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Research Article

Oro-Ago Collapsed Bridge in Ifelodun Local Government Area in Kwara State: Engineering Evaluations and Analysis

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Abstract

Bridges are generally build as a structure over any obstruction (e.g. Rivers) in order to provide easy movement over such an obstruction without any delay during the movement of traffics. The major reason for the movement is for the transportation of goods and services over such an obstruction to other places where such goods and services are needed. When Bridges over any Obstruction becomes Non-Functional to the users, especially when economic development of any Society is involved, a revisitation of such a Bridge would call for the attention of those who designed and carried out the construction of such a Bridge. This paper discussed the Collapse of a Bridge Structure with Engineering Evaluation and Analysis in Ifelodun Local Government area in Kwara State. The paper also proffered solutions for the collapse Bridge.

Keywords: Collapsed Bridge, Engineering Evaluations Analysis

INTRODUCTION

A bridge is a structure that is usually constructed over a river, canal, valley, roadway or any such obstruction for the purpose of providing passage for the intended traffic above the obstruction. A bridge serves as an important land mark and as such the aesthetics of the bridge should be giving proper consideration before deciding on the type of consideration. A proper consideration in terms of design and construction that is not giving to many Bridges is the reason for their failures which eventually lead to the collapse of such Bridges.

MATERIAL AND METHOD

The Methodology adopted for this Paper is under the followings;

(i) A regular visit to the Bridge Construction Site for two years (2012-2014), which finally collapsed in the third week of April, 2014
(ii) Professional remarks from the Engineers that are within the site vicinity of the collapsed Bridge
(iii) Photographs taken immediately after the collapsed of the Bridge.


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Historical records of Collapsed Bridges World Wide

Bridges have collapsed in many parts of the world in the past. The collapsed of these Bridges resulted in causing many damages which could not be accounted for. The Bridges listed below are examples of the ones that are noted with their dates of occurrence in this paper;

Table 1. Historical records of collapsed bridges world wide

S/N	Dates	Descriptions
1	September 11, 1916	Queber Bridge (Canada)
2	December 15, 1967	Silver Bridge (U.S.A.)
3	March 17, 1945	Ludendorff Bridge (Remagen, Germany)
4	May 19, 1980	Sunshine Skyway Bridge (Florida, U.S.A.)
5	June 28, 1983	Mianus River Bridge (Connecticut, U.S.A.)
6	October 21, 1994	Seongsu Bridge (Seoul, South korea)
7	January 4, 1999	Rainbow Bridge (China)
8	March 4, 2001	Hintze Ribeiro Bridge (Castelode Paiva, Portugal)
9	August 28, 2003	Bridge Daman (Daman, India)
10	November 7, 2005	Alumunecar, Spain Bridge
11	December 2, 2006	Bihar, India Bridge
12	August 1, 2007	Minneapolis Bridge (U.S.A.)
13	August 13, 2007	Tuo River Bridge (Humai China)

Source: Civil Engineering disaster University of California, Berkeley, U.S.A. (2008)

Components of a Bridge

A bridge can be broadly sub-divided into parts:-
(i) The superstructure and
(ii) The substructure
The superstructure bears the load passing over the bridge and transmits the same together with the other forces caused by the moving loads to the sub-structure.

Components of Superstructure

The supper structure of a bridge, also termed its decking consists of the following main components:
(i) Deck slab including structural system of longitudinal girders, cross-girders, trusses, etc. provided for supporting deck slab
(ii) Kerbs, footpath, hand rails, etc
(iii) Wearing coat

Components of Sub-Structure

The sub-structure of a bridge consists of the following main components:
1. Abutments, wing walls and piers together with their foundations, which may be of shallow type (isolated footing, combined footing, strip footing or raft) or deep type (piles, wells or caissons)
2. The bearings are usually provided above abutments and piers on which the superstructure rests. The function of bearings is to transmit the load received from superstructure to the substructure and also permit small magnitude of movements due to temperature variations, deflection or sinking of supports of the superstructure without any damage to the bridge.

Classification of Bridges (part one)

Concrete bridges can be broadly classified as follows:
1. **Solid Slab Bridge:** This is the simplest type of bridge wherein the deck slab serves as the main load carrying member. The slab is supported load directly on the embankment or substructure. This type of construction is considered suitable for culverts or small bridges up to span of about 8m. The construction of this type of bridge is economical because of simple arrangement of reinforcement and less expensive form work.
2. Slab and Girder Bridge or T-beam Bridges: This type is commonly built for spans ranging between 10 to 25m. the deck slab is supported by longitudinal girders or beams which are cast monolithically with the slab. The number of longitudinal girders in the bridge depend upon the width of the carriage way.
3. Box Girder Bridge: This type of bridge consists of a top slab that is normally wider than the box girder. The box girder consists of vertical webs and bottom slab usually as broad as the out to out width of the girder webs.
The webs of the box girder may be 250 to 350mm thick and the bottom slab may be 150 to 200mm thick. The top slab, the webs and the bottom slab are usually built so as to acts as one unit. This type of bridge is considered suitable for spans ranging from 30 to 45m. beyond this span range, it is necessary to post torsion the box girder.
4. **Balance Cantilever Bridges:** This is a continuous type between 30 to 60m. The structural arrangement of decking consists of combination of supported stands, cantilevers and suspended spans with the construction of this bridge, the main longitudinal girders from each end span cantilever out from the first pier next to abutment. A gap is normally left between the two free ends arms of the girders. A short beam is thereafter placed on the two free ends of the cantilevered aims to close the gap.
5. **Rigid frame Bridge:** This type of bridge usually consists of a number of parallel longitudinal girders (Solid slab) which are rigidly connected to the supporting columns or piers. The decking and the supporting substructure are normally cast together monolithically.
6. **Arch Bridge:** This type of bridge is used for sites having deep and steep rocky banks which serve as natural abutments for resisting the thrust of the bridge arch. This type of construction offers advantage for large head rooms, and for navigation. The arch could be constructed in the form of single solid slab or in the series of independent ribs connected to each other.
7. **Cable Stayed Bridge:** This type of bridge is considered suitable for spans as from 200m to 600m.
The major components of the bridge are:
i. Towers

ii. Series of high tensile steel cables
iii. Deck made out of concrete or steel spanning across the stiffened girders.
The bridges is normally supported by a number of cables, provided by a number of cables, provided in two parallel planes and connected to the towers. The reason for using multiple cables is to provide support to deck as closer intervals thereby resulting in a closer spacing of deck girders, and thereby achieving reduced depth of the decking.
8. Suspension Bridge: This type of bridge is suitable for spans varying between 400m to 1200m. the major components of this bridge are:
i. Towers
ii. High tensile steel flexible cable
iii. Anchorage
iv. Suspenders made up of high tensile steel wires
v. Deck of concrete or steel spanning across the stiffened girders.
This bridge is usually supported by cables on tower and each cable is anchored to anchorage blocks at both ends. The deck is normally attached to steel suspenders, which transfer the load from the deck to the cable supported on towers.

Classification of Bridges (part two)

Bridges can also be classified by their purpose or specific functions they serve generally. These classifications can be in the following order:
i. Materials as timber, masonry, concrete, pre stressed concrete, reinforced steel, etc.
ii. They can be classified by the span relationship as simple, cantilever continuous, arch type, balanced cantilever suspended, rigid, etc.
iii. They can be classified by the relative position of floor such as deck, semi-through, etc.
iv. They can be classified by the methods of joining of the members such as pre-connected, riveted, welded, etc.
v. They can be classified by the methods of providing clearance for navigation purposes sliding, vertical lift types, transporting or traversing type.
vi. They can be classified as fixed bridges floating bridges, raft bridges, etc.
vii. They can be classified as temporary, semi-permanent and permanent bridges, etc.
viii. They can be classified as straight and skew bridges, etc.

Factors to be considered in selection of Bridge Type

Selection of bridge type involves a number of factors. In general, these factors are related to economy, safety, and aesthetics. It is not possible to place these factors in any particular order of importance; the relative importance is likely to vary from project to project and each must be considered on its merits.

Geometric Condition of the Site

The type of bridges selected will often depends on the horizontal and vertical alignment of the highway route and on the clearance above and below the roadway.

Clearance Requirements

All bridges must be designed to ensure as far as is possible, that they are not struck by vehicles, vessels or trains, which may pass above them. This requirement is normally met by specifying minimum clearances. It must be remembered that designed values must take into account deflections due to any loading that may occur on the bridge structure. Clearance requirements may thus determine the span of a bridge and also have a significant bearing on the construction depth.

Typically, for example, a bridge over a major highway would be expected to have a minimum vertical clearance of about 5.3 meters; even this may not protect it from accidental impact (e.g cases have occurred of the jibs of cranes being moved on transporters becoming free and rising). In addition, pier positions must be such that the likelihood of impact from errant vehicles is minimized, both to protect the pier and the vehicle itself. This requirement is usually achieved by setting the pier back a reasonable distance from the edge of the carriageway.

Navigation authorities specify clearances over rivers, to allow not only for the mast height and width of vessels below the bridge, but also for particular requirements for piers in the waterway (or on a flood plain) to avoid excessive flow velocity and scour of riverbanks.

Road Alignment

• The overall topography of the site will probably determine the line of the road. This may mean that bridges will have to cross other roads, railways or rivers at a substantial angle, resulting in skew spans (Figure 3). A skew bridge requires more materials and is more complicated to design and construct.
• The road may be on a curve; whilst it is possible to curve a bridge to follow this, it is frequently expensive and structurally inefficient, usually dictating the use of torsionally stiff girders even for short spans. If the road way is on a curve, and have a relatively high torsion resistance if the curve is slight, it may be preferable to construct the bridge as a series of straight spans.

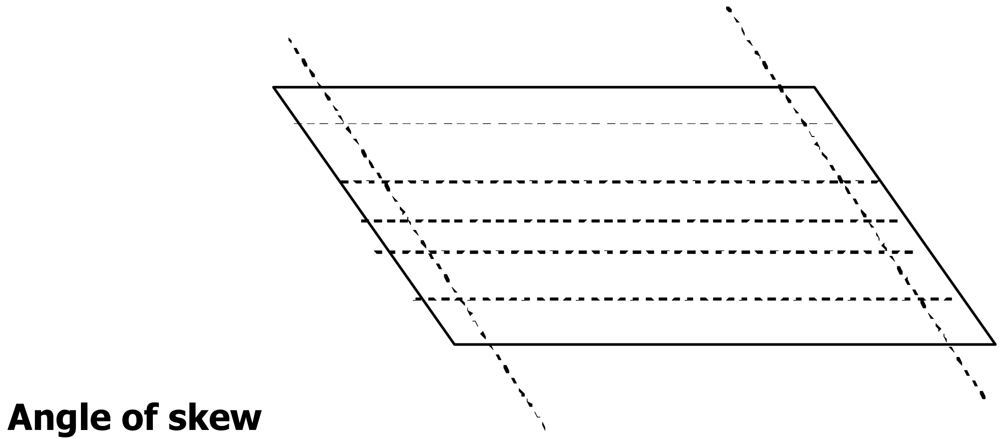

Figure 1. Typical plan view of skew Bridge

• If the subsurface investigation indicates that creep settlement is to be a problem, the bridge type selected must be one that can accommodate differential settlement overtime.
• Drainage conditions on the surface and below the surface must be understood because they influence the magnitude of earth pressure, movement of embankment, and stability of cuts or fills.
• Poor foundation conditions will favor fewer foundations and hence longer spans.
• Sometimes topography alone will point to a particular solution; the classic case is a deep, rocky-sided gorge, which is ideally suited to a fixed arch bridge.

Aesthetics

The appearance of bridges has in recent become a matter of considerable importance. Frequently, a scheme takes a road or railway through an area of great natural beauty, and it is important that any structures in these surroundings do not adversely affect them.
For example, it is commonly accepted that a bridge is more aesthetically pleasing with an odd number of spans than an even number. In addition, a degree of deepening at piers can add to the attraction.

Economy and Ease of Maintenance

It is not possible to separate first cost and maintenance cost over the life of the bridge when comparing the economics of different bridge types. A general rule is that a bridge with a minimum number of spans, fewest deck joints and widest spacing of girders will be the most economical. By reducing the number of spans in a bridge layout by one span, the construction cost is eliminated. Deck joint are a high eliminated. Deck joints are a high maintenance cost item, so minimizing their joint number will reduce the life cycle cost of the bridge.

At the conceptual design stage, a designer should consider whether it would be appropriate to use a material such as weather resistant steel or perhaps whether the structure should be fully enclosed with non-maintenance materials to protect it and give access for inspection. Generally, concrete structures required less maintenance than steel structures. The cost and hazard of maintenance, painting of steel structures should be considered in type selection studies.

Construction and Erection Consideration

The selection of the type of bridge to be built is often governed by construction and erection consideration. The length of time required to construct a bridge is important and will vary with bridge type. In general the larger the prefabricated or precast members the shorter the construction time. However the larger the numbers, the more difficult they are to be transported and lifted into place.

Local Constructional Skills and Materials

The availability of skilled labour and specific materials will also influence the choice of a particular bridge type. It should go without saying that a bridge suited to local technology. It is not sensible to specify a sophisticated design in welded high tensile steel if all the material and labour has to be imported. For example if there are no precast plants for priestesses girders with easy transport but there is a steel fabrication plant nearby that could make the steel structure more economical.

Other factors are:

1. Topography of the area
2. Hydrological date (high flood level and low water level)
3. Nature of subsoil strata (soil investigation)
4. Seismic (earthquake) considerations
5. Navigation or special requirements (clearances required)
6. Traffic load (volume or traffic)
7. Total time of construction
8. Cost

Considering all the above factors, if more than one type of bridge emerges out to be feasible for a particular site, in such a case, economy together with aesthetic should be the guiding criteria in making a final choice.

DISCUSSION

The site for this study is at Oro-Ago town. The town is a fairly big settlement in Ifelodun Local Government Area, being the Local Government Headquarter. Oro-Ago is blessed with many institutions like Primary Schools and Secondary schools, Bank, Health Centres, etc. it is a town that has many commercial activities in operation. It is located in-between Omu-Aran, the Local Government Area headquarter of Irepodun and Share, the Headquarter of Ifelodun Local Government. In-between Oro-Ago and Omu-Aran are the flowing settled towns along the road;

i. Oko
ii. Olla
iii. Omugo
iv. Oke-Owa
v. Ajegunle
vi. Irabon

Between Oro-Ago and Share are also situated the following towns along the road;

i. Oreke (i)
ii. Oreke (ii)
iii. Babanle
iv. Igamu
v. Alaba
vi. Shagbe
vii. Eri-Alahaji
viii. Ologorun
ix. Arola
x. Oke-Ode
xi. Alabe

xii. Budo
xiii. Apata Aje
xiv. Government Secondary School Share

Causes of Oro-Ago Collapsed Bridge

The collapsed Bridge above is of 2.15m span, which is of a few kilometers to Oro-Ago town. It is under construction as a contract awarded by Kwara State Government, and under the execution of a competent contractor. The failures noticed on this bridge were under its Abutment, piers, and steps. These failure are due to poor Geotechnical analysis by the Engineers in-charge of the Bridge design. several Geotechnical analysis and Tests, such as: In-site and Bearing capacities of soil were not given proper attention. Other noticeable failures are the deterioration and damages on the pavement surfaces with different pot holes.

General causes of Bridge Collapse

Failures in Bridges

Failure in bridge, components is a sudden phenomenon which can be wind, earthquake, sliding or overturning of structures, or excessive scour around the foundations, movement or inclined rock strata on which the foundations are supported, inadequate vertical or lateral capacity of piles, inadequate staining to piers and to excessive slip in the river up steam hills.

Failures during construction: Failures during construction of bridges are as follows:-
i. Failures of girders by accidents during erection by erection crane. Usually caused by settlement or untimely sudden flood.
ii. Scouring of supporting soil due to inadequacy in the design or defective execution
iii. Collapsed on the part of construction or earthquake or wind forces that may occur.

Failures during services:
Failure during services period are generally due to the following:
i. Earthquake effects
ii. Wind effect
iii. Abnormal flood that usually cause topping over the deck
iv. Excessive scoring of the foundation, that usually result in the failure of superstructure along with that of substructure and foundation
v. Tilting
vi. Settlement in foundation that will cause excessive rotation of segmental rollers and afterward topping over of the superstructure.

Distress in Bridge

Distress in bridges is a slow and time related process, such as cracks in concrete due to shrinkage, corrosion of reinforcement, overloading, damage of concrete due to alkali or sulphate attack or due to water currying shingles or boulders. It can also cause seizing of bearings or improper or excessive deflection of superstructure, and deterioration of parapets and railings.

Distress in Bridge sub-structures

(A) Open Raft Foundations

(i) Settlement – uniform and differential
(ii) Sliding and overturning
(iii) Undermining scour

(B) Distress in substructures

(i) Settlement or tiling of abutment and wing walls due to bad soil conditions
(ii) Settlement or tiling of abutment and wing walls due to inadequate design or overloading.
(iii) Sliding or tiling of abutments and wing walls due to inadequate provision of weep holes or improper use of black fill materials
(iv) Impact of floating bodies in water, like pebbles, boulders, distress due to concrete used in substrates, such as cracking disintegration, spilling, sulphate attack, abrasion, etc.

(C) Distress in Super structures steel Bridges

(i) Excessive deflection
(ii) Excessive vibration
(iii) Corrosion instructural members and joints
(iv) Loss of section by several corrosion
(v) Bucking of compression members due to inadequate design or overloading
(vi) Cracking in welded steel members
(vii) Corrosion in joints due to inadequate design, overloading, etc
(viii) Corrosion in desk supported steel members
(ix) Corrosion of reinforcement in concrete decking.

(D) Distress in Reinforcement and pre stressed concrete Bridge

(i) Excessive deflection
(ii) Excessive vibration
(iii) Corrosion of reinforcement in concrete girders and deck slab
(iv) Distress in concrete such as cracking, spilling, disintegration, etc.

(E) Distress in Composite Bridges

Distress in composite bridges is similar in nature to those of steel and concrete bridges.
(F) Distress in Arch Bridges
(i) Settlement of abutments or supporting piers.
(ii) Flattering of arch due to sliding, tilting of abutments or support piers.
(iii) Cracks in arch rings due to differential settlement of abutments supporting

Distresses in Suspension Bridges

Suspension bridges are usually constructed with steel used for construction. Suspension cables are the ones susceptible to corrosion damages.

Distresses in stayed Bridges

In cable stages bridges, the towers and deck may be of steel or concrete or composite construction. The distressed in cable stages bridges will be the types in suspension bridges, expect the materials used in construction.

The Effects of Oro-Ago Collapsed Bridge

The collapsed of the Bridge has actually affected the Socio-Economic activities and the development of Oro-Ago and the surrounding villager, because no other bridge is available for the movement of the vehicles and other transportation facilities along the said road. Vehicles coming from Omu-Aran axis have to stop before the bridge, while the passengers walk through the water with their feet. The same applies to others coming from Oro-Ago side as well. This passage now that the rainy season is still at its early stage.

Possible Solution and the Way Forward for the Collapsed Bridge

(i) A re-visit to the construction site by the Geotechnical Engineers is very important at this stage of the Bridge. This will avail them the opportunity to carry out all the necessary analysis that were not done at the initial design stage of the project.
(ii) Re-design the Bridge with the co-operation of the structural Engineers in the state Ministry of works and transport
(iii) The State Government should take up the responsibility of financing the project again from the beginning to the completion level.
(iv) The contractor handling the execution of the project should be giving proper supervision from the beginning to the end of the project.
(v) Competent Engineers should be allowed to supervise the project along side with the contract during the construction period.

CONCLUSION

Oro-Ago and the surrounding towns has had a serious set-back in the area of Economic activities and development negatively which is not so in other towns within Kwara State. The construction works may not be easy now that the rains have started fully. It is believe that proper construction works will be achieved during the dry season, therefore a preparation to commence the construction works in that period will be ideal for the Bridge. An appeal is made to the Kwara State Government and the Local Government to assist this project financially and morally and to make sure the challenges confronting this part of the state are dealt, especially in the area of Economic development now!!!

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