An Eco Friendly Substitute of Asphalt Binder – Review

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Abstract

The review focuses on the potential use of wood lignin as a partial substitute and performance enhancer in asphalt binders. The aim behind this reviews to fight issues like durability, strength and the reduction in aquifer recharging. Lignin is a dead natural polymer occurring in the secondary cell wall of plant cells. During polymerisation, monlignols accumulate in a non uniform manner, thus leaving behind pores in the structure. Using this property in our asphalt binders would render roads as permeable to water. But lignin being hydrophobic in nature, the material would not corrode due to water actions, unlike commonly used bitumen. Various tests have been conducted to generate aging conditions on test using lignin as asphalt binder. All of them show that lignin addition to binder brings stiffness. Lignin also positively effects high temperature rutting performance, without adversely affecting low temperature. Lignin additionally also shows better recovery than bitumen as binder. The fatigue resistance of surface is negatively affected by lignin. Basically the result of various studies suggests that wood lignin is a promising substitution of bitumen as binder, coming with economic savings and environmental benefits.

Keywords: Asphalt, Lignin, Bitumen

Introduction

The first recorded use of asphalt as paving material has been recorded from Babylonia back in 615 BCE, as stated by author Huge Gillepsie in his book "A Century of progress: The history of hot mix asphalt," published by National Asphalt Pavement Association in 1992. Similar uses have also been recorded in the Greek Civilisation also. Despite these early uses of asphalt, it took modern builders centuries before they actually used asphalt as a paving material. Only in the eighteenth century did Englishman John Metcalf make the first attempts, the 180 miles long Yorkshire Roads. And the binder we have been using for this purpose is the petroleum by-product, bitumen [1].

Though bitumen has served the purpose of a binder quite well for centuries now, there are certain issues that have popped up with time. Continuous questions are being raised now about the durability of bitumen binded asphalt. It is a very common experience where we see the pavement cracking due to fatigue, high temperature, or high rain even.

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Another very important issue that has now come up is bitumen being impervious to water, is hindering the aquifer recharging. So, it is high time that we make some growth hacking to generate a common solution to all these issues.So, to cater to these needs, studies were made to figure out a suitable polymer that can be used as a potential substitute of bitumen as asphalt binder. Lignin, a plant based polymer, is predicted to suffice all the issues stated earlier, by replacing bitumen as asphalt binder, atleast partly.

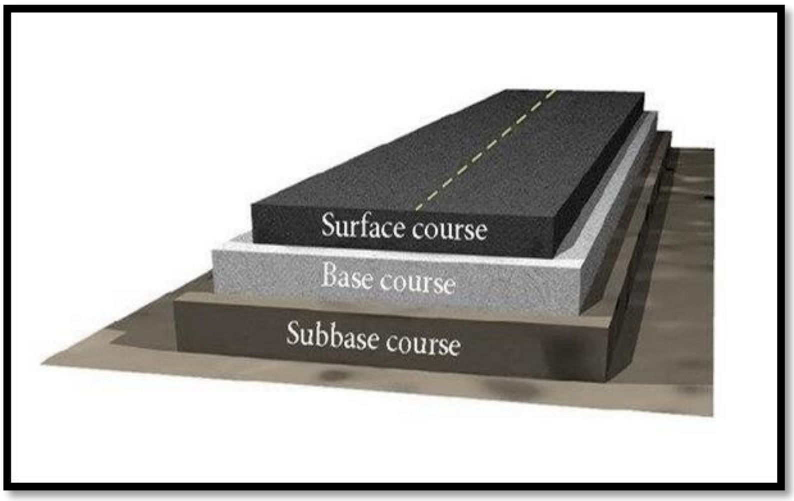

Fig 1: The layers of a normal asphalt road

Water cycle and acquifer recharging

Water cycle is the phenomenon that literally sustains life on earth. It brings back to us the water we lose, by evaporation due to heat. When molecules of water vapor return to liquid form, they create cloud droplets that can fall back to earth's surface as precipitation. Major part of this precipitation lands on the oceans, the part landing on land, flows into rivers and oceans. Only a part, a significant one, seeps into the soil. This seepage goes on through the various layers of soil, fine and coarse, to recharge the under ground water reserve, ie. the aquifer[9].

Occurence and structures

Bitumen is a petroleum by-product, which is hydrophobic in nature. It chemically comprises of Asphaltenes, polar and non polar aromatics, and saturates [6].

Lignin on the other hand is the most abundant organic substance on earth after cellulose. It occurs in amd can be extracted from the cell wall of plants and the middle lamella, where it glues the plant fibres together. Chemically, it is hydrophobic and composed essentially of Guaiacyl, p-hydroxyphenylpropane, Syingyl. These components polymerise in such a manner that they give rise to a structure very much similar to that of bitumen [7-8].

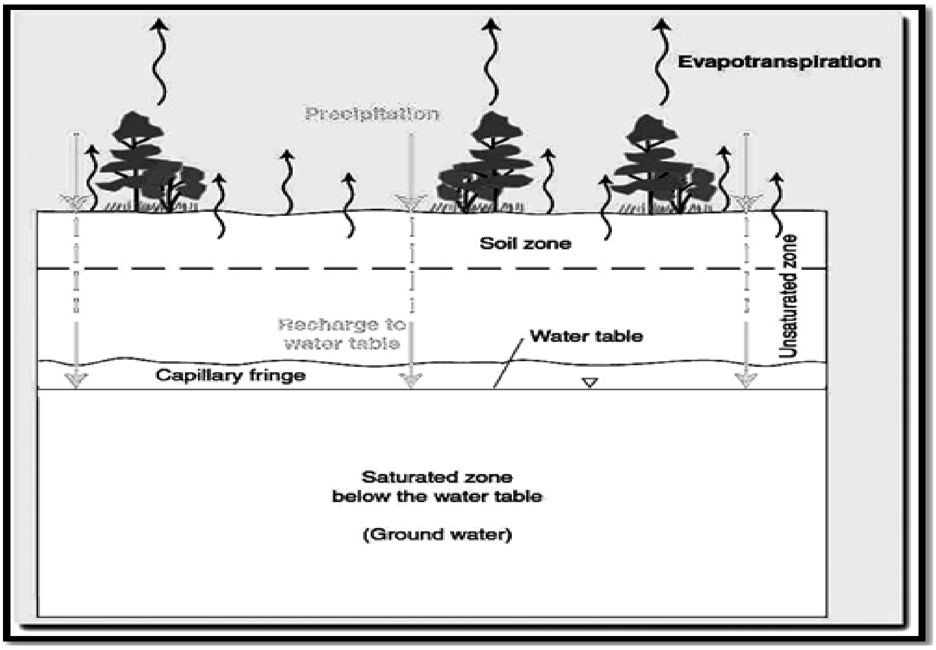

Fig 2: Water table and water cycle (Courtesy: sloarecology.psu.edu)

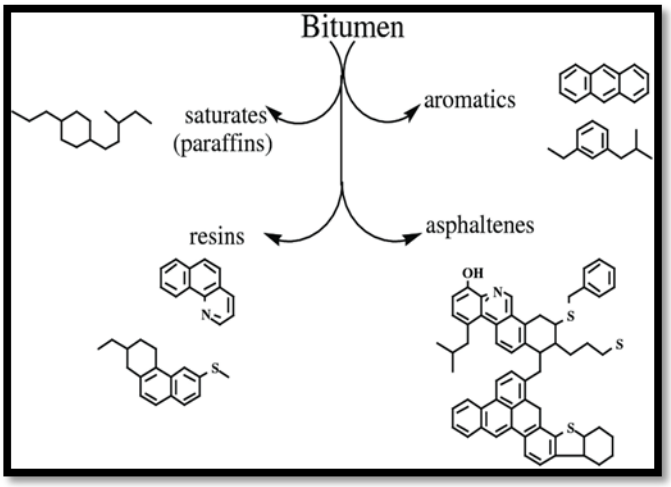

Fig 3: Types of bitumen (Courtesy: researcher.net)

Principle

Lignin is a major component in plant structure. It provides plants with mechanical support. Tissues like bark, vascular bundles, which help tall trees to remain erect, have lignin as a major component. As according to the tissue, there is a regulatory mechanism by which monolignols get polymerized in a plant tissue. And it has been seen that in all tissues lignin shows uneven deposition. Also, tracheids, which help in water conduction in plants, do it through the pores generated in their ends by uneven polymerization of monolignols. So, if we can polymerise monolignols in the asphalt binder as in plant tissues, then the channel sort of structures must feature in our roads also. Now the idea can be opposed by saying that in plants conduction is facilitated by other factors like root pressure and transpiration pull. But in our case, we need not carry a single drop against gravity, so it won't be as tedious, expectedly. And if the water that pours on the surface can be channelized through the pores to the soil surface, the seepage to the bed rocks for aquifer recharging would be natural [9].

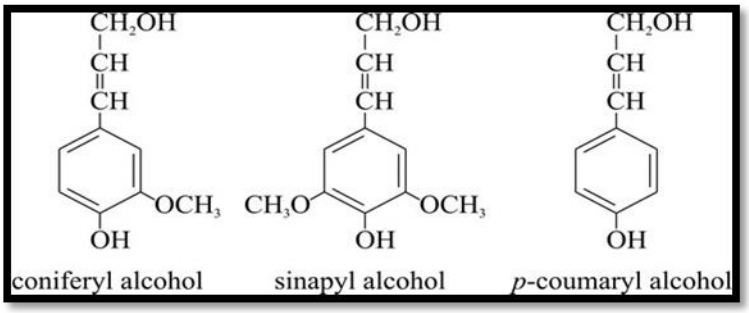

Fig 4: Monolignols (Courtesy: cheresearch.engin.umich.edu)

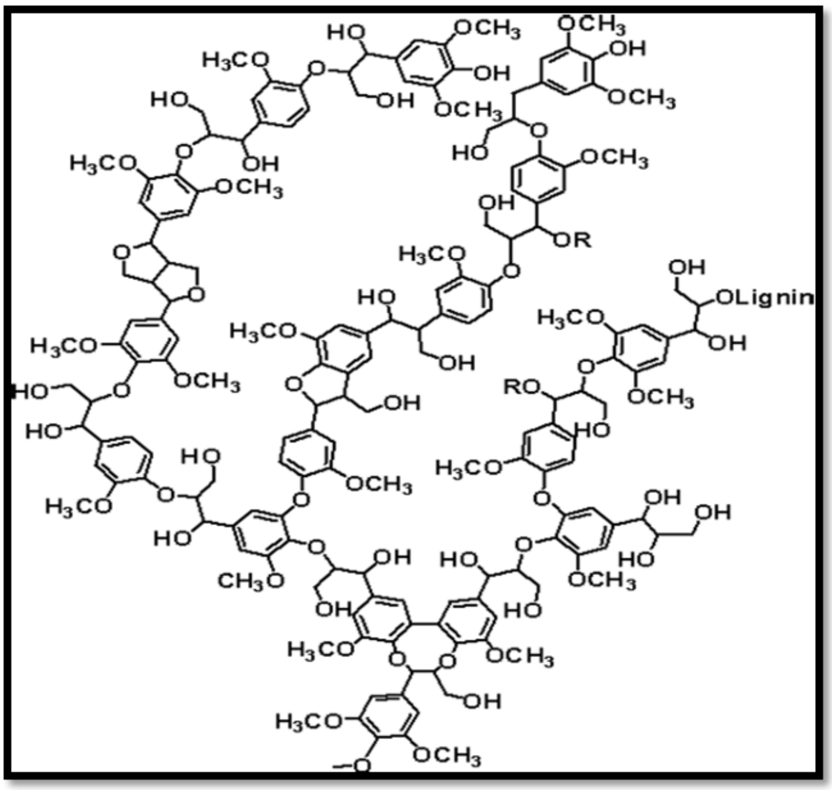

Fig 5: Polymerised lignin (Courtesy: chem.cmu.edu)

Chemically, lignin polymerizes in end wise manner, in which oxidized monolignols undergo cross coupling reactions with radicals formed on the free phenolic ends of growing lignin polymer. In vitro lignin polymerization experiments that produce synthetic lignin polymers via enzymatic or chemical oxidation of monolignols have demonstrated that propensity for lignin linkage formation depends on surrounding conditions, or their chemical structure of monolignols [2].

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In plants what happens is, there is a primary, semi permeable cellulose structure. On that lignin gets deposited, unevenly, thus we get the strength and porous features simultaneously. So what we as developers need to do is, initially abandon the idea of replacing bitumen completely with lignin. We need to plan it as a partial substitution, so that we first are able to retain a strong core, over which lignin will be made to polymerise. We may hold on with the age old practice even, where we make the paving in tri layers. The sub base course and base course are basically loose composition layers of stone chunks and fine gravels, which are permeable to water seepage. And then for surfacing, we might use a framework to support the lignin polymerization.
Also the friction coefficient of lignin with rubber tyres is around 0.68, which is comparable to that of bitumen(0.6-0.9). Lignin being strongly hydrophobic, doesn't get damaged due to heavy rain. Lignin also shows better fatigue recovery than bitumen, rendering the roads stronger [3].
Another positive side of using lignin is that it retards litter decomposition, by forming a tough layer over materials. So if we could use the lignin from plant wastes into paving, the decomposition rate would also be facilitated [4].

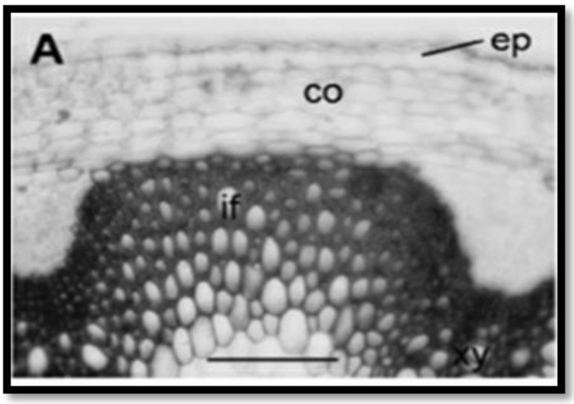

Fig 6: Ectopic deposition of lignin (Courtesy: journal.plos.org)

Conclusion

The challenge that we would face in executing the project is in polymerizing lignin as per our need**.** We need to study the lignin polymerization patterns in various types of tissues and then understand the conditions acting upon to lead to similar polymerization in the tissue pattern which we wish to get featured in our roads[5]. Observing specifically the collenchyma tissues will probably be a good choice as they give a stronger support to their systems too. Basically, the aim behind this study and made proposal is to fight water crisis throughout the world and also make transportation much economical, with introduction of cheaply available lignin, over costly petroleum by product. But even then we remain jammed with another issue. That when we make the crust

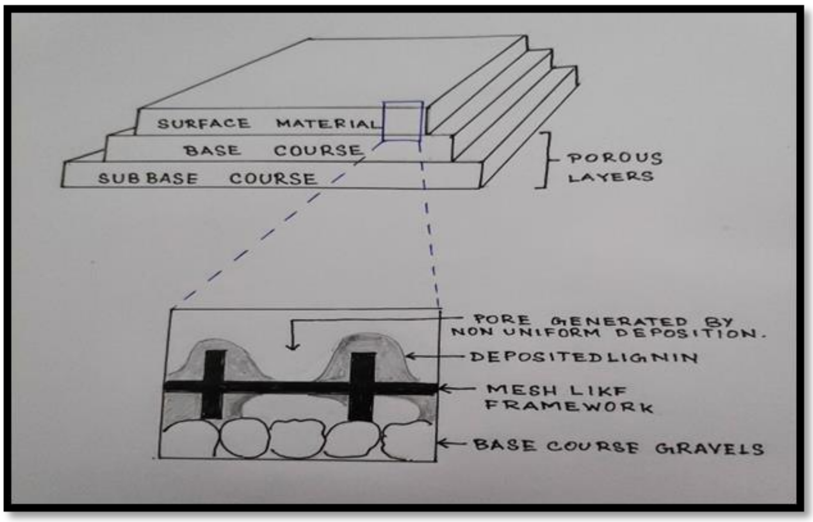

Fig 7: Proposed model

porous, the inner sand core becomes weak. So we need to think of another material that will support the core of our roads.

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