

**Review Article**

# A Review Paper on: Effect of Different Types of Filler Materials on Marshall Characteristics of Bitumen Hot Mix

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**Abstract:** Bituminous hot mix is one of the most widely used and costly flexible pavement layer. It involves a huge outlay of investment. Precise engineering and usage of proper materials can make it more cost efficient, durable, convenient for users and most importantly ecofriendly. To reduce the cost of construction engineers all over the globe are investigating for the alternative material to obtain same amount of output (strength, stability and durability) by paying a little. There are four constituents of a hot mix, coarse aggregate, fine aggregate, binder and filler. Filler in the bitumen hot mix fill the void in between the aggregates which is very important for strength and stability of the pavement. But the fillers are conventionally used (cement and lime) are very costly which affect the total cost of construction. That's why the researchers emphasized on the waste material to serve this purpose as well as to keep the environment clean. A large range of waste material like fly ash, bagasse ash, marble dust, stone dust, brick dust, kiln dust, waste concrete dust, foundry sand, bio gypsum, ceramic dust etc. has been use as a filler for numerous research works by the researchers globally. The materials yielded very satisfactory results. Fly ash, bagasse results in nearly same Marshall properties (stability, OBC, %VFA, %VMA, %V<sub>a</sub>) like the conventional one. Although the brick dust and stone dust provide a high amount of air voids but they also result high stability. More or less all these non-conventional materials are capable to fully or partially replace the conventional filler. This study focused on the effect on the Marshall hot mix design properties after using these fillers mentioned above.

**Keywords:** Marshall Mix Design, Filler, Bitumen Hot Mix, Marshall Properties, Hot Mix Asphalt, HMA

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## 1. Introduction

In a developing country like Bangladesh construction of new roads and highways have taken a big leap in this 21<sup>st</sup> century of globalization. A huge amount of investment is involved this projects on the other hand the outcome in overall development is also very high. In a highway project, a highway has three important component subgrade, base course, and surface course. Surface course or pavement is the surface over which the vehicles run and other components works as a foundation. That's why pavement is a very important component for efficient, convenient and economic operation of vehicles. There are two type of pavement mainly one is rigid and another is flexible pavement or most widely

known as bituminous pavement. In Bangladesh above 90% highways are flexible pavement or more specifically bituminous pavement. During 1900's, the bituminous paving technique was first used on rural roads – so as to handle rapid removal of fine particles in the form of dust, from Water Bound Macadam, which was caused due to rapid growth of automobiles [27]. For the economy of the flexible pavement it may be adopted extensively. As this technique has been accepted globally so it's time to make it more efficient and effective. A flexible pavement is consist of mainly four constituent's coarse aggregate, fine aggregate, mineral filler and binder. A well-built backbone for the mixture is provided by the good packing of the coarse aggregate, fine aggregate and filler [10, 11]. Out of this four filler plays a big role to strengthen, increase internal stability and to increase the

cohesion property of bitumen [5]. The addition of mineral filler increases the resilient modulus of asphalt concrete mixture [9]. An investigation on property of eight different types of mineral filler materials in Europe indicated that the filler quality does not affect the performance of mixture [28].

In this modern time disposal of waste is a great problem. A great number of waste produced from house hold industry or construction sites are non-biodegradable which causes pollution. Waste recycling in the early 1990s began to focus on high volume discarded materials with potential recyclable

value. Over the last two decades, a number of streams previously considered as waste have become valuable byproducts in highway applications [2]. This disposed materials taking part in more or less every part of road. Crushing wastes to very fine powder form (passing through 0.075mm sieve) using as filler for hot mix getting popularity all over the globe as it is free of cost. A significant number of researches carried out on the suitability of this waste using as a filler for hot mix design.

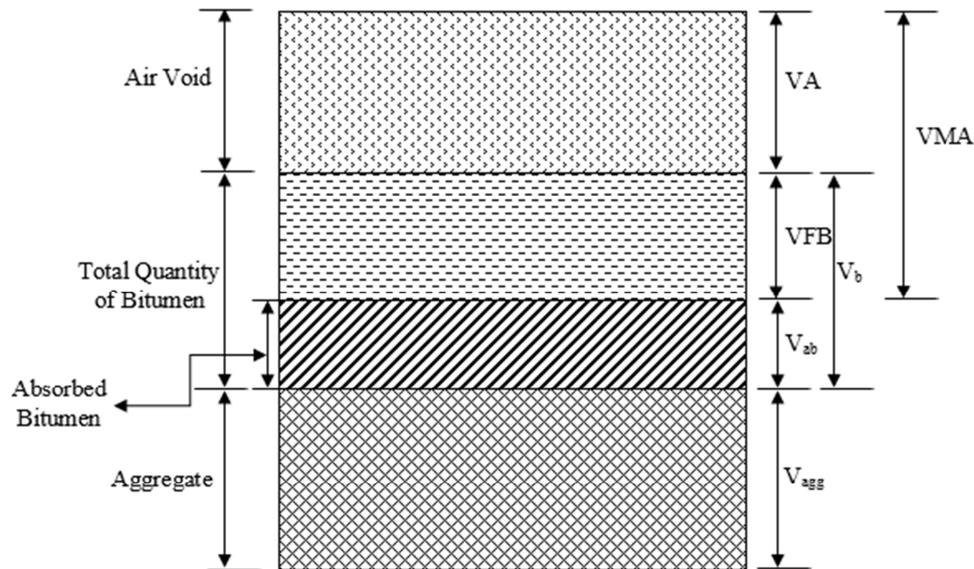


Figure 1. Phase diagram of bitumen mix.

## 2. Bitumen Mix Design

### 2.1. Mineral Aggregate

Aggregate, more specifically coarse aggregate forms the main skeleton structure of the hot mix. It provides a great amount of shear strength as well as compressive strength to the mix by particle to particle contact of coarse aggregate. This skeleton actually forms while the aggregates get interlocked to each other.

There is a wide range of materials used as mineral aggregate in bituminous hot mix. It can be classified in two large categories,

1. Natural.
2. Artificial aggregates.

Aggregates obtained by mining, collecting from the mountainous river are mainly used as natural mineral aggregates. The aggregate from mining may sometimes require to be processing, but generally aggregates from mountainous river is used directly after collection. The natural aggregates most popularly used are, granite, black stone, white stone etc. as per requirements according design standard.

Beside the natural aggregates many other byproducts produced during various industrial process are also used as mineral aggregates. These aggregates can be termed as

artificial one. These are mainly used as a supporting role to enhance the performance of mix. Blast furnace slag and steel slag is commonly used. Nowadays the reclaimed bitumen mixes from the damaged road surface are used as a great source of aggregate.

According to the Federal Highway Administration, McLean Virginia, the following characteristics must be possessed by the aggregates used in hot mix:

1. Cubic shape and rough texture to resist rutting and movements, round and smooth particles are discouraged to use.
2. Sufficient hardness to resist fracturing under heavy traffic loads.
3. High polishing resistance and
4. High resistance to abrasion.

Following are the physical and mechanical properties suggested by AASHTO and IS code.

Table 1. Properties of coarse aggregate for bitumen mix design according to different code [19-21].

Properties of Coarse aggregate	Code: AASHTO	Code: IS: 2386
Specific gravity	2.6-2.9	>2.5
Water absorption	< 2%	< 2%
Impact Value	< 30%	< 24%
Crushing value	< 30%	
Abrasion value	< 40%	< 30%
Flakiness index	< 35%	< 15%
Elongation index	< 35%	< 20%

## 2.2. Mineral Filler

The finer materials than the fine aggregates used in hot mix design to fill the void in the mix are termed as mineral filler. They impart stiffness and toughness to the binder in asphalt hot mix, which save the mix from rutting and fatigue phenomena. Filler also modifies the ageing process of hot mix, and it prevents moisture damages [12-14]. Moreover, filler plays an important role to improve the cohesion of binding materials. In general, it consists of finely graded rock dust, hydrated lime or cement. According to MORTH 2013 [15], grading of filler should be as follows-

*Table 2. Gradation of mineral filler.*

IS sieve (mm)	Cumulative percent passing by weight of total aggregate
0.6	100
0.3	95-100
.075	85-100

To select a material as a finer the following points should be justified, it's not mixed with organic matters.

Plasticity index is below 4.

Water sensitivity measured by retained tensile test (according AASHTO 283) must be above 80%.

In case of cement and hydrated lime the plasticity value is not required to maintain within 4. Water sensitivity is to be strictly followed because it may cause stripping. If it fails in water sensitivity, then it is suggested to provide anti stripping agents with filler.

For large scale production of anything there some conditioned to be fulfilled. Otherwise production will not be scalable due to lack of feasibility. Similar to the other production, using waste materials as a filler material should fill the following condition,

1. Availability.
2. Minimum processing cost.

3. Should not affect environment.

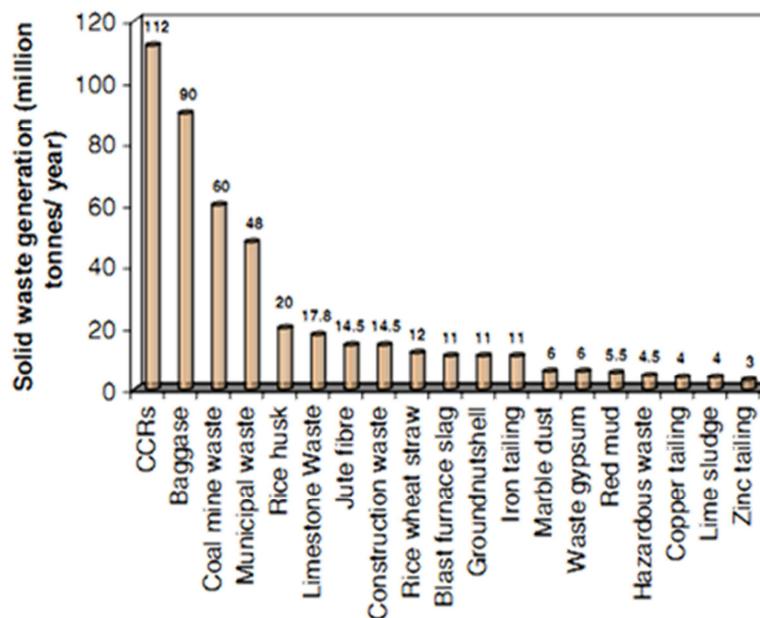
4. Should have all the required characteristics.

Figure 2 shows different types of solid waste that produced per year only in India. In which most of those materials are recyclable and usable for further construction processes. From the figure its most amount of CCRs waste is produced along with bagasse, coal mining waste, limestone waste, rice wheat saw, nutshell, blast furnace, gypsum, construction waste marble waste, lime slag etc. It is evident that, almost all of these waste materials being used as filler material in experiment and also found satisfactory results [1-8]. And all of these are being produced in a very large amount. And figure 3 depicts the potential of production of great amount of brick (12%), Cement (11%), Ceramic (12%) waste along with other waste. So if the materials satisfy all the requirements then it's feasible to use the waste materials as a non-conventional filler.

The processing cost of these waste materials are not that much even in some cases there is no need to process. The RCC waste and ceramic waste need to be crushed in required grain size where bagasse and saw required to burn to use as a filler. In case of brick dust, stone dust, foundry sand and slag only need screening to cancel out the larger particles and foreign materials.

The mentioned waste does not directly pollute the environment but improper disposal of them create a dull appearance, produces dust, and may change soil properties. But reusing these wastes all these problem can be sorted out.

These large amount of waste is a curse for the environment. Improper disposal will affect the environment very badly. On the other hand, the conventional filler like cement and lime are very costly so for small and less important project they are not economical to use. Using these huge amount of waste in construction two-way benefit may be obtained. In such a case the efficient use of disposed waste will save both money and environment simultaneously.



*Figure 2. Waste generation per year in India [18].*

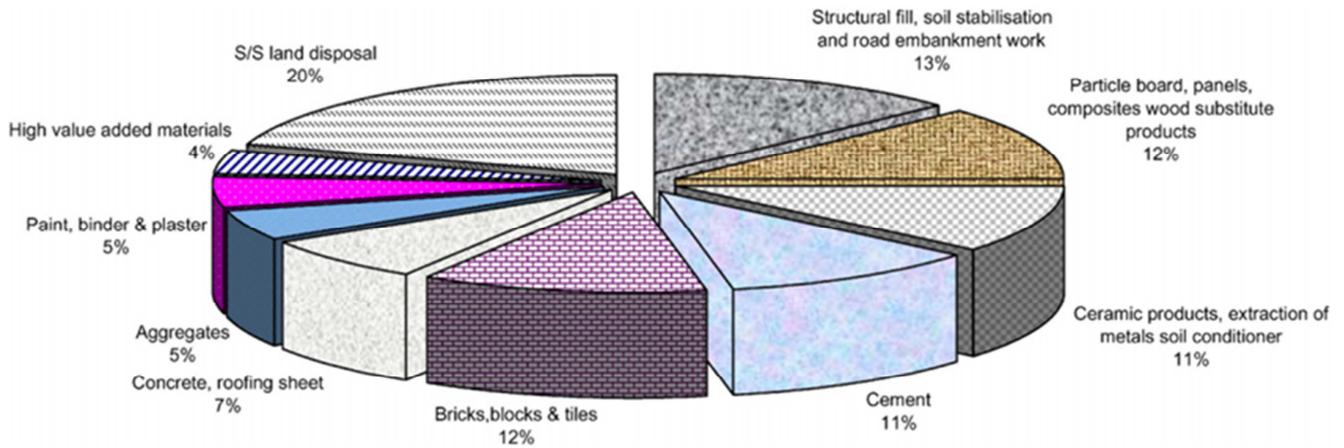


Figure 3. Potential of recycling waste [18].

### 2.3. Binder

To impart an integrated strength to the hot mix binder binds all component materials together. On the basis of the climatic, meteorological, traffic and any other special condition different types of binders are suggested by the codes. Temperature plays a great role to the process of selection of viscosity grade bitumen for different temperatures the following grade of bitumen to be selected,

Table 3. Selection criteria for viscosity graded Bitumen based on climatic conditions [15].

Lower 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 less	VG-10	VG-10	VG-20

As the mean temperature is based on average of 30 to 40 years so these temperatures are significantly lower than the maximum of specific year.

Selected bitumen must have some characteristics that fixed by AASHTO, IS or other codes for binder the following are the limiting values for binder properties.

Table 4. Properties of bitumen binder.

Properties of Bitumen	Code: IS 73: 2013	Code: AASHTO
Specific gravity	> 0.99	1.01-1.05 (T229)
Penetration test	>35 mm	85-10 (T49)
Softening point	>50°C	45-52°C (T53)
Flushing point	>220°C	280-300°C (T48)
Fire point	>220°C	300-320°C (T48)
Ductility test	>25cm	>100 mm (T51)

### 3. Previous Studies

Abbaas Inaayah Kareem investigated the effect of using recycled aggregate filler rather than ordinary Portland cement filler for Marshall Mix design. Constituent materials used for this study was: coarse aggregate (19mm max), well graded fine aggregate (according to SCRB specification 2003), OPC & recycled CC (RCCF) filler and 40-50 penetration grade

asphalt. From this study he concluded that for the optimum asphalt content recycled concrete filler performs better than the OPC filler. RCCF results in higher Marshall Stability, density, stiffness and %VFA as well as lower flow and %VMA the OPC filler. Investigating the chemical content he found lower calcite (CaCO<sub>3</sub>) and higher quartz (SiO<sub>2</sub>) content in cement concrete than OPC which results in improvement of rutting resistance and stiffness modulus simultaneously reduces permanent strain [1].

Afifa Rahman et al. conducted an experiment on replacement of mineral filler of Marshall bituminous mix design by a non-convention material (Brick dust). They prepared total 15 set of specimen using controlled grade aggregate, and 80-100 penetration grade bitumen and cement, stone dust & brick dust as filler according to AASHTO specification for Marshall Mix design. Authors found higher Marshall Stability for brick dust filler than others but the OBC was found higher than other two also. More or less the brick dust filler yields the same result as conventional filler and satisfy the specifications with a high %VTM (voids in total mix). Researchers concluded it as a low cost solution [2].

Dipu Sutradhar et al. evaluated the applicability of crushed waste concrete dust (WCD) (0.075mm sieve passing) and brick dust as a filler material from the point of view of economy than fine sand stone dust. Specimen were prepared using coarse sand, basalt rock and 80-100 penetration grade bitumen accompanied by the mineral filler mentioned above according to AASHTO specification. The authors conclude the study by mentioning it as a economical and environment friendly filler with over all same Marshall characteristics as globally accepted filler. Bick dust and WCD results more stability and unit weight than stone dust. But the %V<sub>a</sub> and the OBC is higher than that [3].

Electricwala Fatima et al. conducted a study to evaluated the effect of using different percentage (3% and 5%) of non-conventional (ceramic dust) mineral filler instead of conventional one (lime) as it is cost free and will help to keep environment clean. Quartzite of 10-20mm used as coarse aggregate, 50-60 grade bitumen as binder and lime & ceramic waste (according to MORT&H 2012) as filler for the preparation of the specimen required to work out the research.

And the authors found that stability increased by 3.96% with the increment in percentage of ceramic dust filler from 3% to 5%. For overall characteristics ceramic dust performs better than lime as a filler and hence satisfy the standards. But from the value of flow for both 3% & 5% ceramic dust filler it's evident that it supports more deformation of surface under traffic load than lime [4].

Yongjie Xue et al. carried out a comparative of the performance of the super pave mix design and Marshall Mix design. In this study municipal solid waste incinerator (MSWI) fly ash was used as a partial replacement of mineral filler in stone matrix asphalt mixtures. Although, the conclusion emphasized on the design method but the result for the filler was good for Marshall Mix design [23].

Debashish Kar et al. this study focused to the use of fly ash (by product from coal based thermal power plant) as a mineral filler for Marshall bituminous mix design to solve the disposal problem and also for cost efficiency of bituminous mix design. Coarse & fine aggregate (according to MORTH (2013)), 60-70 penetration grade bitumen used accompanied by fly ash, stone dust and cement used for this study. Marshall Stability value and the unit weight values are determined for cement followed by stone dust and fly ash simultaneously follows reverse trend for flow values satisfying requirements of standards. Fly ash results higher values than stone and cement for the value of voids filled with bitumen (%VFB) [5].

A. A Muaran and L Sani partially replaced cement by Bagasse Ash (BA) as a mineral filler material for this study to find the influence on the Marshall characteristics. Tests were carried out for different percentage of BA with different percentage of bitumen content to find the optimum one. In this study the mix with 10% BA and 90% OPC satisfy the standard specified by Asphalt institute. 10% of BA yields a good result for all characteristic. They concluded that 10% BA will be optimum to partially replace the OPC [6].

Mustafa Karasahin et al. used marble dust as a filler material. They obtained a result closed to the lime and cement [24].

Dr. Hasan Hamodi Joni and Hussein Hamel Zghair analyzed the Marshall characteristics after using foundry sand as a filler material instead of lime and cement and they compared these three side by side. They used aggregates according to SCRB, R/9 2003 specification, 40-50 grade bitumen accompanied by this three mineral filler and found it's suitability as a filler material. Although the characteristics not more preferable than cement and lime but they are satisfactory enough to be used. The stability for cement, lime and foundry sand is 13.6 KN, 12.5 KN, and 11.25 KN which close to these conventional filler [7].

Jony Hassan et al. carried out an experiment of stone mix asphalt using glass powder as a filler. They varied the bitumen content 4 to 7%. As reference filler material Limestone and Ordinary Portland cement were used and overall results were satisfactory [22].

Tuba Kütük-Sert; and Sezai Kütük conducted an experiment on the use of bio gypsum as filler material which is harmful for environment as a waste. They carried out this

study for lime stone and bio gypsum filler and found a satisfactory result. It reduces the OBC content and %VFA, %VMA and specific gravity it yields is nearly same. Mix with bio gypsum shows more rigid behavior. Authors found its crucial importance for heavy traffic road hot climate region for it excessive %VFA value [8].

Marta Wasilewska, et al. have carried out an advanced experiment on five types of rock that can be used as a filler material. In this study the researchers considered limestone as a reference material to evaluate the results [17]. In this study they had emphasized on the characteristics of the filler set by ASSHTO, ASTM. And they have compared the obtained results with the polish code requirements. They have tested gradation, water content, particle density, Delta R&B temperature, and surface area and Bitumen Number of Five types of rocks that were used as a source of the mineral fillers: gabbro, granite, trashy basalt, quartz sandstone and rocks from postglacial deposits. Performing Scanning Electron Microscopy (SEM) analysis of grain shape and size they observed a significant difference in grain size and shape. They have concluded the study by reporting that binder type plays important role to improve performance not the filler type. And they found all this filler comparable to the limestone are satisfactory [16].

Wu S. and et al. experimented on properties of asphalt mastic in which they used recycled red brick powder (RBP) as a filler. This study emphasized on the effect of temperature on the asphalt mix prepared. They concluded the study saying, RBP may have some positive effect on the performance of the mix but it affects properties in low temperature [26].

#### **4. Objectives and Benefits of Using Non-conventional Mineral Filler**

In this 21<sup>st</sup> century environment pollution is one of the burning issues. Lack of proper disposal of waste material plays a vital role. In this group of improperly disposed materials out construction wastage is a big part and it is greatly accountable. In this era engineers focusing at the construction within the limitation of resources. Hence the recycling of waste getting popular globally. So the objectives of using non-conventional filler are as follows,

1. To save environment.
2. To achieve the goal of green construction.
3. Economic construction.
4. Efficient waste management.

#### **5. Methodology**

First, Laboratory testing is carried out to find the physical properties of aggregate tests like Specific Gravity, Aggregate Impact value, Abrasion Test, Crushing value test, Flakiness and elongation Index (combined), Water absorption etc. For physical properties the standards most widely used are ASTM standards as well as IS: 2386 (Part-I, II, III, IV), SCRB 2003, AASHTO and BS standards. Then by sieve analysis the

Gradation of Aggregate has been decided which satisfied the requirement of Gradation of nominal size of aggregate for Bituminous Concrete design according to the international or regional design standard. For gradation of the aggregates the standards are followed are: MORTH standard, SCRB, R/9 2003, ASTM C136 etc. Then the physical properties of bitumen are studied like Penetration test at 25°C, Softening Point test, Ductility test at 27 °C, Viscosity at 150°C, Specific Gravity etc. For the properties of bitumen the standards are as follows, IS: 1202-1208, AASHTO etc. To investigate the Marshall stability of bituminous mixes with different fillers required number of specimens of 101.6 mm diameter and approximately 63.5 mm thickness are prepared with the standard fraction of each and usually 5 set of bitumen content is adopted for the specimen preparation. The bitumen content (BC) usually adopted from 4% to 6%. After the preparation of the specimens for each the tests are performed to find the Marshall characteristics such as, Marshall Stability, %V<sub>a</sub>, %VFA, %VMA, flow etc. and compared to the standard specified by their regional authorities or international standards.

## 6. Limitations

Undoubtedly there some amazing studies are performed on the uses of non-conventional filler in bitumen mix design. And hope many more will come up. The research work available on this topic has a common limitation. In most of the cases, except the gradation of filler other properties of filler are not taken into consideration and examined. International authorities like AASHTO, ASTM suggested limiting values of some properties of filler they must be obeyed. Although the researcher showed the performance of the mix design due use of that filler but conditions for using that pericocular filler is not mentioned. Grading, water content, plasticity index and organic content, all these characteristics are necessary for quality control, but these are not adequate for obtaining information about expected performance of bituminous mix and other parameter correlated to it [25]. That's why may be the filler did not leave any affective trace on the obtained Marshall properties.

Filler will be accountable for the stripping off loss of integrity of bituminous surface if it is water susceptible. Organic content in the filler materials may affect the strength of mix very badly. So, for large scale use of any non-conventional filler, composition of that filler should be studied to avoid undesirable condition to arise. To check the viability of any waste as filler they may be used for a particular portion of road and observed keenly.

## 7. Conclusion

Main objective of any project is to obtain maximum output with a minimum cost. The filler materials used for the Asphalt Hot Mix in all the study mentioned are waste materials themselves. So each of them would be cost effective. Then we have to emphasize on their Marshall characteristics as per

standard specification. Each of the filler materials mentioned (fly ash, brick dust, ceramic dust, bagasse ash, concrete dust, foundry sand) can be used for the mix designed as they have given satisfactory results and nearly same as the conventional fillers (cement, lime). Their usage will depend on their availability (e.i: in some region bio gypsum may available it may not available in other region). One thing to be considered that is for which filler OBC is minimum comparatively but strength is maximum, that's how the cost of bitumen can be reduced.

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