Introduction to Skeleton Bridge Abutment

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Abstract**—***Abutment in a bridge structure is a vital component, defined as the first and the last support to the bridge deck. Most commonly used bridge abutment type is the wall type abutment. Bridge abutment is subjected to horizontal and vertical forces. Horizontal forces are due to braking of vehicles on the bridge deck and the force due to soil fill behind the abutment. Vertically transferred force on to the abutment from bridge deck is constant for a particular live load combination, but the horizontal force varies with the height of the abutment. Tall abutments are subjected to massive earth* pressure *force. For shorter height of the abutment, the dominating force would be the vertical force and when the abutment height increases the dominating force changes from vertical to horizontal. In order to avoid the massive earth pressure of the embankment, the skeleton bridge abutment could be used effectively. Skeleton abutment supports the bridge superstructure and it does not effectively support the horizontal force due to earth pressure. This paper describes the basic concept of skeleton bridge abutment, its behaviour, advantages and disadvantages, limitations in practice and its practical application in 'Mahaweli Raja Mawatha' from Adikarigama to Mapakada in Sri Lanka.*

Keywords**—**Bridge, Earth Pressure, Skeleton Abutment

I. INTRODUCTION

Bridge is a structure that provides passage over an obstacle without closing the way underneath. The obstacle can be a deep valley, water way, road or any other development. Bridge structures are extremely useful and widely used in infrastructure development work across the globe. Bridges are of various types and shapes depending on the location, span, aesthetic and architectural appearance. Though various types are available, most common type used is the wall type abutment due to its less complication in design and construction. Bridges are made out of different types of construction material such as stones, timber and various other materials in *ancient* times but modern bridges are constructed mainly with steel, concrete or combination of both.

II. BRIDGE SUPER STRUCTURE

The part of the bridge that spans the obstacle is the superstructure. It transfers the traffic and other loading from the super structure to the substructure.

III. BRIDGE SUBSTRUCTURE

The part of the bridge that holds the superstructure in position is the substructure. Substructure consists of end supports and intermediate supports according to their position along the bridge. End supports are called Abutments and intermediate supports are called Piers. They transmit the forces from the super structure to the foundation. The main difference between a Pier and an Abutment is that, Pier supports only the vertical load transferred from bridge deck and Abutment supports the vertical forces as well as horizontal forces.

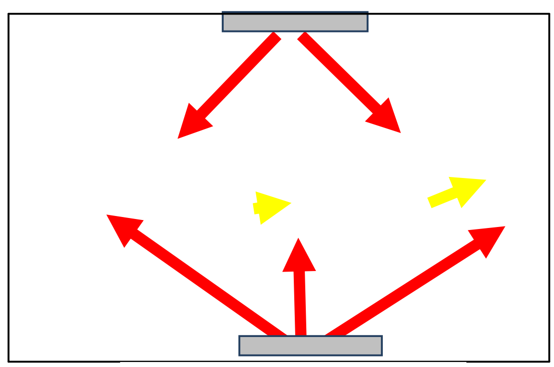

Figure 1: Typical bridge arrangement

IV. ABUTMENT TYPES

There are two basic types of bridge abutments widely used in the construction industry.

A. Wall Type Abutment

This is the conventional wall type structure, constructed with wing walls to retain the approach embankment fill. Wing Walls can be of different shapes and forms as shown in figure 2. These abutments can be in mass concrete, semi mass concrete, and cantilever or counter fort type as shown in figure 3. Wall type abutments support the vertical force imposed by the bridge deck and the horizontal force due to the braking of vehicles on the bridge deck (Braking Force) and the force due to the earth pressure behind the abutment.

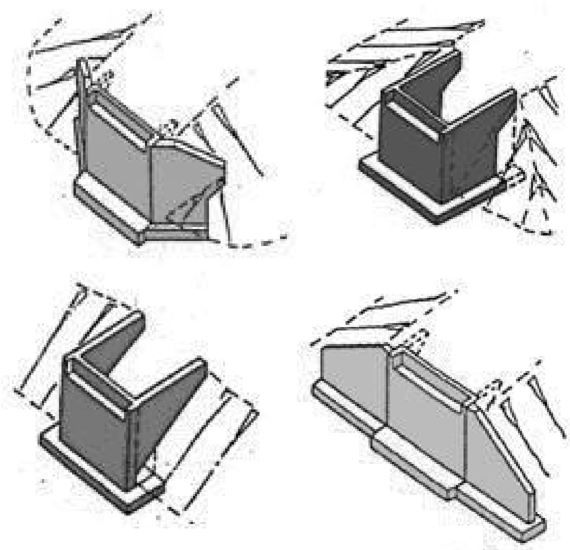

Figure 2: Conventional wall Abutments with wing wall

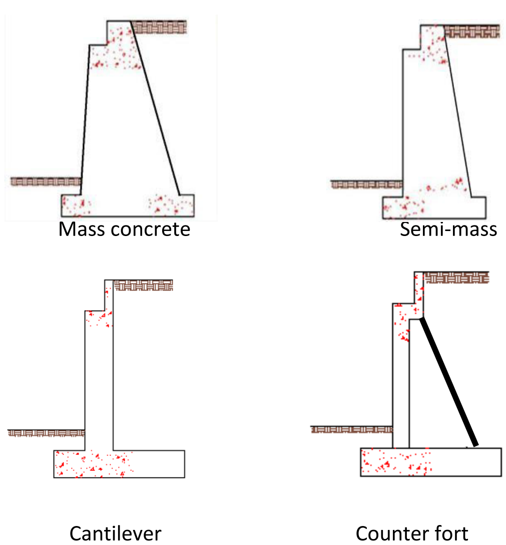

Figure3: Typical Wall Abutment cross Section

1) Some practical Examples

Figure 4: Typical applications of straight wing walls

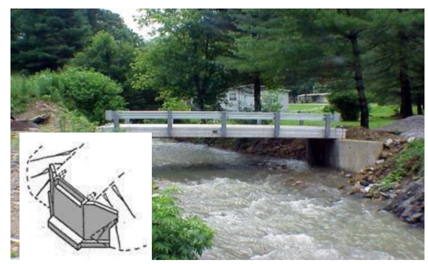

Figure 5: Typical application of splayed wing walls

B. Open Type Abutment

This is a structure without a front wall to support the earth back fill as in conventional abutment. This type is also called as skeleton or spill through abutment, because it is not a closed earth containing structure. Therefore open type abutments do not effectively hold the embankment fill of the approach road fill. Skeleton/spill through abutment is buried. It consists of capping beam sitting on two tapered columns and a base slab under the columns as shown in figure 6.

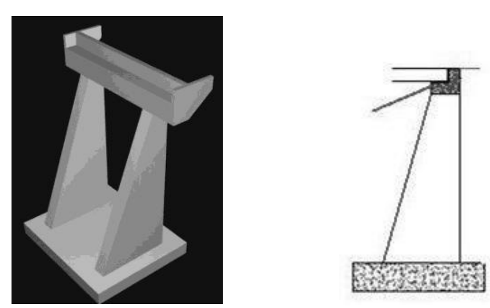

Figure 6: Skeleton or Spill through abutment

1) *Other forms of Open Abutment*

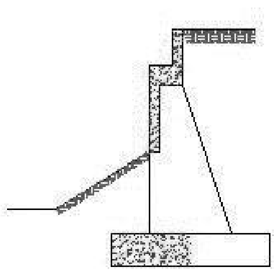

Figure 7: Skeleton abutment with part earth support

2) *Bank Seats on cuttings*

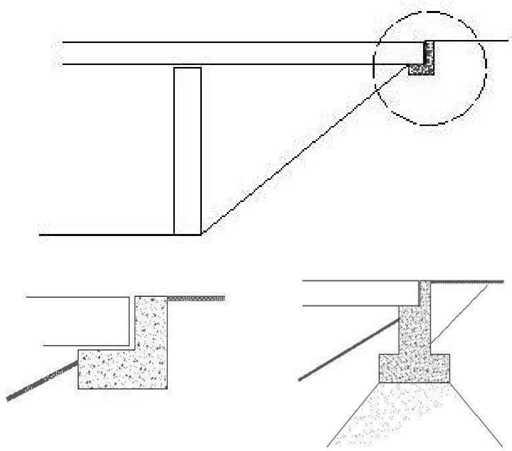

Figure 8: Typical Bank Seats

3) *Bank Seats on Piles for weak grounds*

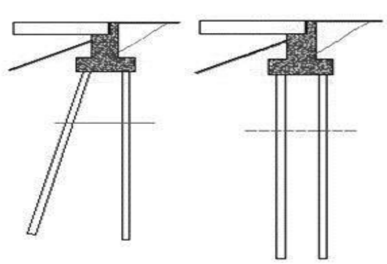

Figure 9: Typical Bank seats on Piles

V. ANALYSIS

A. Main consideration

The height of an abutment depends on the location of the bridge. When the abutment structure is tall, Abutment is subjected to a massive earth pressure force.

In case of tall abutments where conventional wall abutments are used, to meet the stability requirement such as sliding, overturning and foundation bearing, large concrete sections are required. In case of mass concrete walls, the body of the abutment structure becomes massive. This will increase the weight of the structure as well. Therefore the structure has to be founded on sound and strong strata with high bearing capacity. For conventional wall type abutments, where wall is designed as cantilever or counter-fort wall, the thickness of structural components become thick for tall abutments. Due to the massiveness of structure the construction cost will also be high.

In place of these conventional wall abutments, skeleton or open abutments can be considered as an alternative. Due to the skeleton nature of the structure, open Abutments are light in weight and massive structural sections can be avoided. Thereby the cost of the structure can be brought down as well.
The back fill which creates the approach to the bridge, would be made to act as a normal embankment fill with a natural stable slopes.

B. Main functions of Bridge Abutment

Abutments in a bridge structure serve following functions.

- Supports the bridge deck
- Transmit the load from the super structure of bridge to the foundation
- Provides support and retain the earth fill of embankment of approaches
- Serve as a retaining wall
- Gives final formation to the bridge

C. Main Forces acting on the Abutment

1) Forces transferred from the Bridge deck
    - Braking Force
    - Dead load and Live Load

2) Force acting on the back of the wall from backfill earth

Forces acting on a conventional bridge abutment are shown in figure 10.

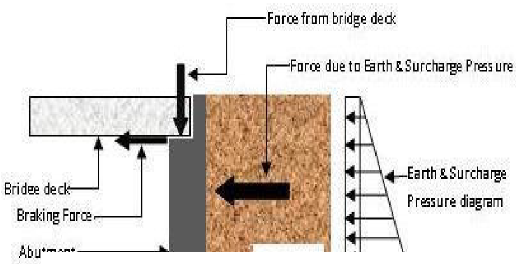

Figure 10: Forces on Bridge Abutment

VI. WHAT IS A SKELETON ABUTMENT

It is a concrete framed structure which supports the bridge Deck and the back fill material is not retained. Skeleton abutment is buried in the embankment. It consists of following structural components.

1) Base Slab
2) Tapered columns
3) Capping beam
4) Wing walls

The vertical load transfer would be from superstructure to the capping beam, then through the two Tapered columns on to the base slab and to the bearing ground.

VII. HOW OPEN ABUTMENTS RETAIN FILL MATERIAL

As the skeleton abutment (spill through abutment) does not retain the backfill material effectively, abutment has to be buried and stable slope is maintained in front of the structure. The earth slope which is in contact with water, need to be protected from erosion and wave action by a riprap or with a gabion mattress with a geo textile underneath.

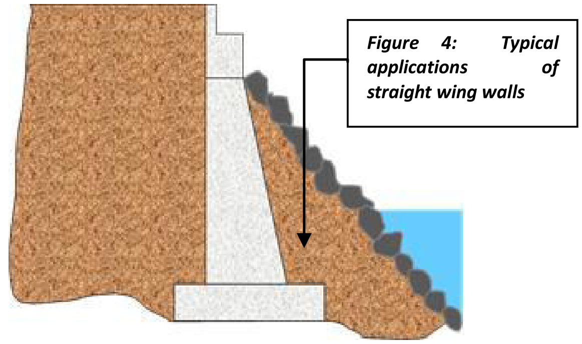

Figure 11 : Embankment Protection

VIII. APPLICATION OF SKELETON BRIDGE ABUTMENT IN MAHAWELI RAJA MAWATHA

Mahaweli Raja Mawatha runs through hilly terrain on the right bank of Mahaweli River from Adikarigama to Mapakada in the central part of Sri Lanka. When the road profile was finalized during the feasibility study, five stream crossing were encountered and stream valleys were found to be fairly steep.

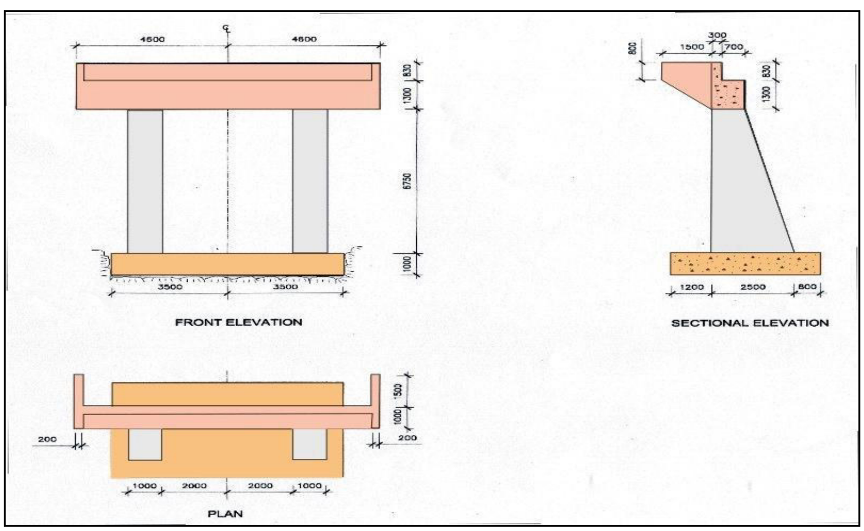

Figure 12: Diyameegolla Kandura Skeleton Bridge Structure

After careful study of various structural options, the economic analysis justified the use of skeleton bridge abutments in these bridges. After initial analysis of forces and stability considerations, structural arrangement and sizes of structural components were decided.

Columns needed to have larger cross section at the bottom to take up the Bending moment due to earth pressure on the column face, and tapered down to a minimum section at the top to match with the capping beam width. Due to the closeness of the 1m wide tapered columns, active earth pressure coefficient (ka) was doubled as recommended by the hand book[1]. Tiny wing walls were used to the depth of the capping beam, to retain the top most part of the earth back fill at road finished level.

A. Practical Applications

The list of bridges where skeleton abutments were used effectively on Mahaweli Raja Mawatha is given below. These bridges were decided based on the technical and economical justification.

1) Diyameegolla Kandura Bridge
2) Belihul Oya Bridge
3) Kurundu Oya Bridge
4) Uma Oya Bridge
5) Badulu Oya Bridge

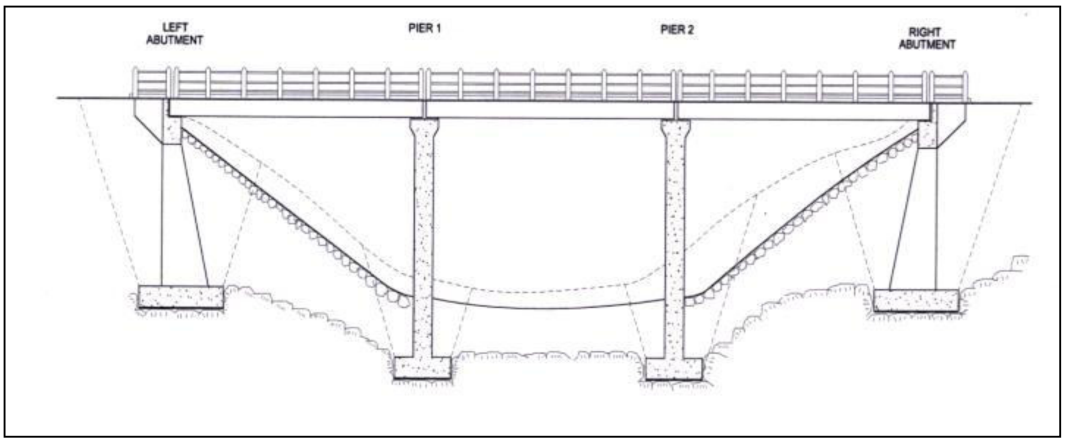

Figure 13 : ***Diyameegolla Kandura Bridge - Longitudinal section on Bridge***

B. Images during Construction

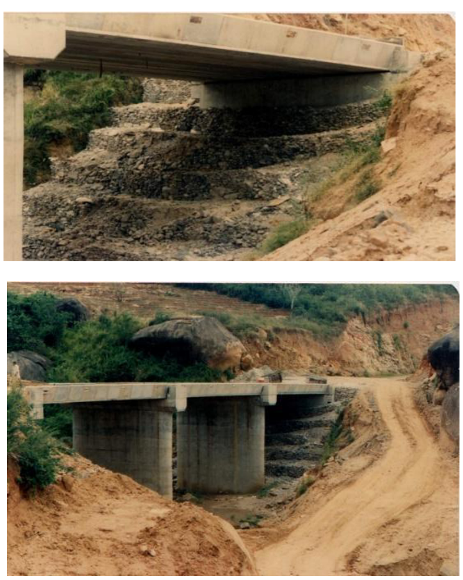

Figure 14: Diyameegolla Kandura Bridge

Figure 15 : Kurundu Oya Bridge

Figure 16: Badulu Oya Bridge

C. Other Applications

Skeleton abutments can also be used in expressways as shown in figure 17.

Figure 17: Express way Application

X. ADVANTAGES

There are several advantages in using skeleton type of abutment. Due to less material involved in construction, the structure is lighter. As such strong foundation material with high bearing capacity may not be essential for these structures. Earth pressure force component on the structure would be minimum; hence concrete sections can be made smaller. If carefully planned, expensive wing walls can be omitted. Comparatively Abutments can be made short. As the structure is placed away from the water stream in the embankment, stream flow is not blocked. This is a better solution for steep banks as conventional abutments become very tall. There would be a cost saving over conventional abutment due to material saving.

XI. DISADVANTAGE

Sufficient space is required in front of abutment for the natural fill slope and the bride span may be slightly more than conventional bridge as the structure is pushed in to the embankment. Comparatively construction is cumbersome due to the presence of more number of individual structural components than conventional abutment. In conventional abutment it is only base slab, wall and wing walls whereas in skeleton abutment there are base slab, tapered columns, capping beam and wing walls (if required).

Comparison with respect to location can be seen from figures 18 and 19.

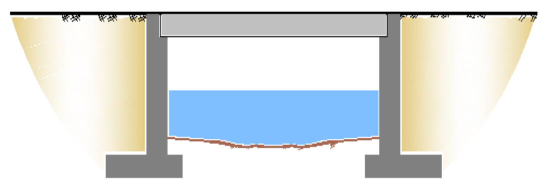

Figure 18: Conventional wall Abutment

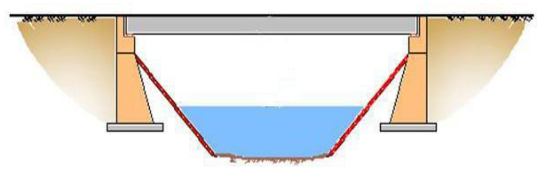

Figure 19: Skeleton bridge Abutment *s*tructure

XII. CONCLUSION

Main deciding factors of skeleton abutment over conventional abutment would be, shape of the Valley, bearing capacity of foundation material, Hydraulic data and Cost comparison. Careful study of the bridge site and cost comparison shall be done along with other alternative abutment options. If selected carefully giving due consideration to structural components and their arrangement, economical solution can be arrived at. There by considerable amount of resources could be saved. Hence it is the responsibility of the designers to look in to these areas before making a final decision. This is a deviation from conventional thinking which can be utilized for the development of the industry.

REFERANCES

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BIOGRAPHY OF AUTHOR

Author is a chartered civil Engineer by profession attached to Central Engineering Consultancy Bureau (CECB) as Additional General Manger. He At He is in-charge of ‘Airport and Road Designs’ division of CECB. He has more than 30 years of experience in the field of Highway Engineering. He was a Design Engineer responsible for Highway and Bridge designs of Mahaweli Raja Mawatha, from Adikarigama to Mapakada in Sri Lanka. He has made Presentations on the theme ‘Introduction to Skeleton Bridge Abutment’ at Engineering organizations and also at the Institution of Engineers, Sri Lanka. He is presently the Chairman of Civil engineering Sectional committee of Institution of Engineers, Sri Lanka