Hydraulic Design of Safe Bridges

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Abstract—This paper presents the reason of bridge failure and tells how to make bridge safer. In this paper it is illustrated mainly the reason of hydraulic action of bridge failure and provide the solution of the problem. Since bridge is a very important structure in civil engineering field so it needs a great attention toward it, for constructing a new safe bridge at any location it is important to analyse and collect the data of analysis. After analysing the execution must be done according to the results and data available. The Bridge designed in this way will always serve people. In this paper all relevant reason of failure and its countermeasure are discussed. In earlier era the designing of Bridges is done on the basis of previous experiences, but due to some accidental failure of Bridges it was seen the need of manuals and guidelines. So, that's why now a days construction of new bridges is done according to these manuals. In this paper some of them are discussed.

Key words: Safe Bridges, construction

I. Introduction

Bridge is a structure built over a water body or any obstacle or depression to allow the passage of pedestrians or vehicles. There are various reasons for the failure of bridges. Some of those are as follows.

1) Earthquake
2) Fire
3) Crash of trains or vehicles
4) Boat impact
5) Flood
6) Manufacturing defects
7) Design defects
8) Poor maintenance
9) Odd occurrences
10) Hydraulic actions

Here we focus only hydraulic action for failure. Hydraulic action may be happened due to any of the following reasons.

- Scour
- Hydrostatic force
- Buoyancy force
- Stream pressure and lift
- Wave force
- Effect of debris
- Effect of ice

The biggest number of failure of bridge is caused by bridge hydraulics. This means anything related to water and includes things like bridge scour, being clogged by ice or debris, approach road wash-outs, Hydrostatic force and just being pushed over by water.

There is a data collection of reason for bridge failure which shows various ways or modes of bridge failure. As shown in table and graph below.

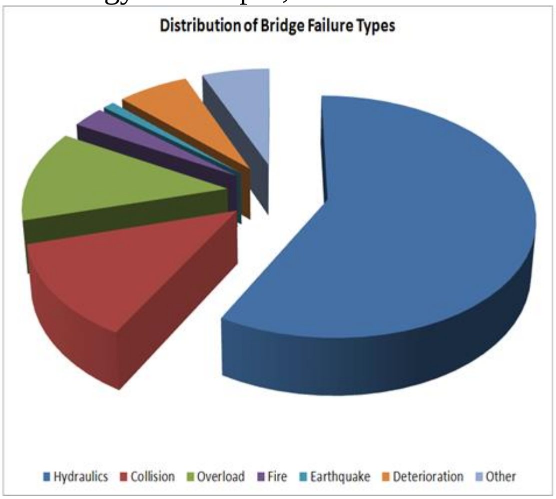

Fig. 1: Percentage failure by various reason Source: Wikipedia.

II. Problem discussion

A. Scour

Bridge scour is defined as the removal of sediment like sand and rocks from around bridge foundation. It is the engineering term for the erosion of soils, alluvium or other materials around the bridge abutments. It is caused by swiftly moving water on the bed of water body like rivers, channels, canal, sea etc. scour can made out scour holes, compromising the integrity of a bridge element. Scour is the most common reason of hydraulic failure of bridges.

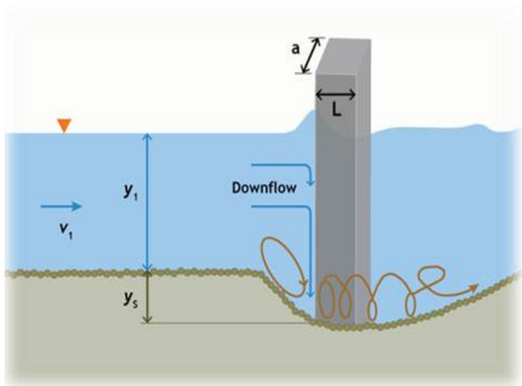

Fig. 2: Scour at Pier Foundation

1) Scour Countermeasures:

Scour and the stream instability have each time threatened the safety of the bridges over water. Countermeasure is proposed to control, inhibit, alteration, delay, or reduce these threats. In addition to countering erosion and scour, with few exceptions countermeasures also alter flow and need to be included in hydraulic models. This section describes hydraulic modeling considerations for several countermeasures.

2) Countermeasures Based On Scour Type:

Scour countermeasures are based on the type of scour, such as contraction and local scour, aggradation or degradation.

The design and selection of scour countermeasures depends on the type of scour problem at a specific site. Scour problems at a specific bridge site can be classified to meet the following objectives:

- Make existing bridges safe against scour.
- To identify common scour problems at bridge locations.
- To group together a family of site conditions causing scour.
- To recognize modes, common traits and physical characteristics causing scour.
- To perform qualitative and quantitative appraisals of the variety of scour problems at bridge sites.
- To find suitable solutions for the scour problems.
- To rate the bridges for the degree and magnitude of scour.
- To implement a safe bridge program, by preventing any scour failures.

3) Recommended Pier Countermeasures:

Different factors will affect the screening and the selection of countermeasures for a particular bridge site. The following pier countermeasures are recommended for applications to bridges:

a) Armoring Countermeasures:
- Riprap
- Gabions and Reno Mattresses
- Articulated Concrete Blocks/Cable Tied Blocks
- Concrete Armor Units

b) Flow Altering Countermeasures:
- Upstream Sheet piles
- Flow Deflecting Vanes or Plates

c) Structural Countermeasures:
- Structural Repairs using concrete
- Grout bags
- Casting concrete aprons
- Shielding by sacrificial piles
- Sheet piles

4) Countermeasures For Footings On Soil And Rock:

The following figure gives Illustrations of Countermeasures on the bridge footings on the rock and soil. Theoretically, good quality bedrock will not require any countermeasure. However, irrespective of erosion, the footing should never be exposed. A layer of insulation of one-foot minimum is required to address anti-frost, thermal changes and vegetation growth. This may be in the form of soil with riprap or an alternate countermeasure at the top of a footing.

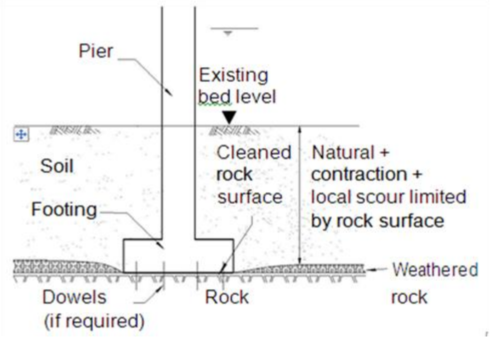

Fig. 3: Spread footing on sound rock.

B. Channel Instability:

In the context of safe bridge design, channel instability includes any channel change that can threaten a bridge foundation. The change may be natural or result from a variety of human activities. Channel instability can create changes in channel geometry that expose foundations and increase scour during floods. Even though these changes may be gradual or episodic, they are usually cumulative and are considered long-term because they alter the channel over the life of the bridge. Therefore, the potential for vertical and horizontal change must be considered in safe bridge design.

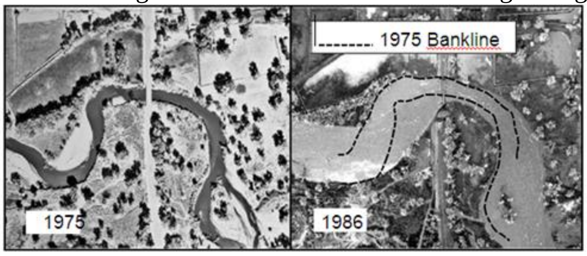

Fig. 4: Channel widening and meander migration on Carson River near Weeks, Nevada.

C. Alluvial Fans

Alluvial fans are very dynamic sedimentary landforms that can create significant hazards to highways as a result of floods, debris flows, deposition, channel incision, and avulsion .They can occur where there is a change from a steep to a flat gradient, especially in mountainous regions. Alluvial fans as sedimentary deposits that are convex in cross-profile and located at a topographic break, such as the base a mountain, escarpment, or valley side, that is composed of stream flow and/or debris flow sediments and that has the shape of a fan either fully or partially extended. As the bed material and water reaches the flatter section of the stream, the coarser bed materials can no longer be transported because of the sudden reduction in both slope and velocity. Consequently, a cone or fan builds out as the material is dropped. Alluvial fans are often characterized by unstable channel geometries and rapid lateral movement. The steep channel tends to drop part of its sediment load in the main channel building out into the main stream. In some instances, the main stream can make drastic changes, or avulsions, during major floods.

Fig. 5: Alluvial Fan

D. Hydrostatic Force:

Weight of water exerts hydrostatic pressure in all direction. Pressure is calculated as multiplying the height of the water level above the point of attention with the density of water. In this way the pressure is highest at the lowermost point of the submerged element and is zero at the water level surface.

Hydrostatic force applied on a bridge element in any certain direction is the summation, or integral, of the product of the pressure and the surface area of the bridge element projected in the plane perpendicular to the direction of the force. Hydrostatic forces on one side of a bridge are at least partly balanced by opposing hydrostatic forces acting on the other side. Any imbalance in the hydrostatic force is due to variation in the water surface elevation. Bridge designers must be informed of the water surface elevation upstream and downstream of the bridge for the design flood in order to evaluate the hydrostatic forces.

E. Buoyancy Force:

Buoyancy is an uplift force equal to the weight of water displaced by the submerged element. It can be a threat to a submerged bridge superstructure if the superstructure design incorporates large enclosed voids as with a box-girder or if air pockets develop between girders beneath the deck. Buoyancy is also a factor in evaluating wave-related forces on bridge decks, discussed later in this chapter. If a pier is constructed with a large empty void, the buoyant uplift force acting on the pier may be significant. Bridge designers must be informed of the water surface elevation upstream and downstream of the bridge for the design flood in order to calculate the buoyancy forces.

F. Stream Pressure on Piers:

The drag coefficient for piers is a function of the shape of the pier nose (upstream end), the plan view shape of the pier, the skew (if any) of the pier axis versus the flow direction, and the presence or absence of debris on the pier. The hydraulic engineer must inform the bridge designer of the magnitude and direction of the local impinging flow velocity for the design event, as well as the flow depth and debris collection potential, in order to evaluate the stream pressure on a pier.

G. Wave Forces:

The design of bridges in coastal settings must consider the potential for significant wave forces.

Waves striking a bridge superstructure impart forces acting both horizontally and vertically. The magnitudes of the forces depend upon several factors including the tide level, storm surge, and properties of the anticipated waves.

The hydraulic engineer should be prepared to provide the following information, with input from a coastal engineer:

Fig. 6: Wave forces on bridge piers.

- Maximum probable wave height for the design event
- Wave length Wave period
- Upwind fetch over which wave can be generated
- Storm tide water surface elevation at the bridge for the design event, including local wind setup where appropriate
- Stream bed elevation at the bridge
- Current velocity from tidal hydraulic modeling for the design event

H. Effect of Debris:

Debris accumulation changes both the geotechnical and hydraulic characteristics of a bridge. Debris may accumulate at the upstream or downstream end of a bridge or under a bridge. Debris consists of indigenous material deposited at the bridge obstruction from continued floods and long-term aggradation. The material transported by water flow varies according to demography and the type of terrain.

Fig. 7: Large Floating Debris Accumulation

I. Countermeasure For Debris Of Bridges:

The most commonly used countermeasures for bridge structures are features incorporated into the design of the structure to reduce the potential for trapping and accumulating debris. Unfortunately, specific guidance or guidelines do not presently exist for these design features. However, general guidance is presented below.

1) Effects Of Ice:

When ice accumulates at a bridge and forms a substantial ice jam, significant problems can develop. Some of the negative consequences include bridge scour and bank erosion, even during times of low stream flow. Ice jams also impart significant lateral forces on the bridge. Similar to debris blockages, ice jams magnify the stream pressure forces by increasing the surface area to which the stream pressure is applied. The upstream water surface elevation (and consequently the hydrostatic force) is affected by the inordinate amount of backwater that often accompanies ice jams. The elevation at which ice is expected to accumulate has a significant influence on the bridge stability calculations.

The design team should perform site -specific research to assess whether ice jamming is a relevant concern. If it is a concern, the hydraulic engineer may be required to develop hydrologic and hydraulic information to assist the bridge designer in evaluating ice forces. It may be beneficial, for instance, to determine the months of the year when ice jamming is most likely to occur. Stream flow records would then be studied to assess the potential for flooding during the most likely ice jamming months, and to identify a stream flow rate that represents a reasonable yet conservative flow rate for assessing the potential elevation of an ice jam on the bridge. Field reconnaissance may reveal evidence of the elevation range within which ice jams typically form.

III. CONCLUSION

Bridge design is a very tough and very complex task of execution. Since, it is a regular used structure in human life, so it requires more attention towards its safety. A new bridge must be constructed according to provided guidelines and manuals to make a bridge safe without any risk. This thesis provides information and discussion on the range of design considerations, environmental considerations, and regulatory requirements that may be encountered during bridge design and construction. There is sufficient information to serve as a reference source on the equations used in open channel and bridge hydraulics.

This paper discusses an extremely important aspect of bridge safety. Scour during floods is a significant part of bridge design and is a primary contribution of the hydraulic engineer to the bridge structural design. This thesis resource for hydraulic engineers to identify additional factors that may impact bridge design and structure safety. These topics include bridge deck drainage, hydraulic forces on bridge decks, piers and pile groups, coincident flows at confluences of rivers, physical modeling, and computational fluid dynamics.

Thesis provides nearly all the information in a way of safe design of bridges. It has been seen in the practice that the bridges which are constructed with these guidelines provided in this thesis are safe during any natural accident. Thus it must be taken as a compulsory task in design and execution of bridges.

IV. REFERENCES

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