min47c |
| 5 | Absoluteviscosity | IS-1206 | 2736 | 2400poise |
| 6 | Kinematicviscosity | IS-1206 | 462 | Min350cst |

**Table 4: Physical properties of the cement**

| SL.NO | PHYSICALPROPERTIES | RESULTS | STANDARDVALUES ASPERINDIAN STANDARDS | CODALPROVISION |
|---|---|---|---|---|
| 1 | SpecificGravity | 3.15 | - | |
| 2 | Finenessofcement | 8.4% | <10 | IS:269-1989 Clause No. 6.1IS:4031(part2) -1988 |

| | | | | |
|---|---|---|---|---|
| 3 | StandardConsistency | 30% | - | IS:269-1989 ClauseNo.11.3IS: 4031(part4)-1988 Clause5.1 |
| 4 | Initialsettingtime | 35 min | Not to be lessthan30minutes | IS:269-1989Clause No. 5.3and 6.3 |
| 5 | Finalsettingtime | 180 min | Notto beless than 300 minutes | IS:269-1989Clause No. 5.3and 6.3 |

**Table 5: Marshall parameters for the regular mix.**

| Bitumencontentin % | Stability inKN | Flow valuein mm | Airvoids in % | VFAin % | Unit weight ingm/cc |
|---|---|---|---|---|---|
| 4.5 | 17.6 | 8.6 | 12.6 | 39 | 2.16 |
| 5 | 18.2 | 8.8 | 7.9 | 66 | 2.2 |
| 5.5 | 19.2 | 11 | 5.3 | 72 | 2.26 |
| 6 | 18.3 | 13.2 | 3.1 | 84 | 2.21 |
| 6.5 | 18 | 14.6 | 2.2 | 90 | 2.19 |
| 7 | 17.5 | 16.9 | 1.9 | 93 | 2.18 |

**Table 6: Parameters employed for the ceramic waste**

| Ceramicc wastecontentin % | Bitumencontentsin % | StabilityinKN | Flow value in(mm) | Air Voidsin% | VMAin% | VFBin % | Unit Weightin gm/cc |
|---|---|---|---|---|---|---|---|
| 3% | 4.5 | 10.4 | 3.36 | 5.56 | 15.76 | 64.08 | 2.33 |
| | 5 | 11.26 | 3.4 | 4.6 | 15.89 | 71.56 | 2.37 |
| | 5.5 | 13.05 | 3.48 | 3.28 | 15.74 | 78.66 | 2.45 |
| | 6 | 12.8 | 3.62 | 2.54 | 16.22 | 82.91 | 2.52 |
| | 6.5 | 12.04 | 3.74 | 2.08 | 16.69 | 87.32 | 2.5 |
| | 7 | 11.8 | 4.0 | 1.98 | 17.37 | 88.12 | 2.5 |
| | 4.5 | 12.96 | 3.21 | 6.55 | 16.77 | 58.18 | 2.34 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5% | 5 | 14.46 | 3.34 | 5.28 | 16.52 | 67.10 | 2.41 |
| | 5.5 | 15.74 | 3.45 | 3.66 | 15.93 | 77.19 | 2.48 |
| | 6 | 15.7 | 3.82 | 2.96 | 16.54 | 80.55 | 2.53 |
| | 6.5 | 14.8 | 4.0 | 3.10 | 17.56 | 82.39 | 2.55 |
| | 7 | 11.8 | 4.0 | 2.24 | 17.76 | 86.37 | 2.45 |

**Table 7: Marshall parameters**

| Sl | MarshallParameter | Range specified inMORT&H2012 | Determined values atOBC | |
|---|---|---|---|---|
| | | | 3%CW | 5%CW |
| 1 | Stability(KN) | Minimum9KN | 13.86 | 15.85 |
| 2 | Unitweight(gm/cc) | - | 2.46 | 2.56 |
| 3 | AirVoids% | 3-5 | 4.83 | 4.94 |
| 4 | FlowValue(mm) | 2-4 | 3.48 | 3.72 |
| 5 | VFB% | 75-85 | 81.2 | 81.5 |
| 6 | VMA% | Minimum13% | 15.94 | 16.48 |

## IV. RESULT AND DISCUSSION

TheOptimumBinderContent(OBC)ofmodelscontaining3%and5%firedwastewasobtainedas 5.43% and 5.74% individually. It was seen that the artistic waste meets all base prerequisiteaccordingtoMORTH2012 determination as afillermaterial in DBM and it is tabulated in table 8.

A. Marshall stability

The Marshall stability values for the ceramic filler for both 3 and 5 percentage filler content. The results of the Marshall stability obtained for the common mixture and ceramic waster is as shown in the below two figure,

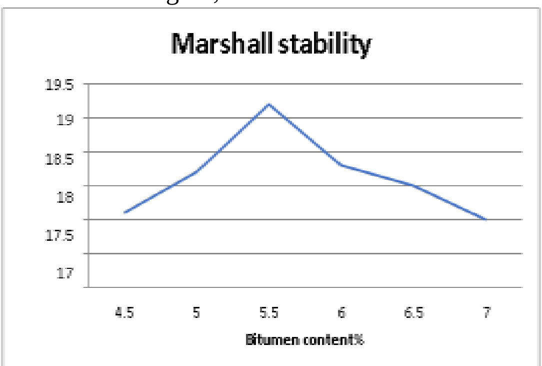


**Figure 9: Marshall Stability for normal mix**

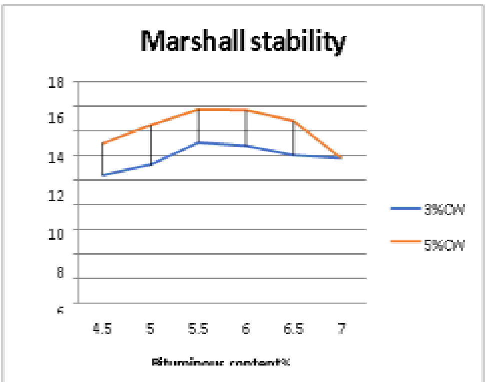


**Figure 10: Marshall Stability for ceramic waste.**

B. Flow values:

Flow measurements are between 3 and 5 percent filler limitations. Ceramic waste mixes boost flow consistently. From the data, we can see that ceramic waste is flexible and adaptable. DBM may be filled with 3% or 5% ceramic waste as shown in the below two figures.

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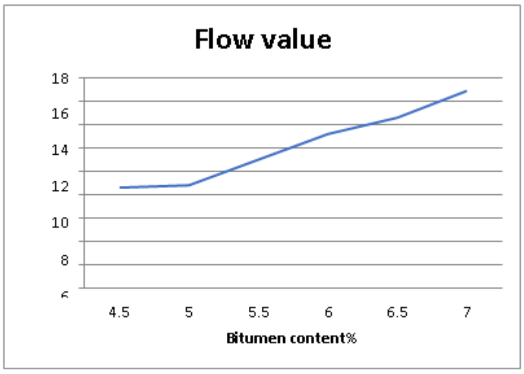


**Figure 11: Flow values for the normal mixture**

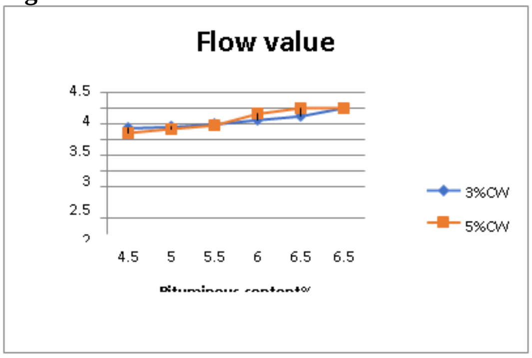


**Figure 12: Flow values for the ceramic waste.**

C. Air Voids

Bitumen increases reduces air spaces. The bitumen compensates for network flaws. MORTH-compliant ceramic waste contains air spaces.

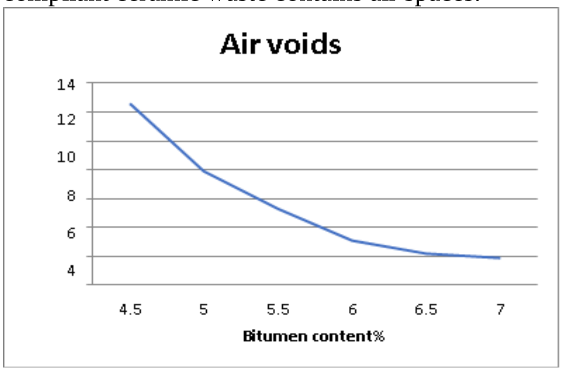


**Figure 13: Air void for the normal mixture**

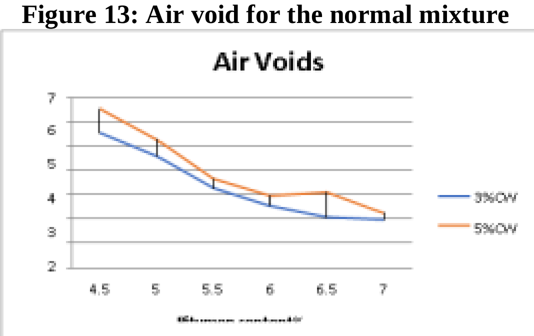


**Figure 14: Air void for the ceramic waste**

**Unit weight**

All samples have the same maximum compressed density. All mixtures' densities climb to a maximum and then decline.

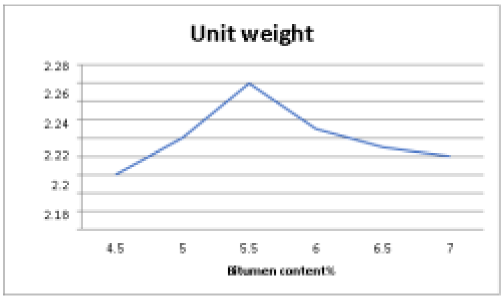


**Figure 15: Unit weight for the normal mixture**


**Figure 16: Unit weight for the ceramic waste.**

D. Voids Mineral Aggregate (VMA)

It is the intergranular space occupied by bitumen and air in mixture prepared and the results are as shown below.

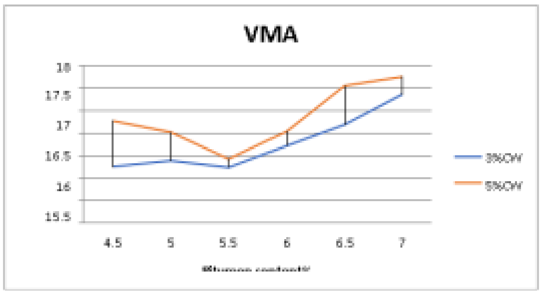


**Figure 17: VMA for the normal mixture**

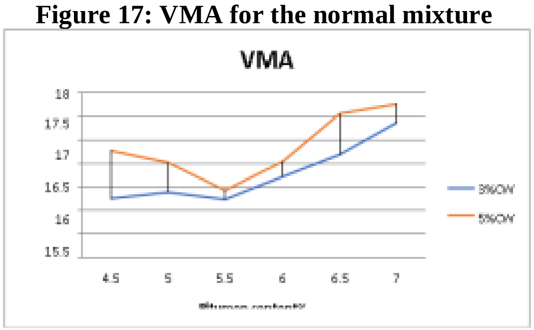


**Figure 18: VMA for the ceramic waste**

E. Voids Filled with Bitumen

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The filled mixture with bitumen is as shown in the below figure

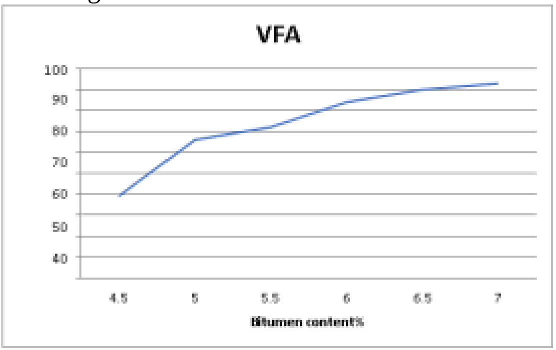


**Figure 19: VFA for the normal mixture**

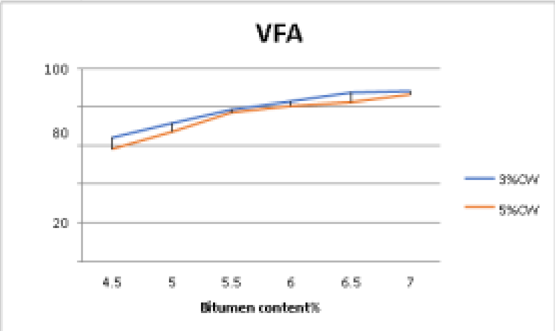


**Figure 20: VFA for the ceramic waste**

## V. CONCLUSION

Laboratory studies reveal that the physical qualities of ceramic waste aggregates are within I.S. limitations, therefore they may be utilised in bituminous concrete.

The graph pattern reveals that ceramic waste will misshape more under moving traffic and have more flexibility.

Both 3% and 5% ceramic waste filler meet the cutoff values and may be used in DBM.

Ceramic waste used in this project meets all MORTH-Bituminous concrete mixture mineral filler criteria.

In bituminous mixes, ceramic industrial waste may replace standard mineral fillers. Using ceramic waste in asphalt concrete mixtures will reduce environmental waste.

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