A Review on Marshall Parameters of BC Mix Using High-Density Polyethylene and Wollastonite

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Abstract

Bituminous is widely used in the construction of flexible pavements but due to the repetition of overloaded vehicles and change in seasonal temperature, various defects may arise like raveling, rutting, cracking, potholing of bitumen surface. To provide strength and durability to various construction projects bitumen concrete mix is added with some admixture. It was found that polyethylene and wollastonite are very good admixture. Concrete which emits a large amount of carbon dioxide in the atmosphere leads to the greenhouse effect. In this case use of these admixtures helps to create green building projects. Polyethylene and wollastonite are used to improve the engineering properties of the bitumen mix.The addition of polyethylene and wollastonite helps to enhance Marshall characteristics such as flow value, stability,and air voids. Plastics are everywhere now these days and rapidly increasing in developing countries. These are non-biodegradable and this is a big challenge to manage this solid waste. So it is very beneficial to use this as an admixture in bitumen concrete mix also, wollastonite is available in a large amount. Using these admixtures not only provides strength to structure but also reduces the overall cost of the project because these admixtures are very cheap which ultimately results in an overall cost project.

Keywords: *Pavement; wollastonite; HDPE; Concrete; Marshall stability.*

Introduction

Pavement consists of different layers i.e base course, binder course, and the concrete layer of bitumen. The main constituents of bituminous concrete (BC) are aggregate and bitumen. The Marshall method is generally used for designing a bitumen concrete mix in which maximum load is applied on a sample at a standard temperature of 600C to determine the stability of the mix. This stability test is done to check the durability of the pavement due to the repetition of. Admixture like high-density polyethylene and wollastonite are added to enhance the engineering property and structural characteristics of the bitumen mix. Marshall Stability vs. % bitumen is drawn to determine the strength. [1]

Flexible Pavement:Flexible pavement is constructed from bitumen and this pavement is termed as flexible because it is bend and deflected due to the repetition of heavy traffic load. Admixtures are used to reduce economic costs.
Rigid Pavement: In this pavement is constructed from cement concrete. This pavement is stiffer and durable than flexible pavement because of the higher modulus of elasticity. Reinforcing steel is provided to transmit the heavy traffic load and to eliminate the cracks and joints. The economical cost of rigid pavement is much more than flexible**.**

Polyethylene in bitumen concrete mix: The addition of polyethylene in bitumen concrete mix impacts the physical property of the sample without affecting the chemical property. Polyethylene provides flexibility and durability in construction projects.

Wollastonite in bitumen concrete mix: wollastonite is calcium meta-silicate and has similar properties to cement .wollastonite can be used as an admixture in bitumen concrete mix to improve the mechanical and durability properties of the mix. Addition of wollastonite results in an increase of compression strength by 40% and flexural

strength by 25%. Wollastonite has various properties like low thermal conductivity which makes it more advantageous over concrete.

Factors affecting bitumen concrete mix with these admixtures:

- Increase compressive strength and flexural strength of the mix
- The decrease in the economical cost of the project
- Helps to decrease the greenhouse effect.
- Increases binding properties of mix

Polyethylene: Polyethylene is designed as a chain of single units termed as monomers which are joined together to form a long chain of carbon atoms.These are the most commonly used polymer now these days across the globe [2]. Its structure looks like this:-

Types of polyethylene:

- Medium-density polyethylene.
- Chlorinated polyethylene.
- High-density polyethylene.
- High-density cross-linked polyethylene.
- Ultra-low-molecular-weight polyethylene
- Low-density polyethylene.
- Linear low-density polyethylene.
- Very-low-density polyethylene.
- Ultra-high-molecular-weight polyethylene
- Cross-linked polyethylene.
- High-molecular-weight polyethylene.

Role of polythene in the pavement: Plastic/Polythene used in the bituminous concrete mix because of various properties which play a major role in the construction industry :

- To improve the fatigue life of the structure
- It is economical and longer life
- Under high temperature and heavy load, it provides strength to resist shear deformation.
- Due to the repetition of heavy traffic load, it gives flexibility to the pavement and avoids cracking in pavement.
- Resistant against Corrosion and give durable to the pavement.
- A decrease in ruttingthermal cracking in pavement Good insulation for cold heat

High-Density Polyethylene: High-density polyethylene is formed when hydrogen and carbon are joined together to obtain thermoplastic material. Methane gas is changed into ethylene which is then converted into polyethylene by applying pressure and heat.

History and Background: The polymer chain varies from 500000 to 1000000 carbon units long. Chemically high-density polyethylene is written as (C_2H_4)nonlinear polyethylene are termed as high-density polyethylene and branched polyethylene are termed as low-density polyethylene. . Polyethylene is made by the polymerization of ethylene (olefin) monomers.[5]Ethylene molecules are made from two methylene units by forming a double bond between two carbon atoms. The chemical reaction of polymerization is given below-

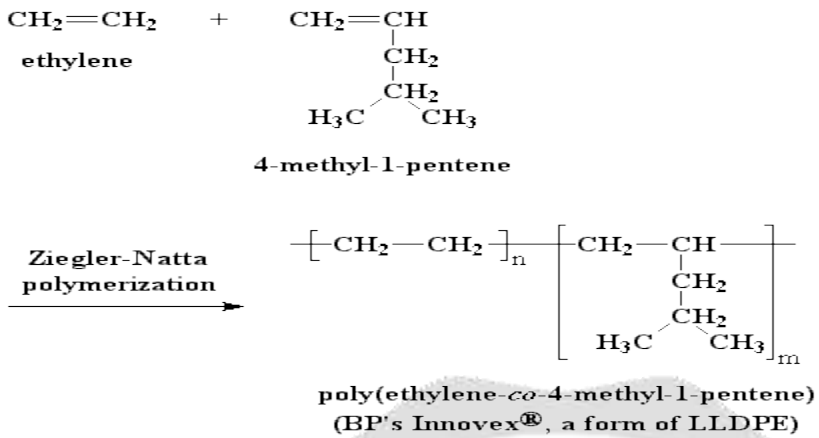

Figure 1: Chemical reaction of polymerization

Two types of catalyst are used for manufacturing of high-density polyethylene:

1. Ziegler-Natta catalyst
2. Phillips-type catalyst

Types of the Manufacturing process of high-density polyethylene are:

1. Slurry process
2. Gas-phase process
3. Solution process

In 1899, Agerman scientist Hons von Bachmann observed white precipitation when he was experimenting methane in ether. After that in the 19th century, his colleague Eugen Bamberger and FriedrickTschirner observed similar white precipitation from his experiment and give name it as polymethylene[6].In 1930, Dr. Marvel faculty of the University of Illinois in Urbana experimented with ethylene by subjecting it to large pressure (300 MPa.) . This results in a solid form of polyethylene by British scientists in 1935. After world war 2, in 1953, Karl Ziegler and Hans George Gellert, they used aluminum trialkyl as catalysts for making high molecular polyethylene. The aluminum electrons are grouped so that active
aluminum atom

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Figure 2: Polyethylene in granular form

Properties of high-density polyethylene:

- **Density-**Density of polyethylene can vary from 0.88–0.96 g/cm^{3}due to its branching effect in linear and branched structures. Higher the density stronger the material is and lower density tends to weak material.

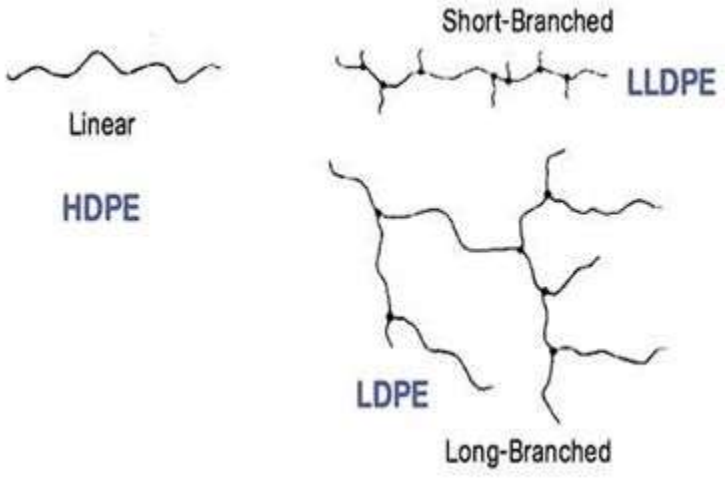

Figure 3: HPDE structure

- **Melting point:** The melting point of high-density polyethylene is 120 to 180 °C**.**Its melt viscosity is extremely high.
- **Specific heat capacity:** The heat capacity of high-density polyethylene depends on temperature and molecular weight distribution,normally value varies between 1330 to 2400 J/kg·K.
- The temperature of crystallization for high-density polyethylene is 111.9 °C.
- The latent heat of fusion for high-density polyethylene is 178.6 kJ/kg.[7]

Application of High-Density Polyethylene:

It is used in many daily usable items like-

- Flexible high-density polyethylene pipe
- Monobloc chair
- House wrap
- Older ice cube trays
- Milk jug
- Packaging bottles and films[5-6]

Low-Density Polyethylene (LDPE): Low-density polyethylene is made under high pressure and high temperature by the process of free radical polymerization (stirred autoclave or tubular routes) yield the polymer structure with short and long branches.its makes the polyethylene hard and stiff. Its melting point is around 108 ° C and it is a translucent polymer and semi-rigid.

Low-density polyethylene is used in packaging film, grocery bags, squeeze toys, housewares, etc. [32-33]

Medium-density polyethylene: It is made from chromium catalysts or silicacatalysts.its density varies from 0.926-0.940 g/cm^3

Cross-linked polyethylene: It is polyethylene with cross-links.it is used in domestic pipes,chemical transportation,insulation to high tension electric cables.

Table 1: Comparison between low high-density polyethylene and density polyethylene-

Types of polyethylene	High-density polyethylene	Low-density polyethylene
1. Structure type	Low degree of short-chain branching	long-chain branching + High Degree of short-chain branching
2. Catalyst and process	Ziegler-Natta catalyst and Phillips-type catalyst	autoclave method and tubular method.
3. Density	0.943-0.967 g/cm^3	0.912-0.92 g/cm^3
4. crystallization	low amorphous i.e more than 90% crystalline and High crystalline.	high amorphous i.e less than 50-60% crystalline and Low crystalline.
5. Characteristics	• Good acid Resistance • High tensile strength • Good moisture-resistant property. • Hard to semi-flexible	• Flexible and excellent transparency • Good moisture resistant property • High impact strength at low temperature • Good resistance to acids, bases and vegetable oils.
6. Application	• flexible high-density polyethylene pipe • monobloc chair • house wrap • older ice cube trays • milk jug • packaging bottles and films	• squeezing the bottle ,pouch bags • Shrinkwrap film • extrusion moldings • laminating covers
7. Recycling code		

Wollastonite:.The chemical name of wollastonite is calcium inosilicate mineral ($CaSiO_3$) consist of iron,magnesium and manganese. ($CaSiO_3$) has a composition of 47.5% calcium oxide and 52.3% silicon dioxide with a minority of aluminum, magnesium, manganese etc.

History and Background: Wollastonite is the name given by English mineralogist and scientistW.H.Wollaston in the year 1766-1828. It is obtained from limestone or dolomite when it put under high temperature and pressure. It is white colour.There are two types of the manufacturing process of wollastonite first one is by direct crystallization from molten rock and the second one is when limestone and silica are raised to the temperature of 400°C-460°C. wollastoniteis mined in California and newyork. In California,mining is done in a limited time period between 1930 to 1970. And in newyork mining is done for more than 50 years.currently, there are two companies –

- NYCO Mineral Inc. in Essex country
- R.T.Vanderbilt co. Inc. in Lewis country

In the manufacturing of wollastonite, the concentration of pure wollastonite should be 97-99%.The manufacturing process consists of drilling,blasting, and partical crushing and milling.The ore with minerals wollastonite,garnet, and diopside with 60%of wollastonite.garnet and diopside are separated through a magnetic separator. In many industries wollastonite is used as an alternative of asbestos and wollastonite is used as filler and extender in the manufacturing of plastics.china is the largest producer of wollastonite followed by America. accounts for about 25% of the total production of wollastonite.[3]. Naturally occurring wollastonite consists of α-wollastonite. After heating this at 1120°C ± 10°C,this α-wollastonite is converted in β-wollastonite and termed it as pseudo wollastonite[13]. Pictorial representation of wollastonite is shown below-

Properties of wollastonite:

- **Specific gravity** range of wollastonite lies between 2.87-3,09.This variation is due to various impurity minerals.
- **Color** white, yellow,grey, Red, Brown this variation is due to a certain amount of impurities in it
- **Melting point** for wollastonite is 1540 °C
- **Tenacity** wollastonite is brittle.
- **H**ardness for wollastonite generally lies between 4.5-5 on Mohs scale.
- **Thermal conductivity** generally wollastonite has low thermal conductivity i.e 2.70 ± 0.07 W/m °K
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Application of Wollastonite: Wollastonite can be used for:-

- Plastics,wollastonite increases tensile and bending strength of plastic
- Wollastonite is used in the manufacturing of ceramics in many industries.
- Metallurgy,it can be used as surface protection of molten metal.
- It increases the durability of Paint film and provides protection against weather
- Wollastonite resists chemical attack so it can be used in place of floor tiles,friction products,roofing products, etc.

Future scope and novelty of this review paper: According to the IMARC group high-density polyethylene market size reached a value of US 68Billion dollar in 2019.Increasing the application of polyethylene in various industries drives the market growth wollastonite has a large scope in concrete technology.It may be added with some admixtures to enhance the property of concrete. wollastonite can also be used for soil stabilization and it can be used in plastics, paints, friction devices, etc. In bitumen concrete, polyethylene and wollastonite act as a reinforcement agent and provide got strength and durability to the concrete mix.

Conclusion: The results indicated that the use of polyethylene and wollastonite shows the improved property in bitumen concrete mix.it shows a good binding property while added in bitumen concrete mix. The addition of wollastonite to the concrete as a partial replacement of sand adversely affects the slump of concrete. The reduction in slump increases with an increase in replacement level of sand by wollastonite. Concrete containing wollastonite is denser than concrete without wollastonite. The addition of Wollastonite increases the flexural strength, compressive strength, abrasion resistance and overall durability of concrete in comparison with concrete without Wollastonite. wollastonite can be used in the green building concept because concrete releases harmful gases like carbon dioxide to the atmosphere .so the replacement of these admixtures leads to an eco-friendly environment.

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