LOAD RATING OF SALVATION BRIDGE OVER THE WHITE NILE IN KHARTOUM, SUDAN

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مُسْتَخْلَص

هذه الورقة تتناول المعايرة الحملية لاحد اهم الكباري في السودان, هو كبري الانقاذ على النيل الابيض في الخرطوم.الورقة استعرضت طرق المعايره الحملية الرئيسة للكباري المتبناة بواسطة المواصفة الأمريكيةAASHTO. المعايرة الحملية للأحمال التصميمية تمت بالنسبة لأحمال التصميم الحية وفقا للمواصفة الأمريكية AASHTO-LRFD. أما المعايرة الحملية للأحمال القانونية فتمت بستخدام أحمال الشاحنات القانونية المستخدمة في السودان,وتم ايضا إجراء معايرة حملية للأحمال التي تتطلب إذنا وذلك باستخدام اثقل الشاحنات التي استعملت في السودان خلال العشرين سنة الماضية. تم إجراء المعايرة بافتراض أن سعة العزوم للعارضة الصندوقية الخرسانية مسبقة الإجهاد –والتي تكون الجسر الرئيسي -قد انتقصت بنسب متدرجة من صفر وحتى 50% ,ومن ثم تم حساب معامل المعايرة وفقا لذلك. تم استخدام برمجية مناسبة لذلك وهى برمجية Csi-Bridge ورصدت النتائج. الورقة تنبأت بمعاملات المعايرة الحملية للعارضة الصندوقية الخرسانية مسبقة الإجهاد بالنسبة للعزوم لنقص مقدر في السعة يمكن حدوثه لعدة أسباب, وأقترحت عدة توصيات للحفاظ على هذا الإنشاء المهم.

ABSTRACT:

This paper tackles load rating process on one of the most important bridges in Sudan, which is the Salvation Bridge over the White Nile in Khartoum. The paper reviewed the main load rating types adopted by AASHTO standards. Design load ratings have been made with respect to AASHTO-LFRD highway live loads. Legal load rating process has been made using the Sudanese legal loads adopted by National Highway Authority in Sudan. Permit load rating process has been made using actual special heavy truck used in Sudan during the last 20 years .The rating process has been made on the assumption that the capacity of the main structural element of the bridge, which is the pre-stressed concrete box girder, had been decreased with different percentage from zero up to 50%, due to different factors. Suitable software, CSi Bridge, has been used for calculations and the results are presented. The paper predicted the load rating factors for the box girder of the bridge- moment wise- for considerable capacity loss in future and suggested several recommendations to save such vital structure.

Keywords: *Bridge Load Rating, Salvation Bridge, AASHTO-LRFD*

1-Introduction

Load rating analysis is a component of the inspection process and consists of determining the safe live load carrying capacity of any bridge, determining if Sudan legal loads or the permit load can safely cross the bridge and determining if a bridge needs to be restricted and the level of posting required.

2-RATING Procedures:

According to AASHTO MBE -2011 [1], load rating is performed either to design loads (inventory or operating), legal loads or permit load.

2-1 General load rating equation:

$$RF=(C-Y_{DC}\,DC-Y_{DW}\,DW-Y_P\,P)/(Y_L\,{}^{LL+IM})$$

*For **the*** Strength Limit States:

$$C=Ø_C Ø_S Ø\,Rn$$

where the following lower limit shall apply:

$$Ø_C Ø_S \geq 0.85$$

for the service limit states

$$C=F_R$$

where :

RF=rating factor

C=capacity

FR=Allowable stress specified in the LRFD code

Rn=Nominal member resistance

DC=dead load effect due to structural components and attachments

DW=Dead load effect due to wearing surface and utilities

P=Permanent loads other than dead loads

LL=Live load effect

IM=Dynamic load allowance

Y_{DC}*=LRFD load factor for structural components and attachments*

Y_{DW}*=LRFD load factor for wearing surfaces and utilities*

Y_p*=LRFD load factor for permanent loads other than dead loads*

Y_l=Evaluation live load factor

$ø_c$*=Condition factor*

$ø_s$*=System factor*

ø=LRFD resistance factor

components subjected to combined load effects should be load rated considering the interaction of load effects (i.e. axial –bending interaction or shear-bending interaction) as provided in the Manual

2-2 DESIGN LOAD RATING

Design load rating is a first-level assessment of bridges based on the design live loads, HL-93 AASHTO loading and LRFD design standards [2], using dimensions and properties of the bridge in its present as-inspected condition. Under this check, bridges are screened for the strength limit state at the design level of reliability (Inventory level), or at a second lower evaluation level of reliability (Operating level). As per AASHTO MBE-2011 [1], live load factor is taken as 1.75 for inventory level, while it is taken as 1.35 for operation level.

2-3 Legal Load Rating

Bridges that do not have sufficient capacity under the design-load rating shall be load rated for legal loads to establish the need for load posting or strengthening. This second level rating provides the safe load capacity of a bridge for the Sudanese legal loads [3], [4]. The Figures shown below present them.

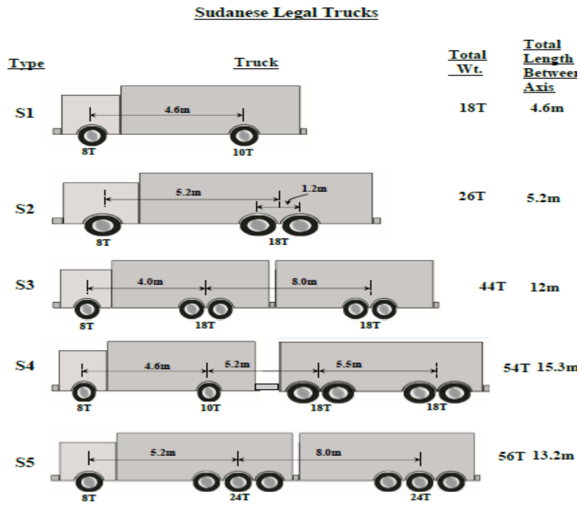


Figure (1): Sudan Legal Loads

Strength is the primary limit state for legal load rating. Live load factors were selected based on the ADTT at the bridge as shown in Table 6a.4.4.2.3a-10f the MBE [1]. For Salvation Bridge load factor is 1.8.

2.4 Permit Load rating:

Permit load rating checks the safety of bridges in the review of permit applications for the passage of vehicles above the legally established weight limitations. This is a third level rating that should be applied only to bridges having sufficient capacity for legal loads. The Figure below presents the configurations of the most common permit trucks in Sudan [5], [6], which were used during last 20 years.

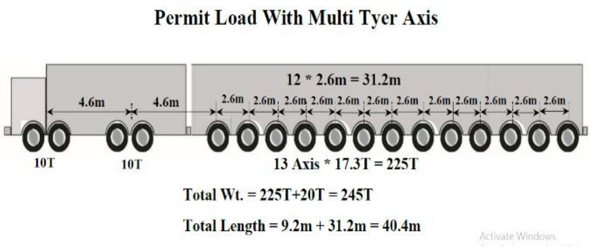


Figure (2): Sudan permit load

3. Salvation Bridge

3.1 Outlines and Features [5]

Total Length = 757.2 m

Width = 23.55 m (dual carriageway, each lane 8.75m)

Median strip width = 1.25 m

Sidewalks = 2.0 m wide

Cross slope = 2%

Longitudinal slope = from 2-4%

Capacity = 90 thousands PCU per day

No. of spans = 25

3.2 Structural Forms of Super structure [7]

The total bridge(757.2m) over 25 spans are composed of three structural forms:

(a) Main Bridge of 172 m total length over three spans 46m, 80m,46m. It is a single

Two-cell box girder pre-stressed concrete, pre-tensioned, continuous over 2 inner piers and simply supported on the outer piers. see Figure (3). The girder pre-stressing system is as shown in Table (1). From design drawings [8] the tendons had been pre-tensioned initially to 1060 N/mm^2. The deck being pre-stressed laterally, and vertical threaded high tensile bars of 32mm diameter spaced at 600mm c/c has been used to increase shear capacity of the girder.

(b) Approach I- girders Bridge of 434.4m total length. It is composed of 12 spans of pre-cast pre-stressed I beams 36.2 m each. Depth is 2.1m of each, and all are simply supported.

(c) Viaduct of 150 m total length. Composed of 10 spans each is 15 m long, of precast hollow core concrete units. They are 80 cm deep and 124cm wide.

3.3 Analysis models

The sectional elevations of the bridge and x-section of the box girder shown in

Figure (3) are those of the design information. Structural analysis are performed

using CSi bridge software [9]

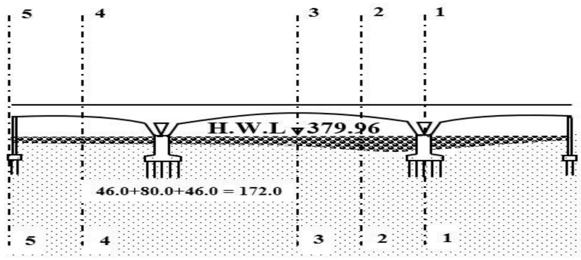
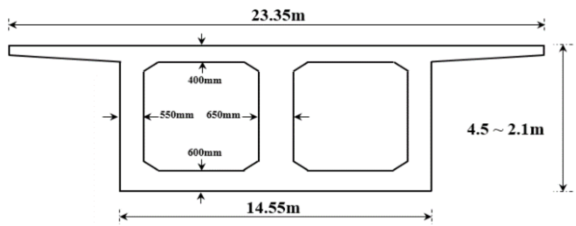


Figure (3): (a) Main Bridge: Box Girder Elevation



(b) Section (1-1)

Table (1): Main Bridge Pre-stressing Tendons

Section	Pre-stressing Tendon Area	Pre-stressing Tendon Area
	Top Flange (mm2)	Bottom Flange(mm2)
1:1	67843.6	63852.8
2:2	67843.6	63852.8
3:3	67843.6	63852.8
4:4	67843.6	27935.6
5:5	67843.6	27935.6

3.4 Rating Assumption of Salvation Bridge

1- The pre-stressed concrete box girder bridge is the major and critical part of the Whole bridge.
2- The moment capacity to live load is the governing factor of the bridge rating,

Since the girder is highly reinforced against shear.

3- Losses in capacity can occur due to different reasons, i.e. loss of pre-stress, loss of section properties, etc.

3.5 Moment Capacity of Box Girder

The nominal strength of pre-stressed Box girders has been calculated using the software Csi [9]. Alternative method of calculating the nominal strength of the girders is by the following equation [10]:

$$M_u = A_{ps} F_{cu} d \left(1 - \frac{0.6\rho^* f_{su}}{f_c^-}\right)$$

Where the variables as in reference [10]. The calculated capacities are shown in the Table below

Table2: Results of Moment Capacity of box girder

Section	1-1	2-2	3-3	4-4	5-5
Moment kN.m	238822.1	136483.7	52757.2	126521	34404.7

3.6 Rating Factors Results

3.6.1 Girder Dead and live load Moments Calculations

The girder moments due to dead loads, different live loads levels are calculated using CSi Bridge software [9]. Live loads moments are calculated due to HL93-AASHTO-LRFD, Sudan Legal loads and Sudan Permit Load. The following Tables present the results.

Table 3: Dead load Moments

Section	1-1	2-2	3-3	4-4	5-5
Moment kN.m	83671.5	18188.7	48605.2	6810.577	17277.0

Table 4: AASHTO life load HL-93 Girder Moments

Section	1-1	2-2	3-3	4-4	5-5
Moment kN.m	12983.32	2137.5	1727.83	7070.28	4712.45

Table 5: Sudanese legal truck type S5 Moments

Section	1-1	2-2	3-3	4-4	5-5
Moment kN.m	21650.6	5030.0	2767.6	4275.8	8556.3

Table 6: Sudanese Permit truck Moments

Section	1-1	2-2	3-3	4-4	5-5
Moment kN.m	35647.7	6843.0	4248.2	5269.5	14066.9

3.6.2 Rating Factors Calculation Results

The rating factors of the different sections of the pre-stressed concrete box girder have been calculated using the rating equation given above. The results of RF with respect to each live loads are shown in graphical form in the following figures.

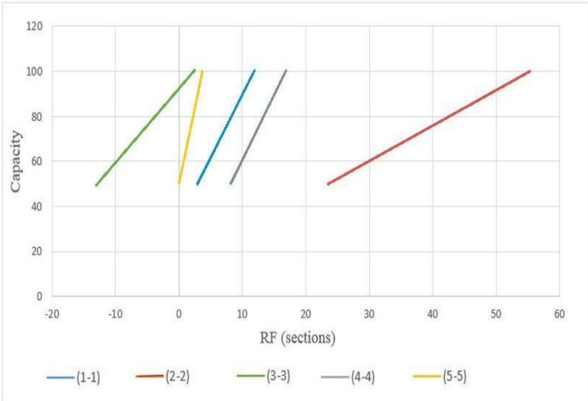


Figure. 4: RF Variation due to decreasing capacity with respect to AASHTO HL 93- LRFD, Design Rating

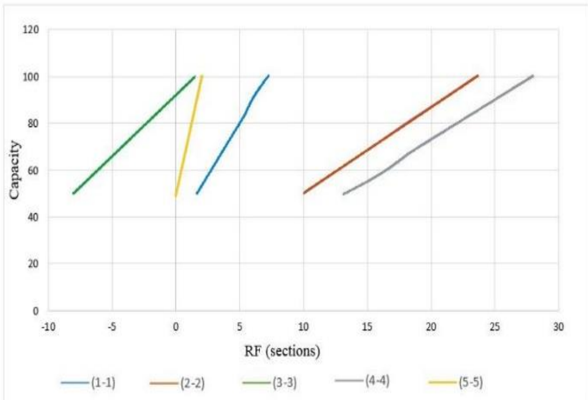


Figure 5: RF Variation due to decreasing capacity with respect to legal Truck type S5

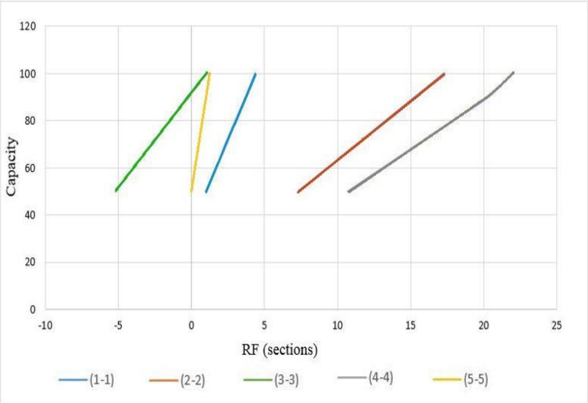


Figure 6: RF Variation due to decreasing capacity with respect to Sudan Permit Truck

4. Conclusions and Recommendations

1- Salvation Bridge design load rating w.r.t. AASHTO HL93 live load is safe –greater than one- for 100% capacity in all sections. However, the mid section of the bridge is the critical section and RF will be less than unity if capacity is loosed by 10%.

2- Bridge legal load rating is greater than unity in all sections for capacity loss up to 50 % except the mid section where it is not safe for 10 % capacity loss.

3- Permit load rating is safe for sections other than mid section, where it is just critical at 100 % capacity and unsafe for any loss.

4- It is recommended to make necessary monitoring system to check and avoid capacity loss, especially at mid section.

5. References

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