Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume-7, Issue-3; October-December, 2020 pp. 247-253

http://www.krishisanskriti.org/Publication.html

Sustainable and Green Innovative Road Repair and Maintenance Technologies

A Comparative Study of Conventional Hot Mix with EN-1000 Cold Mix

Jayditya Vikram Bagrodia

Vasant Valley School, New Delhi, India

1. INTRODUCTION

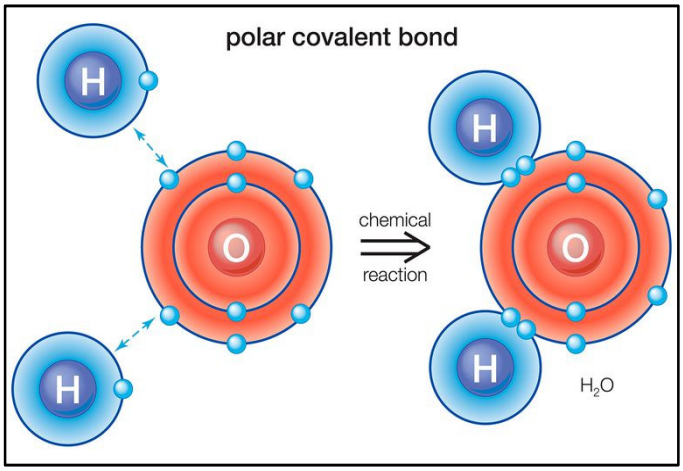
A well-developed road network, acting as the primary platform for the transportation of passengers and goods, is of extreme importance in any country. Such a network is especially crucial in a large, geographically and physiographically diverse country like India, where 66% of the population lives in rural areas. Thisnecessitates proper transportation connectivity with urban areas for economic development to take place.

These roads face several problems regarding their upkeep due to sunlight, intense climatic and environmental factors, and heavy traffic over long periods. This report aims to bring to light better methods of maintenance than those practiced today, which are environmentally sound, as well as cost effective and economical for a government to implement.

2. DRAWBACKS OFASPHALT-BITUMEN ROADS:

1. Oxidation: Asphalt for road construction is mainly obtained as a residue from the distillation of petroleum. As a result, Asphalt consists of hydrocarbons with minor proportions of nitrogen, sulphur, and oxygen.Once the asphalt road is exposed to the ultraviolet rays of the sun and oxygen, molecular processes cause new polar bonding sites to commence. Polar bonding, a type of covalent bonding, causes the electrons between two atoms in a bond to be unequally distributed. This forms electrically dipole molecules, having one end slightly positive and the other slightly negative. These molecules then try to interact with dipoles in other molecules in order to attain a state of equilibrium, in a process known as "self-assemblage". As this continues, the asphalt molecules form tight bonds with the aggregates (base material used in road building such as sand and crushed stone), causing the roadway to harden and become brittle.

2. Cracking: Once oxidised and brittle, the road loses its elastic properties and cannot bend or flex under the load of traffic any longer. This results in cracking, first along the seam lines of the asphalt, and then in longer and straighter cracks across the road. Larger cracks must be sealed swiftly using expensive crack-sealing equipment.



Polar bonding in H_2O molecule.

3. Water Intrusion: Moisture attacks the molecular bonds formed between the asphalt- binder (bitumen) and the aggregates. As cracks develop, water on the surface of the road is able to seep through them onto the base structure of the road containing the aggregates. This sub-surface saturation of the main support base causes a higher degree of traffic bearing stress on the surface asphalt, eventually resulting in a deterioration in road condition. Moisture can also contribute to:

   a. Ravelling: The disintegration of the surface asphalt layer downward as a result of the dislodgement of aggregate particles. This leads to loose debris on the road and water collecting in ravelled areas.

   b. Rutting: Formation of surface depressions on the wheel path. These ruts then fill with water and cause vehicle hydroplaning. Hydroplaning leads to loss of traction between the vehicle and road and may result in accidents.

c. Stripping: The process by which bonds between the aggregates and bitumen start breaking at the bottom of the surface asphalt layer and progress upwards. The chemical nature of the aggregates affects this process.Acidic aggregates are hydrophilic and suffer from stripping, while basic aggregates such as limestone and basalt, which are used in road construction, are hydrophobic and do not suffer from stripping.

4. Method of repair: The current methods used to repair ruts and ravelled areas in roads are detrimental to the environment, but can be controlled with existing technology. Deep depressions or potholes in roads are fixed by using large amounts of aggregates and asphalt. For this purpose, aggregates must be obtained through mining and quarrying.These practices then result in heavy loss of biodiversity, human habitat, soil erosion, and blasting effects, which may further lead to excessive dust, fumes and ground vibrations. Aggregate mining also requires the conversion of land use, most likely from undeveloped or agricultural land. Often, rehabilitation of the mining area is not feasible after the mining process, and the land is redeveloped for other purposes apart from agriculture.In India, aggregate mining is majorly undertaken in mountainous areas, again resulting in destruction of biodiversity. Mining and quarrying in mountains also disrupts the lives of large segments of the rural population, cutting fresh water and food supply.

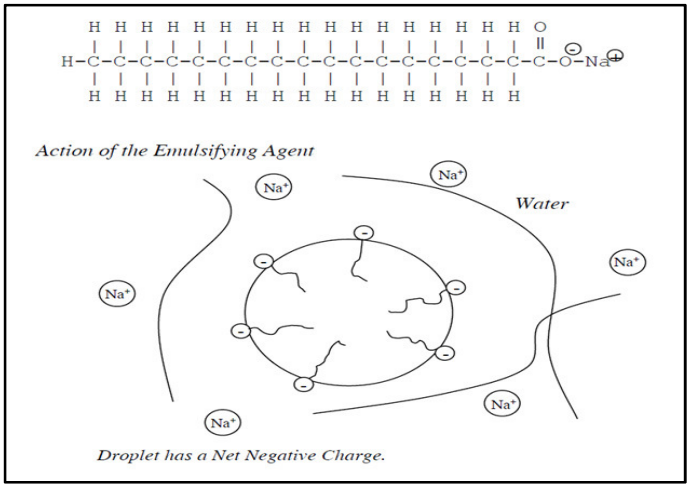
3. CONTEMPORARY HOT MIX AND COLD MIX ASPHALT:

Hot mix asphalt consists of a combination of aggregate uniformly mixed and coated with asphalt cement, or bitumen. To dry the aggregates and to obtain sufficient fluidity of asphalt cement for proper mixing and workability, both the aggregate and asphalt must be heated prior to mixing.

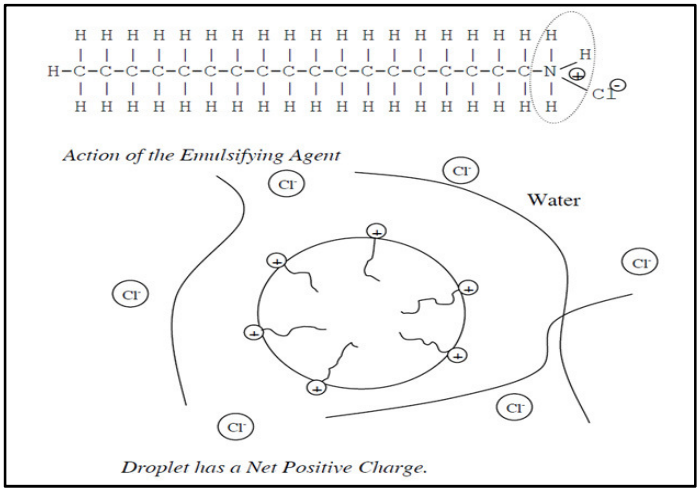
Cold mix asphalt is produced by mixing unheated mineral aggregate with emulsified bitumen. Emulsified bitumenusually consists of bitumen droplets suspended in water, and the emulsifying agent. The emulsifying agent, or surfectant, migrates to the asphalt-water interface and prevents the bitumen droplets from coalescing. These agents are large organic molecules with head and tail parts. Heads contain a group of atoms with both positively and negatively charged areas, resulting in them being polar in nature. Due to its polarity, the head is soluble in water. The tail is a long chain organic group which is soluble in other organic material such as bitumen. There are two main types of bitumen emulsions practiced, depending on the dispersing agent used:

1. Anionic Emulsions: The tail of the agent aligns itself in the bitumen droplet. The positive portion of the head faces the water, leaving the negatively charged portion at the surface of the droplet. This imparts a negative charge on the bitumen. Thus, every bitumen droplet acquires a negative charge and repels each other, remaining as distinct droplets in a suspension. Anionic emulsifying agents include SodiumLaurylSulphate (SLES) and Sodium Oleate ($C_{18}H_{33}NaO_2$).

2. Cationic Emulsions: Cationic emulsifying agents work in a similar manner. The negative portion of the head faces water. Thus, a positive charge is imparted on all the bitumen through the positively charged portion. These droplets repel each other due to identical charge and stay as distinct bitumen droplets. Cationic emulsions are preferred as they coat aggregates efficiently due to their positive load, leading to better adhesion properties in the asphalt. Cationic emulsifiers are long chain amines or quaternary ammonium salts including Benzalkonium Chloride (BZK) and Centrimonium Bromide (CTAB).



Anionic emulsion of bitumen in water.



Cationic emulsion of bitumen in water.

4. NEW AND IMPROVEDCOLD MIX REPAIR MATERIAL EN-1000:

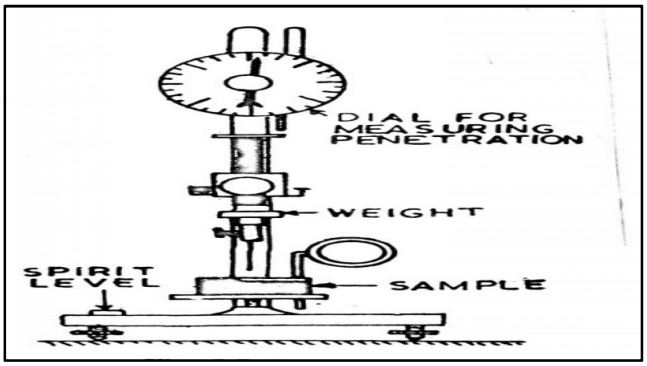
EN-1000 is a ready-to-use recycled asphalt cold mix product for permanently repairing potholes, cracks, and other defects in asphalt and concrete surfaces, which is simply poured into potholes in need of patching. This process can be performed manually without machinery and roads can then be opened for traffic immediately. It can also be stored for delayed usage over long periods of time. The mix adheres to the surrounding asphalt and is then unnoticeable in a few days because of the traffic load. Potholes can also be repaired while filled with water, as it will be displaced by the material once poured in.

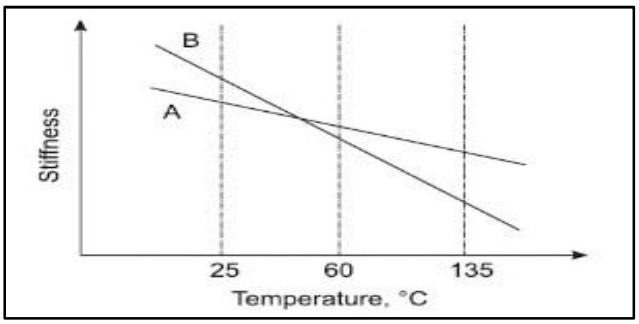
5. PROCESS OF PREPARATION:

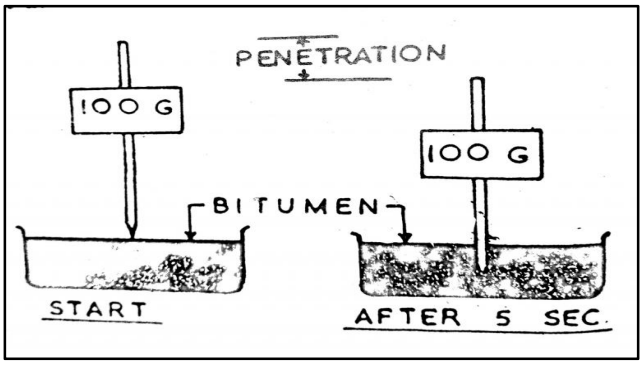
EN-1000 is based on a technology that primarily uses Reclaimed Asphalt Material (RAP) anda binding additive. In fact, the final product consists of 95-98% RAP and 2-5% additives.RAP refers to removed or reprocessed pavement materials containing asphalt and aggregates. This materialis generated when asphalt pavements are removed for reconstruction or resurfacing. When properly crushed and screened, RAP consists of well-graded aggregates coated with bitumen.It is obtained from road or highway reconstruction and repair sitesfound all across India.

The RAP is crushed in a manufacturing plant and then mixed with SOUP,a unique, single component black polymeric bitumen compound in order to create a multi-purpose cold mix asphalt. SOUP is prepared by taking blown bitumen of grade 85/25 and heating it to 140 to 150 degrees celsius.Blown (Oxidized) bitumen is produced by passing air through bitumen under controlled temperature conditions.A key product (proprietary information) consisting of antioxidants, glycerine, bitumenand polymers is prepared in a mixer, to which the molten bitumen is then added under constant stirring. The bitumen grade (85/25) is used to measure the point at which the binder will obtain the required degree of viscosity, and its penetration grade.

The softening point at which bitumen obtains fluidity, is the temperature in ºC at which a standard steel ball passes through a sample of bitumen in a mould and falls through a height of 2.5 cm, when heated under water or glycerine at specified conditions of the test. This is important as different types of blown bitumen have different relationships between heat and their consistency.Penetration grade of bitumen determines the hardness or softness of bitumen by measuring the depth in millimeter to which a 100 grams loaded needle will penetrate vertically in five seconds while the temperature of the bitumen sample is maintained at 25 ºC. Therefore, the blown bitumen used in SOUP softens at 85 ºC and a penetration grade of 25mm.RAP of size less than 9mm, obtained through a crusher and vibrating screen with sieves, is then mixed with 1.5% to 2% of SOUP by weight. This finished product is called EN-1000, which is packed in 25 Kg bags and sealed for market.







6. ADVANTAGES OF USING EN-1000:

1. Recycled aggregates and bitumen: A major constituent of EN-1000 is RAP, which already consists of aggregates and bitumen. As a result, there is no need to purchase fresh materials for road repair. This in turn discourages mining and quarrying for fresh aggregates and crude oil by reducing the demand for these goods.Further, the aggregates in RAP have already undergone processing, permitting, washing and blasting. Hence, the destruction of mountains and biodiversity, and significant greenhouse gas emissions are prevented by eliminating much fuel consumption needed to acquire and process aggregates. Since bitumen is also a part of RAP, the amount of fresh binder required is also reduced, cutting down on total repair costs.

2. Pre-oxidized material: RAP is mainly obtained from deteriorating roads which have been in use for a substantial amount of time. Due to this prior usage, its bitumen is already oxidized, which causes it to bond faster and stronger with the in-use bitumen around the pothole undergoing repair. Mixtures with RAP can also be expected to age at a slower rate than mixes with fresh material on account of the oxidized binder.

3. Machinery and Labour Requirements: EN-1000 can be applied to roads with simple tools such as hand rammers and even brooms, with no need of compactors or rollers. Its application can also be performed by unskilled labour with minimal training with such tools. Compaction of the material is provided by traffic once the road is immediately opened.

4. All-weather Usage: Present cold-mix repair materials in India use bitumen emulsions with water based resins, which use water as the main carrying solvent, to improve adhesiveness between the stone aggregates and bitumen. However, the desired adhesion cannot be achieved before the water evaporates. This evaporation takes a long time in rainy or humid areas, which increases the time before which the cold mix is actually effective. Rainfall and water filled in the potholes also diminish the adhesive strength of the emulsion. Further, in extremely cold areas, this water also freezes. This prevents conventional cold mix materials from being used in areas with temperature below 10ºC. On the other hand, the resins used in SOUP, in which the RAP is emulsified, are not water based and can hence immediately enhance adhesion. In fact, potholes have been repaired using EN-1000 in Russia and Siberia, with temperatures as low as -30 ºC.

7. DISADVANTAGES OF COMMON HOT MIX AND COLD MIX IN INDIA

The preparation of a hot mix requires the heating of both aggregates and bitumen to achieve the desired dryness and fluidity of the asphalt cement. The aggregate driers cause dust emissions which includesulphur dioxidegas and other hazardous particulate matter. The heating of bitumen to a liquid state releases dangerous pollutants such as carbon monoxide, nitrogen dioxide, sulphur dioxide and hydrogen sulphate gas. In addition, machines like aggregate feeders, drier drums, screens and mixers cause severe sound pollution.It is also impractical and expensive to use hot mix asphalt to repair only a few potholes on a road. Therefore, it is common in India for the entire road to be re-carpeted with a fresh layer of asphalt when in bad condition instead of only tending to a few scattered potholes. This leads to the unnecessary consumption of bitumen and aggregates, and also raises the entire level of the road, causing further problems for users and buildings beside the road.

The cold mix requires the water to evaporate from the bitumen emulsion before the aggregates are able to develop any adhesion with bitumen. Hence, a traditional cold mix may take several weeks before it can reach its full strength, as it is quite fragile in its initial stages after installation. It is also highly porous and the water in its mixture may result in moisture damage, potentially reducing its durability to a great extent.

Sl.No	Item	Unit	Value
1	Gas flow	m^3/ Sec	0.51
2	Total dust concentration	mg/N m^3	9640
3	Suspected particulate matter	mg/N m^3	220
4	SO_2 concentration	mg/N m^3	540
5	Rate of gas emission	m^3/tonne	15.3
6	Rate of dust emission	Kg/tonne	0.1475
7	Rate of suspected particulate matter emission	Kg/tonne	0.0033
8	Rate of SO_2 emission	Kg/tonne	0.0083

Dust and gas emissions caused by aggregate drier in hot mix asphalt plant.

Sl.No	Item	Unit of measurement	Concentration
1	Carbon monoxide	ppm	6.00000
2	Nitrogen dioxide	ppm	0.10000
3	Sulfur dioxide	ppm	2.00000
4	Hydrogen sulfate	ppm	1.50000
5	Phenol	ppm	1.00000
6	Ozone	ppm	0.10000
7	Hydrocarbons (C1 -C14)	ppm	1.50000
8	Hydrocarbons (C2 -C6)	ppm	1.00000
9	Particulate matter	mg/m^3	7.20000
10	Poly nuclear aromatic compunds (total)	mg/m^3	0.00036
11	Vanedium, V2U5 fumes	mg/m^3	0.00010
12	Nickle and soluble nickle compunds (as Ni)	mg/m^3	0.00004
13	Cadmium fume	mg/m^3	0.00005
14	Lead and inorganic compunds	mg/m^3	0.00005

Air pollutant emissions caused by bitumen heating.

8. COST EFFECTIVENESS AND BENEFITS OF EN-1000:

India has the second largest road network in the world at 5.89 million kilometers, out of which 132,500 kilometers is part of the National Highways. Hugh investments, to the tune of Rs. 158,839 crore in 2019 alone, have been made to develop the road infrastructure in our country.The local government bodies, state governments and national government spend significant parts of their annual budgets on road maintenance and repair, much of which could besaved by implementing better and more robust repair technologies than those used.

EN-1000 repair material is sold in twenty five kg bags at the rate of nineteen rupees per kg. Although other current cold mix material may be available at marginally cheaper rates, they are generally of poorer quality. The application of EN-1000 guarantees that no further repair of the road will be needed for at least ten years.

The National Green Tribunal has also banned the operation of hot mix plants within any city all over India. As a result, hot mix repair material must be transported from distant plants in remote areas. Due to its propensity for rapid cooling, it is advised to apply a hot mix as soon as possible after production. If the mix is too cold coming off the truck, it will harden and be too stiff to compact properly. Further, if it is allowed to reach temperatures as low as even 80ºC during its transport, compaction efforts will actually crush the aggregates in the mix which have bonded with the bitumen, which would ruin the mix and render its application futile.

The cost of transporting bitumen at a fixed high temperature to prevent worsening in quality from a remotely located plant will not only increase total transportation costs but also contribute to air pollution and extreme fuel consumption.Hot mix is also re-repaired every two to three years, adding a considerable amount to the total sum.

Repair Material	Cost per Kilogram	Quantity Purchased	Cost over 5 year period	Cost over 10 yearperiod	Total Repair Costs
Conventional Hot Mix Material	Rs. 6-7	1000 kg	Rs. 15000	Rs. 30000	Rs. 30000
EN-1000 Cold Mix Material	Rs. 18-19	1000 kg	Rs. 19000	Rs. 19000	Rs. 19000

9. ASPHALT PROTECTIVE COATING MATERIAL EN-2000:

EN-2000 is a unique, single component black polymeric bitumen compound which seals and prevents the oxidation of asphalt surfaces.It also averts the breakdown of road surfaces and widening of microscopic cracks by disallowing water penetration and erosion, which would lead to further deterioration.EN 2000 guarantees a considerable increase in the service life of the pavement and is resistant to water, acids, alkali, oil, gasoline and saltsolutions.The application of a thin membrane EN-2000 increases the service life of the road by five to eight years, as it rejuvenates the bitumen binder and also restores its elastic properties to some extent. Thisallows an increase in the road grip of a rubber tire by about 20-30% and thereby considerably shortens thebreaking distance and improves traffic safety. It can be mechanically or manually cold-applied to the road either using rubber squeegees or spraying equipment. The road can be opened an hour after application. EN-2000 can be applied not only to paved asphalt roads but also to stabilized soil road for prevention of water damage, which are present in abundance in rural India. EN-2000 has also been successfully used in countries including South Africa, China and Russia.

Furthermore, the cost of resurfacing of asphalt roads with conventional coating products varies from Rs. 200 to Rs. 450 per square meter. Its expected life is five years but in actual practice, cracks are seen to develop in abouttwo years' time, which then need additional repair.On the other hand, the cost of supply and application of EN 2000 is Rs. 350 per square meter, with a guarantee of satisfactory repair. In fact, an 80 meter stretch of a road in Rohini, Delhi was coated with EN 2000 in August 2014 and was checked in March 2019. The road and coating were in remarkable conditions.

Coating Product	Cost per square meter	Surface Area	Cost over 5 year period	Cost over 10 year period	Total Expenditure
Conventional Micro Surface Coating	Rs. 200-450	10square meter	Rs. 2940	Rs. 4940	Rs. 4940
EN-2000 Micro Surface Coating	Rs. 350	10square meter	Rs. 3500	Rs. 3500	Rs. 3500

10. PROCESS OF PREPARATION OF EN-2000:

EN-2000 is a mixture of 16% blown bitumen 85/25, 9% to 15% xylene, 5% proprietary key product and 70% dolomite powder by weight.Xylene and the key product act as solvents and are taken in a mixer and mixed well. The blown bitumen is then heated to 150 °C and added to the mixer under continuous stirring. Additional xylene may be added to thin the mixture in order to achieve a viscosity of around 73 centipoise. Then dolomite is added along with xylene to bring the final viscosity to 40 poise.Styrene monomer may be used in place of xylene. In the unavailability of blown bitumen grade 85/25, bitumen of grade 75/25 can also be used. This type of blown bitumen actually requires fewer parts of xylene to obtain correct viscosity than grade 85/25. Dilutents can be added after production while it's on the shelf to reduce viscosity if needed.

11. CONCLUSION

India suffers a loss of 6.6 billion dollars annually due to delays in transport resulting from poor road conditions and lengthy repair practices. For example, hot mix takes 48 to 72 hours to dry, which ceases any transport activity on the road for that duration.This is worrying as road freight consists of 63% of total freight movement in India. Subpar roads also cause severe safety issues, exacerbate the wear and tear of vehicles, and lead to increased fuel consumption. In fact, the cost of additional fuel consumption due to delay is 14.7 billion dollars per year.Several accidents are alsocaused daily because of inferior road repair in India. In 2015, in the state of Karnataka alone, 1,032 accidents were caused by poorly repaired roads, loose road surfaces, or potholes. In Delhi, 80 deaths were caused by unrepaired potholes in 2019.The accidents can be prevented through the appliance of superior repair methods, which will also improve road quality to facilitate the faster transportation of goods.

CITATIONS

[1] https://kidefm.org/wp-content/uploads/2015/08/2.4-RAP_Brochure_all-on-RecycledAsphalt-Paving.pdf

[2] https://pdhonline.com/courses/c803/c803cotnent.pdf

[3] https://www.hindustantimes.com/cities/delhi-tops-list-of-cities-in-terms-of-road-accident-deaths-speeding-is-top-cause/story-Ddu1VPkIv9j9zZ4tf1FDbM.html

[4] https://www.basicconstructionco.com/blog/5-benefits-of-recycled-asphalt-pavement

[5] https://pavementinteractive.org/let-it-drain-protecting-roads-from-moisture-damage/

[6] https://www.business-standard.com/article/pti-stories/ngt-prohibits-use-of-hot-mix-plants-in-delhi-ncr-115083101116_1.html

[7] https://www.researchgate.net/figure/Examples-of-cationic-and-anionicpolymers_tbl1_280735349

[8] https://www.slideshare.net/CHJanardanRao/bitumen-logistics-51703619

[9] https://www.thehindu.com/news/cities/bangalore/over-50-of-road-accidents-due-to-bad-roads-traffic-cops/article19841766.ece

[10] https://theconstructor.org/practical-guide/ring-ball-softening-point-bitumen-asphalt-tar/2571/

[11] https://cementconcrete.org/material-testing-guide/penetration-test-of-bitumen/1216/

[12] https://www.sciencedirect.com/science/article/pii/S0143749614001110.