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I, **ANNADASU NIRMAL PRASAD NAIDU,** certify that the work embodied in this thesis is my own bonafide work and carried out by me under the supervision of **Dr. AGNIVESH PANI and Dr. NIKHIL SABOO** from JAN 2019 to JUNE 2025 at the **Department of Civil Engineering, Indian Institute of Technology (BHU), Varanasi**. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not willfully lifted up any other's work, paragraphs, text, data, results, *etc*., reported in journals, books, magazines, reports dissertations, thesis, *etc*., or available at websites and included them in this thesis and cited as my own work.

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Nirmal Prasad

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

40A	Binder with 40% aged binder and rejuvenator A
80A	Binder with 80% aged binder and rejuvenator A
40B	Binder with 40% aged binder and rejuvenator B
80B	Binder with 80% aged binder and rejuvenator B
A	Asphaltenes
A1	First acidaffins
A2	Second acidaffins
AASHTO	American Association of State Highway and Transportation Officials
AFR	Asphalt Flexibility Ratio
AI	Aging index
ANOVA	Analysis of Variance
APO	Arizona pine oil
ASTM	American Society of Testing and Material
B	Commercial rejuvenator B
B4	Binder with rejuvenator B and 40% RAP binder
B8	Binder with rejuvenator B and 80% RAP binder
BOF	Bio rejuvenator fluid
BYE	Binder Yield Energy
C=C	Alekne functional class
C=O	Aldehydes and Ketones functional class
C-H	Alknes/Alkenes/Arenes
CWE	Cationic water-based emulsion
CII	Colloidal Stability Index

cm	Centimeter
C-N	Amine functional group
CO_2	Carbondioxide
CR	Commercial Rejuvenators
cSt	Centi stokes
CT_{index}	Cracking tolerance index
D	Diameter of the sample
DBM	Dense bituminous macadam
DCC	Dynamic creep compression
df	Degrees of freedom
DS	Dynamic stability
DSR	Dynamic shear rheometer
DTS	Dynamic testing system
E	Waste engine oil
E4	Binder with waste engine oil rejuvenator and 40% RAP binder
E8	Binder with waste engine oil rejuvenator and 80% RAP binder
EN	European
FI	Flexibility index
FTIR	Fourier Transform Infrared Spectroscopy
G^*	Complex shear modulus
GDP	Gross Domestic Product
G_f	Fracture energy
G_g	Glassy modulus
G-R	Glover-Rowe
GTRV	Global total rank value

h	Height of the sample
HPE	Heavy paraffinic extract
HMA	Hot Mix Asphalt
HSD	Honest significant difference
HWRT	Hamburg wheel rut test
Hz	Hertz
IDEAL-CT	Indirect Tensile Cracking Test
IDEAL-RT	Indirect Tensile Rutting Test
IRC	Indian Road Congress
IS	Indian Standard
ITS	Indirect tensile Strength
ITS_{dry}	Indirect tensile Strength of sample in dry condition
ITS_{wet}	Indirect tensile Strength of sample in wet condition
$J_{nr3.2}$	Non-recoverable creep compliance at 3.2 kPa
kBr	Potassium Bormaide
kg	kilogram
kPa	Kilo pascals
l_{75}	displacement at 75% of peak load (post-peak)
LAS	Linear amplitude sweep
LTA	Long term aging
LVDT	Linear Variable Differential Transformer
LVE	Linear viscoelastic
min	Minutes
Mm	Millimetre
MoRTH	Ministry of Road Transport and Highways

MPa	Mega Pascals
M_R	Resilient Modulus
MS	Masrshall Stability
ms	Milli seconds
MSE	Mean square erorr
NAPA	National Asphalt Pavement Association
NCHRP	National Cooperative Highway Research Program
N-H	Amine functional class
NMAS	Nominal maximum aggregate size
nPB	n-propyl bromide
NV	Normalized value
O-H	Alcohols and phenols functional class
PAV	Pressure aging vessel
PND	Petroleum neutral distillate
PG	Performance grading
PGH	High temperature performance grading
PGI	Intermediate performance grading
P_{max}	Maximum load
PP	Parallel plate
R-index	Rheological index
R	Commercial rejuvenator R
R4	Binder with rejuvenator R and 40% RAP binder
R8	Binder with rejuvenator R and 80% RAP binder
rad	Radians
RAP	Recycled/Recliamed Apshalt Pavement

RILEM	Réunion Internationale des Laboratoires et Experts des Matériaux
rpm	Rotations per minute
RTFO	Rolling Thinf Film Oven
RT_{index}	Rutting tolerance index
RV	Ranked Value
SHRP	Strategic Highway Research Program
SP	Softening point
SS	Sum of sqaures
STA	Short term aging
SUPERPAVE	Superior Performing Asphalt Pavements
t	Time
T	Torque
τ_f	Shear strength
TRV	Total rank value
TSR	Tensile strength ratio
TTSP	Time temperature superposition principle
VG	Viscosity grading
VMA	Voids in Mineral Aggregate
W	Waste vegetable oil
W4	Binder with waste vegetable oil rejuvenator and 40% RAP binder
W8	Binder with waste vegetable oil rejuvenator and 80% RAP binder
ω	Frequency
ω_c	Cross-over frequency
WCO	Waste cooking oil
WEO	Waste engine oil

WF	Weightage factor
WVO	Waste vegetable oil
ZSV	Zero shear viscosity
δ	Phase angle
θ	Deflection
τ	Shear stress
γ	Shear strain
μ	Poissons ratio
ΔH	Horizontal deformation