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Wind Analysis of Bridges by Gust Load Factor Method

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ABSTRACT

Wind is a widespread and costly natural hazard to mankind. Adequate of wind effect in design is essential for the safety and economics of structure. Wind engineering is an emerging discipline. Even though there is vast amount of literature available in this field, it is dispersed in journals and technical reports that relate to the discipline of structural engineering, fluid dynamics, mechanical engineering, atmospheric sciences, and others. Because of this dispersion architects and engineers have difficulty in leaning and understanding problems associated with wind load. The bridges are made of different materials. Timber, masonry, concrete and steel are the primary materials which are most common in the design of bridges. The timber bridges are constructed only over small spans and for temporary purpose. The masonry bridges can also be used to cover only the small spans. The ratio of permissible stress to weight for masonry is fairly small and in spans larger than about 12 m the dead load of the masonry will make its use uneconomical.

Reinforced concrete is probably the most popular material for permanent highway bridges in India. Balanced cantilever bridges and pre stressed concrete girder bridges can be used for spans up to 60 m. Concrete arch has been used for spans of 200 m. In India for railway bridges steel is used for very small spans to very large spans. Bridges are built for many purposes e.g. carrying a highway, a railway track, for support of water pipes, gas or oil pipes etc. Nearly all important bridges are built primarily for purposes of carrying a highway or railway over a river, canal, another highway or railway or some other natural or artificial obstacle.

INTRODUCTION

The bridges are made of different materials. Timber, masonry, concrete and steel are the primary materials which are most common in the design of bridges. The timber bridges are constructed only over small spans and for temporary purpose. The masonry bridges can also be used to cover only the small spans. The ratio of permissible stress to weight for masonry is fairly small and in spans larger than about 12 m the dead load of the masonry will make its use uneconomical. Reinforced concrete is probably the most popular material for permanent highway bridges in India. Balanced cantilever bridges and pre stressed concrete girder bridges can be used for spans up to 60 m. Concrete arch has been used for spans of 200 m. In India for railway bridges steel is used for very small spans to very large spans. Bridges are built for many purposes e.g. carrying a highway, a railway track, for support of water pipes, gas or oil pipes etc. Nearly all important bridges are built primarily for purposes of carrying a highway or railway over a river, canal, another highway or railway or some other natural or artificial obstacle.

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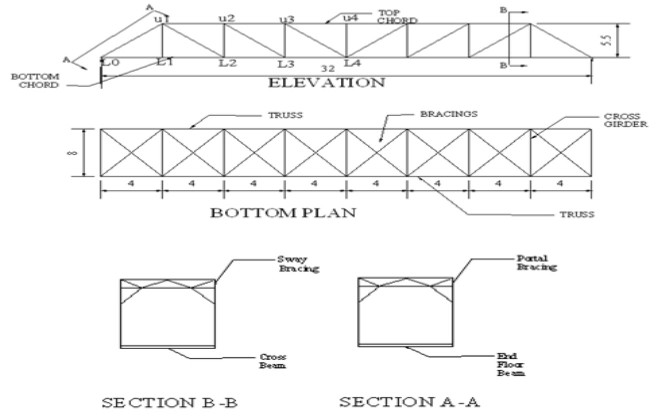
GENERAL ARRANGEMENT

For spans greater than what can be spanned economically by the plate girder bridges, we use truss bridges. It is difficult to draw a demarcating line in the lengths of the span above which the plate girders will not be economical. For the same weight a plate girder may be economical due to smaller cost of fabrication. Roughly, a truss bridge should be used for spans greater than about 30 m.

There are three types of truss bridges (a) through type (b) deck type and (c) half-through bridge.

The general arrangement of different members in a through truss bridge is shown in Fig. 1.1. Top and bottom chord members form a flange system. The diagonal and vertical members form the web system of the truss. The end members of the truss form a part of the web and these are called end posts. The points of intersection of web members (diagonals and verticals) with chord members are called panel points. The corresponding lower panel points of the two trusses are joined by girders, called cross beams or floor beams. These floor beams support stringers which run parallel to the length of the truss. In the railway bridge, the sleepers rest directly on the stringers. The ballast may be laid on steel or concrete decking supported by stringers



General arrangement or through bridge

In addition to the vertical loads, a bridge is subjected to lateral forces due to wind, seismic and racking forces. To transfer these lateral forces to bearings, laterals are used at the level of bottom and top chords. Along with the bottom chord members, bottom laterals form a truss which can transfer lateral loads to bearings. The similar truss formed at the level of top chords can transfer the lateral loads acting on it to the top of the end posts. For obvious reasons, the diagonal members cannot be provided in the end diagonal panel and the load must be transferred from top of end posts to bearings by the portal action. The bracing provided in the plane of the end posts is called the portal bracing. Similar to portal bracing, sway bracing is used in the planes of corresponding verticals of the two trusses. The sway bracing keeps the rectangular shape of the bridge cross-section. The specifications differ in the recommendation regarding the loads to be taken by the sway bracing. The 'Steel Bridge Code' recommends that the sway bracing between the vertical web members shall be proportioned to transmit to the lower chords, through web members, at least 50% of the top panel wind load. The portal and sway bracings should have maximum depth permissible with the required head room.

The spacing between centers of the main girders should be sufficient to resist overturning with the specified wind pressures and loading conditions, otherwise provision should be made to prevent this. In any case, the spacing should not be less than $1/20^{th}$ of the effective span and also not less than one-third of the height of the main girders.

The arrangement of different parts in a deck-truss bridge is exactly similar to the arrangement in a deck plate girder bridge except that the plate girder is replaced by a truss. The flanges of the girder are analogous to chord members and web is replaced by verticals and diagonals. No portal or sway bracings are required but instead cross-frames are used. There are some advantages in using deck truss bridge as compared to through bridge. The cost of the floor is smaller in a deck bridge because smaller cross-beams are required. Height of piers is shorter. Additional cost of higher approaches required for the deck bridge usually off-sets the other advantages of the deck bridge.

WIND FORCES ON THROUGH BRIDGES

The wind forces will be acting on the moving train on the bridge and also on he exposed area of the trusses. In computing the exposed area of the truss, full area of projection of windward truss not converted by train or stringers plus half the area of projection of leeward truss not covered by train or stringers is used.

The following effects of wind pressure are to be considered.

(1) Lateral effect on top lateral bracing.
(2) Lateral effect on bottom lateral bracing.
(3) Overturning effect.
(4) Bending and direct stresses in the members transmitting the wind load from the top to the bottom chords or vice-versa i.e. in Sway Bracing and Portal Bracing.

The wind load that acts on a bridge has to be transferred to the bearings by the truss members and the lateral bracing. A part of the wind load can be assumed to be acting at the panel points of the top lateral truss and the remaining on the panel points of the lower lateral truss. The wind load acing on the truss members above the moving load will be assumed to be acting on the top lateral truss and the remaining on the bottom and also some additional stresses in top and bottom chords as these form the chord members of the lateral trusses.

LITERATURE REVIEW

The detailed literature survey for the project work has been carried out. It includes in brief the history of development of the wind and their origin. The work regarding the latest additional development has been carried out. The various technical papers published in journals concerning the project topic have been studied.
Dan Lungu, Pieter van Gelder and Romeo Trandafir[14] et al. (2000) presented a comparative study of basic parameters involved in prediction of the wind loads with Euro code 1, ISO DIS 4354 and ASCE 7 standards. The parameters compared are reference wind velocity, exposure factor, turbulence intensity, gust factor.

Xinzhong Chen & Ahsan Kareem[2] et al. (1999) expressed the equations of bridge motion in a frequency independent state-space format by introducing frequency dependent unsteady self-excited forces in terms of rational functions. It is applied to the coupled multi-mode flutter analysis of long span bridges through the solution of a line complex eigen value problem. The contribution of aerodynamic coupling among modes and the contribution of each self-excited force component along the bridge axis to the system damping are identified. The coupling effects on the buffeting response are also discussed.

K.Aas-Jakobsen Jr. and E.Strommen[11] et al. (1999) post calculated buffeting and vortex shedding response measured on a concrete box girder during the construction stage. The bridge has a main span of 298m. Wind tunnel tests suggest that vertical oscillations are primarily caused by vortex shedding. A procedure for calculating vortex shedding response in the frequency and time domain is suggested. Comparison with full-scale measurements shows encouraging results.

OVERVIEW OF WIND STANDARDS

GENERAL

In this wind load clauses covered in IS: 875(Part 3) – 1987, AUS/NZS 1170.2:2000, IRC:6-2000 and bridge rules are overviewed.

IS: 875(PART 3) – 1987 Code of practice for design loads (other than earthquake) for buildings and structures Part3

WIND LOADS

The Sectional Committee responsible for the preparation of this standard has taken into account the prevailing practice in regard to loading standards followed in this country by the various authorities and has also taken note of the developments in a number of other countries. In the preparation of this code, the following overseas standards have also been examined:

a) BSCP 3: 1973 Code of basic data for design of buildings: Chapter V Loading, Part 2 Wind loads.
b) AS 1170, Part2- 1983 SAA Loading code Part 2 - Wind forces.
c) NZS 4203- 1976 Code of practice for general structural design loading for buildings.
d) ANSIA58.1- 1972 American Standard Building code requirements for minimum design loads in buildings and other structures.
e) Wind resistant design regulations, A World List. Association for Science Documents Information, Tokyo.

COMPARISON OF IRC: 6-2000 AND IS: 875(PART 3)-1987

In this a comparison of IRC: 6-2000 and IS:875(PART 3)-1987 has been done. The factors considered for comparison are calculation of wind load, wind zones and wind pressure

WIND LOAD

According to IRC:6-2000 the total wind load on bridge is given by

Wind load=(wind pressure) x (obstruction area in elevation)

The obstruction area is given below

1. Deck type bridges: Area of structure seen in elevation.

2. Through type bridges: Area of elevation of wind-ward truss plus half area of elevation of all other trusses

According to IS: 875(PART 3)-1987

Wind load= (wind pressure) x (obstruction area in elevation) x C_f

Where C_f is force coefficient

WIND ZONES

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According to IRC:6-2000 the entire country is given two wind zones

1. Coastal zone along the northern coast of Andhra Pradesh, Orissa, West Bengal, and on the west coast Kathiawar Peninsula (Gujarat).This is high wind zone.

2. Normal wind zone other than that specified above.

According to IS:875(PART 3)-1987 the entire country is given six zones

WIND PRESSURE

Procedure for calculating wind pressure as per IS:875(PART 3)-1987

$p_z=0.6V_z^2$ (clause 5.4)

Where p_z=Design wind pressure in N/m^2 at height z

V_z=Design wind velocity in m/s at height z

$V_z=V_b k_1 k_2 k_3$

Where V_b=basic wind speed in m/s (Fig.3.1)

k_1=risk coefficient

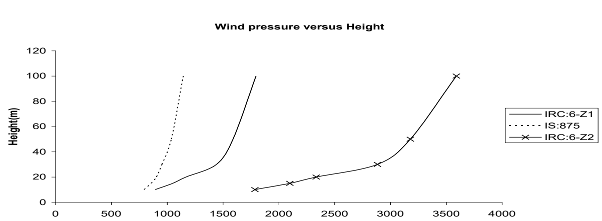
k_2=terrain height and structure size factor

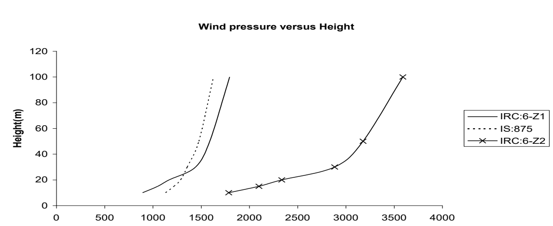
k_3=topography factor.

VARIATION OF WIND PRESSURE WITH HEIGHT

In this section a comparison of wind pressure given by IRC:6-2000 and IS:875(PART 3)-1987. For this purpose a graph of height versus wind pressure is plotted. According to IRC:6-2000 the entire country is given two wind zones. For these two wind zones the graph of variation of wind pressure with respect to height is plotted. On the same graph pressure calculated according to IS:875(PART 3)-1987 is plotted.

- IS:875(PART 3)-1987 divides the country into six wind zones.
- For each wind zone the graph of height versus intensity is plotted.
- Basic wind speed is taken for all the six wind zones.
- The value of k_1 is taken for mean probable design life of 100 years.
- The value of k_2 is taken for terrain category 1, class A building. .
- The value of k_3 is taken as 1(upwind slope less than 3^0).





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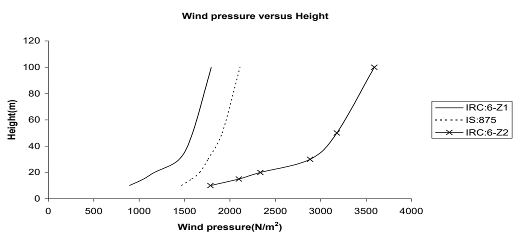
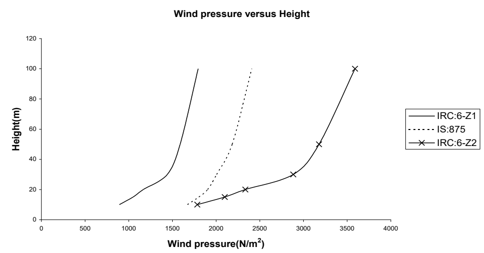
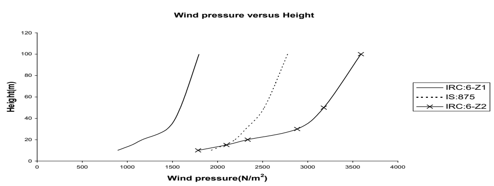
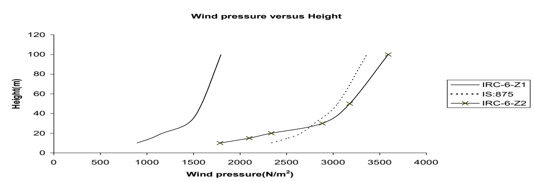
Wind pressure versus height for basic wind speed 33 m/s   wind pressure versus height for basic wind speed 39 m/





Wind pressure versus height for basic wind speed 44 m/s   Wind pressure versus height for basic wind speed 47 m/s





Wind pressure versus height for basic wind speed 50 m/s   Wind pressure versus height for basic wind speed 55 m/s

ANALYSIS OF 32 M SPAN ROAD BRIDGE

Data:

Span of bridge = 32.00 m

Center to centre spacing of truss = 8.00 m

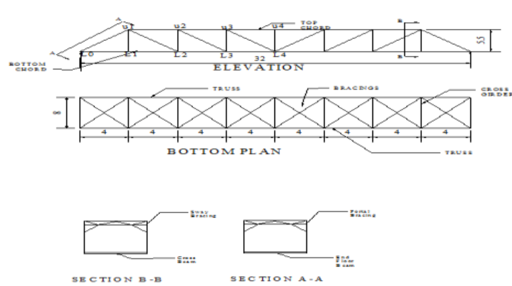
Panel length = 4.00 m

Height of truss = 5.50 m

Members	Wind (kN)

Design wind pressure = 150.00 Kg/m^2

Moving load = two lanes of Class A



Details of 32 m span Road Bridge

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	Bottom	Top	Overturning	Portal	Sway
U_1U_2		±4.35	±21.82		
U_2U_3		±0.57	±27.27		
U_3U_4		±3.78	±29.09		
U_1L_1			±5.00		±1.21
U_2L_2			±7.50		±1.21
U_3L_3			±2.50		±1.21
U_4L_4			±0		±1.21
L_0L_1	±19.20		±12.72	±3.61	
L_1L_2	±4.06		±12.72	±3.61	
L_2L_3	±8.66		±21.82	±3.61	
L_3L_4	±14.6		±27.27	±3.61	
U_1L_0			±21.63	±6.14	
U_1L_2			±15.45		
U_2L_3			±9.27		

Force in Members

Member	Dead Load (kN)		Live Load (kN)		Wind Load (kN)
	Compression	Tension	Compression	Tension	
U_1U_2	1035.00		943.00		± 34.00
U_2U_3	1294.00		1155.00		±41.00
U_3U_4	1380.00		1166.00		±45.00
U_1L_1		151.00		269.00	±4.00
U_2L_2	226.50		291.00	43.00	±8.00
U_3L_3	75.00		198.00	86.00	±3.00
U_4L_4	0	0	0	0	±0.00
L_0L_1		603.90		561.00	±9.00
L_1L_2		603.90		561.00	±9.00
L_2L_3		1035.00		943.00	±5.00
L_3L_4		1294.00		1155.00	±14.00
U_1L_0	802.60		745.00		±26.00
U_1L_2		573.00	22.00	582.00	±19.00
U_2L_3		344.10	65.00	441.00	±12.00
U_3L_4		114.70	131.00	300.00	±4.00

ANALYSIS OF 32 M SPAN RAILWAY BRIDGE

Data:

Span of bridge = 32.00 m

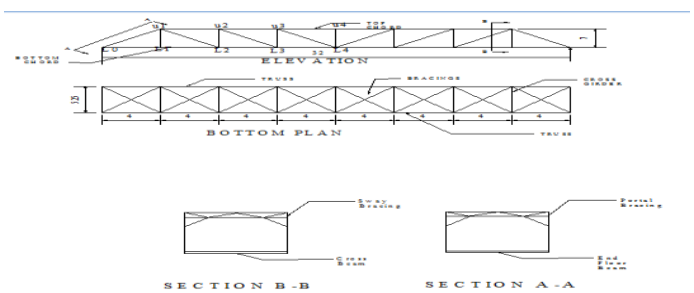
Center to centre spacing of truss = 5.25 m

Panel length = 4.00m

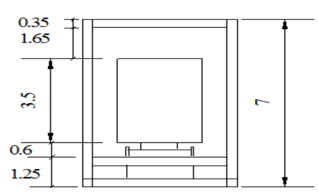
Height of truss = 7.00 m

Design wind pressure = 150.00 Kg/m^2

Moving load = Broad gauge loading



Details of 32 m span Railway Bridge



Details of area exposed

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Details of area exposed	Top chord(m^2)	Bottom chord(m^2)
1.Projected area of stringers and track upto rail level=1.25 x 32		40.00
2.Area above rail level and below moving load		
a. Verticals= 0.25 x 0.6 x 7		1.05
b. Diagonals = 0.3 x 0.79 x 6		1.42
c.End post = 0.35 x 0.79 x 2		0.53
3.Top chord = 24 x 0.35	8.40	
4.Area above moving load and below top chord		
a. Verticals= 0.25 x 1.6 x 7	2.89	
b. Diagonals = 0.3 x 2.17 x 6	3.91	
c.End post = 0.35 x 2.17 x 2	1.52	
5.Gussets @ 20% of top chord area	1.68	
TOTAL	18.40	43.02

Exposed area of moving load = 3.5 x 32
= 112 m^2

Wind load on top chord = 1.5 (18.4 x 1.5)
= 41.4 kN

Wind load on Bottom chord =1.5(112+1.5x43.025)=176.54 kN

Bottom laterals:

Load on each node = 176.54/8 = 22.06 kN

Top laterals:

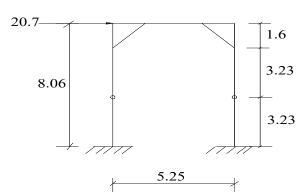
Load on each node = 41.4/6 = 6.9 kN

Overturning effect

Details	Force due to wind(kN)	Lever arm above bottom bracing(m)	Moment (kN-m)
1.Stringer load track etc.	1.5x 43.025x1.5=96.80	0.62	60.50
2.Moving load	112 x 1.5 = 168.00	3.60	604.80
3.Top chord	1.5x 18.4 x 1.5 =41.40	7.17	297.05
		TOTAL =	962.35

Wind load per panel point = $\dfrac{962.35}{5.25x8}$ =23.00 kN

Portal effect



Portal frame

Additional load in each end post = $\dfrac{20.7(3.23+1.6)}{5.25}$

=19.04

Additional load in bottom chord = $\dfrac{19.04\times 4}{8.06}$

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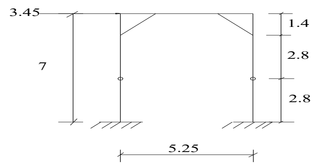
Sway effect



Sway frame

$$\text{Additional force in verticals} = \frac{3.45(1.4+2.8)}{5.25} = 2.73$$

After analyzing the following member forces are obtained

Member forces

Members	Dead (kN)		Live+Imp(kN)		Wind (kN)				
	Comp	Ten	Comp	Ten	Bottom	Top	Overturning	Portal	Sway
U_1U_2	138.00		910.00			±8.23	±79.00		
U_2U_3	172.00		1132.00			±17.52	±99.00		
U_3U_4	182.00		1206.00			±23.00	±106.00		
U_1L_1		40.00		505.00			±23.00		±2.76
U_2L_2	60.00		567.00	226.00			±35.00		±2.76
U_3L_3	20.00		377.00	242.00			±11.00		±2.76
U_4L_4	0.00	0.00	0.00	0.00			±0.00		±2.76
L_0L_1		80.00		529.00	±36		±46.00	±9.44	
L_1L_2		80.00		529.00	±82		±46.00	±9.44	
L_2L_3		138.00		910.00	±116		±79.00	±9.44	
L_3L_4		172.00		1132.00	±132		±99.00	±9.44	
U_1L_0	162.00		1058.00				±93.00	±19.04	
U_1L_2		116.00	48.00	837.00			±67.00		
U_2L_3		70.00	253.00	629.00			±40.00		
U_3L_4		23.00	279.00	430.00			±14.00		

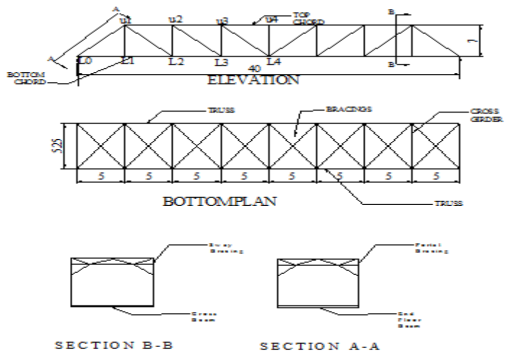
Member area required

Members	DL+LL+IL(kN)		DL+LL+IL+WL(kN)		Area(mm^2)	
	Comp	Ten	Comp	Ten	Without wind	With wind
U_1U_2	1048.00		1136.00		8733.00	7118.00
U_2U_3	1304.00		1421.00		10867.00	8904.00
U_3U_4	1388.00		1517.00		11567.00	9505.00
U_1L_1		545.00		574.00	3633.00	2877.00
U_2L_2	627.00	226.00	668.00	267.00	5255.00	4185.00
U_3L_3	397.00	242.00	414.00	259.00	3333.00	2593.00
U_4L_4	0	0	0	0.00		
L_0L_1		609.00		701.00	4060.00	3514.00
L_1L_2		609.00		747.00	4060.00	3745.00
L_2L_3		1048.00		1253.00	6986.00	6281.00
L_3L_4		1304.00		1545.00	8693.00	7744.00
U_1L_0	1220.00		1333.00		10167.00	8353.00
U_1L_2	48.00	953.00	115.00	1020.00	6353.00	5113.00
U_2L_3	253.00	699.00	293.00	739.00	4660.00	3704.00
U_3L_4	279.00	453.00	293.00	467.00	3020.00	2314.00

ANALYSIS OF 40 M SPAN RAILWAY BRIDGE

Data:

Span of bridge = 40.00 m
Center to centre spacing of truss = 5.25 m
Panel length = 5.00 m
Height of truss = 7.00 m
Design wind pressure = 150.00 Kg/m^2
Moving load = Broad gauge loading



Details of 40 m span Railway Bridge

Details of area exposed

Details of area exposed	Top chord(m^2)	Bottom chord(m^2)
1.Projected area of stringers and track upto rail level=1.25 x 40		50.00
2.Area above rail level and below moving load		
a. Verticals= 0.25 x 0.6 x 7		1.05
b. Diagonals = 0.3 x 0.74 x 6		1.33
c.End post = 0.35 x 0.74 x 2		0.51
3.Top chord = 30 x 0.35	10.5	
4.Area above moving load and below top chord		
a. Verticals= 0.25 x 1.65 x 7	2.89	
b. Diagonals = 0.3 x 2.03x 6	3.65	
c.End post = 0.35 x 2.03 x 2	1.42	
5.Gussets @ 20% of top chord area	2.1	
TOTAL	20.56	52.9

Exposed area of moving load = 3.5 x 40

= 140.00 m^2

wind load on top chord = 1.5 (20.56x 1.5)

= 46.26 kN

Bottom laterals:

Load on each node = 41.13 kN

Top laterals:

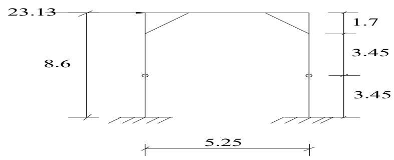
Load on each node = 7.71 kN

Overturning effect

Details	Force due to wind(kN)	Lever arm above bottom bracing(m)	Moment (kN-m)
1.Stringer load track etc.	1.5x 52.9x1.5=96.8	0.625	74.39
2.Moving load	140 x 1.5 = 168	3.60	756.00
3.Top chord	1.5x 20.56 x 1.5 =41.4	7.175	332.00
		TOTAL =	1162.39

Wind load per panel point = $\frac{1162.39}{5.25x8}$ =28.00 kN

Portal effect



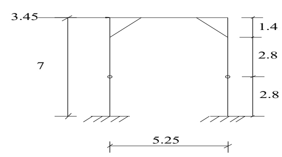
Portal frame

Additional load in each end post = $\dfrac{23.13(3.45+1.7)}{5.25}$

= 22.68 kN

Additional load in bottom chord = $\dfrac{22.68\times 5}{8.6}$ =13.18 kN

Sway effect



Sway frame

Additional force in verticals= $\dfrac{3.45(1.4+2.8)}{5.25}$

=3.08 kN

Members forces

Members	Dead (kN)		Live+Imp(kN)		Wind (kN)				
	Comp	Ten	Comp	Ten	Bottom	Top	Overturning	Portal	Sway
U_1U_2	215.00		1235.00			±8.00	±120.00		
U_2U_3	268.00		1554.00			±24.00	±150.00		
U_3U_4	286.00		1753.00			±31.00	±160.00		
U_1L_1		50.00		553.00			±28.00		±3.08
U_2L_2	75.00		612.00	153.00			±42.00		±3.08
U_3L_3	25.00		436.00	273.00			±14.00		±3.08
U_4L_4	0.00	0.00	0.00	0.00			±0.00		±3.08
L_0L_1		125.00		675.00	±82		±70.00	±13.18	
L_1L_2		125.00		675.00	±193		±70.00	±13.18	
L_2L_3		215.00		1235.00	±274		±120.00	±13.18	
L_3L_4		268.00		1556.00	±314		±150.00	±13.18	
U_1L_0	216.00		1319.00				±121.00	±22.68	
U_1L_2		154.00	63.00	1005.00			±87.00		
U_2L_3		93.00	189.00	745.00			±52.00		
U_3L_4		31.00	332.00	534.00			±18.00		

Member area required

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Members	DL+LL+IL(kN)		DL+LL+IL+WL(kN)		Area(mm²)	
	Comp	Ten	Comp	Ten	Without wind	With wind
U_1U_2	1450.00		1578.00		12083.00	9888.00
U_2U_3	1823.00		1996.00		15183.00	12506.00
U_3U_4	2039.00		2230.00		16991.00	13973.00
U_1L_1		603.00		634.00	4020.00	3178.00
U_2L_2	687.00	153.00	732.00	198.00	5725.00	4586.00
U_3L_3	461.00	273.00	478.00	290.00	3841.00	2995.00
U_4L_4	0.00	0.00	0.00	0.00		
L_0L_1		800.00		966.00	5333.00	4843.00
L_1L_2		800.00		1077.00	5333.00	5398.00
L_2L_3		1450.00		1858.00	9666.00	9314.00
L_3L_4		1822.00		2300.00	12147.00	11528.00
U_1L_0	1535.00		1679.00		12791.00	10520.00
U_1L_2	63.00	1159.00	150.00	1246.00	7726.00	6246.00

ANALYSIS OF 50 M SPAN RAILWAY BRIDGE

Data:

Span of bridge = 50.00 m

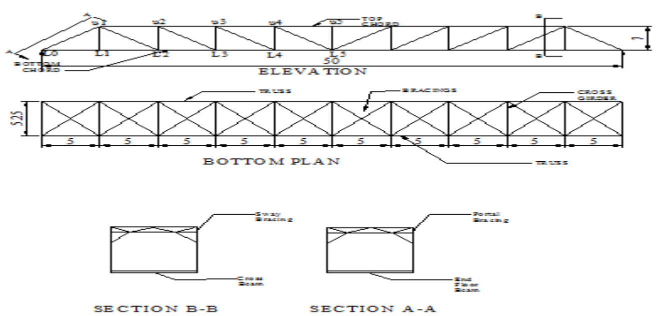
Center to centre spacing of truss = 5.25 m

Panel length = 5.00 m

Height of truss = 7.00 m

Design wind pressure = 150.00 Kg/m^2

Moving load = Broad gauge loading



Details of 50 m span Railway Bridge

Members forces

Members	Dead (kN)		Live+Imp(kN)		Wind (kN)				
	Comp	Ten	Comp	Ten	Bottom	Top	Overturning	Portal	Sway
U_1U_2	286.00		1439.00			±11.00	±160.00		
U_2U_3	375.00		1657.00			±34.00	±210.00		
U_3U_4	429.00		1957.00			±48.00	±240.00		
U_4U_5	447.00		2573.00			±55.00	±250.00		
U_1L_1		50.00		553.00			±28.00		±3.00
U_2L_2	125.00		843.00	118.00			±70.00		±3.00
U_3L_3	75.00		648.00	216.00			±42.00		±3.00
U_4L_4	25.00		487.00	341.00			±14.00		±3.00
U_5L_5	0.00	0.00	0.00	0.00			±0.00		
L_0L_1		161.00		773.00	±204.00		±90.00	±18.00	
L_1L_2		161.00		773.00	±356.00		±90.00	±18.00	
L_2L_3		286.00		1439.00	±474.00		±160.00	±18.00	
L_3L_4		375.00		1657.00	±554.00		±210.00	±18.00	
L_4L_5		429.00		1957.00	±595.00		±240.00	±18.00	
U_1L_0	276.00		1590.00				±155.00	±29.57	
U_1L_2		216.00	50.00	1294.00			±121.00		
U_2L_3		154.00	150.00	1033.00			±86.00		
U_3L_4		93.00	260.00	789.00			±52.00		
U_4L_5		31.00	419.00	594.00			±18.00		

Member area required

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Members	DL+LL+IL(kN)		DL+LL+IL+WL(kN)		Area(mm²)	
	Comp	Ten	Comp	Ten	Without wind	With wind
U_1U_2	1725.00		1896.00		14375.00	11879.00
U_2U_3	2032.00		2276.00		16933.00	14261.00
U_3U_4	2386.00		2674.00		19883.00	16755.00
U_4U_5	3020.00		3325.00		25166.00	20833.00
U_1L_1		603.00		634.00	4020.00	3187.00
U_2L_2	968.00	118.00	1041.00	191.00	8066.00	6523.00
U_3L_3	723.00	216.00	768.00	261.00	6025.00	4812.00
U_4L_4	512.00	341.00	529.00	358.00	4266.00	3315.00
U_5L_5	0.00	0.00	0.00	0.00		
L_0L_1		934.00		1246.00	6226.00	6246.00
L_1L_2		934.00		1398.00	6226.00	7008.00
L_2L_3		1725.00		2377.00	11500.00	11915.00
L_3L_4		2032.00		2814.00	13546.00	14106.00
L_4L_5		2386.00		3239.00	15906.00	16235.00
U_1L_0	1866.00		2051.00		15550.00	12851.00
U_1L_2	50.00	1510.00	171.00	1631.00	10066.00	8175.00

Effect of Wind on Various Configurations of Truss

Analysis of Pratt truss

Data:

Span of bridge = 50.00 m

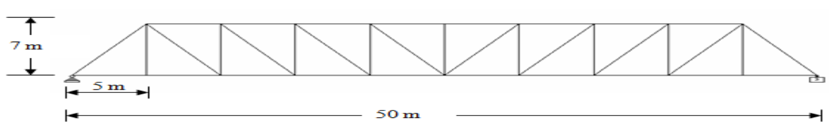
Center to centre spacing of truss = 5.25 m

Panel length = 5.00 m

Height of truss = 7.00 m

Design wind pressure = 150.00 Kg/m^2

Moving load = Broad gauge loading



Details of Pratt truss

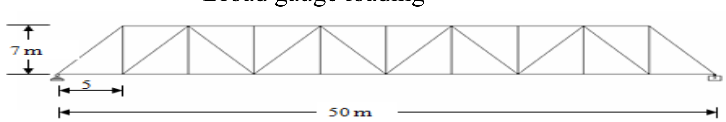
Member area required

Members	DL+LL+IL(kN)		DL+LL+IL+WL(kN)		Area(mm²)	
	Comp	Ten	Comp	Ten	Without wind	With wind
U_1U_2	1725.00		1896.00		14375.00	11879.00
U_2U_3	2032.00		2276.00		16933.00	14261.00
U_3U_4	2386.00		2674.00		19883.00	16755.00
U_4U_5	3020.00		3325.00		25166.00	20833.00
U_1L_1		603.00		634.00	4020.00	3187.00
U_2L_2	968.00	118.00	1041.00	191.00	8066.00	6523.00
U_3L_3	723.00	216.00	768.00	261.00	6025.00	4812.00
U_4L_4	512.00	341.00	529.00	358.00	4266.00	3315.00
U_5L_5	0.00	0.00	0.00	0.00		
L_0L_1		934.00		124.60	6226.00	6246.00
L_1L_2		934.00		1398.00	6226.00	7008.00
L_2L_3		1725.00		2377.00	11500.00	11915.00
L_3L_4		2032.00		2814.00	13546.00	14106.00
L_4L_5		2386.00		3239.00	15906.00	16235.00
U_1L_0	1866.00		2051.00		15550.00	12851.00
U_1L_2	50.00	1510.00	171.00	1631.00	10066.00	8175.00
U_2L_3	150.00	1187.00	236.00	1273.00	7913.00	6381.00
U_3L_4	260.00	882.00	312.00	914.00	5880.00	4582.00
U_4L_5	419.00	625.00	437.00	643.00	4166.00	3223.00

Steel required = 37.15 tonne

- **Analysis of warren (with vertical support) truss**

Data:
Span of bridge = 50.00 m
Center to centre spacing of truss = 5.25 m
Panel length = 5.00 m
Height of truss = 7.00 m
Design wind pressure = 150.00 Kg/m^2
Moving load = Broad gauge loading



Details of Warren (with vertical support) truss

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Member area required

Members	DL+LL+IL(kN)		DL+LL+IL+WL(kN)		Area(mm²)	
	Comp	Ten	Comp	Ten	Without wind	With wind
U_1U_2	971.00		1072.00		8092.00	6717.00
U_2U_3	2157.00		2378.00		17975.00	14899.00
U_3U_4	2195.00		2409.00		18292.00	15094.00
U_4U_5	2532.00		2780.00		21100.00	17419.00
L_0L_1		943.00		1267.00	6287.00	6350.00
L_1L_2		1632.00		2178.00	10880.00	10917.00
L_2L_3		1667.00		2313.00	11113.00	11594.00
L_3L_4		2420.00		3206.00	16133.00	16070.00
L_4L_5		2439.00		3166.00	16260.00	15869.00
U_1L_1		1580.00		1716.00	10533.00	8602.00
U_2L_2	10.64	261.00	36.74	287.00	1740.00	1439.00
U_3L_3	0.00	0.00	3.00	3.00		
U_4L_4	9.12	255.00	33.12	279.00	1700.00	1398.00
U_5L_5	0.00	0.00	25.00	2.5.00		
U_1L_0	1950.00		2130.00		16250.00	13346.00
U_2L_1	1437.00	27.80	1569.00	159.80	11975.00	9831.00
U_2L_3	65.00	1189.00	155.00	1279.00	7927.00	7000.00
U_4L_3	777.00	203.00	829.20	256.00	6475.00	5194.00
U_4L_5	304.00	588.00	322.00	606.00	3920.00	3038.00

❖ **Analysis of Warren (without vertical support) truss**

Data:

Span of bridge = 50.00 m

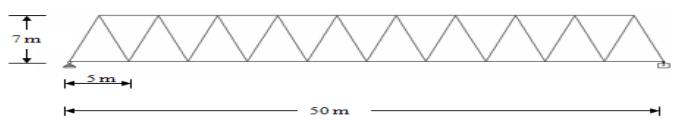
Center to centre spacing of truss = 5.25 m

Panel length = 5.00 m

Height of truss = 7.00 m

Design wind pressure = 150.00 Kg/m^2

Moving load = Broad gauge loading



Details of Warren (without vertical support) truss

Member area required

Steel required = 39.00 tonne

Members	DL+LL+IL(kN)		DL+LL+IL+WL(kN)		Area(mm²)	
	Comp	Ten	Comp	Ten	Without wind	With wind
U_1U_2	913.00	0.00	1013.00	0.00	76089.00	6347.00
U_2U_3	1677.00	0.00	1847.00	0.00	13975.00	11572.00
U_3U_4	2138.00	0.00	2356.00	0.00	17817.00	14762.00
U_4U_5	2476.00	0.00	2721.00	0.00	20634.00	17049.00
U_5U_6	2494.00	0.00	2747.00	0.00	20784.00	17212.00
L_1L_2	0	465.00	0.00	803.00	3100.00	4025.00
L_2L_3	0	1297.00	0.00	1793.00	8647.00	8987.00
L_3L_4	0	1913.00	0.00	2409.00	12754.00	12075.00
L_4L_5	0	2307.00	0.00	3084.00	15380.00	15459.00
L_5L_6	0	2495.00	0.00	3247.00	16635.00	16275.00
U_1L_1	1618.00	0.00	1772.00	0.00	13483.00	11103.00
U_1L_2		1623.00	0.00	1769.40	10820.00	8867.00
U_2L_2	1352.00	101.27	1469.00	126.93	11267.00	9204.00
U_2L_3	6.80	1353.00	116.96	1463.16	9020.00	7333.00
U_3L_3	947.20	79.00	1029.00	160.72	7894.00	6447.00
U_3L_4	79.00	947.20	155.00	1023.00	6315.00	5127.00
U_4L_4	762.00	142.00	811.00	191.00	6350.00	5081.00
U_4L_5	142.00	762.00	187.00	807.00	5080.00	4045.00
U_5L_5	442.00	310.00	460.00	328.00	3683.00	2882.00
U_5L_6	310.00	442.00	324.00	456.00	2947.00	2286.00

❖ **Analysis of Baltimore truss**

Data:

Span of bridge = 50.00 m

Center to centre spacing of truss = 5.25 m

End Panel length = 5.00 m

Intermediate panel = 4.00 m

Height of truss = 7.00 m

Design wind pressure = 150.00 Kg/m^2

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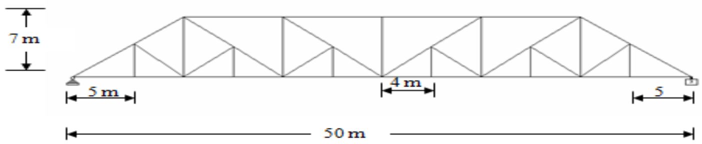
Moving load = Broad gauge loading



Details of Baltimore truss

Member area required

Members	DL+LL+IL(kN)		DL+LL+IL+WL(kN)		Area(mm²)	
	Comp	Ten	Comp	Ten	Without wind	With wind
U_1U_2	1876.00	0.00	2135.00	0.00	15633.00	13377.00
U_2U_3	2101.00	0.00	2377.00	0.00	17508.00	14894.00
L_1L_2	0.00	1623.00	0.00	1934.00	10820.00	9694.00
L_2L_3	0.00	1833.00	0.00	2393.00	12220.00	11995.00
L_3L_4	0.00	1778.00	0.00	2336.00	11854.00	11714.00
L_4L_5	0.00	1797.00	0.00	2299.00	11980.00	11524.00
L_5L_6	0.00	2588.00	0.00	3407.00	17253.00	17077.00
L_6L_7	0.00	2607.00	0.00	3362.00	17380.00	16852.00
U_1M_1	2326.00	0.00	2552.00	0.00	19383.00	15989.00
M_1L_1	2495.00	0.00	2737.00	0.00	20792.00	17149.00
M_1L_2	10.64	230.00	34.64.00	254.00	1534.00	1273.00
M_2L_4	7.00	196.00	31.00	220.00	1306.00	1103.00
M_3L_6	7.56	195.00	28.56	216.00	1300.00	1083.00
U_1M_2	101.00	1370.00	219.00	1488.00	9133.00	7458.00
M_2L_5	147.00	1282.00	248.00	1383.00	8546.00	6933.00
U_2M_3	336.00	771.20	374.00	809.00	5140.00	4055.00
M_3L_7	413.00	708.00	436.00	731.00	4720.00	3664.00
U_1L_3	7.00	618.00	57.00	668.00	4120.00	3349.00
U_2L_5	510.00	222.00	543.00	255.00	4250.00	3402.00
U_3L_7	0.00	0.00	5.00	5.00		
M_1L_3	193.00	9.70	211.00	27.70	1608.00	1322.00
M_2L_3	154.00	12.40	172.00	30.40	1283.00	1078.00
M_3L_5	153.00	12.50	169.00	28.50	1275.00	1059.00

Steel required = 42.00 tonne

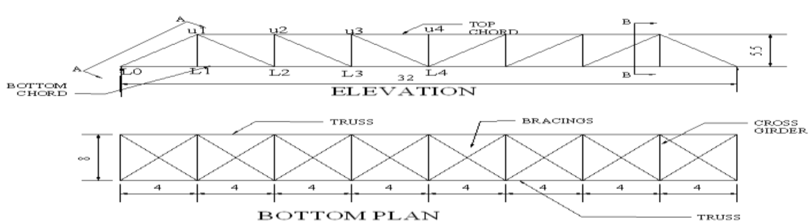
MATHEMATICAL MODELING OF THROUGH BRIDGE

THE PROBLEM:

The problem considered is a 32m spam road bridge. The loads considered to be acting on it are wind load, live load, dead load and impact load.

Data:

Span of bridge = 32.00 m
Center to centre spacing of truss = 8.00 m
Panel length = 4.00 m
Height of truss = 5.50 m
Design wind pressure = 150.00 Kg/m^2
Moving load = two lanes of Class A
(Refer Figure 8.1)



Details of through bridge

COMPARISON OF RESULTS

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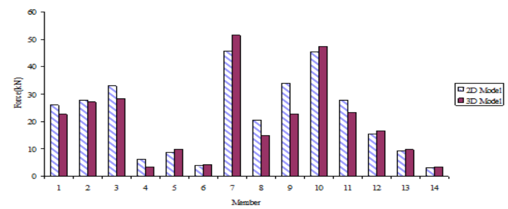
Member forces due to wind load

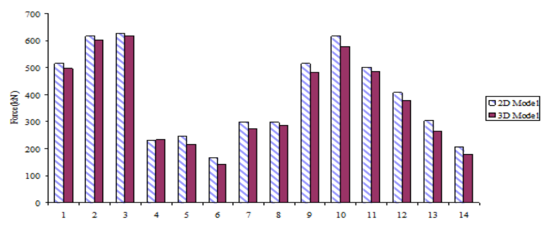
Member	Forces (kN)	
	2D	3D
U_1U_2	26.00	22.60
U_2U_3	27.84	27.00
U_3U_4	32.87	28.30
U_1L_1	6.21	3.31
U_2L_2	8.71	9.73
U_3L_3	3.71	4.15
U_4L_4	1.21	1.17
L_0L_1	35.53	51.40
L_1L_2	20.39	14.80
L_2L_3	34.09	22.60
L_3L_4	45.48	47.40
U_1L_0	27.77	23.40
U_1L_2	15.45	16.60
U_2L_3	9.27	9.63
U_3L_4	3.09	3.30



Comparison of member forces due to wind load

Member forces due to moving load

Member	2D Model (kN)		3D Model (kN)	
	Compression	Tension	Compression	Tension
U_1U_2	514.20		496.00	
U_2U_3	617.50		602.00	
U_3U_4	628.00		616.00	
U_1L_1		229.00		234.00
U_2L_2	247.10	36.80	216.00	36.73
U_3L_3	167.50	73.60	140.00	90.30
U_4L_4	0.00	0.00	0.00	0.00
L_0L_1		297.30		275.00
L_1L_2		297.30		286.00
L_2L_3		514.20		483.00
L_3L_4		617.50		577.00
U_1L_0	501.76		467.00	
U_1L_2	15.20	408.30	8.40	378.00
U_2L_3	45.00	304.30	45.52	265.00
U_3L_4	90.86	207.10	103.50	173.00



Comparison of member forces due to moving load

CONCLUSIONS

From the study performed the following conclusions can be drawn:

1. IS: 875(Part 3)-1987 gives lower pressure values than that of IRC: 6-2000

2. IS: 875(part 3)-1987 and AS/NZS 1170.2:2002 give lower values k_2 as that of other international standards

3. IRC: 6-2000 gives higher member forces as pressure values given in IRC:6-2000 are higher

4. IS: 875(part 3)-1987 gives higher member forces than AS/NZS 1170.2:2002 as values of C_f given in IS: 875(part 3)-1987 are higher than that of AS/NZS 1170.2:2002.

5. For same span (32 m) the effect of wind is more critical on Railway Bridge than on Road Bridge because
 a. Width of Railway Bridge is less than Road Bridge
 b. Wind load on moving load is higher in case of Railway Bridge

6. As span of Bridge increase wind becomes more critical. At 50 m span the whole bottom chord become critical.

7. For same span (50 m) of Railway Bridge Baltimore truss is safer against wind among the four configurations considered. But the most economical configuration is Warren (with vertical support).

REFERENCES

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