1 INTRODUCTION

1.1 General

Half-Warm Mix Asphalt (HWMA) is the technology of producing asphalt mixtures within 60–90°C. HWMA can be produced using different bitumen types, even with foamed bitumen, emulsified bitumen or modified bitumen blended with fluxing oil. In Half-Warm-Mix Asphalt (HWMA) technology, the lowering of temperature is even more pronounced. The binder is the bitumen foamed with water which lowers the binder viscosity and the process temperature is lower by about 40–60 °C in comparison with traditional HMA.

Bituminous road construction using conventional paving grade bitumen (i.e, Hot Mix Technology) adversely affects the environment. Because the procedure involves heating the mixture in very high temperature (200°C) which releases hazardous carbon compounds and also contribute in global warming. This can be improved by using half warm mix technology. Here, the blended aggregates of different sizes conforming to the specification for construction of Bituminous Concrete (BC) were charged in drum of hot mix plant. The aggregates were heated to 90°- 100° C. Therefore, comparatively low temperature results in less emission of fume exposure.

The main advantages of cold mix technologies for construction of roads are, Construction of binder course and wearing course, using HWMA in various specifications is feasible in all weather. The working window is enhanced significantly by this. Environment friendly technology due reduced temperature heating process. The main advantage of using half warm mix technology is reduced paving costs, extended paving season, improved asphalt compaction. It allows asphalt mix to haul longer distances and improves working conditions by reducing exposure to fuel emissions, fumes, and odors.

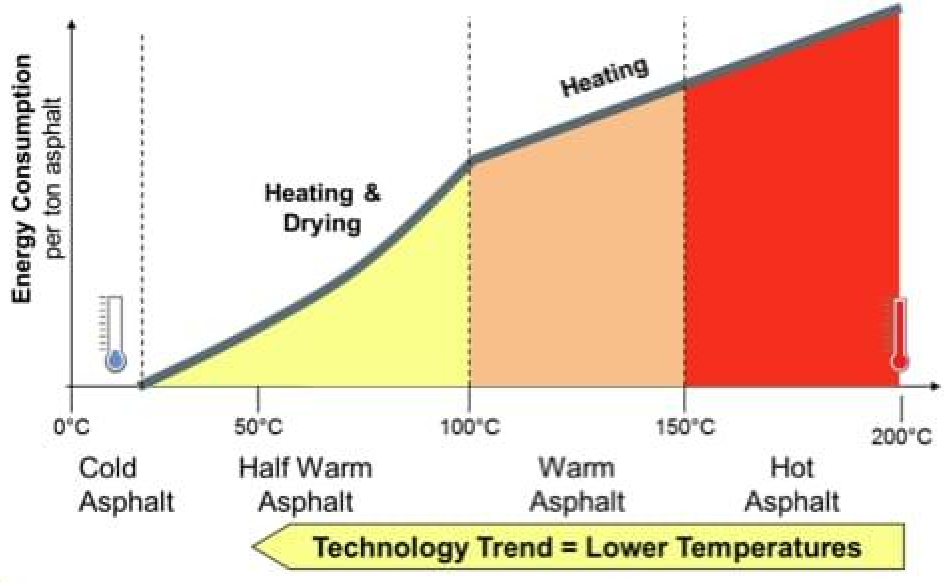


Fig. 1.1: Difference between Hot, Warm, Half Warm and Cold Mix Asphalt

1.1.1 Hot Mix Asphalt

Hot Mix Asphalt must be heated and spread at temperatures between 300- and 350-degrees Fahrenheit. It is the most common type because the heating process helps weatherproof it. Hot mix asphalt therefore withstands UV rays well, slows oxidation, and resists moisture penetration. This prevents cracks and potholes from forming and extends the surface's lifespan. It cools very quickly, so it cannot be laid on days where the temperature is below 40 degrees Fahrenheit.

Fig. 1.2: Hot Mix Asphalt

1.1.2 Warm Mix Asphalt

Laid at temperatures of 200 to 250 degrees Fahrenheit, Warm Mix Asphalt costs less and utilizes less energy to produce than the hot mix variety. It is very flexible, as it cools less quickly than hot mix asphalt does, so it is ideal for nighttime and winter construction, and it can be shipped over longer distances. Perhaps a third of all construction projects use this variety.

Fig. 1.3: Warm Mix Asphalt

1.1.3 Half Warm Mix Asphalt

Half Warm Asphalt is produced between approximately 70 °C and roughly 100 °C. The current global situation regarding climate change makes it necessary to promote the circular economy and the use of more environmentally friendly technologies in the construction sector. To that end, it is of interest to deepen our understanding of the performance of half-warm mix asphalt (HWMA)) manufactured with high proportions of reclaimed asphalt pavement (RAP).

1.1.4 Cold Mix Asphalt

The third type of mix, as its name suggests, does not require any heat to produce. It is therefore the most economical and environmentally friendly mix since it utilizes no fossil fuels to manufacture. It is ideal for quick repairs of cracks and potholes, particularly during winter months. However, cold mix patches do not last as long or provide the same weather resistance as the others do. Proper repairs with hot or warm mix asphalt may be required later.

Cold asphalt mixes do have some limitations. These mixes should not be used when ambient temperatures under 10°C are expected during construction. Cold

asphalt mixes are typically suitable for light to medium trafficked roads when used in base and surface courses. Since their structural strength is relatively lower than that of HMA, the pavement structure should be designed properly

Fig. 1.4: Cold Mix Asphalt

1.2 Potholes

Potholes can be defined as bowl-shaped depressions of varying sizes that penetrate all the way through the surface layer down to the base course, frequently encountered on the surface of flexible pavements. It is one of the most common deteriorations of asphalt pavement, occurring mainly in cold weather regions. Potholes are an annoyance to drivers and potentially a dangerous hazard on the roadways. The repair of pothole distresses in asphalt pavement is often considered low on a road agency's agenda; however, their repair consumes a large portion of time and funds. Many road crews are ill-informed on the proper materials and methods for pothole repair. Correct selection of pothole patching materials and proper application of repair procedures can greatly increase the longevity of pothole repairs, lead to fewer driver frustrations, and lower road maintenance budgets.

A Pothole is a depression in a road surface, usually asphalt pavement, where traffic has removed broken pieces of the pavements. 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 affected area. Continued traffic action ejects both asphalt and the underlying soil material to create a hole in the pavement. To avoid these potholes regular maintenance is needed, for filling of potholes we use waste materials as filler such as brick powder, rice husk and the glass powder.

Fig. 1.5: Potholes

1.2.1 Formation of Potholes

In Flexible Pavements, Pothole Formation begins in the weakened areas. Usually, a more severe inter connected alligator crack in pavement surface turns into a pothole when it is broken down and pulled up by the heavy loads of travelling vehicles. In addition to fatigue cracks, potholes can also be initiated from longitudinal cracks of high severity and raveling of pavement surface Structural response of flexible pavement is largely influenced by the variation of paveme0nt temperature. Daily and seasonal fluctuation of temperature causes expansion and contraction of pavement material that result in the generation of thermal strain. Thermal cracking is the result of thermal induced stress. It is one of the most serious distresses in flexible pavement, especially in regions where daily and seasonal temperature change is significant and rapid.

Potholes are commonly caused from water seeping into cracks in the roadway during wet and freezing conditions. The water weakens the underlying support of the road surface, and when it freezes, it pushes up on the asphalt layer and down on the underlying material. When traffic passes over the weakened and stressed portion of asphalt, the loads and vibration cause the weak underlying material to sink and the surface layer to crack and break up. Under the vibration of the passing traffic, the material will work its way lose and come out of the surrounding pavement, forming a pothole. Other ways potholes are formed are through poor workmanship, poor mix design, or natural deterioration of the pavement. As traffic passes over the stressed area of the asphalt, the asphalt weakens and material is removed from the surface, leaving behind a pothole.

1.2.2 Types and Sizes of Potholes

Potholes range from small, shallow pick-out ravel of the road surface layer to large failures related to loss of strength in subgrade where total failure occurs. For the purpose of these guidelines, potholes are considered small if they have an area below 0.9 m and shallow if they involve only the top layers of the road (up to 15 cm deep)

Shallow potholes are referred to as non-structural potholes. For these potholes, there hasn't been a loss of compaction in the structure of the road, with the possible exception of the very top of the base layer immediately beneath the road surface. Deep potholes which involve failures in the base, subbase and subgrade of the road, are referred to as structural potholes. They can also start as small-area failures, but can quickly evolve into large isolated failures or generalized failures of the entire structure Under extreme environmental conditions and with heavy truck traffic involved, such potholes have been known to progress from small to general failures in less than 24 hours.

Fig.1.6: Types of Potholes

1.2.3 Pothole Patching

Pothole patching is one of the important forms of maintenance operations for asphalt pavements. The basic requirement for the scope of pothole repair according to the Strategic Highway Research Program (SHRP) is that a pothole developed in flexible pavement with a size limit of 25 mm to 150 mm (0.09 to 0.93 m^2) closely or infrequently spaced should be repaired in any weather condition (Blaha 1993). Patching of potholes is performed under various weather conditions and temperature cycles. The quality of the pothole patching operation depends on the choice of patching material as well as the repair procedure. Various combinations of patching materials and repair techniques can be used in different seasons

Fig. 1.7: Pothole Patching

1.3 Waste Materials Used

1.3.1 Bottom Ash (BA)

Bottom Ash is part of the non-combustible residue of combustion in a power plants, boiler, furnace or incinerator. In an industrial context, it has traditionally referred to coal combustion and comprises traces of combustibles embedded in forming clinkers and sticking to hot side walls of a coal-burning furnace during its operation. The potion of the ash that escapes up the chimney or stack is, however, referred to as Fly Ash. The clinkers fall by themselves into the bottom hopper of a coal-burning furnace and are cooled. The above portion of the ash is also referred to as Bottom Ash

Fig.1.8: Bottom Ash. The properties of BA are shown in table 1.1

Table 1.1: Properties of Bottom As

Sl. No.	Properties of Bottom Ash	Values
1	Specific gravity	2.12
2	Bulk density	0.642-0.747
3	Fines modules	6.28
4	Maximum dry density (KN/m3)	7.20
5	Water absorption (%)	14.10

1.3.2 Waste Glass Powder (WGP)

Waste Glass Powder is a waste material and it becomes granulated by sieving by means of sieve after they are crushed in the beaker and milled, it is used for surface treatment by blasting, reinforcement of synthetic resins, and path lines.

Table 1.2: Physical and Chemical Properties of Waste Glass Powder

Sl. NO.	Composition	Values
1	SiO2	64.32%
2	AI2O3	2.90%
3	Cao	18.18%
4	Fe2O3	-
5	SO3	-
6	MgO	-
7	Na2O	13.03%
8	K2O	1.56%
9	Density	2555kg/m3

Fig.1.9: Waste Glass Powder

1.3.3 Rice Husk Ash (RHA)

The application of include its use as a pozzolan in the construction industry, as a filler, additives, abrasive agent, oil adsorbent, sweeping component, and as a suspension agent for porcelain enamels. In the construction industry, RHA can be used as a partial replacement for cement.

Fig:1.10: Rice Husk Ash

Table 1.3: Physical Properties of Rice Hush Ash

Sl. No.	Particulars	Properties
1	Colour	Gray
2	Shape	Irregular
3	Mineralogy	Non crystalline
4	Particle size	<45 micron
5	Odour	Odourless
6	Specific gravity	2.3
7	Appearance	Very fine

1.3.4 Blast Furnace Slag

Blast furnace slag (BFS) is a by-product from iron production in blast furnaces, which are fed by a mixture of iron-ore, coke and limestone. In the process, the iron ore is reduced to iron while all remaining materials form the slag, which is tapped off as a molten liquid and cooled. Depending on the cooling method the BFS can be produced as air-cooled, granulated, expanded and pelletized. The main components are silica, calcium oxide, magnesium oxide, ferrite and aluminum oxides.

Table 1.4: Chemical Properties Of Blast Furnace

SiO2	Cao	MgO	Al203/Fe2O3	Specific gravity	Bulk density
30-35%	28-35%	1-6%	1.8-2.5%	2.9	1200-1300

2. LITERATURE REVIEW

2.1 General

Present work will be carried out on the basis of various supporting literatures. Some of the literatures are collected and their main essence is briefed as follows.

Ibrahim M. Ari *et al.* (2007) conducted a study on steel slag as a byproduct of steel manufacture which is produced during separation of molten steel from impurities in steel

making furnaces. This slag evolves as a molten liquid and is composed of complex solution of silicates and oxides that solidifies upon cooling. Not all type of slag is Suitable for processing, as steel slag have high percentage of lime and magnesium oxides that effects environment and can used for variety of civil engineering applications. These steel slag as aggregates aren't used in India but few countries like America Malaysia have implant implemented and succeeded.

Anne V *et al.* (2009) tested Both half-warm and warm mix technologies allow reducing the use of fossil energy sources (fuel, natural gas) in mixing plants, yet in different proportions, as reported in the technical literature. In this study, a half-warm mix process called LEA® will be assessed by means of measurements at the plant as well as during actual road works, within the framework of a Life Cycle Assessment. Inventory fluxes and environmental impacts were both determined for hot mix and half-warm mix asphalts. This paper presents the environmental comparison drawn between the consumption and pollutant fluxes of hot and half-warm mix asphalt produced by the same plant and laid on the same heavily-traveled road section near Paris (France). The experimental program was jointly conducted by three partners: the road owner, the road contractors, and an independent organization responsible for performing environmental assessments. This experiment reveals a positive contribution from the half-warm-mix process in reducing all calculated indicators, in comparison with the hot-mix process, thereby confirming previous studies on predicted energy savings yielded by theoretical models. Results from this study however need to be completed by an inventory of environmental data on additives, and a mechanical behavior assessment of the two pavements types over a relevant service period.

Carmen R G ***et al.*** **(2013)** conducted research study whose main objective was to analyze the environmental benefits derived from a cleaner production technology for manufacturing asphalt mixes. This study measured polluting emissions during the construction of two consecutive stretches of highway on which a hot mix and a half-warm mix were spread. Combustion gases (CO, NOx, O2, CO2), total organic carbon (TOC), particles, volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs), were measured during the manufacturing of hot and half-warm asphalt in plant and also during the spreading and compaction processes. The results obtained in this research project show that for the same manufacturing and spreading conditions, the half-warm mix asphalt (manufactured at less than 100 °C) is a cleaner production technology and can be considered more environmentally friendly since it considerably reduced polluting emissions.

MC Rubio ***et al.*** **(2013)** conducted research study whose main objective was to analyze the environmental benefits derived from a cleaner production technology for manufacturing asphalt mixes. This study measured polluting emissions during the construction of two consecutive stretches of highway on which a hot mix and a half-warm mix were spread. Combustion gases (CO, NOx, O2, CO2), total organic carbon (TOC), particles, volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs), were measured during the manufacturing of hot and half-warm asphalt in plant and also during the spreading and compaction processes. The results obtained in this research project show that for the same manufacturing and spreading conditions, the half-warm mix asphalt (manufactured at less than 100 °C) is a cleaner production technology and can be considered more environmentally friendly since it considerably reduced polluting emissions.

Sravani A ***et al.*** **(2015)** conducted test on Hot mix asphalt (HMA) is used for construction and maintenance of bituminous roads in India. These mixes are prepared, laid and compacted at fairly high temperatures requiring high energy input. Higher greenhouse gas (GHG) emissions in hot mix technologies are issues of concern and reasons of the quest among the researchers for development of low energy and environment friendly cold and warm mixes, involving use of cationic bitumen emulsion as binder. These are considered as sustainable alternative to hot mix asphalt, which have gained prominence due to their use for construction of rural roads. Cold mix asphalt

(CMA) is compacted and laid at ambient temperatures. A mix compacted at 70-90 degrees C temperature is known as half warm mix asphalt (HWMA). In the present study, a new type of mix named as mild warm mix asphalt (MWMA) is developed, where mix is compacted at 50 degrees C instead of 70 to 90 degrees C. This can be prepared, laid and compacted at 50-60 degrees C, which saves energy and also contributes to carbon credit in road construction. This paper reports findings of a comparative study on laboratory performance of CMA, MVVMA and HWMA.

Mahyar A *et al.* (2017) conducted a study using rice husk ash as a waste by product of rice milling in bituminous roadways as a filler that provides valuable advantages such as reduction of environmental degradation, lowering construction costs and saving natural resources. However, there are limited number of studies on application of this materials in asphalt mix. The objective of this study was to investigate the effects of RHA as an asphalt modifies on hot mix asphalt. Bitumen blends with 5%, 10%, 15% and 20% RHA modifier for evaluation of the rheological properties of asphalt. By using RHA as mineral filler in place of conventional filler increased the stability of roads, thus the road can withstand heavy traffic loads and shows better service life.

Merrin B *et al.* (2017) conducted the feasibility of improving the properties of bituminous concrete (BC) mix with water glass as filler in place of conventional costly fillers like lime and cement. BC mixes were prepared at OBC with three different fillers namely cement, lime and glass powder at three different dosages (4%, 6% and 8%). The Marshall and volumetric properties of these samples were investigated and compared. BC mixes with glass powder displayed nearly same properties as those of BC mixes with conventional fillers. Also at the optimum dosage of 6.2% glass modified BC mixes displayed higher stability, density and lower flow values as compared to normal BC mixes with quarry dust alone as filler. Thus, glass powder waste from industries can be safely disposed by using as an alternative for conventional fillers to produce more stable and durable bituminous paving mixes.

Hugo Alexander R Q *et al.* (2018) Blast furnace slags (BFS) have interesting physical properties and chemical compositions for the production of mastics in asphalt mixtures. However, most of the studies conducted on this material and their applications in asphalt mixtures have been as substitutes for the coarse fraction of natural aggregates (NGA). In the present study, an experimental program was devised to evaluate the effect on the resistance of a hot mix asphalt (HMA), due to the replacement of fine fraction of a NGA by a BFS. The mechanical properties investigated were indirect tensile strengths, resilient modulus, permanent deformation, resistance to fatigue, and moisture damage. Analysis of variance (ANOVA) tests were performed to verify or reject the null hypothesis that the results are statically equal to those of the reference mixture. X-ray diffractometry (XRD) and X-ray fluorescence (XRF) tests were carried out on particles of BFS and NGA. Additionally, the samples were subjected to imaging processing in a scanning electron microscope (SEM). Characterization tests (viscosity, softening point, penetration, and indirect tension) were performed on mixtures made of fine particles (NGA and BFS) and asphalt. The BFS used as fine aggregate tends to generate, in conjunction with asphalt, a material with improved properties of resistance under monotonic and dynamic load. DOI: 10.1061/(ASCE).

M Mohiey *et al.* (2020) conducted to study the replacement of mineral filler with rice husk ash. For this purpose, five different mixes were prepared; the first was a control mix (traditional mix) containing 100% Lime Stone Dust (LSD) has as filler and 0% RHA. While, the other mixes contain 25%, 50%, 75% and 100% of RHA as a percentage of filler weight. Optimum Bitumen content was determine using Marshall test, also all Marshall parameters.

Jayvant C *et al.* (2021) conducted a study to investigate the engineering, economic and environmental viability of recycling waste glass powder (GP) and glass-hydrated lime (GL) composite as alternative fillers, in place of stone dust(SD). All fillers were characterized, and asphalt concrete mixes incorporating asphalt mixes was analyzed using the static creep analysis, indirect tensile fatigue test, Cantabria test, modified Lottman test, resilient modulus test, mixing time analysis and boiling water test. However, GP mixes also displayed poor moisture resistance and adhesion due to the high amount of silica in GP.

László Gr *et al* (2021) conducted a study on blast furnace slag here is a global trend to increase the sustainability of road construction and maintenance technologies. The growing use of various industrial by-products as economical and eco-friendly construction and maintenance techniques can be observed in many countries. Problem Statement. The utilization of various forms of blast furnace slag in the road sector can be cost effective, however, several special technological measures have to be taken. Purpose Presenting best practices for the use of blast furnace slag in road construction and maintenance techniques based on Hungarian and other decade-long experiences. Materials and Methods. The main types investigated are air-cooled blast furnace slag, expanded or foamed slag, pelletized slag, and granulated blast furnace slag. The utilization areas in road sector: asphalt layers, surface treatments, rut repair, hydraulically bound pavement layers, unbound base layers, frost protection layer, subgrade, cement production. Results Presenting best practices for the use of blast furnace slag in road construction and maintenance can be beneficial for the experts of countries with limited experience in the field. Keywords: blast furnace slag, industrial by-products, road construction, road maintenance, environmental protection.

Syakirah A M *et al*. (2021) conducted and effective method to minimize the increasing cost in the construction industry by using coal bottom ash waste as a substitute material. The high volume of coal bottom ash waste generated each year and the improper disposal methods have raised a grave pollution concerned because of the harmful impact of the waste on the environment and human health. This method concluded that recycling coal bottom ash is an effective way to reduce the problems associated with its disposal. This paper reviews the current physical and chemical utilization of coal bottom ash as a substitute material in the construction industry and encourages and promotes effective recycling of coal bottom ash and identifies the vast range of coal bottom ash applications in the construction industry.

2.2 Objectives of the Present Work

Based on detailed literature review, the following objectives are drawn, viz;

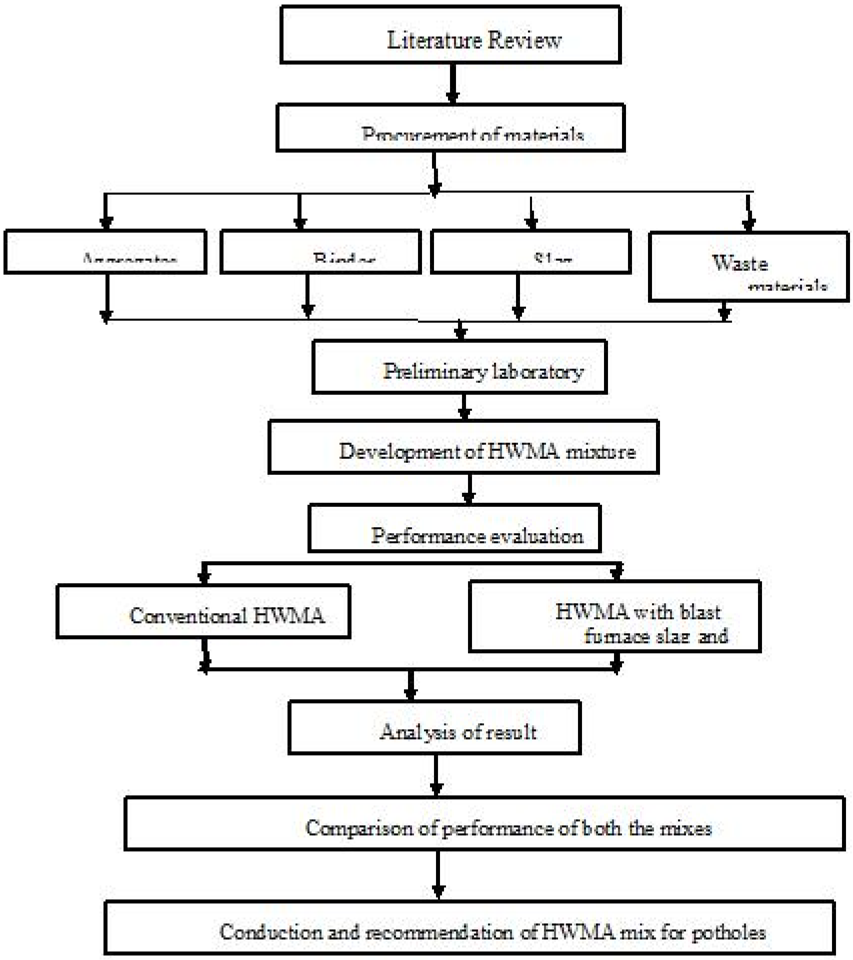
1.To conduct various preliminary laboratory tests on all materials as per standard specifications.

2.To design and develop a Conventional Half Warm Mix Asphalt (HWMA) and the Half Warm Mix Asphalt with Blast Furnace Slag replaced aggregates and waste materials replaced fillers as per standard design method in the laboratory and to conduct standard performance evaluation tests on the developed mixes.

3.To compare the performance of both mixes and to recommend the suitable Half Warm Mix Asphalt mixture with Blast Furnace slag and fillers for the patching of pothole.

3. METHODOLOGY

The methodology is explained using flow chart.



The Methodology Is Explained as Below ;

1. The first and the foremost thing of the project is that procurement of materials such as aggregate, Binder, Blast furnace Slag and waste materials as fillers.

2. Preliminary laboratory test will be conducted as per relevant code specifications.

3. Next, development of Half warm mix asphalt mixture will be conducted for the pothole gradation based on IRC: 116-2014.

4. The comparison between conventional HWMA and HWMA with Blast Furnace slag and waste materials will be made based on performance evaluation.

5. At last, conclusions will be made for pothole patching with optimum strength based on detailed resist analysis.

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