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Study and Design of Bridge Substructure and Foundation

Chidbhav Mishra[1] , Mr. Piyush Das[2]

[1] Student MTech (Structural Engineering),Kalinga University Atal Nagar, Raipur Chhattisgarh India
Email:-chidbhav852@gmail.com

[2]Assistant Professor, Department of Civil Engineering, Kalinga University Atal Nagar,Raipur Chhattisgarh India
Email:-piyush.das@kalingauniversity.ac.in

ABSTRACT

Bridge is consisting of mainly two components like superstructure and substructure. Till nowadays lot many investigations and research work is done on Bridge superstructure's type and shape. But the substructure topic is not being in light till now. Economy of bridge depends on the cost of substructure and superstructure and therefore the bridge should be designed in such a manner that the cost of substructure and superstructure should be almost equal.

Substructure and Foundation design consist of:

- Pier cap design
- Pier design
- Pile cap design
- Pile foundation design for central span
- Well foundation design for end span

Pier cap is designed and reinforced to take care of loads of superstructure dispersing in pier. According to positions of bearings and top section of pier, when bearings are placed centrally over the pier, the load from bearings is directly transferred to pier and the pier cap need not to be designed for flexure but when bearings are not placed centrally over the pier, the part of pier cap have to be designed as cantilever portion.

The forces considered for pier design are Dead load, Buoyancy Force Live load (70 R Wheeled Vehicle), Impact Load, Braking force, Seismic Force, Wind Force, Water Current Force etc. The various load combinations are done for construction condition as well as for service condition. The pier behaves as an ordinary R.C.C. column and is designed as a R.C.C. column subjected to biaxial bending.

A rigid pile cap in reinforced concrete should be provided to transfer the load from the pier to the piles as uniformly as possible under normal vertical loads. Pile cap can be designed either by Truss analogy method or by bending theory. Here the pile cap is designed by Truss analogy method. In truss analogy method pile cap area is divided into various strips in both the directions considering number of pile and pile diameter. The truss is in triangular form with a node at the center of loaded area. The lower node of the truss lies at the intersection of the center line of the piles. Strips in both directions are designed as beam elements while remaining portion are designed as slab element.

For the analysis of pile, the forces considered are Dead load, Buoyancy Force Live load (70 R Wheeled Vehicle), Impact Load, Braking force, Seismic Force, Wind Force, Water Current Force. The various load combinations are done for construction condition as well as for service condition. Load distributed on individual pile is compared with load carrying capacity of individual pile which should be higher than the load on individual pile. The pile behaves as an ordinary column and is designed as a column subjected to biaxial bending.

The forces considered for analysis of Abutment wall are Dead Load, Live Load, Braking Force, Seismic force and Earth Pressure. For Earth pressure any rational theory shall be accepted subjected to modification that the centre of pressure exerted by the backfill is located at an elevation of 0.42 of the height of the wall above the base instead of 0.33 of that height (As per IRC Provisions). The various load

combinations are done for construction condition as well as for service condition. Abutment wall is also considered as column, so it isdesigned as a column with biaxial bending.

Abutment cap should be suitably designed and reinforced to take care of concentrated point loads dispersing in abutment. Some part of the Abutment cap is designed as corbel portion. A dirt wall is provided to prevent the earth from approaches spilling on the bearings. Dirt wall is designed for self-weight, Earth Pressure, Live load acting directly on dirt wall and braking force due to Live Load.

The main components of well foundation are Well Cap, Staining, Well Curb, and Bottom Plug. The forces considered for analysis of Well foundation are Dead Load, Live Load, Impact Force, Seismic Force and Earth pressure. A well cap is needed to transfer the loads and moments from the pier or abutment to the well or wells below. Well cap is designed by bending theory. Lateral stability of well is most important check for well foundations. Lateral Stability of well is checked by Elastic approach and Ultimate resistance approach.

The parametric study for "Loads and moments on Pier and Pile" is carried out for span of superstructure ranging between 15m to 40m is carried out. For parametric study the programis prepared in Visual Basic which gives design loads and moments for design of pier and pile.

INTRODUCTION

The civil engineer makes a vital contribution to the development of the modern world. Society relies heavily on the abilities of civil engineers to create a sustainable environment which is both functional and pleasing. The need of bridge is felt by people and it is communicated to Government through public representatives. Bridge structure is designed to provide continuous passage over an obstacle. Bridges commonly carry highways, railroad lines, and pathways over obstacles such as waterways, deep valleys, and other transportation routes. Bridges may also carry water, support power cables etc

A good bridge is one that is simple in order, has functional performance, graceful in view, balanced in distribution of mass, harmonious in proportion, orderly in lines, integral with the environment and serene in character. The subject bridge engineering is being given greater emphasis in the new curricula for engineering studies. A successful bridge engineer has to have an appreciation of aesthetics and economics, besides ability in analysis and dexterity in design.

Steps for design of bridge:

The below mentioned steps should be followed while designing a bridge

- Survey and selection of bridge site
- Collection of design data for bridge projects.
- Select type of bridge as per requirement.
- Choice of span for bridge.
- Select suitable section of superstructure.
- Select suitable type and shape of substructure as per geological condition.
- Select suitable type and size-shape of foundation as per soil condition.

LITRETURE REVIEW

1 Rakshit K. S., "Design and construction of highway bridges", New central book Agency, Calcutta, India.

The book covers various types of piers and abutments, design considerations for pier and abutment. It also covers shallow and deep foundations for bridge and their design. In particular deep foundations like pile foundation and well foundation design are covered. It explains load transfer mechanism of pile andits load carrying capacity.

2. Swami Saran, "Analysis and design of substructures- Limit state design", Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India.

It coves analysis and design of substructure and foundation of bridge. Pier design problem and well foundation design problem is also covered in this book. It also covers lateral stability of well foundation by elastic analysis and ultimate resistance approach and also stresses on well steining and well curb.

3 Victor D.J., " Essentials of bridge Engineering", Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India.

This book deals with various types of pier and abutment and their design. It covers forces due to water current and collision on pier and abutment. Examples of design of pier and abutment are discussed in this book. It also covers various types of foundation- pile foundation, well foundation and shallow foundation and their design.

4 Raina V. K., “Concrete bridge handbook”, Galgotia Publication Pvt. Ltd.
This book covers the basic principle of bridge structure analysis and design, forces to be
considered in the analysis for the design of a bridge substructure and foundation. It covers analysis and design of slender exposed piles in a group. It also deals with evaluation of base pressures and contact area under foundations subjected to direct load and any axis bending. It also covers design procedure for short-cantilever portion of pier cap and pile cap.

5 IRC-6-2000, “Load and Stresses”, Standard specifications and code of practice for road bridges, The Indian Road Congress.
This code deals with different Loads, stresses and forces acting on bridge substructure and foundation. It explains how to calculate various forces acting on bridge substructures. All substructures unit and foundation are analyzed and designed using this codal provisions .resulted when a three legged tower is compared with a four legged type

METHODOLOGY

Superstructure

Components of superstructure:
Superstructure Loads
Combinations of Live Load as per IRC:
Superstructure details for further substructure analysis and design
Pier and Pier Cap
Forces on Pier
Various Load Combinations
Steps for Pier design
Check for Stresses at the base of Pier
IRC Code Provisions for pier
Analysis and Design of pier cap
Analysis and design of Pier Cap
Analysis and design of pier
Calculation of forces on pier
Summary of Forces on pier
Load Combinations for pier
Design Loads and Moments
Design of reinforcement of Pier
Check for Stresses at the base of pier

Pile Foundation
Pile Spacing:
Minimum diameter of pile
Load transfer mechanism of Pile:
Load distribution in pile group:
Load Carrying capacity of Pile based on pile soil interaction
Capacity of individual Pile in Rock:
Capacity of individual Pile in Soil:
IRC Code Provisions for piles:
Pile load analysis
Forces on pile
Steps for Pile analysis:
Steps for reinforcement design of pile:

Pile cap
Steps for Analysis of pile cap in STAAD. Pro:
Procedure for Design of pile cap
Analysis and Design of pile cap
Analysis for forces on Pile cap
Design of reinforcement pile cap
Analysis and Design of Pile
Calculation of forces on pile
Summary of Forces on pile
Load Combinations for pile
Load carrying capacity of a pile
Loads and Moments at base of pile cap
Design of reinforcement of Pile

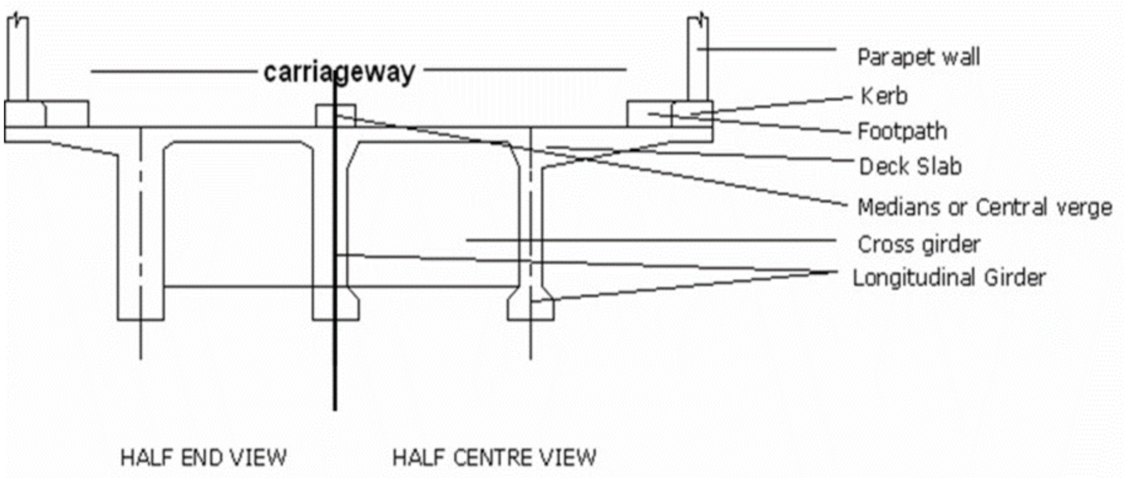
Abutment Component
Components of Abutment:
Abutment wall:
Forces on Abutment wall:
Load Combinations:
Design of Abutment wall:
Abutment Cap:

Side wall of Abutment:
Dirt wall:
Design of Abutment cap
Well Foundation

Analysis and Design of Well Foundation
Design of Well Cap

Components of superstructure:

The Figure No. 3.1 shows different components of superstructure.



Carriageway:

The minimum clear widths of carriageway to be adopted for various types of traffic areas below:

- Single Lane Bridge – 4.25m
- Two lane Bridge – 7.5m
- Multilane Bridge – 7.5m plus 3.5m for every additional lane over two lanes.

Medians or Central Verge

In case of bridges with four or more number of lanes, it would be desirable to have a raised median along the centre line of bridge. The median serves to physically separate the traffic from opposing directions and improve road safety. For economic reasons, the width of the median may be kept low, but should not be less than 1.2m.

Kerbs:

It is desirable to provide a kerb of 600 x 225mm on either side of the roadway on the bridge. The roadside edge of the kerb will have a slope of 1 in 8 for 200mm height and a curved edge with a radius of 25mm at top.

Footpath:

The width of footpath is minimum of 1.5m on bridges in rural areas and it is increased suitably in urban areas. The capacity of the side walk is taken as 108 persons per minute. The width should be increased in steps of 0.6m for every additional capacity of 54 persons per minute.

Parapets or Railings:

Railing should be for a height of 1.1m less one half of the horizontal width of the top rail. The space between the bottom rail and the top rail should be filled by means of closely spaced horizontal or inclined members.

Girders and Slabs:

Concrete bridge decks which are transversely connected only by situ slabs are usually referred to as Girder and Deck bridge. These bridges are by far most commonly adopted type in the span range of 10 to 50m. The majority of girders and slab decks have number of girders spanning longitudinally between pier to pier or pier to abutment with a thin slab spanning transversely across the top. The longitudinally spanning girder is known as longitudinal girder and transversely spanning girder is known as transverse girder or cross girder. Usually

I-section or T-section is used for the girder. T-section girders are one of the most common example under this category and very popular because of their simple geometry, low fabrication cost, easy erection or casting and smaller dead loads. T-section girder bridges with cross beams extending into and cast monolithically with deck slab is found to be more efficient and is recommended for adoption. Simply supported R.C. T-section girder is normally adopted for spans up to 25m. Span-depth ratio is generally kept as 10 for simple spans and 12 to 15 for continuous span. In some cases, single cell or multicell box girder bridges are also preferred. For more than 25m span I-section girder is generally provided. One typical section and plan of a 40m span bridge superstructure as given by MOST (Ministry Of Surface Transport) .

DISCUSSION AND FUTURE SCOPE

Aim of the study will help to analyse and design the substructure units of the bridge and its foundation. As per IRC-6, 2000, the following loads will be acting on the substructure unit:

- Dead Load of superstructure for span of 40m (As per MOST)
- Live Load of vehicle (70-R Wheeled Vehicle)
- Impact effect
- Buoyancy force
- Effect of wind on moving load and on the superstructure
- Forces due to water current
- Longitudinal forces due to braking effect of vehicles and due to bearing rigidity.
- Seismic force.

REFERENCES :

1. Rakshit K. S., "Design and construction of highway bridges", New central book Agency, Calcutta, India.

2. Swami Saran, "Analysis and design of substructures- Limit state design", Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India.

3. Victor D.J., " Essentials of bridge Engineering", Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India.

4. Raina V. K., "Concrete bridge handbook", Galgotia Publication Pvt. Ltd.

5. Ministry Of Surface Transport (MOST) Classification

6. Mark E. Williams, Marc I. Hoit, "Bridge pier live load analysis using neural networks", Science-direct Journal, Advance in Engineering Software, Vol. 35-2004

7. Kyle M. Rollins, Robert J. Clayton, Rodney C. Mikesell, and Bradford C. Blaise, "Drilled Shaft Side Friction in Gravelly Soils" Journal of Structural Engineering, Vol. 131, No. 8, August 1, 2005

8. Al-Homoud A.S.,Whitman R. V.," Seismic analysis and design of rigid bridge abutments considering rotation and sliding incorporating non-linear soil behavior", Science-direct Journal, Computers and Structures, Vol. 18-1999.

9. IRC-6-2000, "Load and Stresses", Standard specifications and code of practice for road bridges, The Indian Road Congress.

10. IRC-78-2000, "Foundation and substructure", Standard specifications and code of practice for road bridges, The Indian Road Congress.

11. IRC-5-1998, "General features of Design", Standard specifications and code of practice for road bridges, The Indian Road Congress.

12. N. Krishnaraju, "Design of bridges", Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India.

13. J. C. Sarkar, "A seismic design of bridge", New central book Agency,Calcutta, India

14. Khaled Sennah and John B. Kennedy Fellow, "Simply Supported Curved Cellular Bridges: Simplified Design Method", Journal of Bridge Engineering, Vol.4, ASCE, pg-85-94, 1999

15. Khaled Sennahi, Xuesheng Zhang and John B. Kennedy Fellow, "Impact Factors for Horizontally Curved Composite Box Girder Bridges", Journal of Bridge Engineering, Vol.9, ASCE, pg-573-520, 2004