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Analytical Assessment of Residual Fatigue Life of Steel Truss Girder

[1]R H S Bhaskar [2] Prof. M.Muthukumar, [3] Narasaiah Naidu
[1] M.tech vit university ,[2] Professor at VIT university, [3]ADEN track manager

***Abstract:*— Majority of the railway bridges are under study as they are facing the risk of their service life completion. The present study describes the importance of the residual fatigue life available for a truss bridge. The modeling and analytical work was done using TEKLA Structures 17.0. The analytical interpretation of the stress range of the model with the load cycles taken by the structure were co-related to obtain the necessary parameters. The most common method used is Miner's damage contribution. The effect due to variation of loading amplitude is approximated by means of deterministic approach. Finally the obtained results will be compared with the BS-5400.**

***Index Terms*—Miners damage factor, Probability density, Residual Fatigue life.**

I. INTRODUCTION

With the ageing of existing steel bridges and accumulated stress cycles under heavy axle traffic loads, fatigue cracking in steel bridges has become more frequent. From fatigue point of view, it is necessary to ascertain whether sufficient residual fatigue life exists or not. Among the different approaches available to determine the residual life of steel frames, Miner's theory is most commonly used for assessing the Residual life of a structure. Although this deterministic approach based on measured stress histories or ADT (Annual daily traffic) values has proven satisfactory for predicting the residual life of structure the uncertainties involved in loading sequence are not addressed. And also the theory held good results only for constant amplitude loading condition over the structure. To overcome these limitations, probabilistic approach is suggested to derive more appropriate damage factor. Comparisons of both approaches were done to predict the residual life of a steel truss bridge.

II LITERATURE REVIEW

ADRIAN FREDRICK C. DYA et al (2015) derived service-life function considering actual changes in the **ADT** & Miner's rule for damage factor for prediction of remaining service life to effective management of steel bridges

KWON et al(2015) has proposed a probabilistic bilinear S-N curve approach for fatigue life assessment of steel bridges.

SHARIFI et al (2014) has discussed experimental S-N approach & the stress concentration factor effect over the fatigue life of structure. The corrosion depth of structural members has considerably shown impact.

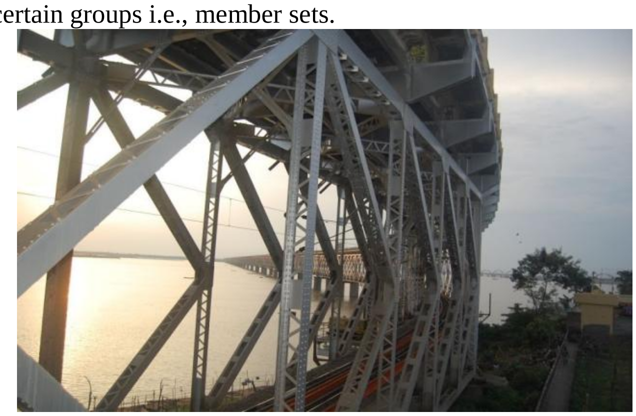
III.OBJECTIVES OF STUDY

- To obtain service life factor for determining actual residual life of structural members.
- To compare between deterministic & probabilistic approaches for obtaining a approximate damage factor

IV.METHODOLOGY

Case study:

The selected bridge is a K-truss steel bridge spanning 48m.It is an old road cum Railway Bridge with double lane road deck over the single lane rail deck. The bridge deck is made of high tensile steel and the piers are of cast iron castings with in-filled concrete. Based on the cross-section properties, the bridge components are categorized to certain groups i.e., member sets.



Typical view of the truss bridge

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V. STRUCTURAL ANALYSIS:

The bridge structure was modeled in TEKLA structures 17.0 BIM software. The bridge structure was analysed in Staad.pro V8i .A 3-dimensional model of the truss bridge was analysed for under actual traffic loads for determining stresses and deflections. The material properties of the deck are given in Table no 01. All the riveted connections are assumed to be fully fixed. The model is subjected to past and present stress histories due to passage of different locomotives.

Loading spectrum

Locomotive type	Weight of each axle(kN)	Frequency of loading (per annum)
Diesel locomotive	2*245kN	2920
Double headed electric locomotive	2*250kN	3650
Electric locomotive	2*250kN	4380

TABLE 1
load conditions

Live Loads:
Railway Loads:
Trailing load : 7.67 tonnes/mt
Tractive Force : 47.6 tonnes
Axle Load : 22.9 tonnes
Impact Factor : 20/(14+(Length of girder))
***Roadway Loading*:**
One way of Class AA loading (or) Two way Class A loading as per IRC Bridge Code.

VI: DETERMINISTIC APPROACH

This method proposes a new indicator for determining the damage accumulation of the member. Based on the S-N curve, number of load cycles for failure (N_f) corresponding to stress range (σ_f) indicates the completion of fatigue life. The damage stres s indicator (D_i) represents the damage level at ith level for the respective stress range σ_i level.

$D_i = (\sigma_{i\,eq} - \sigma_i)/(\sigma_u - \sigma_i)$
$= (\sigma_{i+1\,eq} - \sigma_{i+1})/(\sigma_u - \sigma_{i+1})$ ---eq(1)

σ_{ieq} = Corresponding equivalent stress range at $(N_i\text{-}n_i)^{th}$ no. of load cycle;
n_i = No.of load cycles subjected on member;
$(N_i\text{-}n_i)$ = No.of residual load cycles required for failure;

σ_u = Ultimate tensile strength amplitude;

Stress range applied over cross girder (vs) Number of load cycles

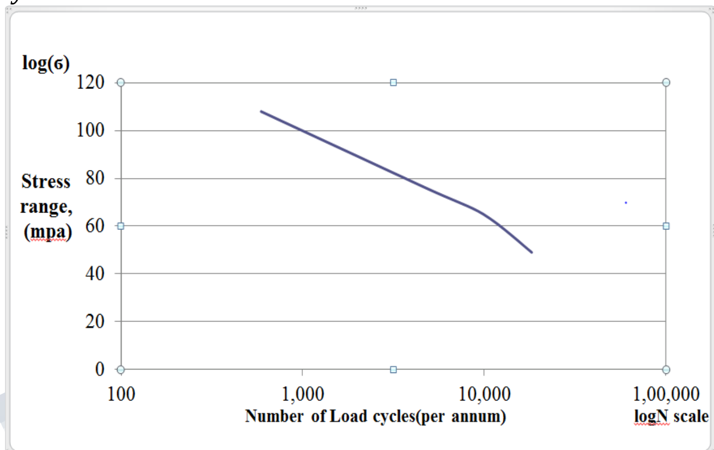

FIGURE 1

Logarithmic graph for Stress range applied over longitudinal girder (vs) Number of load cycles

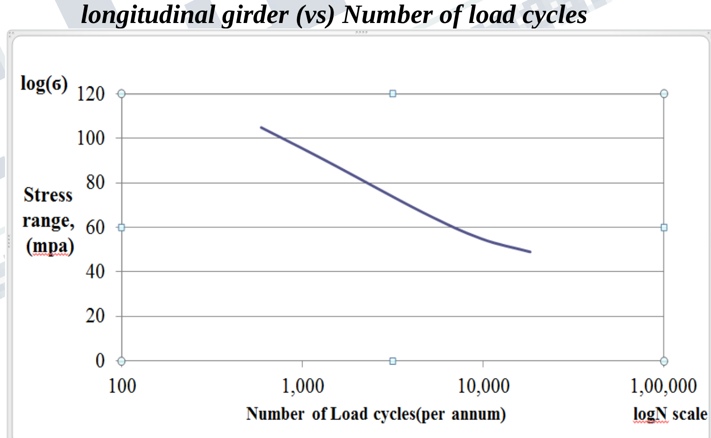

FIGURE 2

$\log N = \log k - (m)\log\sigma$
i.e., { $N = k^*(\sigma_r)^{-m}$ } ---eq.(3)
m= material constant = 3.0
k= fatigue coefficient;
σ_r= Equivalent stress range

VII.PROBABILISTIC APPROACH

The method is based on probabilistic bilinear S-N approach. In case of fatigue, the safety of structure can be assured by probability of not exceeding the fatigue limit state f(t). Probability of fatigue failure can be known by this function.

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$F(t) = M_c - D_m$

M_c= Critical Damage accumulation index(fatigue assumed to be at critical state)

Mean value of Damage factor(taken as 1.0);

D_m=Miner's damage factor;

The parameter D_m is determined based on number of load cycles N(t) undergone by member over a certain period of its lifetime(t).

Interpreted from S-N curve,

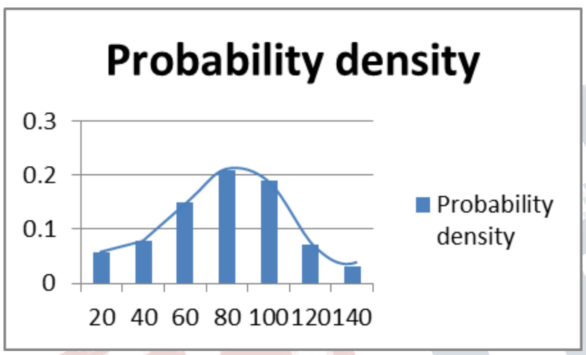
$D_m = N(t)^* \Sigma(1/(k^*\sigma^{-m}))$

& From eq(3)

$N_{equivalent}/(k^*\sigma_{eq}^{-m}) = \Sigma(1/(k^*\sigma^{-m}))$

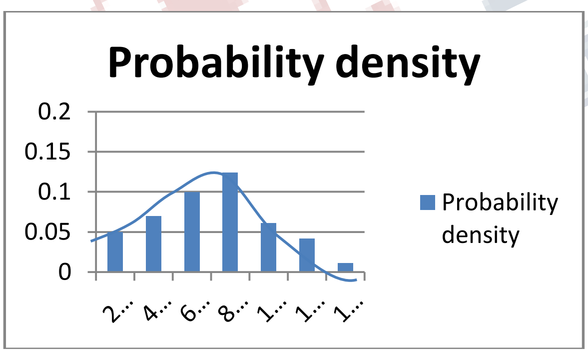
$\sigma_{equivalent}$ =Equivalent stress for variable amplitude loading.

Probabaility density (vs) Stress amplitude (Cross girder& longitudinal girder)



Stress range (mpa)

FIGURE 3



Stress range(mpa)

FIGURE 4

Experimental S-N graph for Wrought iron(BS:5400)

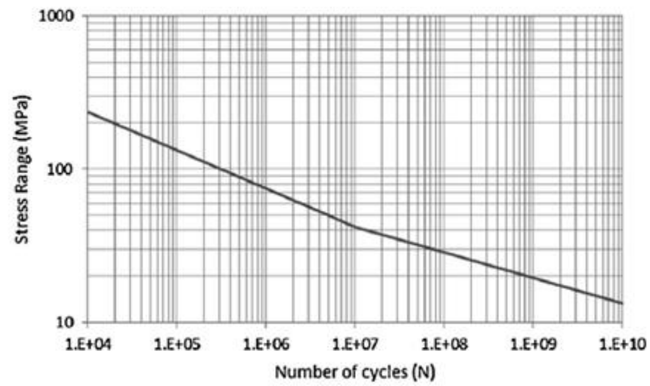
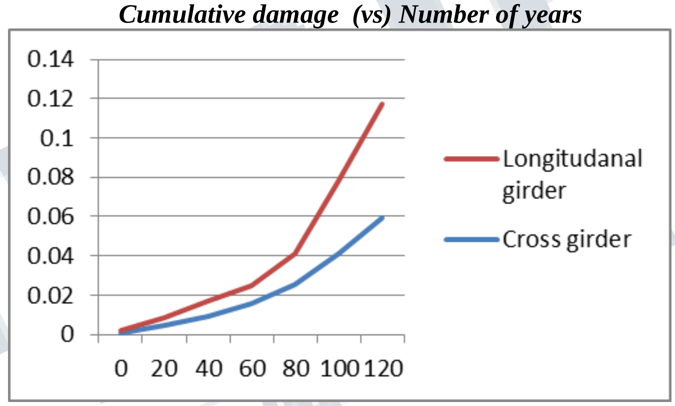


FIGURE 5

Cumulative damage (vs) Number of years



Number of years (lifetime)

FIGURE 6

VIII. RESULTS AND CONCLUSIONS

Fatigue life(years)

Bridge Components	Deterministic approach	Probabilistic approach
Cross girder member set	136	118
Longitudanal girder member set	127	108

Both the approaches have approximated closer values of fatigue residual life. The consideration of variation in sequence of loading has shown significant impact in life prediction of members. Damage indices proposed by deterministic approach has shown 10%-12% whereas probabilistic approach suggests 11.3% damage of fatigue damage of structure. By considering the repetition of similar loading spectrum, the fatigue lives of the member sets are predicted.

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