Binding properties of cashew nut shell liquid resin and its application in Building construction

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ABSTRACT

The present research work include the synthesis and study of binding properties of cashew nut shell liquid (CSNL) resin. It was studied with two physical different construction materials: bitumen and fly-ash. FTIR analysis of the fabricated CSNL fly-ash composite and CNSL-Bitumen blend revealed enhanced adhesion properties and better molecular binding ability. Good adhesion and water resistance property of CNSL, makes it suitable for construction works. This can be concluded that the defects in conventional systems of building construction can be eliminated, using CSNL-fly-ash composite and CNSL-Bitumen blend. Synthesized CNSL resin-fly ash composite revealed the FTIR spectral band at position 3007 cm^{-1} (for –OH group of cardanol), 1099 cm^{-1} (methylation of cardanol) and 1126 cm^{-1} (fly ash) and CNSL-Bitumen blend revealed FTIR spectral band at position at 1584 cm^{-1}. Thus, this is quite evident from shifting in band positions that interaction upto chemical and physical bonding has taken place. The synthesized composite is an overall package of flexibility, durability, high tensile strength together with toughness, robustness and harder surface.

KEYWORD: Cashew nut shell liquid (CSNL), resin, bitumen, fly-ash, composite, adhesion and binding ability.

INTRODUCTION

Cashew Nut Shell Liquid (CNSL)

The CNSL [1], a byproduct of cashew industries is available in huge quantity in our country. It was found that CNSL has certain important properties regarding the construction road developments. CNSL resin does not soften once cured/set. Hence no deformation /softening of road during extreme hot weather. Better adhesion of CNSL resin with aggregates causes no stripping out of binder during rain. Thus life span of roads significantly improves. Cross linking in the resin makes the road resistant to petroleum products (diesel, petrol etc.). CNSL resin is an indigenous agro waste, eco-friendly and low price material. It is isolated from cashew nut shell as a by-product [2, 3]. The chief components of CNSL have been found to be Anacardic acid, Cardanol and Cardol. Minor components include Methyl Cardol and a small amount of polymeric materials. The first four components have been found to comprise a mixture of four constituents differing in the side chain unsaturation, monoene, diene and triene .

Constituents of CNSL

Phenolics obtained from CNSL have a better alkali resistance and are less brittle than usual phenolics [4,5]. Commercially available CNSL mainly contains the phenolic constituents such as Anacardic acid, Cardol, and Cardanol. Their phenolic constituents are themselves heterogenous , and each of them contains saturation, monoene, dienes, trienes in the 15 carbon side chain.

Anacardic acid

It is a hydroxy carboxylic acid having the molecular formula $C_{22}H_{22}O_3$. Scientists have also reported Anacardic acid as being a homologue of salicylic acid with an olefinic hydrocarbon side chain of formula $C_{15}H_{31}$ attached to benzene nuleus at position 3 and separated [4].

Cardol

It is a benzene derivative having two –OH groups at position 1 and 3 and a straight chain of 15 carbon atoms in position 5-having two double bonds and the molecular formula $C_{21}H_{32}O_2$.

Cardanol

Its molecular formula is $C_{21}H_{32}O$. Its structure includes (i) 3-pentadecylanisole, (ii) 3-(8'-pentadecenyl)-anisole, (iii) 1-methoxy-3-(8',11'-pentadecadienyl)benzene and (iv) 1-methoxy-3-(8',11',14'-pentadecatrienyl)benzene (Fig.1).

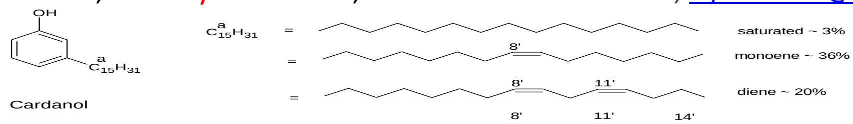


Fig.1

2-Methylcardol

It is a mixture of four components, different in their side chain unsaturation.

As CSNL is a resin of many polymeric forms in pre-crosslink form so it is expected it must have possessed the special binding properties [6]. These binding properties differ with different materials at different conditions.

Besides of this CSNL polymeric form bitumen is also a conventional and good material which is being used since long for the construction purposes. The bituminous materials are very commonly used in highways construction because of their binding and water proofing properties. Due to the drawbacks associated with bitumen, they are modified with crump rubber, styrene-butadiene-rubber, natural rubber etc.

Another very important aspect of the construction material is supposed to be the thermal waste; the fly ash. Several researchers have worked for applications of fly ash and they found it as best embankment fills. They found multiple applications of fly ash. Singh and co-workers reported their work in the journal of Cleaner Production in the year 2015, Kim et. al gave their view on application of fly ash in construction & building material in the year 2015.

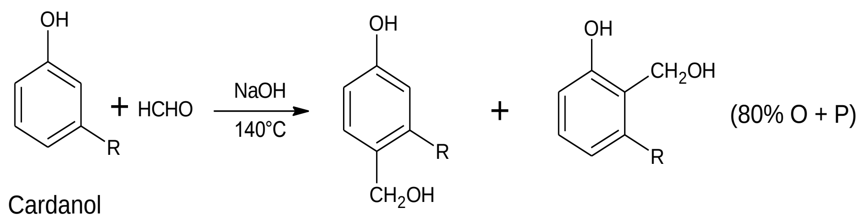
Chemical composition of fly ash

Chemical composition suggests the possible applications for coal ash. Roode [7] reported that loss on ignition is generally equal to the carbon content. Throne and Watt [8] observed that the amount of Si02 or Si02 ± A1203 in fly ash influences the pozzolonic activity. Minnick [9] has reported that a relatively high percentage of carbon decreases the pozzolonic activity. Fly ash from American coals contains large quantities of silica (SiO_2), alumina (Al_2O_3), and ferric oxide (Fe_2O_3), with smaller quantities of various oxides and alkalis. The oxides of Si, Al, Fe and Ca comprise 95 to 99% of the composition of ash [10]. The average values of different chemical constituents in the Indian fly ashes fall within the range of the average values reported for fly ashes produced in other countries [11, 12, 13]. Indian fly ashes are however, characterized by higher contents of SiO_2, Al_2O_3 and un-burnt fuel as determined by loss on ignition (L.O.I.) and lower contents of Fe_2O_3 and SO_2. Indian fly ashes exhibit greater variation in their composition partly due to variable quality of Indian coals and partly due to lack of standardization in collection and disposal plants.

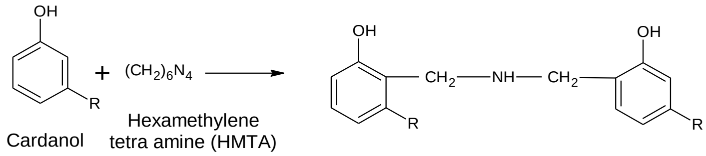
CNSL RESIN, BITUMEN BLENDS AND EMULSION

Chemistry of formation of CNSL-Resin

Polymerization reactions and therefore the structure of CNSL is best explained by analyzing its constituents. CNSL is distilled under atmospheric and reduced pressure between 180^{o}C-230^{o}C, to obtain cardanol. The application of cardanol in resin production is of great value in the production of thermoset resin. At low temperature and in presence of alkali, and using formalin (40% aqueous formaldehyde which is w/v), the main products is 4-hydroxy-6-pentadecyl bezyl alcohol, together with a 2-hydroxy-6-pentadecyl benzyl alcohol as shown in scheme-1 & scheme-2.



Scheme-1: Reaction of cardanol with formalin



Scheme-2: Crosslinking due to bonding with HMTA

The understandings of cure characteristics of thermoset resin are based on the principle that the heat flow in an isothermal reaction is proportional to the reaction rate. This relationship is valid only in a single curing reaction where no other enthalpy reaction occurs. This implies that there is no evaporation of solvents, no enthalpy relaxation and there is no significant change in capacity with conversion. In this work, therefore, CNSL has been polymerized using formaldehyde using by sodium hydroxide as a catalyst. Polymerization was repeated with the addition of HMTA as a hardener. The phenolic –OH of CNSL contributes more polarity, better adhesion and cross linking. Long side chain impart flexibility due to internal plasticizing, resulting in the formation of soft resin at elevated temperatures unlike phenol-formaldehyde resin which, is hard.

EXPERIMENTAL

Synthesis of CNSL Resin

The 500 g of CNSL, 30 g of formaldehyde and 30 g of hexamethylenetetramine (HMTA), were taken in a three necked flask (fig. 6). The catalysts used were conc. sulphuric acid and sodium hydroxide. The reaction mixture was heated to 80-90°C in a heating mental and temperature was maintained till the frothing stops. The temperature was raised to 140-150°C and maintained till the oil starts giving threads of 6”-8” i.e. low molecular weight polymer is formed. The material was transferred into a beaker for further studies.

Bitumen Emulsion

The bitumen emulsion is mixed in colloidal mill or the high speed mixer and after manufacturing the material put in the closed vessel. When emulsion is applied on road, it breaks down and start binding aggregates and the water evaporates. Binding power develops with time and its colour changes from chocolate brown to black. In rapid set quality the emulsion breaks rapidly. The main advantage of emulsions is that they can be used in wet weather, even during rain, need no heating (no pollution, no fire hazards, time saving, no handling problem, no loss of natural resources like fire wood etc.).

Preparation of CNSL bitumen blend

The blends were prepared in various ratios, CNSL resin: bitumen as 25:75, 40:60, 50:50, 60:40 and 75:25 using the following method. Calculated amount of bitumen was taken in a beaker and melted on a hot plate. To this melted bitumen a calculated amount of CNSL resin was added. Both the materials were heated to 80°C and stirred. After 15 min of stirring a homogeneous mass was obtained. The compatibility was tested on glass plate. All the five batches were prepared in similar manner with varying proportion. These 5 batches along with 100% CNSL resin and bitumen) were kept for further study.

Preparation of blend emulsion

The blend was emulsified as: 130 g of blend was heated to 120-130°C 70 g of 1.5% emulsifier solutions was prepared in water. The hot (about 50-60°C) emulsifier solution was added slowly to the above blend with vigorous stirring. After complete addition of emulsifier solution (which took about 25 min), the calculated amount of drier solution (1% on the basis of CNSL resin in the blend) was added to it. The stirring was continued while cooling. The emulsion was brought to the room temperature and kept for further studies. Driers were not added to bitumen emulsion. All the seven samples were prepared using similar methods.

Aggregate Mixing

The calculated amount of aggregates (stone chips 5-6 mm) were mixed with the emulsion at room temperature. The aggregate mix was tested in laboratory and in field as well. It was found that the CNSL with large quantity in bitumen blend emulsion aggregate, possess good resisting power, towards acids and temperature

Synthesis of CNSL fly ash composite

The low molecular weight polymer is formed. The material was transferred into a beaker for and mixed with the powder of fly ash [14, 15, 16, and 17]. Thus a blend of CNSL-fly ash is obtained which is further characterized for different aspects.

CHARACTERIZATION OF CNSL BASED COMPOSITES

Infrared (IR) spectroscopic study

The IR spectrum of formed IPN was recorded in IIT (Indian institute of technology), Kanpur, on Vertex 70 (Bruker) instrument using KBr pellet. The data acquisition is based on two channel delta sigma ADCs with 24-bit dynamic range, which are running in parallel and integrated into the detector pre-amplifier electronics. The structural IR analysis of the CNSL composite was studied by IR spectroscopic technique.

RESULT AND DISCUSSION

This can be concluded that the defects in conventional systems of building construction can be eliminated, using CSNL-fly-ash composite and CNSL-Bitumen blend. Synthesized CNSL resin-fly ash composite revealed the FTIR spectral band at position 3007 cm^{-1} (fig. 2) (for –OH group of cardanol), 1099 cm^{-1} (methylation of cardanol) and 1126 cm^{-1} (fly ash) and CNSL-Bitumen blend revealed FTIR spectral band at position at 1584 cm^{-1}(fig 3). Thus, this is quite evident from shifting in band positions that interaction upto chemical and physical bonding has taken place. The synthesized composite is an overall package of flexibility, durability, high tensile strength together with toughness, robustness and harder surface.

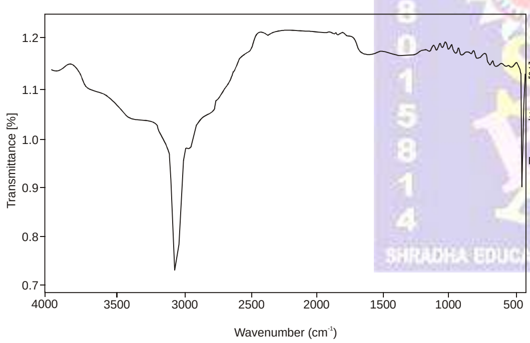


Fig.1 : FTIR spectrum of pure CNSL.

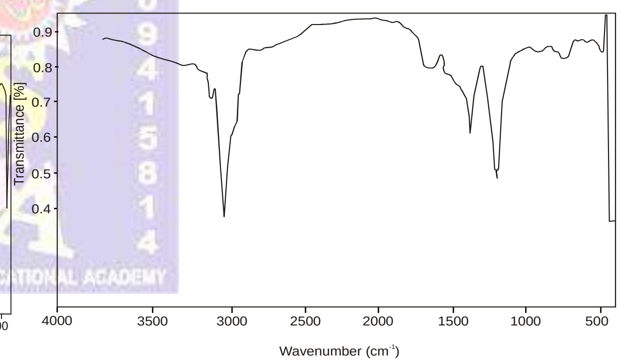


Fig.2 : FTIR spectrum of CNSL resin fly ash blend.

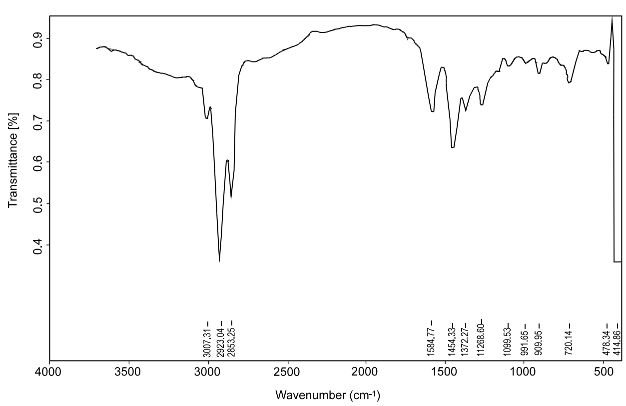


Fig. 3: FT-IR spectrum of CNSL resin-bitumen blend

Uniform particle size of the fly ash collected from different sources. The grain size distribution of all ash particles falls within the silt range with small percentage in the fine sand. Because of uniform silt size, spherical shape and surface area of individual particles fly ash possessed no plasticity *and nearly very much similar to the clay*. Chemical composition of Indian coal ashes and soil depicts presence of Silica (SiO_2), and alumina (Al_2O_3) in large proportion and magnesium oxide (MgO) and calcium oxide (CaO) in moderate range. As fly ash resembles in many of the respect withgh thye soil so it is observed that CNSL fly ash composite contained strong binding with each other and making it applicable for the building construction purposes [Table1, 2 & 3].

Table 1: CNSL-Fly ash composite

Sl. No.	CNSL Resin (%)	Fly ash (%)	Code
1.	40	60	CF-40
2.	50	50	CF -50
3.	60	40	CF -60
4.	75	25	CF -75
5.	100	0	CF

Table 2: Testing

Properties	**CF-40**	**CF -50**	**CF -60**	**CF -75**	**CF**
Water Resistance 40 C, 48 h	No effect	No effect	No effect	No effect	No effect
Acid Resistance (2% H_2SO_4)	Good	Good	Good	Good	Good
Alkali Resistance (5 % NaOH)	Good	Good	Good	Good	Good
Setting (h) Toughness	10 Moderate	13 Good	13 Good	16 Good	24 V. Good
Effect of Temp. Fluctuation	Fair	Good	V. Good	V. Good	Excellent

CONCLUSION

The present research work include the synthesis and study of binding properties of cashew nut shell liquid (CSNL) resin was studied with two physical different construction materials: bitumen and fly-ash. This can be concluded that the defects in conventional systems of building construction can be eliminated, using CSNL-fly-ash composite and CNSL-Bitumen blend.. Thus, this is quite evident from shifting in band positions that interaction upto chemical and physical bonding has taken place. The synthesized composite is an overall package of flexibility, durability, high tensile strength together with toughness, robustness and harder surface. As fly ash resembles in many of the respect with the soil so it is observed that CNSL fly ash composite contained strong binding with each other and making it applicable for the building construction purposes

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