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ANALYSIS AND DESIGN OF A T-BEAM BRIDGE

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Abstract: This project deals with the planning and designing the superstructure of a **Girder and Slab (T-beam) Bridge**. A complete design is worked out for a typical T-beam bridge of 19.2m effective span, as this is the most frequently used type. The procedure used therein could be adapted for other types. The procedure involves the usage of **IRC : 6 – 2000 for loads and stresses, IS 456 : 2000 for concrete and IS 800 : 2007 for steel**. We also used **AutoCAD 2013 and MS Excel** for designing purpose.
At first we visited an on-going **NHAI** project over "**BADA GANGUA NALLAH**" AT 8.128km of NH-316 (NH 203, Old),Odisha. From there we got to know the dimensions of the bridge. In present study a two lane simply supported RCC T- Beam Girderwas analysed for dead load and IRC moving load. The dead load as well as live load calculation has been done manually and cross checked with the help of Excel. The study gives the solution based on the prevailing rates of construction cost to be adopted by design Engineer

INTRODUCTION

What is a bridge?
A **bridge** is a structure built to span physical obstacles such as a body of water, valley, or road, for the purpose of providing passage over the obstacle. There are many different designs that all serve unique purposes and apply to different situations. Designs of bridges vary depending on the function of the bridge, the nature of the terrain where the bridge is constructed and anchored, the material used to make it, and the funds available to build it.

- Bridge is a structure which covers a gap
- Generally bridges carry a road or railway across a natural or artificial obstacle such as, a river, canal or another railway or another road
- Bridge is a structure corresponding to the heaviest responsibility in carrying a free flow of transport and is the most significant component of a transportation system in case of communication over spacing/gaps for whatever reason such as aquatic obstacles, valleys and gorges etc.

HISTORY

The first bridges were made by nature itself — as simple as a log fallen across a stream or stones in the river. The first bridges made by humans were probably spans of cut wooden logs or planks and eventually stones, using a simple support and cross beamarrangement. Some early Americans used trees or bamboo poles to cross small caverns or wells to get from one place to another. A common form of lashing sticks, logs, and deciduous branches together involved the use of long reeds or other harvested fibres woven together to form a connective rope capable of binding and holding together the materials used in early bridges.

The Arkadiko Bridge is one of four Mycenaean corbel arch bridges part of a former network of roads, designed to accommodate chariots, between Tiryns to Epidaurus in the Peloponnese, in Greece. Dating to the Greek Bronze Age (13th century BC), it is one of the oldest arch bridges still in existence and use.

Several intact arched stone bridges from the Hellenistic era can be found in the Peloponnese in southern Greece.

The greatest bridge builders of antiquity were the ancient Romans. The Romans built arch bridges and aqueducts that could stand in conditions that would damage or destroy earlier designs. Some stand today. An example is the Alcántara Bridge, built over the river Tagus, in Spain. The Romans also used cement, which reduced the variation of strength found in natural stone.[1] One type of cement, called pozzolana, consisted of water, lime, sand, and volcanic rock. Brick and mortar bridges were built after the Roman era, as the technology for cement was lost then later rediscovered.

The Arthashastra of Kautilya mentions the construction of dams and bridges. A Mauryan bridge nearGirnar was surveyed by James Princep. The bridge was swept away during a flood, and later repaired by Puspagupta, the chief architect of emperor Chandragupta I. The bridge also fell under the care of the Yavana Tushaspa, and the Satrap Rudra Daman. The use of stronger bridges using plaited bamboo and iron chain was visible in India by about the 4th century. A number of bridges, both for military and commercial purposes, were constructed by the Mughal administration in India.

Although large Chinese bridges of wooden construction existed at the time of the Warring States, the oldest surviving stone bridge in China is the Zhaozhou Bridge, built from 595 to 605 AD during the Sui Dynasty. This bridge is also historically significant as it is the world's oldest open-spandrel stone segmental arch bridge. European segmental arch bridges date back to at least the Alconétar Bridge (approximately 2nd century AD), while the enormous Roman era Trajan's Bridge (105 AD) featured open-spandrel segmental arches in wooden construction.

Rope bridges, a simple type of suspension bridge, were used by the Inca civilization in the Andes mountains of South America, just prior to European colonization in the 16th century.

During the 18th century there were many innovations in the design of timber bridges by Hans Ulrich, Johannes Grubenmann, and others. The first book on bridge engineering was written by Hubert Gautier in 1716. A major breakthrough in bridge technology came with the erection of the Iron Bridge in Coalbrookdale, England in 1779. It used cast iron for the first time as arches to cross the river Severn.

With the Industrial Revolution in the 19th century, truss systems of wrought iron were developed for larger bridges, but iron did not have the tensile strength to support large loads. With the advent of steel, which has a high tensile strength, much larger bridges were built, many using the ideas of Gustave Eiffel.

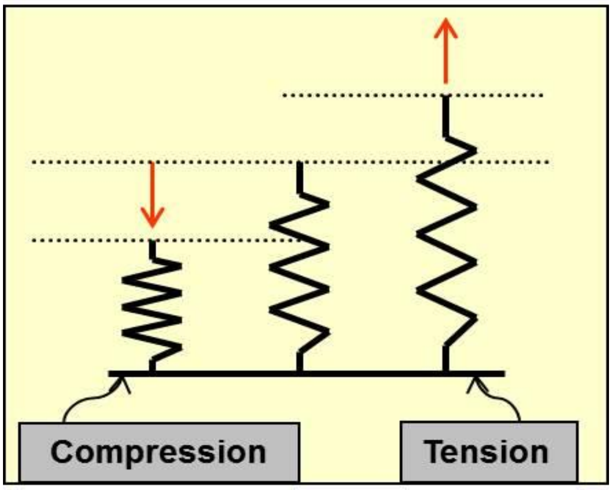
In 1927 welding pioneer Stefan Bryła designed the first welded road bridge in the world, the Maurzyce Bridge which was later built across the river Słudwia at Maurzyce near Łowicz, Poland in 1929. In 1995, the American Welding Society presented the Historic Welded Structure Award for the bridge to Poland.

HOW BRIDGES WORK?

Every passing vehicle shakes the bridge up and down, making waves that can travel at hundreds of kilometers per hour. Luckily the bridge is designed to damp them out, just as it is designed to ignore the efforts of the wind to turn it into a giant harp. A bridge is not a dead mass of metal and concrete: it has a life of its own, and understanding its movements is as important as understanding the static forces.

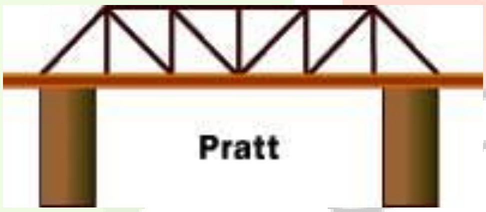
BASIC CONCEPTS

Span - the distance between two bridge supports, whether they are columns, towers or the wall of a canyon.
Force - any action that tends to maintain or alter the position of a structure.
Compression - a force which acts to compress or shorten the thing it is acting on.
Tension - a force which acts to expand or lengthen the thing it is acting on.

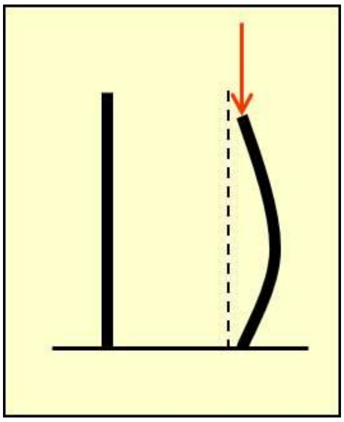


<u>Beam</u> - a rigid, usually horizontal, structural element.

<u>Pier</u> - a vertical supporting structure, such as a pillar.
<u>Cantilever</u> - a projecting structure supported only at one end, like a shelf bracket or a diving board.
<u>Load</u> - weight distribution throughout a structure.
<u>Truss</u> - a rigid frame composed of short, straight pieces joined to form a series of triangles or other stable shapes.

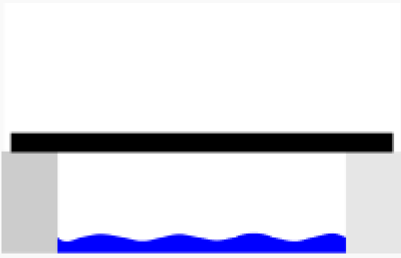
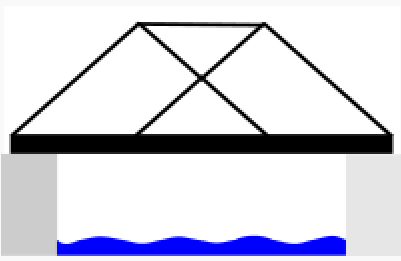


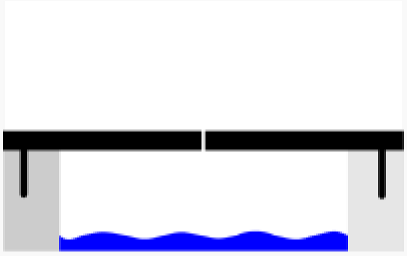
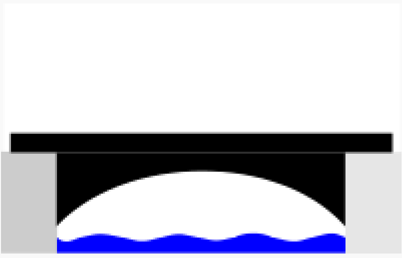
<u>Stable</u> - (adj.) ability to resist collapse and deformation; stability (n.) characteristic of a structure that is able to carry a realistic load without collapsing or deforming significantly.
<u>Deform</u> - to change shape
<u>Buckling</u> is what happens when the force of compression overcomes an object's ability to handle compression. A mode of failure characterized generally by an unstable lateral deflection due to compressive action on the structural element involved.

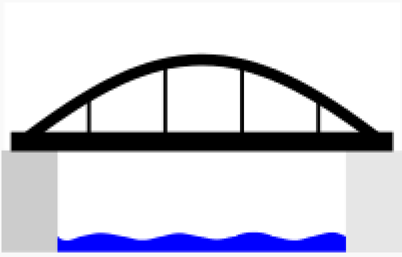
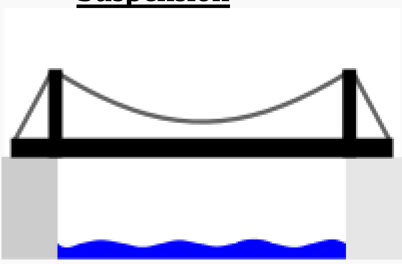
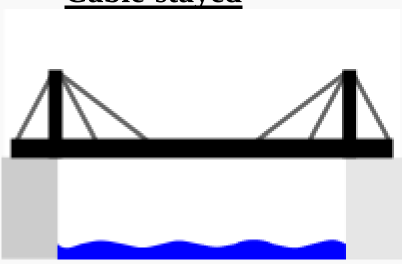


<u>Snapping</u> is what happens when tension overcomes an object's ability to handle tension.
To **<u>dissipate</u>** forces is to spread them out over a greater area, so that no one spot has to bear the brunt of the concentrated force.
To **<u>transfer</u>** forces is to move the forces from an area of weakness to an area of strength, an area designed to handle the forces.

TYPES OF BRIDGES

Beam bridge 	Beam bridges are horizontal beams supported at each end by substructure units and can be either simply supported when the beams only connect across a single span, or continuous when the beams are connected across two or more spans. When there are multiple spans, the intermediate supports are known as piers. The earliest beam bridges were simple logs that sat across streams and similar simple structures. In modern times, beam bridges can range from small, wooden beams to large, steel boxes. The vertical force on the bridge becomes a shear and flexural load on the beam which is transferred down its length to the substructures on either side. They are typically made of steel, concrete or wood. Beam bridge spans rarely exceed 250 feet (76 m) long, as the flexural stresses increase proportional to the square of the length (and deflection increases proportional to the 4th power of the length). However, the main span of the Rio-Niteroi Bridge, a box girder bridge, is 300 metres (980 ft). The world's longest beam bridge is Lake Pontchartrain Causeway in southern Louisiana in the United States, at 23.83 miles (38.35 km), with individual spans of 56 feet (17 m). Beam bridges are the most common bridge type in use today.
Truss bridge 	A truss bridge is a bridge whose load-bearing superstructure is composed of a truss. This truss is a structure of connected elements forming triangular units. The connected elements (typically straight) may be stressed from tension, compression, or sometimes both in response to dynamic loads. Truss bridges are one of the oldest types of modern bridges. The basic types of truss bridges shown in this article have simple designs which could be easily analyzed by nineteenth and early twentieth century engineers. A truss bridge is economical to construct owing to its efficient use of materials.

Cantilever bridge		Cantilever bridges are built using cantilevers—horizontal beams supported on only one end. Most cantilever bridges use a pair of continuous spans that extend from opposite sides of the supporting piers to meet at the center of the obstacle the bridge crosses. Cantilever bridges are constructed using much the same materials & techniques as beam bridges. The difference comes in the action of the forces through the bridge. The largest cantilever bridge is the 549-metre (1,801 ft) Quebec Bridge in Quebec, Canada.
Arch bridge		Arch bridges have abutments at each end. The weight of the bridge is thrust into the abutments at either side. The earliest known arch bridges were built by the Greeks, and include the Arkadiko Bridge. With the span of 220 metres (720 ft), the Solkan Bridge over the Soča River at Solkan in Slovenia is the second largest stone bridge in the world and the longest railroad stone bridge. It was completed in 1905. Its arch, which was constructed from over 5,000 tonnes (4,900 long tons; 5,500 short tons) of stone blocks in just 18 days, is the second largest stone arch in the world, surpassed only by the Friedensbrücke (Syratalviadukt) in Plauen, and the largest railroad stone arch. The arch of the Friedensbrücke, which was built in the same year, has the span of 90 m (300 ft) and crosses the valley of the SyrabachRiver. The difference between the two is that the Solkan Bridge was built from stone blocks, whereas the Friedensbrücke was built from a mixture of crushed stone and cement mortar.[15] The world's current largest arch bridge is the Chaotianmen Bridge over the Yangtze River with a length of 1,741 m (5,712 ft) and a span of 552 metres (1,811 ft). The

	bridge was open April 29, 2009 in Chongqing, China.
Tied arch bridge 	Tied arch bridges have an arch-shaped superstructure, but differ from conventional arch bridges. Instead of transferring the weight of the bridge and traffic loads into thrust forces into the abutments, the ends of the arches are restrained by tension in the bottom chord of the structure. They are also called bowstring arches.
Suspension  **bridge**	Suspension bridges are suspended from cables. The earliest suspension bridges were made of ropes or vines covered with pieces of bamboo. In modern bridges, the cables hang from towers that are attached to caissons or cofferdams. The caissons or cofferdams are implanted deep into the floor of a lake or river. Sub-types include the simple suspension bridge, the stressed ribbon bridge, the underspanned suspension bridge, the suspended-deck suspension bridge, and the self-anchored suspension bridge. The longest suspension bridge in the world is the 3,909 m (12,825 ft) Akashi Kaikyō Bridge in Japan.[17]
Cable-stayed  **bridge**	Cable-stayed bridges, like suspension bridges, are held up by cables. However, in a cable-stayed bridge, less cable is required and the towers holding the cables are proportionately higher.[18] The first known cable-stayed bridge was designed in 1784 by C. T. (or C. J.) Löscher. The longest cable-stayed bridge is the Sutong Bridge over the Yangtze River in China.

GENERAL BRIDGE COMPONENTS

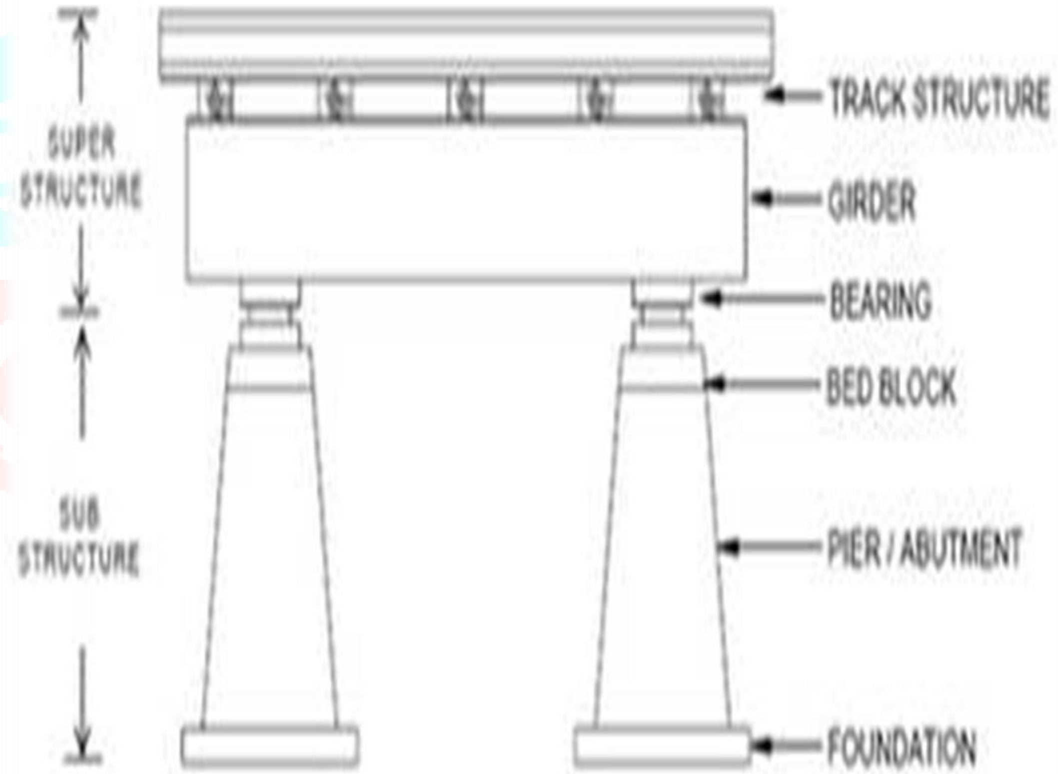
GENERAL BRIDGE COMPONENTS

- Bridge Deck

- Girder
- Abutment
- Bridge Pier
- Bridge Deck
- Foundation

❖ Additional requirement

1) Bridge Dampers
2) Expansion joints



LITERATURE REVIEW

Comparative Study of the Analysis and Design of T-Beam Girder and Box Girder Superstructure

Amit Saxena, Dr. Savita Maru: The goal of study is to determine most favourable option from above two. The decisions based on obvious element of engineering that are safety, serviceability and economy. Following these aspect a design for both T-Beam and Box Girder has been performed. After calculation two basics material consumption steel and concrete the most economical has been selected. This study is on the basis of moment of resistance of section, shear capacity of section and cost effective solution from both T-Beam and Box Girder Bridge. The study gives the solution based on the prevailing rates of construction cost to be adopted by design Engineer.

EFFECT ON SUPPORT REACTIONS OF T-BEAM SKEW BRIDGE DECKS

Trilok Gupta and Anurag Misra:refers to the behavior of T-beam skew bridges with respect to support reactions under standard IRC-70R wheeled loading is presented and the study was based on the analytical modeling of T-beam bridges by Grillage Analogy method. Effects of support reactions for different spans have been studied. The analysis provides the useful information about the variation of support reactions with respect to change in skew. The negative reactions were observed with increase in the span and skew angles. It was found that in skew T-beams bridges, the high positive and negative reactions develop close to each other. Negative reactions were very less in the 8m right span and introduced at an angle of 500 and onwards, while for 16m right span it was introduced an angle of 300. In 24m and 32m right spans the negative reactions develops at smaller skew angles (i.e. 200 and onwards).

EFFECT OF SKEW ANGLE ON BEHAVIOR OF SIMPLY SUPPORTED R. C. T-BEAM BRIDGE DECKS

Ibrahim S. I. Harba:refers to the effect of skew angle on behavior of simply supported reinforced concrete T-beam bridge decks. The parameters investigated in this analytical study were the span lengths and skew angle. The finite element analysis (FEA) results for skewed bridges were compared to the reference straight bridges (nonskewed). The geometric dimensions of the T-beam bridge decks and the loading used are in compliance with AASHTO standard specifications. The FEA results and comparison of skewed bridge with straight bridge indicate that max. Live load bending moments and deflections decreases in T- beams for skewed bridges, while max. shear, torsion and supports reactions increases in some T-beams for skewed bridges for all considered span lengths (12, 16, 20 and 24m). This study disagreement with the AASHTO standard specifications as well as the LRFD in recommending that bridges with skew angle less than or equal 20° be designed as straight (non skewed) bridges also it recommended that engineers are better to perform three dimensional finite element analysis for skewed T-beam bridge decks.

Observed integral abutment bridge substructure response

Scott A. Civjan ,EmreKalayci , Brooke H. Quinn , Sergio F. Breña, Chad A. Allen :refers to the substructure response from 30 months of field data.The bridges are single span steel girder bridges of approximately 40 m on pile foundations. One bridge is straight while the other has a 15_ skew. Variations in substructure displacements, backfill pressures and pile moments are reported under hot, cold and moderate ambient temperatures. Abutment and pile deformation plots highlight maximum displacements at the top of piles that are often only 1/3 to 1/2 of the values at the top of the abutment. Maximum pile moments correspond to concentrated curvature at the pile–abutment interface which did not correspond to peak temperatures. Substructure deformation response was predominantly elastic under bridge contraction, but highly non-linear under bridge expansionand varied from year to year. No indication of soil ratcheting was observed in the backfill materialsand design for full passive pressure appears to be overly conservative for these single span structures. No indications of pile yielding were observed in the Grade 345 steel piles. Backfill pressures were consistent across the abutment in the straight bridge, but highly variable in the 15 degree skew bridge.

DESIGN OF BRIDGE

Given data:

Length (L) = 19.2 m
Wearing coat = 0.075 m
Spacing of cross beam = 4.7 m
Spacing of main girder = 3.75 m
Unit weight of concrete = 25 kN/m^3
Unit weight of bitumen =22 kN/m^3
Assume thickness of slab = 225 mm
Effective span in transverse direction = 3.75 m
Effective span in longitudinal direction = 4.7 m

DEAD LOAD CALCULATION
Weight of deck slab =0 .225*25 = 5.625 kN/m^2
Weight of wearing coat = .075*22 = 1.65 kN/m^2
Total dead load = 7.275 kN/m^2

K = short span/long span = 3.75/4.7 = 0.8
1/K = 1/0.8 = 1.25
Now referring to code , IS456 : 2000
$\alpha_y^+ = 0.037$ $\alpha_x^+ = 0.0375$
$\alpha_y^- = 0.028$ $\alpha_x^- = 0.049$
for severe condition
Maximum BM(M_{max}) = 0.049*7.275*3.75^2 = 5.013 kN-m
Live Load BM due to IRC class AA tracked vehicle
Size of one panel of deck slab: 4.7*3.75
U = $((.85+2*.075)^2+.225^2)^{1/2}$ = 3.757
U/B = 1.025/3.75 = 0.273 V/L = 3.757/4.7 = .799
m_1 = 0.105 m_2 = 0.055
Total load per track including impact = 1.25*350 = 437.5 kN
M_1(moment along short duration)= (0.105+0.15*0.055)*437.5 = 49.547 kN-m
M_2(moment along long duration) = (0.055+0.105*0.15)*437.5 = 30.953 kN-m
Live load due to IRC tracked AA wheeled vehicle
(a) BM due to wheel -1
Tyre - contact dimension : 300 mm*150 mm
u = $(((0.3)+2*0.075)^2 + 0.225^2)^{1/2}$ = 0.503 m
v = $((0.15 + 2*0.075)^2+0.225^2)^{1/2}$ = 0.370 m
u/B = 0.503/3.75 = 0.134 v/L = 0.370/4.7 = 0.079
K_1 = 0.8
m_1 = 21.5/100= 0.215
m_2 = 22/100 = 0.22
Total load allowing for 25% impact = 1.25*62.5= 78.1 kN
M_1 = (0.21 + 0.15*.22)*78.1 = 18.978 kN-m
M_2 = (0.22 + 0.15*0.21)*78.1 = 19.64 kN-m
(b) BM due to wheel -2
Intensity of loading = (37.5*1.25)/(0.503*0.370) = 251.88 kN/m^2
Considering a strip of 1.703*.370 m
Now, u/B = 1.703/3.75 = .454
v/L = 0.370/4.7 = 0.079
K = 0.8
m_1 = 0.135
m_2 = .1405
M_1 = (0.135 + 0.15*0.1405)*251.88 = 24.771 kN-m
M_2 = (0.1405 + 0.15*0.135)*251.88*1.703*0.370 = 25.513 kN-m
Considering the located area = 697*370
Now, u/B = 697/3750 = 0.18 ,v/L = 370/4700= 0.079
K = 0.80 m_1 = 0.212 m_2 = 0.225
M_1 = (0.212 + 0.15*0.225)*251.88*0.697*0.370 = 15.963 kN-m
M_2 = (0.225 +0.15*0.212)*251.88*0.697*0.370 = 16.681kN-m
M_1 = (24.771-15.963)/2 = 4.404kN-m
M_2 = (25.513-16.681)/2 = 4.416kN-m
(c)BM due to wheel – 3
Intensity of loading due to 62.5 kN =(62.5*1.25)/(0.503*0.370) = 419.8kN
Considering a strip of area 2503*370
u/B = 2503/3750 = 0.667 v/L = 370/4700 = 0.79
m_1 = 0.112 m_2 = 0.136
M_1 = (0.112 + 0.15*0.136)*419.8*0.370*2.503 = 51.475kN-m
M_2 = (0.136 + 0.15*0.112)*419.8*0.370*2.503 = 59.406kN-m
Now,considering a strip 1.497*.370
u/B = 1.497/3.75 = 0.399 v/L = o.370/4.75 = 0.079
m_1 = 0.143 m_2 = 0.17
M_1 = (0.143 + 0.15 * 0.17)*419.8 * 1.497 * 0.370 = 39.180 kN-m
M_2 = (0.17 + 0.143 * 0.15)*419.8 * 1.497 * 0.370 = 44.517 kN-m

(d) BM due to wheel - 4
Now,load intensity due to 37.5 kg = (37.5*1.25)/(0.37*0.503)= 251.867 kN/m
Now,considering the strip 3703mm*370 mm
u/B = 3703/3750 =0.987 v/L = 370/4700 = 0.079
m_1 = 0.082 m_2 = 0.095
M_1 = (0.082+0.15*0.095)*251.867*3.703*0.370 = 33.214kN-m
M_2 = (0.095+0.15*0.082)*251.867*3.703*0.37 = 37.028kN-m
now considering the strip 2697*370
u/B = 2697/3750 = 0.719 v/L = 370/4700 = 0.079
m_1 = 0.112 m_2 = 0.127
now,
M_1 = (0.098 + 0.15 *0.127)*251.87*2.697*.370 = 29.419kN-m
M_2 = (0.127+0.15*0.098)*251.867*2.697*0.370 = 34.614 kN-m
M_1 = (33.219-29.419)/2 = 1.898kN-m
M_2 = (36.665-34.614)/2 = 1.207kN-m

(e) BM for load - 5
M_1 = 1.897 kN-m M_2 = 1.964 kN-m
(f) BM due to load - 6
M_1 = 1.897 kN-mM_2 = 1.964 kN-m
(g) BM due to load - 7
M_1 = 1.897 kN-m M_2 = 1.964 kN-m
(h) BM due to load - 8
M_1 = 1.897 kN-m M_2 = 1.964kN-m
Total wheel load due to all wheel
M_1 = 1.897*5 +6.148 + 4.404 + 18.98 = 38.99kN-m
M_2 = 1.964*4 + 1.207 + 6.974 + 4.416 + 19.64 = 40.093kN-m

DESIGN BM :

CLASS AA tracked vehicle causes
M_1 moment along short direction = 49.547kN-m
M_2 moment along long direction = 30.953kN-m
So,the loading condition due to IRC tracked vehicle gives most severe condition
Design BM along short span = (4.194 + 49.547)*0.8 = 43 kN-m
Design BM along long span = (4.194 + 30.953)*0.8 = 28.12 kN-m

DESIGN OF SLAB

f_y = 415
l_x = 3.75 m
l_y = 4.7 m
Short span between the centre of the bearing = 3.75 + 0.3 = 4.05 m
Long span between the centre of the bearing = 4.7 + 0.3 = 5 m
Since, the short span is larger than 3.5 m, the effective depth will be estimated as simply supported one way slab.
Assuming 0.3% steel,
Modification factor, m.f = 1.43
Effective depth, $d_{required}$ = (Short span)/20 *m.f = (4.05*1000)/20*1.43 = 142 mm
Providing 8 mm diameter and a cover of 15 mm
Overall depth required for short span, D = 142 + 15 + 4 = 161 mm ≈ 170 mm
Effective depth of short span, d_{eff} = 170 – 15 – 4 = 151 mm
Actual effective depth for long span = 151 – 8 = 143 mm
l_x = clear span + effective depth for short span = 3.75 + 0.151 = 3.901 m
l_y = clear span + effective depth for long span = 4.7 + 0.143 = 4.843 m
l_y / l_y = 4.843 / 3.901 = 1.24 < 2
So we have to design the slab as a 2-way slab
LOADS

Dead load of the slab = 25 * 170 = 4250 N/m^2
20mm floor finish = 24 * 20 = 480 N/m^2
Wheel live load = 37.5 /(0.503 * 0.375) + 62.5 /(0.503 * 0.375) = 530 N/m^2
Total load, W = 4250 + 480 + 530 = 5260 N/m^2
W_u = 1.5 * 5260 = 7890 N/m^2

MOMENT CALCULATION

Referring to IS 456 : 2000
For K = 1.24
α_x^- = 0.045
α_x^+ = 0.055
α_y^- = 0.037
α_y^+ = 0.028
$M_{ux} = \alpha_x * W_u * l_x^2 = (0.055 * 7890 * 3.901^2)/1000 = 6.6037$ kN-m < 42 kN-m
For short span,
Design moment M = 42 kN-m

$$P_{t,\,lim} = 50*\left(\frac{1-\sqrt{1-\frac{4.6*Mu}{fck*bd^2}}}{\frac{fy}{fck}}\right) = 50*\left(\frac{1-\sqrt{1-\frac{4.6*42*10^6}{25*1000*151^2}}}{\frac{415}{25}}\right) = 0.56\%$$

A_{st}= ($P_{t,\,lim}$* b * d)/100 = (0.56 * 1000 * 151) / 100 = 845.6 mm^2
No of bars required, n = 845.6 / (π * 8^2/4) = 16 bars
Spacing of 8 mm bars = ((π/4) * 8^2 * 1000) / 845.6 = 59.13 mm
Provide 8mm φ, 16 numbers of bars @ 50 mm from c-c
For long span,
Design moment M = 42 kN-m

$$P_{t,\,lim} = 50*\left(\frac{1-\sqrt{1-\frac{4.6*Mu}{fck*bd^2}}}{\frac{fy}{fck}}\right) = 50*\left(\frac{1-\sqrt{1-\frac{4.6*42*10^6}{25*1000*143^2}}}{\frac{415}{25}}\right) = 0.63\%$$

A_{st}= ($P_{t,\,lim}$* b * d)/100 = (0.63 * 1000 * 143) / 100 = 910 mm^2
No of bars required, n = 910 / (π * 8^2/4) = 18.2 bars ≈ 20 bars
Spacing of 8 mm bars = ((π/4) * 8^2 * 1000) / 910 = 54.9 mm
Provide 8mm φ, 20 numbers of bars @ 50 mm from c-c

SHEAR CHECK

Shear force, $V_u = W_u$ * L/2 = (7890 * 3.75)/2 = 14793 N = 14.793kN
Nominal shear stress = V_u / (b * d) = 14793/(1000 * 151) = 0.098
For P_t = 0.56%
Design shear strength of concrete = 0.5N/mm^2
K_s * design shear strength of concrete = 1.24 * 0.5 = 0.715N/mm^2
So,
Nominal shear stress < K_s * design shear strength of concrete
So the design slab is safe in shear

CHECK FOR DEVELOPMENT LENGTH

For bars of short span,
A_{st} = 845.6 / 2 = 422.8 mm^2

$M_1 = 0.87 * f_y * A_{st} * d * (1 - \frac{Ast*fy}{fck*bd})$

$= 0.87 * 415 * 422.8 * 151* (1 - \frac{422.8*415}{25*1000*151})$

= 21.9 kN-m

V_u = 14793 N

l_0 = (300 / 2) -15 = 135 mm > 12d (12 *8 = 96 mm)

L_d = (0.87 * 415 * 8) / (4 * 1.4 *1.6) = 322.66 mm ≈ 325 mm

$1.3 \frac{M1}{Vu} + l_0 = 1.3 \frac{21.9*10^6}{14793} + 135 = 2059$

$L_d < 1.3 \frac{M1}{Vu} + l_0$

So, our design is safe.