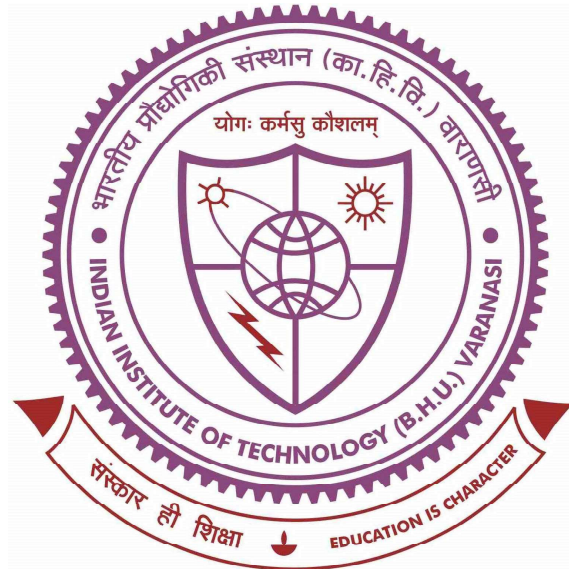


An Integrated Approach for Condition Assessment of Steel Railway Bridges



**Thesis submitted in partial fulfilment
for the Award of Degree
Doctor of Philosophy**

by

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December, 2023



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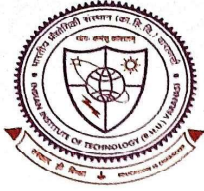
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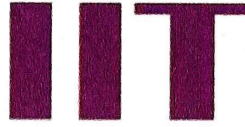
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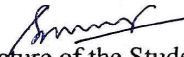


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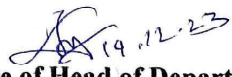
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Dedicated to my parents

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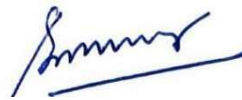
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Sudhir Babu Patel

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List of Symbols and Acronyms

Acronyms and other notations

CNN	Convolutional Neural Network
CSN	Crack Segmentation Network
CV	Computer Vision
DCNN	Deep Convolutional Neural Network
DL	Deep Learning
DSPP	Dilated Spatial Pyramid Pooling
DTL	Deep Transfer Learning
FCN	Fully Convolutional Network
FPN	Feature Pyramid Network
ML	Machine Learning
NN	Neural Network
SS	Semantic Segmentation
SVM	Support Vector Machine
UAV	Unmanned Aerial Vehicle
FPN	Feature Pyramid Networks
PSPNet	Pyramid Scene Parsing Network
VGG	Visual Geometry Group
ReLU	Rectified Linear Units
RNN	Recurrent Neural Network
ResNet	Residual Neural Network
IoU	Intersection over Union
BCE	Binary Cross Entropy
TP	True positive
TN	True negative
FP	False positive
FN	False negative
HCF	High cycle fatigue
LCF	Low cycle fatigue
LEFM	Linear elastic fracture mechanics
BGML	Broad gauge main line
RBG	Revised broad gauge

MBG	Modified broad gauge
DFC	Dedicated freight corridor
CC	Carrying capacity
PT	Passenger train
FTE	Freight train empty
FTL	Freight train loaded
GMT	Gross metric tonne
RDSO	Railway design and standard organization
IRICEN	Indian railway institute of civil engineering
CDA	Coefficient of dynamic augment
EUDL	Equivalent Uniformly Distributed Load
SB	Stress band or stress range band
PDF	Probability density function
BMS	Bridge management system
IBMS	Indian bridge management system
MF	Membership function
FWGM	Fuzzy weighted geometric mean
CRN	Condition rating number
CCRI	Component's condition rating index
ORN	Overall rating number of bridge
BRI	Bridge rating index

Symbols

N	Number of repetitions to failure at the stress range σ_r .
σ_r	Range of stress or stress range in any one cycle
ΔK	Stress intensity factor measured in $\text{MPa}\sqrt{m}$
D	Damage
n_i	Number of cycles at the i^{th} stress range.
N_i	Cycles to failure for the i^{th} stress range
$\mu_{\tilde{A}}(x)$	Membership function of element x in the fuzzy set A
A_α	α level set of fuzzy number A
$(R_{E_i})_k$	k^{th} fuzzy rating set of i^{th} element
$\tilde{w}_{E_i}$	Weight or structural importance of i^{th} element.
N_{comb}	Number of combinations
R_C	Fuzzy rating of bridge component

R_E	Fuzzy rating of element of bridge component
$\Delta\sigma$	normal stress range
$\Delta\tau$	shear stress range
$\Delta\sigma_C, \Delta\tau_C$	Fatigue strength reference value at $N_C = 2$ million cycles
$\Delta\sigma_D, \Delta\tau_D$	Fatigue limit for constant amplitude stress range at N_D
$\Delta\sigma_L, \Delta\tau_L$	cutoff limit for stress ranges at N_L
γ_{Mf}	partial factor for fatigue strength $\Delta\sigma_C, \Delta\tau_C$
N_R	number of cycles related to constant stress range
n_{Ei}	number of cycles corresponding to stress range $\gamma_{Ff}\Delta\sigma_i$ for band i in the factored spectrum
N_{Ri}	number of cycles to failure or endurance corresponding to stress range $\gamma_{Ff}\Delta\sigma_i$ for obtained from factored $\frac{\Delta\sigma_C}{\gamma_{Mf}}$ — N_R curve
σ_0	constant amplitude non-propagating stress range (σ_r at $N=10^7$)
f_f	Uncorrected normal fatigue stress range for N_{SC} life cycle
τ_f	Uncorrected shear fatigue stress range for N_{SC} life cycle
f_{fn}	Normal fatigue strength of the detail at 5×10^6 cycles, for the given detail category
τ_{fn}	Shear fatigue strength of the detail at 5×10^6 cycles, for the given detail category
γ_{mft}	partial safety factor against fatigue failure
f	actual normal stress ranges corresponding to detail category
τ	actual shear stress ranges corresponding to detail category