Comparative Study Of Pile Foundation Design For Bridge Pier With Working Stress Method And Limit State Method

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Abstract **- To study the effect of bridge code for limit state method (IRC 112:2011) and bridge code for working stress method (IRC 21:2000) on pile foundation design of bridge pier. we are also comparing Hong kong limit state method with IRC code. The main objective of this study is to prepare comprehensive spreadsheets to incorporating with all forces as per IRC 6:2014 in limit state method and working stress method. In future which can be used by bridge design engineers effectively. Calculate and compare various design loads, moments and area of steel with both methods.**

INTRODUCTION

Bridge, Dam and Water tank that all special structures are still design in India as per working stress method. In working stress method, material is used up to elastic limit and In limit state method, material is used up to plastic limit. So this leads to greater savings and reductions in time and cost. In developing country like India, wastage of material are not feasible. Now a day, Due to development of nation, trade, heavy traffic the requirement of bridge is increased so it is necessary that design is must be economical as well as safe. That requirement is fulfilled by limit state method.

As per Ministry of Surface Transport(MOST) and Indian Road Congress(IRC), Government of India. It is mandatory to create a bridge design using Limit State Method from January 2016.

From last sixty years, we are using working stress approach in design of bridge structures so sudden change in design philosophy is comparatively hard due to unavailability of educational training session and knowledge of LSM for bridge structure so time period is extended from 2011 to 2016.

There is more elaborate in calculation of shear, flexure and serviceability limit state in new code as compare to IS 456. Explanatory handbook of IRC 112 (as per LSM) is just release in 2014 so now we can design the structure as per IRC 112 with the help of handbook. Making Spreadsheets of bridge foundation as per new code which are useful for Bridge engineer and as well as Government authorities.

Hypothetical River bridge is the best critical choice to compare that two philosophy Because of many forces acting like Dead load, Live load, Braking force, Seismic Force, Wind Force, Water Current Force, Buoyancy Force on it.

Due to Scour in River bridges, Bridge foundation has to be taken deeper and below to scour level. Hence pile foundation is more used for bridge structure as deep foundation.

Bridge Configuration

General Design Data Of Bridge :-

Concrete and Reinforcement Details:-				
Concrete Grade	M	35		
Steel Grade	Fe	500		
Modular Ratio(m)	=	10		(m= As per IRC21:2000 pg.18)
Seismic Zone	=	III		
Span c/c of pier				
Left Side Span	=	24	m	
Right Side Span	=	24	m	
Effective Span				
Left Side Span	=	23.2	m	
Right Side Span	=	23.2	m	

Overall Width Of Bridge	=	8.4	m
Carriageway width	=	7.5	m
Superstructure			
Left span super structure			
Super Structure Quantity		110.98	
Super Structure Quantity (half)	=	55.49	m^3
Depth of super structure	=	2.4	m
Right span super structure			
Super Structure Quantity		110.98	
Super Structure Quantity (half)	=	55.49	m^3
Depth of super structure	=	2.4	m
Bearing			
Type of Bearing		Pot-ptfe	
Centre of Bearing (From centre of pier in longitudinal Direction)	=	0.4	m
Length of Bearing	=	0.5	m
Width of Bearing	=	0.4	m
Thickness of Bearing	=	0.096	m
Pedestal			
Number	=	3	No.
Length of Pedestal	=	0.8	m
Width of Pedestal	=	0.7	m
Thickness of Pedestal	=	0.204	m
Quantity of Pedestal	=	0.114	m^3
Crash Barrier			
Height Of Crash Barrier	=	1.1	m
Width Of Crash Barrier	=	0.45	m
C/S area	=	0.285	m^2/m
No. Of Crash Barrier	=	2	No.
Wearing Coat Thickness (Avg.)	=	0.075	m
Pier cap			
Shape of cape	=	Square	
Thickness of cap at free end(h)	=	0.75	m
Thickness of cap at pier(H)	=	1.5	m
Thickness of slant portion of pier cap	=	0.75	m
Width of cap at Top	=	1.8	m
Width of cap at Bottom	=	1.8	m
Length of cap Top	=	8	m
Length of cap at Bottom	=	6.4	m
Pier			
Shape of Pier	=	Rectangular with round ended	
Length Of Pier at Top	=	6.4	m

Length Of Pier at Bottom	=	6.4	m
corner radius	=	1.4	m
Straight Length Of Pier	=	5	m
Width of Pier at Top	=	1.4	m
Width of Pier at Bottom	=	1.4	m
Height of Pier	=	8.0	m
Foundation			
Soil Properties			
Foundation Strata		Medium Soil	
Pile Cap			
Width of Pile cap	=	5.1	m
Length of Pile cap	=	8.7	m
Thickness of Pile cap	=	1.8	m
No. of Piles		6	No.
Dia. Of Piles	=	1.2	m
c/c distance of pile in longitudinal direction	=	3.6	m
c/c distance of pile in transverse direction	=	3.6	m
Pile Length	=	19.77	m
Reduce Level (RL)			
Road RL with cross barrier	=	35.58	m
Road RL	=	34.48	m
Bottom RL of Super Structure	=	32.0	m
Top RL of Pier cap	=	31.7	m
Top RL of Pier	=	30.2	m
Ground RL	=	23.0	m
Bottom RL of Pier	=	22.2	m
Bottom RL of Pile cap	=	20.4	m
Fixity RL	=	5.63	m
Foundation RL	=	0.6	m
Obstructed velocity	=	4.0	m/sec
Skew Angle	=	0.0	
AHFL RL	=	30.5	m
HFL RL	=	30.0	m
Scour RL	=	13.5	m

LOAD CONSIDERING:
Following primary loads are considered for design of bridge.

1. Dead Load (DL)
2. Super Imposed load(SIDL)
3. Live Load (LL)
4. Wind force
5. Water current force
6. Earthquake Load along X direction
7. Earthquake Load along y direction

8. Buoyancy

After manually calculation of forces summary of loads and moments at pile cap bottom is listed below. That is same in all three method for best comparison.

1. IRC Working Stress Method
2. IRC Limit State Method
3. Hong Kong Limit State Method

Calculation of Loads

Dead Load:

The dead load of superstructure consists of weight of rail, footpath, kerb, deck slab, girder etc. These dead loads of superstructure are then transferred on pier and abutment. The MOST (Ministry Of Surface Transport) gives these superstructures dead load for span ranging from 16m to 40m as given in table 3.1. These superstructure dead loads are for various standard sections of girder, deck slab, rail and kerb depending on span of bridge.

Live Load

As per IRC-6, Road bridges are designed for following live loads:
Class A Loading: This loading is to be normally adopted on all roads on which permanent bridges are constructed.
Class B Loading: This loading is to be normally adopted for temporary structures and for bridges in specified areas.
Class AA Loading: This loading is to be adopted within certain municipal limits, in certain existing or contemplated industrial areas, in other specified areas, and along certain specified highways.
Class 70 R Loading: This loading is to be adopted within certain municipal limits, in certain existing or contemplated industrial areas, in other specified areas, and along certain specified highways.

Buoyancy force:

In the design of submerged masonry or concrete structures the buoyancy effect may be limited to 15 percent of fully buoyancy.

Water current force:

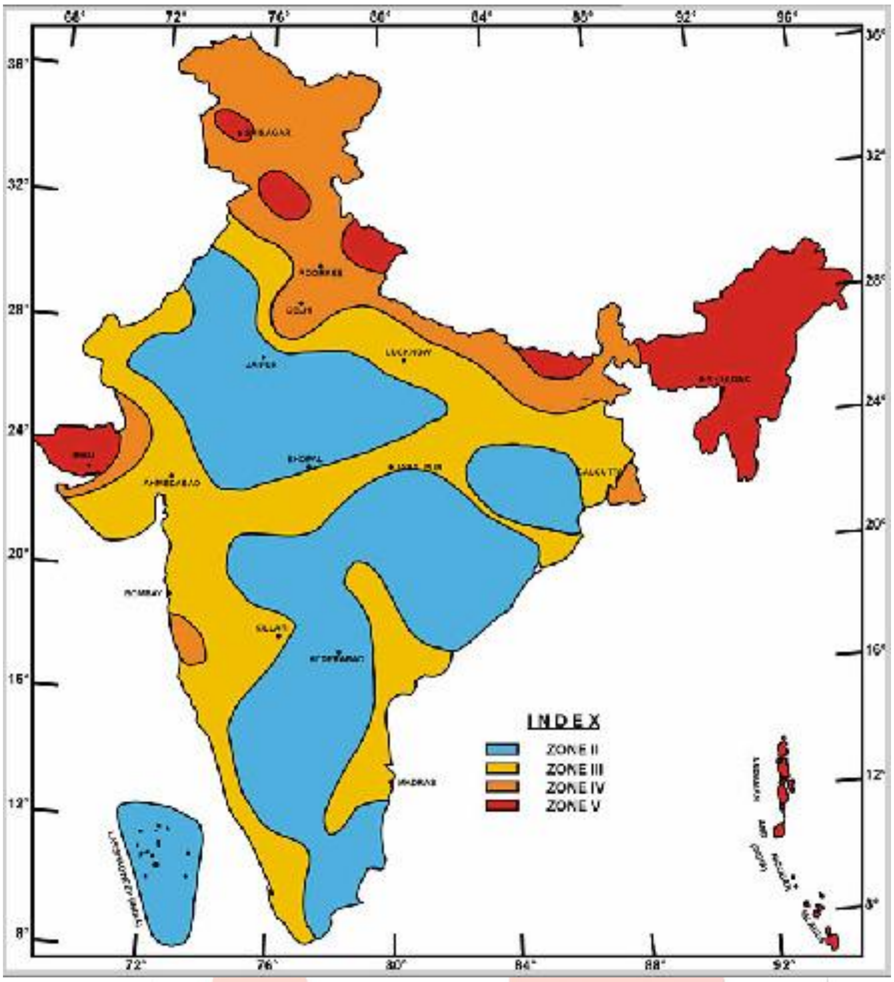
Any part of a road bridge which is submerged in running water shall be designed to sustain safety the horizontal pressure due to force of the water current. On piers parallel to the direction of the water current, the intensity of pressure shall be calculated from the following equation

$$P = 52\,K\,V^2$$

Where P = Intensity of pressure due to water current in kg/m^2
V = The velocity of the current at the point where the pressure intensity is being calculated in meter per second.
K = A constant having the different values for different shapes of piers mentioned in IRC-6 cl. No. 213.Which is given below
(A) Square Ended Piers 1.5
(B) Circular piers of piers with semi-circular ends 0.66
(C) Piers with triangular cut and ease waters, the angle included between the faces being 30° or less 0.5
(D) Piers with triangular cut and ease waters, the angle included between the faces being more than 30° but less than 60° 0.5-0.7
(E) Piers with triangular cut and ease waters, the angle included between the faces being more than 60° but less than 90° 0.7-0.9

Seismic force:

Bridges in seismic zones II and III need not be designed for seismic force provided both conditions are met, first one is span is less than 15m and second is total bridge length is less than 60m.



All ether bridge shall be designed for seismic force. For the purpose of determining the seismic force, the country is classified into four zones. The horizontal seismic forces to be resisted shall be computed as follows.

$F_{eq} = A_h$ * (Dead load).

Where F_{eq} = Seismic force to be resisted.

A_h = horizontal seismic coefficient

Z = zone factor as given in table 5 of IRC-6 -2000.

I = Importance factor, for important bridges…..1.5

For other bridges ………1.0

T = Fundamental period of the bridge member for Horizontal vibration

R = response reduction factor

Sa/g = Average response acceleration coefficient for 5 percent damping depending upon fundamental period of vibration T.

After Calculate the forces as per IRC 6:2014, Design of Pile foundation as per IRC 112:2011 for limit state method and IRC 18:2000 for working stress method.

Summary of Loads and moments at pile cap bottom

Sr. no.	**Case Considered**	**Load (T)**	**Force**		**Moment**	
			trans.(T)	**longi(T)**	**trans.(T.m.)**	**longi(T.m.)**
1	**Dead load**					
I	**SIDL**	67.95				0
	Left span SIDL	33.98				13.59
	Right span SIDL	33.98				13.59
II	**Super Structure**	277.45				0
	Left span Super Structure	138.73				55.49
	Right span Super Structure	138.73				55.49
III	**Pier cap + pedestal**	52.16				
IV	**pier**	209.99				

V	**Pile cap**	199.67				
VI	**Buoyancy force**	164.23				
	Total	**642.99**				
2	**Live load**	**87.74**			**101.34**	**31.85**
3	**wind force**	**17.85**	**23.11**	**5.58**	**303.89**	**74.67**
4	**Braking Force**	**3.17**		**36.657**	**0**	**425.22**
5	**Water Current**		**27.60**	**16.10**	**76.04**	**75.69**
6	**Seismic Force**					
I	In Longitudinal Direction	**0.32**		**96.87**		**765.84**
II	In Transverse Direction	**0.32**	**98.97**		**790.27**	

LOAD COMBINATION:
For IRC Working Stress Method

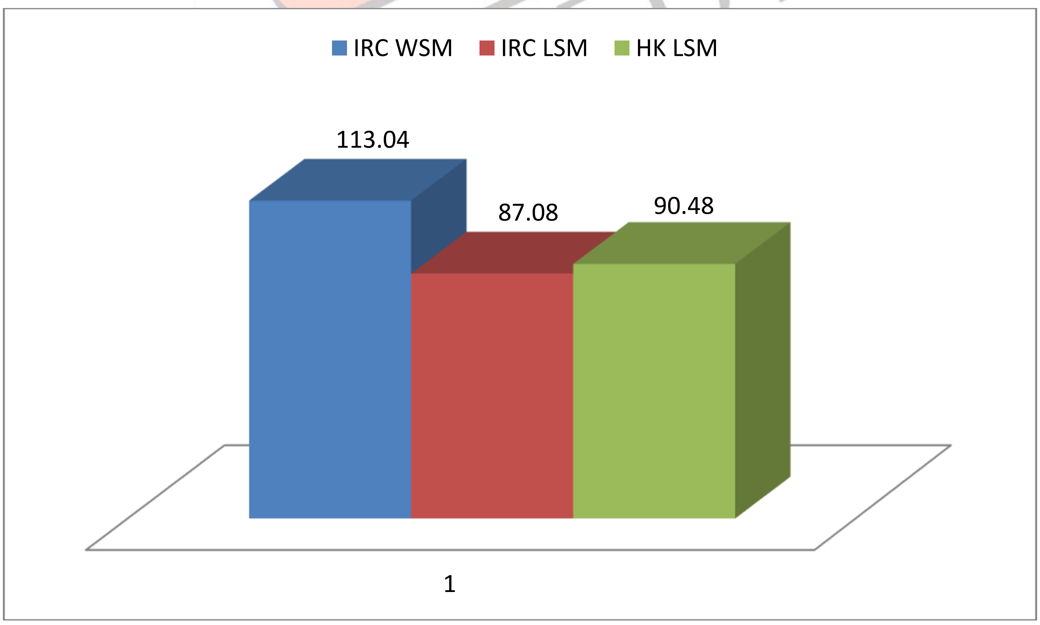
1. DL+LL+W+WC+B
2. DL+0.2LL+WC+B+EQL+0EQT
3. DL+0.2LL+WC+B+EQT+0EQL

For IRC Limit State Method

1. 1.35DL+1.75SIDL+1.5LL+0.9W+1WC+0.15B
2. 1.35DL+1.75SIDL+0.75LL+1.5EQL+1WC+0.15B
3. 1.35DL+1.75SIDL+0.75LL+1.5EQT+1WC+0.15B

For Hong Kong Limit State Method

1. 1.15DL+1.75SIDL+1.3LL+1.2W+1.1WC+1.1B
2. 1.15DL+1.75SIDL+1.3LL+1.4EQL+1.1WC+1.1B
3. 1.15DL+1.75SIDL+1.3LL+1.4EQT+1.1WC+1.1B



Reinforcement in Pile Ast chart (in cm2)
For M35 Grade concrete, Fe 500 Reinforcement

24m span, 8m pier height, 4m/s velocity, 1.2m Dia., 6 no. of pile, 3D c/c pile, III Seismic Zone

CONCLUSION

In Bridge foundation, IRC Limit State Method is consuming 23% less Reinforcement in comparing with IRC working stress method.

Hong kong Limit state method and IRC limit state method are comparatively same in Reinforcement detailing for Bridge pile foundation.(4-5% variation)

In Indian limit state method and Hong kong limit state method material utilize up to proper limit.

In Indian limit state and Hong kong limit state, The Hong kong limit state method is comparatively conservative.

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