HEAVY CARGO TRANSPORTATION THROUGH THE HIGHWAY BRIDGES IN NEPAL

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ABSTRACT

Bridge maintenance, rehabilitation and/or replacement of highway bridge component are mandatory with increase in movement of vehicle. In addition, transportation of heavy cargos results costly maintenance of existing highway bridge. In general, highway bridges are designed as per national building code for average vehicle traffic and bridgesare the most vulnerable infrastructure of highway system, so movement of heavy cargo may damage the bridge component and may halt the nation movement. That's why, demarcation of critical vehicle load for highway bridges must be done in order to ensure stability and safety. In this study, critical vehicle load and its length is quantified for highway bridges of two major highway alignment of Nepal from bridge load analysis. Alternative solution for heavy cargo transportation on Terai and Hilly region is proposed too.

Keywords: *bridge capacity; bridge design load; bridge propping; heavy cargo transportation; modular train*

INTRODUCTION

Bridges are the civil engineering structure built over the river, road, rail-way tracks, water drainages or other obstacle for safe movement of people and vehicle. It creates the shortest path for movement of people and vehicle from one side to other. Proper functioning of bridges ensures easy shipment of raw material and finished good to big factories, mega engineering projects and beneficiary's people. They are the most vulnerable component of highway system and are considered as the infrastructure that supports the nation movement. Bridge must be designed in such a way that it should be strong enough to withstand their self weight, vehicle load, pedestrian load, earthquake load, wind load, freezing and thawing actions too. Furthermore, the operation and maintenance of bridges is much more crucial part. In general practice, bridgesare designed with respect to design load suggested by national code. This design load basically accounts the average vehicle traffic, pedestrian load, wind load and earthquake load for economical purpose. But, an exceptional case may arise during transportation of goods and services through bridges. Sometimes, heavy cargos whose load can't be dismantled and having load greater than the bridge design load should be transported to big industries and mega engineering projects like electrical power station, hydro power station,wind mill, etc. Design of bridge components to this exceptional condition leads to un-economical design andinappropriate section of component. That's why, it is utmost important to access the possibility of heavy cargo transportation within national highway bridges.

Identifying the alternative solution for heavy cargo transportation through highway bridges and suggestingthe safe load and its length that could be transported as per the bridge design code have been made key concern in this study. Kennedy et al.[1] had researched on Canadian highway bridge evaluation using the loadand resistance factor and calculated various factor for developing the rating curve of bridge. The dead load factor is suggested from the field observation and live load factor is calculated from one-year field survey data of 4 type of truck. The resistance factor is evaluated based on the material property and member size of Highway Bridge. Kim et al.[2] found that the real load effect tended to increase with increase in average dailytraffic volume and heavy vehicle for PSC highway bridges. T.L Wang [3], Nowak et al.[4] and Jacob et al.[5]presented a report that the heavy truck had direct influence on the fatigue life of highway bridges. Consequently, the bridge maintenance becomes more difficult and costly, since the maintenance, rehabilitation and/or replacement of bridge structural member become more frequent. Similarly, the impact effect of heavy vehicle on Highway Bridge is investigated and evaluated by T.V Hung [6] from both computations of dynamic analysis and field loading test. Load capacity evaluation of existing steel girder and pre-stressed bridge was performed by Moses and Verma [7] under the American Association of State Highway and Transportation Officials (AASHTO) in cooperation with the General Highway Administration using reliability based strategy. They recommended the load and resistance method for uniform and consistent reliability level.

$$\text{Rating Factor (R.F)} = (\emptyset\times R_n - \gamma_D\times D)/(\gamma_L\times L\times(1+I)) \quad (1)$$

Where R_n= Nominal Member Capacity, Φ = Resistance or Capacity Reduction Factor, D = Dead Load Effect, γ_D = Dead Load Factor, L = Nominal Live Load Effect, γ_L = Live Load Factor, I = Impact Factor.

ALIGNMENT SELECTION AND BRIDGE SITE INVESTIGATION

In context of Nepal, Birgunj and Sunauli, located on southernmost part of Nepal near to Indian Border, areconsidered as most important gateway to Nepal from India. These are the busiest gateway centre to Nepal in context of transporting goods and services to capital city, Kathmandu and throughout the whole country. Heavy cargos enter frequently from this entry point for big industrial state and mega engineering projects. For these reasons, highway bridge evaluation is unavoidable. Here, two alignments are selected. One starts from Birgunj to Hetauda, to Narayanghat to Kathmandu and next one is from Sunauli to Butwal to Narayanghat. According to Department of Road (DOR)[8], 156 numbers of bridges are listed along this two alignment on list of Strategic Road Network (SRN). Out of 156 numbers of bridges, 100's number of the highway bridges (64.12%) and numerous culverts are observed to access their serviceability. The Khahare Khola Bridge between Narayanghat and Muglin Bazaar is the longest one span (66 m) arch bridge along the selected alignment, which is shown in

Figure 1. Figure 2 represents the longest span Girwari Steel Bridge (61m) that is located at Nawalparasi district.

Figure 1 : Khahare khola bridge-arch bridge

Figure 2 : Girwari bridge-steel bridge

Similarly, Figure 3 represents the Martal RCC T-Beam Bridge of span 23m located at Chitwan District and Figure 4 represents the RCC Slab culvert with stone masonry abutment, which is located between Bhairahawa and Butwal alignment. As well, it is observed that various countries like India, China, USA, UKetc had helped Government of Nepal for construction of highway bridges located within this selected alignments. Majority of the bridges are RCC T-Beam, RCC Slab and PSC bridge along the alignment that lieswithin the Bara, Makwanpur, Rupandehi and Nawalparasi district. Steel bridges are constructed more in number along Narayanghat to Butwal section and Dhading district. While, Narayanghat to Muglin alignmentare full of arch bridges.

Figure 3 : Martal bridge-RCC T beam

Figure 4 : RCC slab culvert

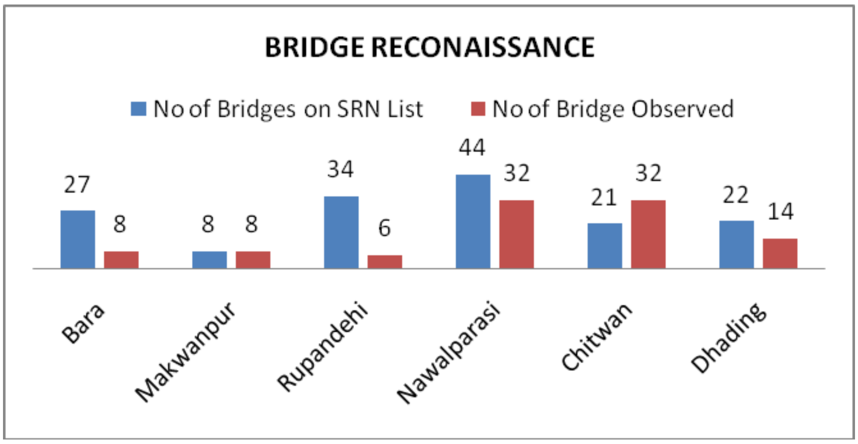

Figure 5 : Bridge Reconnaissance

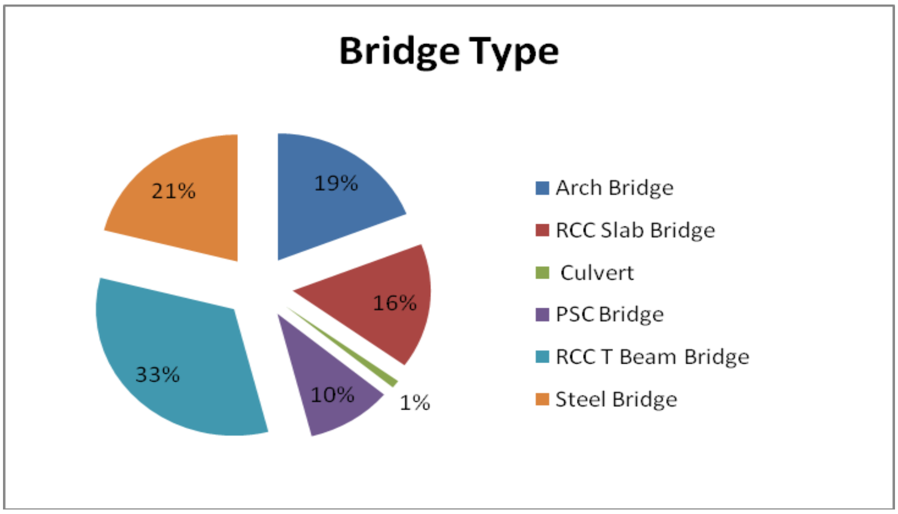

Figure 6 : Pie Chart showing bridge type

From the field observation data, it is observed that high priority should be given to Butwal to Narayanghatalignment during transportation since large number of bridges was located in Nawalparasi district in comparison to other districts. Although, the percent of RCC T Bridges are more than other bridges, major priority is given to PSC, Steel and Arch bridges as their span is greater than 25m. 44 numbers of surveyed bridges (39.63%) have span larger than 25m while remaining bridges (60.37%) are RCC T girder beam having span less than 25m. Obviously, the real load has greater effect on bridges having larger span.

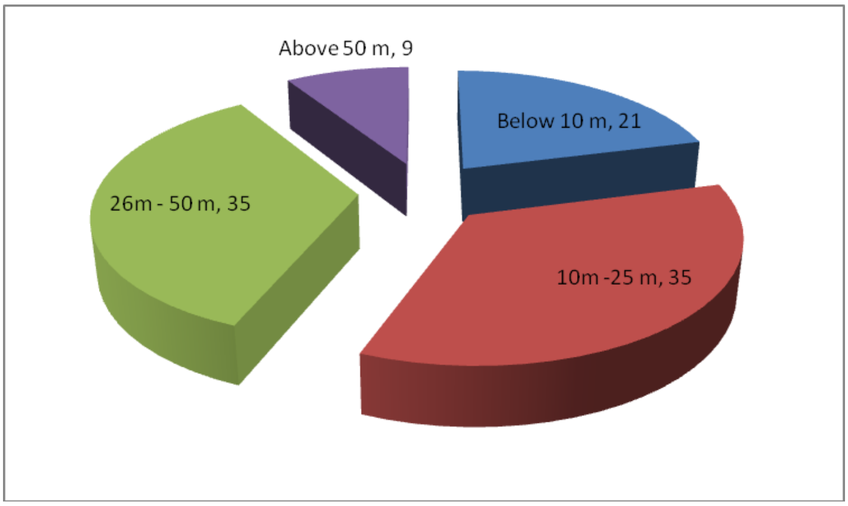

Figure 7 : Bridge classification as per span length

BRIDGE LOAD ANALYSIS

With reference to bridge design list provided by DOR, highway bridges lying along the selected two alignment were designed based on the following bridge design load: (a)AASHTO HL1993-American Standard Loading, (b) JTG-D60 2004-China Standard Loading and (c) IRC 6:2000-Indian Standard Loading.

A. *AASHTO Bridge Design Load*

1) Design Truck

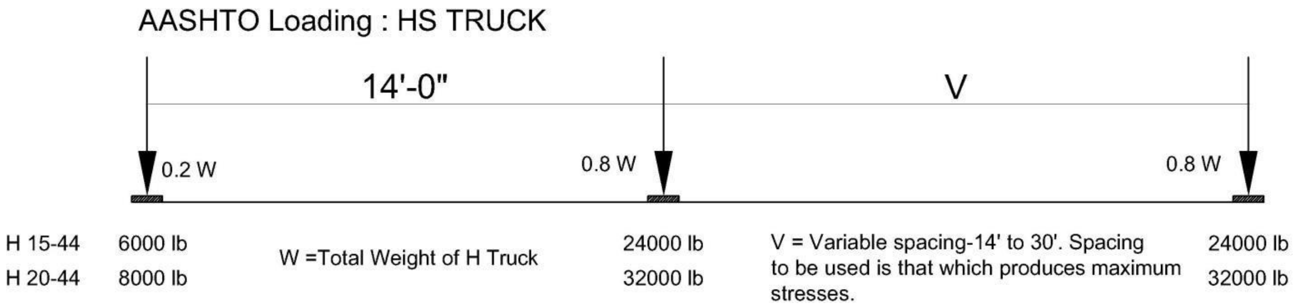

Figure 8 : AASHTO bridge design load-HS Truck

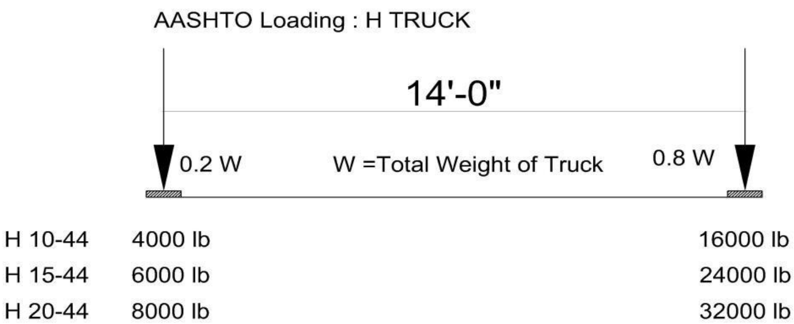

Figure 9 : AASHTO bridge design load-H Truck

2) Design Tandem and Design Lane Load

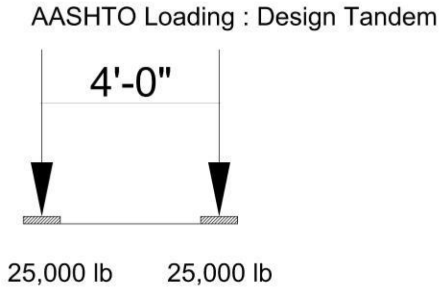

Figure 10 : AASHTO design tandem load

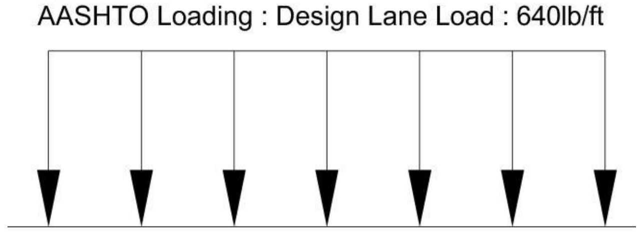

Figure 11 : AASHTO design lane load

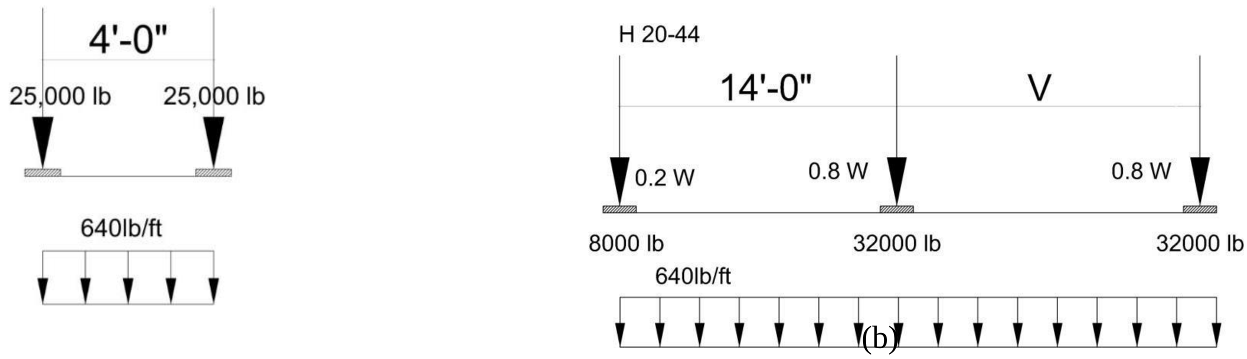

Figure 12 : (a) Design tandem load plus lane load and (b) Design truck load plus lane load

Figure 8 and Figure 9 represents the Design Truck for HS and H truck respectively [9]. Similarly, Design Tandem Load is represented in Figure 10 while Figure 11 denotes the Design Lane Load. The combination ofTruck Load or Tandem load with Lane load is as shown in Figure 12. For a design lane of twelve feet, the transverse spacing of Design Truck wheel is six foot. The design lane load consists of a load of 640 lb per foot uniformly distributed in the longitudinal direction. Transversely, the design lane load is assumed to be uniformly distributed over a ten-foot width. The combination having maximum influence on bridge was adopted for design process [10]. This standard load was proposed based on a research study by Transportation Research Board 1990 under the assistance-ship of US Department of Transportation, Federal Highway Administration. From load analysis, combination of two HS Truck 20-44 each having total weight of 72000 lb (32 ton approx.) and 8.53m in length with Design Lane load has greatest influence on double lanebridge.

B. Indian Road Congress Design Load

1) CLASS AA Tracked and Wheeled Vehicle Load

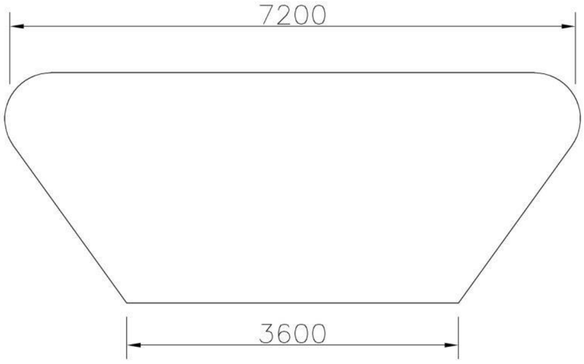

Figure 13 : Class AA tracked vehicle -70 ton

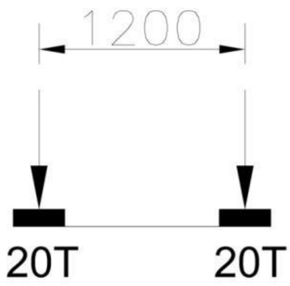

Figure 14 : Class AA wheeled vehicle-40 ton

2) CLASS A Vehicle Load

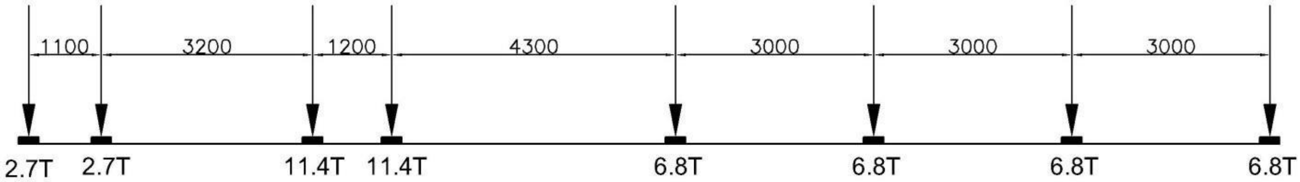

Figure 15 : Class A vehicle-55.4 ton

3) Class B Vehicle Load

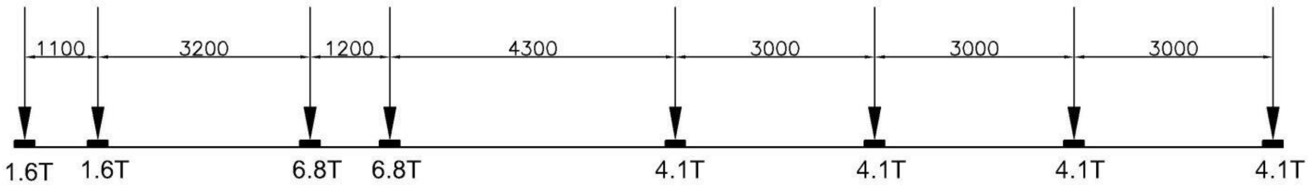

Figure 16 : Class B vehicle -33.2 ton

The above mentioned design vehicle load was approved by Indian Road Congress [11] as IRC 6:2000 “Standard Specification and Code of Practice for Road Bridge”. Figure 13 and Figure 14 represents the ClassAA Tracked and Wheeled Load respectively. On the other hand, Class A and Class B vehicle is shown in Figure 15 and Figure 16 respectively. From load combination analysis for double lane bridge, two Class A Vehicle having total 110.8 ton weight (55.4×2) and 20.3 m in length shows the greatest influence on bridge supports.

C. China bridge design load: JTG D60:2004

1) Traffic 20 Vehicle Load

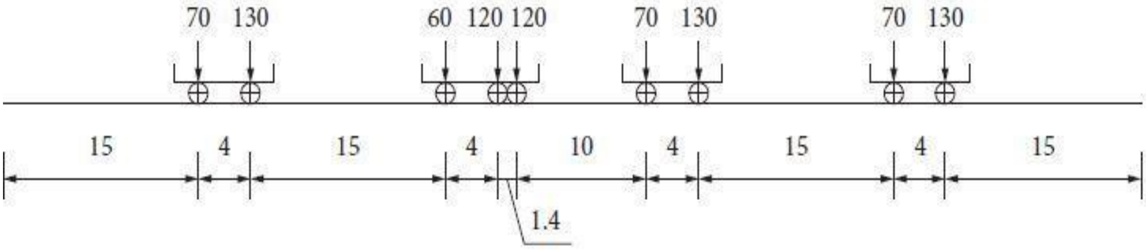

Figure 17: For highway grade II - Traffic 20: 900 kN

2) Traffic over 20 Vehicle Load

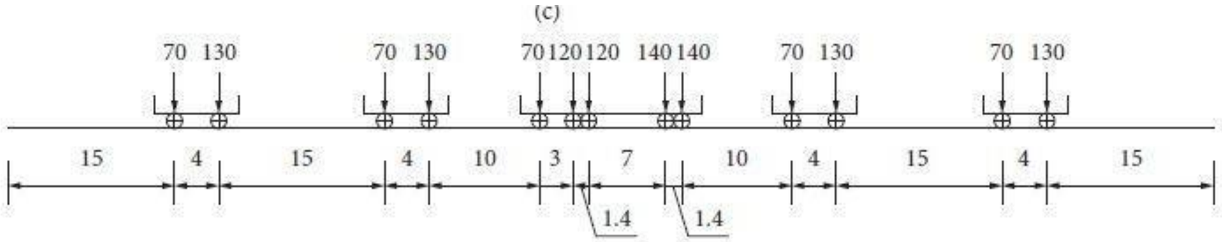

Figure 18 : For highway grade I - Traffic over 20 : 1390 kN

3) Standard Vehicle Load

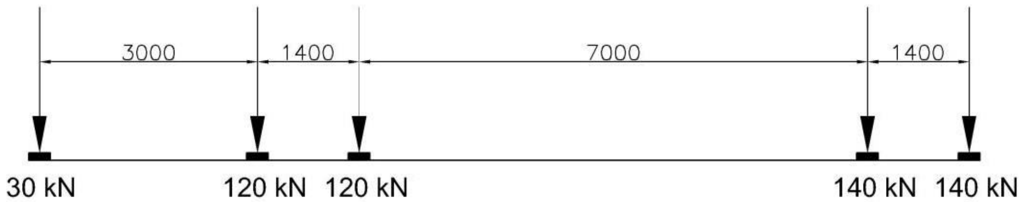

Figure 19 : Standard vehicle load-550 kN

The above mentioned vehicle load is adopted for highway bridge design in China. Different vehicle load are adopted for highway bridge design for different state. JTG D60:2004[12] was issued by Ministry of Housing and Urban Rural Development of People's Republic of China for consistent design. Figure 17 represent the Traffic 20 Vehicle for Highway Grade II while the Figure 18 represents the Traffic over 20 for Highway Grade I[13]. The Standard Vehicle[14] presented in Figure 19 seems to represents a part of Traffic over 20 Vehicle, generally USED for design of for short span bridge. From load analysis, Traffic over 20 Vehicle has greatest influence on bridge support than other load.

HEAVY CARGO TRANSPORTATION

For mega engineering projects and big power stations, shipment of heavy goods to construction site is unavoidable. Factors like truck axle, length of transporting vehicle, bridge type, terrain slope, radius of horizontal and vertical curve of road, etc play crucial role during transportation of heavy goods. In context ofour alignment, first they passes through Terai region and enter into the Hilly region. For plain region of Teraiup to Narayanghat, by-pass culvert using RCC Hume pipe or box culvert will be best option for transporting cargo regarding the small rivers and rivulets. For large river, propping under the existing bridge deck with help of coffer dam could be the alternative solution for cargo transportation. In context of Highway Bridge located in hilly region, propping to bridge deck can be a good option for accessible bridge. While increasing the number of truck axle i.e to increase the length of carrying truck will be best alternative solution for shipment in both regions. Self propelled modular transport are popular means to transport because of their power, stability, loading capacity, axle configuration, different axle type, control of axle, etc.

Figure 20 : Modular Trailer [15]

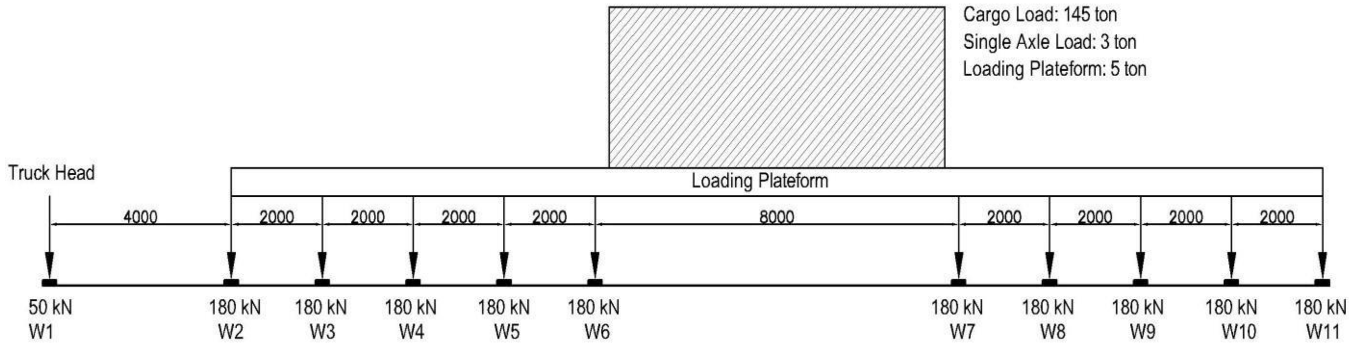

Figure 21: Schematic Diagram of Modular Train

From Bridge Design Load analysis, the maximum bending moment at mid-span and maximum shear forceat support due to JTG D60: 2004-traffic over 20 for 25 m span bridge is 4743.00 kNm and 837.92

kN respectively. From load carrying capacity, axle configuration and axle control characteristic of modular train,length of heavy cargo carrying truck could be easily increased and load can be distributed equally to all axles.The length of modular train presented in Figure 21 is 28 m and carries cargo of 145 ton. The maximum bending moment occurs when the load W6 is at mid-span of bridge. Likewise, maximum shear force occurs when W1 is just right to left support of bridge span. The maximum bending moment at mid-span and maximum shear force at support due to total modular train load of 185 ton is 4512.50 kNm and 726.8 kN respectively. Not only bending moment but also shear force due to modular train is less than that of JTG D60:2004. Thus, heavy cargos, having weight greater than bridge design vehicle load, could be transported easily through 25m span bridges with help of modular train.

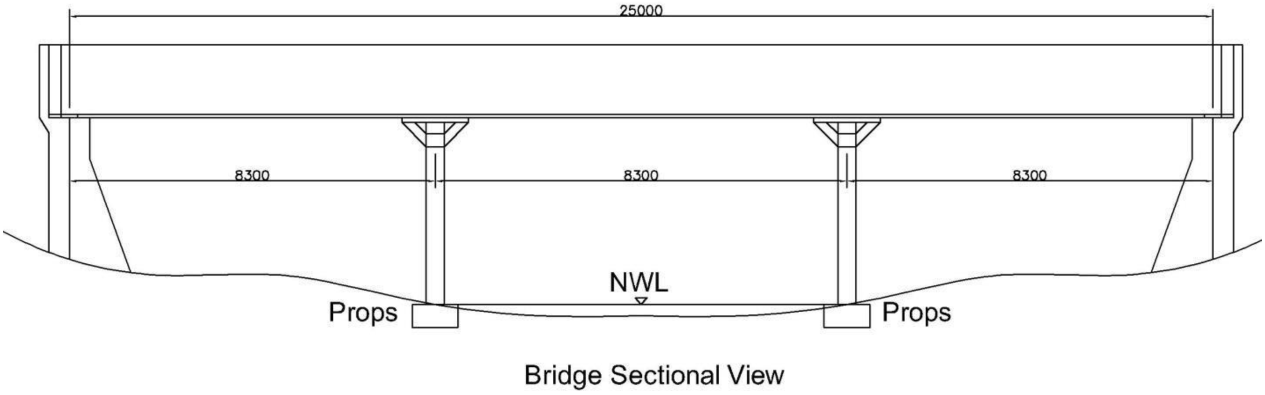

Figure 22: Schematic Diagram for Bridge Deck Proping

Even, propping to bridge deck also reduce the BM and shear force greatly. Propping the bridge deck near average water level reduce the bridge span. For instance, let the 25m bridge span is divided into the three portions of 8.3m. The maximum bending moment at mid-span and maximum shear force at support due to total modular train load of 185 ton is 580.50 kNm and 466.67 kN respectively. While, propping to the bridgedeck induce the negative BM about WL/10 at continuous support (approx 149.4 kNm). The minimum reinforcement provided for top reinforcement of deck slab easily compensates the induced negative BM too. Thus, heavy cargos could be easily transported.

CONCLUSION

From the vehicle load analysis presented by various national codes, critical load that can be safely transported through the bridge can be identified. Now, for transporting the heavy cargo greater than critical load, following method were presented for safe movement.

- According to AASHTO 1990 bridge loading, for double lane bridge having span less than 44 m, total truck load of 236,392.26 lb (approx 105.15 ton) having length not less than 8.53 m can pass safely through the selected alignment bridges. For span greater than 44m, loading can be increasing proportionately.

- As per IRC 6:2000 bridge loading, for double lane bridge having span less than 56.9 m, total truck load of 110.8 ton having length not less than 20.3 m can pass safely through the selected alignment bridges. For span greater than 56.9 m, loading can be increasing proportionately.
- According to JTG D60 : 2004, for double lane bridge having span less than 42.8 m, totaltruck load of 118 ton having length not less than 12.8 m can pass safely through the selected alignment bridges. For span greater than 42.8 m, Traffic over 20 Vehicle has greatest influence on bridge support.
- Both bending moment and shear force reduce significantly on increasing the length ofmodular truck used for heavy cargo transportation.
- Up to Narayanghat Section of selected alignment, by-pass culvert method and propping underthe bridge deck method would be the alternative method for transporting the heavy cargos.
- The common alignment from Narayanghat to Kathmandu passes through hilly region of Nepal. For such terrain, increasing the length of cargo with different axle configuration or propping under the bridge deck for accessible site can be alternative way for movement of heavy goods.

REFERENCES

[1] J. G. Kennedy, D. J. L ; Gagnon, D. P.; Allen, D. E.; MacGregor, "Canadian Highway BridgeEvaluation : Load and Resistance factors," 1992.

[2] S. H. Kim, W. H. Heo, D. woo You, and J. G. Choi, "Vehicle loads for assessing the required loadcapacity considering the traffic environment," *Appl. Sci.*, vol. 7, no. 4, 2017.

[3] Wang and T.-L. Liu, "Influence of Heavy Trucks on Highway Bridges," *Fatigue*, no. October 2000,pp. 4–5, 2000.

[4] A. S. Nowak, J. A. Laman, and H. Nassif, "Effect of truck loading on bridges." p. 371, 1994.

[5] B. Jacob and O. Labry, "Evaluation of the Effects of Heavy Vehicles on Bridges Fatigue," *7th Int.Symp. Heavy Veh. Weight. Dimens. Delet. Netherlands June 16 - 20. 2002*, pp. 185–194, 2002.

[6] V. H. Tran, "The impact effect of highway bridge due to heavy vehicle," *Eng. Progress, Nat. People*,no. April, pp. 3039–3046, 2014.

[7] F. Moses and D. Verma, "Load Capacity Evaluation of Existing Bridges.," *Natl. Coop. Highw. Res.Progr. Rep.*, no. 301, 1987.

[8] DOR, "List of Main Road of SRN," 2018.

[9] AASHTO, *Standard Specifications for Highway Bridges*, 17th Editi. American Association of StateHighway and Transportation Officials, Washington, D.C., 2002.

[10] Federal Highway Administration (FHWA), "Load and Resistance Factor Design," *Eng. J.*, vol. 18, no. 3, pp. 74–82, 2015.

[11] I. R. C. (IRC), *Standard Specification and Code of Practice for Road Bridges*, 4th Edition. 2000.

[12] J. D. 60, *General Specification for Design of Highway Bridge and Culvert*. Bei Jing:People's trafficpress, 2004.

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[13] Q. Gao, B. Wu, J. Li, K. Cui, and C. Xu, “Investigation of Traffic Loading Effects for DifferentCodes on Medium- And Small-Span Girder Bridges in China,” *Adv. Civ. Eng.*, vol. 2020, 2020.

[14] Y. Dai, “Study on Highway Bridge Vehicle Load Standard Value*,” no. Iccte, pp. 216–223, 2016.

[15] Www.anstertrailer.com, *Heavy Cargo Transportation*. .