Lecture Notes in Civil Engineering

Dharamveer Singh
Lelitha Vanajakshi
Ashish Verma
Animesh Das *Editors*

Proceedings of the Fifth International Conference of Transportation Research Group of India

5th CTRG Volume 1

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Preface

Transportation Research Group of India (TRG) is a not-for-profit registered society, which was established to bring all transportation researchers, academicians, and professionals on one platform to enable transportation research on problems faced in India and elsewhere and develop solutions for betterment. The TRG is celebrating completion of its 10 years.

TRG has brought this edited book titled *Proceedings of the Fifth International Conference of Transportation Research Group of India* in three volumes. Volume I of the book contains the papers on themes, TCT-A01: Pavements and materials, TCT-D01: Travel behaviour and transport demand, and TCT-H01: Emerging travel technology (ITS and IOT) Volume II contains the papers on the themes TCT-B01: Traffic flow theory, operations and facilities; TCT-C01: Transport planning, policy, economics and project finance, and TCT-I01: Other transportation modes (including NMT) and pedestrian. Likewise, Volume III contains the papers on the themes TCT-E01: Environment (including energy) and sustainability in transportation, TCT-F01: Transportation safety and security, and TCT-G01: Transport and mobility networks (including public transportation, freight and logistics). This book on conference proceedings is a compilation of quality research papers that are selected through a journal-style double-blind review process.

We acknowledge the support extended by Prof. Abdul Rawoof Pinjari and Prof. Gitakrishnan Ramadurai in managing the review process. This Volume I of the 5th Conference of TRG consists of 37 papers. Out of these, 31 papers are related to pavement and materials; 5 papers present works done in the travel behaviour and transport demand; and 1 paper has a focus on emerging travel technologies. Research areas covered under theme TCT-A01 include use of innovative materials, recycling and stabilization of highway materials, pavement managements and preservation techniques, characterization of binders, performance of various types of asphalt mixes, use of waste materials in asphalt mixes, concrete pavement, and innovative mixes. TCT-D01 covers new travel demand forecasting approaches, and TCT-H01 includes emerging technology for transportation application. We are quite hopeful that the papers contained in this volume, as well as in the other two volumes, will be significantly useful to the future researchers in the area of Transportation Engineering.

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About TRG and CTRG

Transportation Research Group of India (TRG) is a not-for-profit registered society with the mission to aid India's overall growth through focused transportation research, education, and policies in the country. It was formally registered on May 28, 2011, and has completed 10 years of its journey this year. The following are the vision and objectives of TRG.

Vision

- To provide a unique forum within India for the interchange of ideas among transportation researchers, educators, managers, policymakers from India and all over the world, with the intention of covering all modes and sectors of transport (road, rail, air, and water; public and private; motorized and non-motorized) as well as all levels (urban, regional, inter-city, and rural transport) and for both passenger and freight movement, in India, and at the same time to also address the transportation-related issues of safety, efficiency, economic and social development, local and

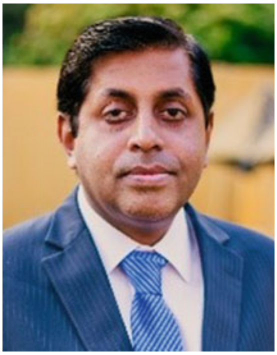
global environmental impact, energy, land-use, equity and access for the widest range of travellers with special needs, etc.
- To serve as a platform to guide and focus transportation research, education, and policies in India towards satisfying the country's needs and to assist in its overall growth.

Objectives

- To conduct a regular peer-reviewed conference in India so as to provide a dedicated platform for the exchange of ideas and knowledge among transportation researchers, educators, managers, and policymakers from India and all over the world, from a perspective which is multi-modal, multi-disciplinary, multi-level, and multi-sectoral, but with an India-centric focus. Initially, this conference will be held every two years; however, the frequency may change as per the decision of the society from time to time.
- To publish a peer-reviewed journal of good international standard that considers and recognizes quality research work done for Indian conditions, but which also encourages quality research focused on other developing and developed countries that can potentially provide useful learning lessons to address Indian issues.
- To conduct other activities such as seminars, training and research programs, meetings, discussions as decided by the society from time to time, towards fulfilling the mission and vision of the society.
- To identify pertinent issues of national importance, related to transportation research, education, and policy through various activities of the society and promote transportation researchers, educators, managers, and policymakers in an appropriate manner to address the same.
- To collaborate with other international societies and organizations like, WCTRS, ASCE, TRB, etc., in a manner that works towards fulfilling the mission and vision of the society.

The Conference of Transportation Research Group of India (CTRG) is the premier event of TRG. It is held every two years and traditionally moves around India. In the past, CTRG has been organized in Bangalore (December 2011), Agra (December 2013), Kolkata (December 2015), Mumbai (December 2017), Bhopal (December 2019), and Trichy (upcoming in December 2021 jointly with NIT Trichy, in association with IISc Bangalore, IIT Madras, IIT Palakkad and NATPAC). CTRG has been getting wide scale recognition from reputed Indian and international institutions/organizations like IIT Kanpur, IIT Kharagpur, IIT Guwahati, IIT Bombay (Mumbai), SVNIT Surat, MANIT Bhopal, NIT Trichy, TRB, WCTRS, CSIR-CRRI, ATPIO, T&DI-ASCE, EASTS, to name a few. CTRG is a large conference typically attended by around 400–500 participants, usually from 12 to 15 countries, with about 200 double-blind peer-reviewed technical papers being presented. The conference provides a wide range of executive courses, tutorials, workshops, technical tours, keynote sessions, and special sessions.

Transportation in Developing Economies (TiDE) is the official journal of TRG and is published by Springer. TiDE was formally launched in 2014 and has so far published seven volumes.



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Contents

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Experimental Studies on Bio-bitumen Produced Using Charcoal from Coconut Shell Waste

Nishant Garg, Tanuj Chopra, and Anush K. Chandrappa

1 Introduction

In India, viscosity grade 30 (VG30) binder is most commonly used in pavement applications other than national and state highways. It is the last residue in the fractional distillation of crude petroleum and harder than VG10 and VG20 bitumen. Bitumen is a viscoelastic material having hydrocarbons, which softens gradually when heated and hardens at low temperature [1]. More than 80% of the highways are made of bituminous mixtures in the world [2]. During the last few years, many distress like pothole, edge cracking, corrugation, etc. were observed in the flexible pavement with rutting and fatigue cracking being the major distresses. These distresses are mainly due to repetitive overloaded commercial vehicles, high temperature, incorrect mix design, and climate conditions. The rutting of bituminous mixtures mainly involves subsidence/depression along the wheel path causing permanent deformation. Due to the depression of the surface, water get accumulates in ruts and this water further deteriorates the pavement. As a result, bituminous pavement possess insufficient structural adequacy before the end of design period and increase the maintenance cost of the pavement [3]. The other factor is the poor quality of bitumen and inadequate physical and rheological properties (resistance to rutting and fatigue cracking), which leads to structural and functional distresses. Several types of modifiers and additives are used to enhance the physical and rheological properties of the bituminous binder [4].

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As bitumen shares 40% contribution to reduce rutting in bituminous mixtures [5], many organizations are studying modified bitumen with various additives such as polymers, crumb rubber, hydrated lime, and natural rubber to improve the performance ability of bitumen in mixtures [6]. However, high raw materials costs, high production costs, storage issues, and limitations in availability as per demands have seen reduced utilization of such modified binders. In order to find an alternative with sustainability considerations, modifiers derived from the bio-waste are gaining attention among the bitumen technologists. As bio-wastes are known to create environmental hazard by consuming land for filling and altering the properties of natural ground soil over time, a sustainable solution needs to be developed to utilize them effectively. Owing to their better compatibility with bitumen and lower cost, modification of bitumen using bio-wastes is gaining attention among bitumen technologists to investigate the influence of bio-wastes on performance of bitumen. Naturally occurring materials such as palm oil fuel ash and rice husk ash are used as additives to modify the base binder to enhance the rheological properties and performance of the bitumen [7]. Among several bio-waste materials, coconut shell charcoal powder has more potential of being one of the bio-waste modifiers due to high carbon content and fine nature for better dispersion. Coconut shell is an agricultural waste and is richly available; it is also discharged by various industries [8]. Among other countries, India is ranked third in production of coconut all over the world with an annual production of 21,500 million tons [9]. In India, more than 15 states and union territories produce coconuts. Tamil Nadu ranked on top with more than 31% share of the total production of coconut in India. Coconut shell is lightweight, extremely strong, rigid and eco-friendly due biodegradability and emission of carbon dioxide is in low amount when burnt [8, 10] and microscopic image of the coconut shell revels that the surface of coconut shell is very rough which increase the compressive strength in composite structure [11, 12].

The main aim of this paper is to utilize coconut shell waste as charcoal powder with their unique characteristics as additive in binder modification to investigate the physical and rheological properties of bio-bitumen by using dynamic shear rheometer (DSR).

2 Objective and Scope

The objective of this research was to evaluate rheological performance of the bitumen modified using charcoal powder and understand the permanent deformation characteristics using multiple stress creep-recovery (MSCR) test. The scope of the research study included:

- Modification of bitumen with charcoal powder at various percentages
- Determination of basic properties of modified bitumen
- Determination of complex shear modulus and phase angle

- Determining percent recovery and creep compliance of modified bitumen
- Understanding the stress sensitivity of modified bitumen

3 Materials and Methods

3.1 Bituminous Binder

Viscosity grade 30 (VG30) control bituminous binder was used in this research, which was procured from construction site in Barnala city, Punjab. For modification purpose, 750 g of control binder was taken for each percentage of coconut charcoal powder.

3.2 Preparation of Micromaterial

The coconut shell charcoal as shown in Fig. 1a was powdered in Los Angeles abrasion machine to produce the finer size particles. The crushed material was sieved through 75 μm sieve to obtain fine material for modification as shown in Fig. 1b.

(a) (b)

Fig. 1 **a** Coconut shell charcoal, **b** micro charcoal powder

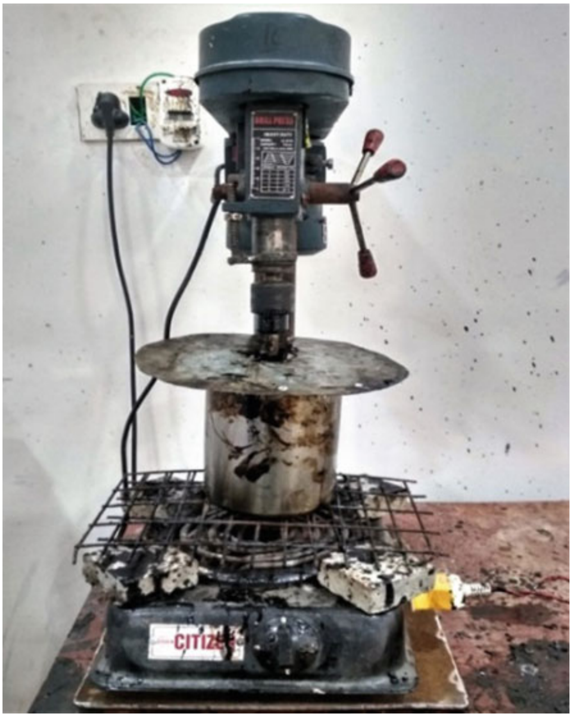


Fig. 2 Blending machine

3.3 Blending Process

The microcharcoal powder was added at various percentages, which included 1, 2, 3, and 4% by weight of bitumen. The blending process was done with shear mixture having 1750 rpm at constant temperature of 150 °C for 60 min. The mixing time, temperature, and speed were tentatively chosen for uniform dispersion of charcoal powder in the bitumen. The blender used in the mixing process is shown in Fig. 2.

3.4 Basic Bitumen Property Tests

Penetration test
Penetration test is the simplest test to determine the consistency of the bitumen. The modified bitumen was heated up to pouring consistency while stirring continuously. The hot bitumen was poured on standard cup and allowed to cool at room temperature for 90 min. Further, it was conditioned in water bath maintained at 25 °C for 1 h. Penetration test was done as per IS 1203 [13].

Softening point

The softening point is an important test to determine the temperature at which bitumen changes phase from solid to flow-able phase. The test was conducted as per IS: 1205 [14] using ring and ball apparatus. Bitumen was heated between 100 and 110 °C or above until it was completely fluid and poured into the rings and allowed to cool down for 30 min in room temperature. The excess bitumen was trimmed with hot knife and placed on the metallic support. After that, trimmed sample was placed in the water bath maintained at 5 °C for 15 min, and then two steel balls having weight of 2.5 g with centering guide were placed on the each ring in the liquid and heated. The temperature at which the bitumen touches the base plate placed at distance of 25 mm below rings was recorded as softening point.

Storage stability test

The addition of modifiers in bitumen tends to settle at the bottom when stored for long duration. In addition, large differences in densities between bitumen and modifier may lead to issues in stability for storage. In order to determine the storage stability of bitumen modified with coconut charcoal powder, storage stability test was performed as per IS-15642 [15] and ASTM D5976 [16]. About 50–55 gm of modified bitumen was poured into the steel pipes having 1 mm thickness, diameter of pipe was 25.4 mm (1 in.) and height was 150 mm. The sealed steel pipes with modified bitumen were conditioned in oven for 24 h at 163 °C. Following this, hot modified bitumen was placed in the deep freezer for four hours. The steel pipes with frozen modified bitumen were cut into three equal parts. The softening points of top and bottom portion were tested to determine the softening temperature.

Strain sweep and oscillation tests

The bitumen being viscoelastic in nature has a characteristic region where applied oscillating shear stress is proportional to shear strain rate, which is referred to as linear viscoelastic region. In order to determine the linear viscoelastic region of unaged bitumen, strain sweep test was conducted at different strain levels of: 2, 4, 6, 8, 10, 12, 14, and 16%. The linear viscoelastic range was determined such that the reduction in complex shear modulus shall not be less than 0.95 times the complex shear modulus corresponding to 2% strain. Further, the oscillation test was carried out to determine the complex shear modulus and phase angle of bitumen within the determined LVR. The test was conducted as per AASHTO T-315 [17] on a 25 mm diameter sample and 1 mm thickness at a temperature of 65 °C; representing pavement surface temperature during peak summer and loading frequency was 1.57 Hz and 4% strain to ensure the measurement in linear viscoelastic region.

Multiple stress creep recovery (MSCR)

MSCR test was conducted to evaluate the stress sensitivity and recovery behavior at 65 °C, which gives an indication of resistance to permanent deformation. The test was conducted as per AASHTO TP70 [18, 19] which uses percentage recovery ($\%R$) as shown in Eq. 1 and non-recoverable creep compliance (J_{nr}) as shown in Eq. 2 to describe the elastic and plastic state of the unaged bituminous binder using dynamic shear rheometer (DSR). The sample was placed between the parallel plate assembly with 25 mm diameter and 1 mm gap between the plates. Ten creep-recovery cycles were run on each different stress levels of 0.1, 1, 2 and 3.2 kPa to understand the stress sensitivity of control and modified binders. One cycle in MSCR test consists of 1 s of creep loading followed by 9 s of recovery. Two parameters, which includes: percentage recovery (%*R*) indicating the amount of recovery achieved in binder during recovery period and non-recoverable creep compliance indicating the amount of residual strain left in the binder were calculated from the creep-recovery data.

- % Recovery equation:

$$\varepsilon_{\mathrm{r}} = \frac{(\varepsilon_1 - \varepsilon_{10})}{\varepsilon_1} \times 100 \tag{1}$$

where,

ε_{r} Percentage recovery.
ε_1 Strain value at the end of creep portion.
ε_{10} Stain value at the end of recovery portion.

- Non-recoverable creep compliance equation (J_{nr}) kPa^{-1}:

$$J_{\mathrm{nr}} = \frac{\mathrm{Non-recoveredstrain}}{\mathrm{Stress}(0.1, 1, 2, 3.2\mathrm{kPa})} \tag{2}$$

The different tests conducted on bitumen are shown in Fig. 3.

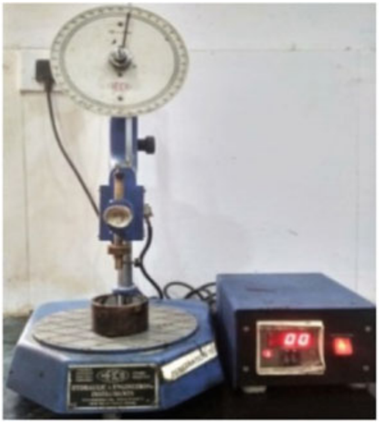
4 Results and Discussion

4.1 Penetration Test

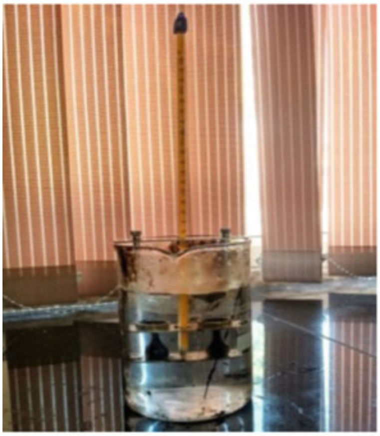
Table 1 shows that penetration value of modified binder decreases at certain limit as the addition of MCP content increases. The reductions in penetration value of modified binder were 19.07, 24.52, 17.1, and 14.99% as compared with control binder for 1%, 2%, 3% and 4% addition, respectively. The maximum reduction was 24.52% for 2% addition of MCP.

4.2 Softening Point

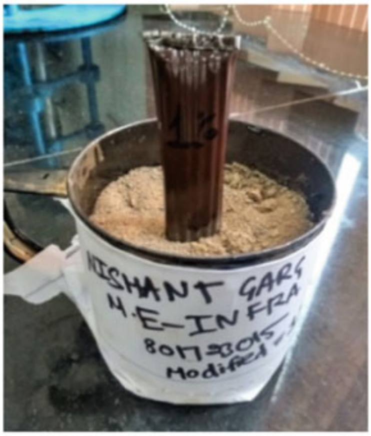
The softening point test results indicated that the softening point temperature initially showed an increasing trend up to 2% as shown in Table 1. The softening point of



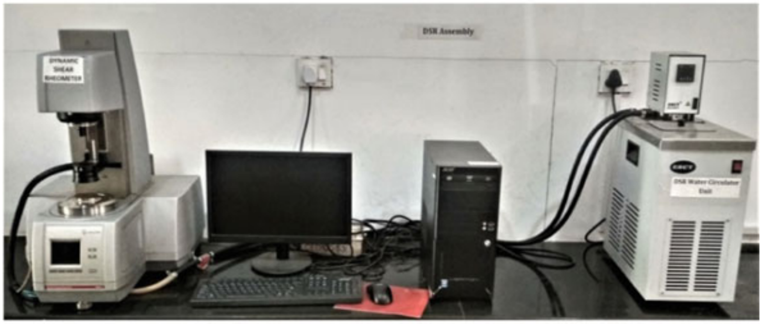
(a)



(b)



(c)



(d)

Fig. 3 **a** Penetration test, **b** softening point test, **c** storage stability test, **d** dynamic shear rheometer (DSR)

Table 1 PI of C.B and modified binder

MCP (%)	Penetration test, 1/10th mm	Softening point test, °C	PI
0	61	47.5	−1.380
1	50	55.0	−0.045
2	46	57.5	0.325
3	51	58.0	0.656
4	52	58.0	0.721

control binder was 48 °C, whereas the softening point temperature at 2% addition was 58 °C indicating a 10 °C increase in softening point. After 2%, any further addition did not show significant increase in the softening point temperature.

4.3 Penetration Index (PI) or Temperature Susceptibility

The PI value for control and modified binder was calculated from Eq. 3 [8]. From Table 1, the PI value of control binder is less than −1 indicating that it is highly susceptibility to temperature. However for modified binders, the value of PI is approaching to + 1 and more than control binder indicating that addition of MCP, the modified binder has low susceptibility to temperature and resist the rutting and cracking in permanent deformation.

$$\mathrm{PI} = \frac{(1951.4 - 500\log P - 20\mathrm{S.P})}{(50\log P - \mathrm{S.P} - 120.14)} \tag{3}$$

where,

P Penetration value.
S.P Softening point value.

4.4 Storage Stability Test

Table 2 shows the results of storage stability test. It can be seen that the differences in the top and bottom portion of the specimen are within the prescribed limit. The addition of charcoal powder in bitumen does not lead to any storage stability concerns.