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Cast in-Situ Balanced Cantilever for Building a Bridge

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ABSTRACT

Construction industry refers to the combination of several types of arts as well as applied sciences that several companies in the construction industry apply. Bridge has been considered as one of the significant branches in this industry which is commonly constructed over different kinds of obstructions or conjunctions like railway, river, highway, pipeline, canal and urban roads in order to solve several traffic challenges and make transportation system as easy as possible. In this paper Cast In-Situ Balanced Cantilever for Building the bridge has been reviewed and discussed critically. Several databases like reports, journal articles, books and internet sources have been reviewed in order to analyse the constructional activities required for the mentioned types of the bridges. In this paper, researchers had several objectives namely introducing different methods of bridge construction especially in-situ balanced cantilever method additionally the proportions of balanced cantilevered built bridges have been evaluated critically.

KEYWORDS: Bridge, Segmental concrete, In-situ balanced cantilever, Super structure, Post tensioning, Span.

1. INTRODUCTION

Nowadays construction industry has been identified as a competitive business and several involved companies in this industry attempted to develop their required technologies significantly. Construction industry refers to the application of arts and sciences in the construction sites and it has been considered as an art in the construction sites rather than a single science, additionally it refers to the design, construction operations and finally project managements (Blank, M. M., &Luberas, L. R. 2003).

Bridge is a structure which is usually built over several obstructions or depressions like railways, rivers, highways, pipelines, canals and also urban roads for decreasing the traffic jam. Main goal of constructing the bridge refers to enhancing safety, ease of mobility, reducing time and cost, decreasing the traffic jam and congestion that has significant impact on the environment as well as socio-economic situation of the society. One of the most important elements in the bridge construction that should be more focused relates to the decision making process. Different factors should be considered for better decision making in this field such as future modernization cost, safety of drivers, pedestrians, workers and controlling the traffic, quality of work, user costs, impacts on the business and society, ecosystem and etc. (MRUTC Project, 2006).According to Megally (2002) using segmental type of bridge has several advantages in comparison with conventional bridge construction methods such as improving seismic performance like joint behavior in terms of opening and closure under repeated cyclic loads simulating earthquake effects and also improving crack issues and modes of failure. (Megally, S. H. 2002).For example in the Bangkok Light Rail Transit System, balanced cantilevering have been applied in the urban context in order to avoid disruption of the current road services below (Chen, W., Duan, L., 2000).One of the significant advantages of cast in-situ balanced cantilever method is to evaluate the influence of longtermcreep and also pre-stressing on the instant rearrangement. As a practical example, the Pathum Thani Bridge has been made over the Chao Praya River (Pimanmas, A. 2007). Several researches on balance cantilever bridge construction discuss about the constructability and also to the confrontation of the cantilever bridge systems against fixed mixtures, and also rearrangement of different reactions because of creep, shrinkage and relaxation in comparison withhold method of bridge manufacture (Kwak, H. G., & Son, J. K. 2002).Segmental bridge construction usually changes practical way of thinking in engineering designs. Up to now, several designers have been concerned mainly about designing the project after some preparations on computations and also plans so segmental construction has been affected this thinking style(Muller, J. M., & Barker, J. M. 1985). By applying post tensioning during in situ balanced cantilever method the durability of the construction sites can be developed and also it has several structural advantages for the construction system during the construction procedure (Schokker, A. J. 1999). In the In situ balanced cantilever type of the bridges, spans, segments, piers and foundations seems to be different from other types of the bridges due to its different applications (Moretón, A. J. 1990).

Writers of the current paper had several objectives such as presenting ways of bridge structure mostly in-situ balanced cantilever method furthermore the parts of balanced cantilevered manufactured bridges have been assessed critically. Additionally, some differences between old method of bridge construction and also balanced cantilever method such as using

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new method for the certain curve alignment has been reviewed. In this method there is not a special need for scaffolding, rational design could be done, and it can increase safety and decreases number of workers for doing repeated works and it wouldn't be affected by the land condition. (Chen, W., Duan, L., 2000)Each bridge includes two main parts namely superstructure or deck, bearing and substructure. Superstructure consists of girder, truss, slab, etc. Usually bearing transfers the load of the deck to substructure. Substructure includes abutments and piers, wing walls and foundation.

Hopefully the results of the current study seem to be useful for a number of people in charge in the construction activities and they can benefit from the findings. Scientific contribution of the paper are as follows: 1. Results of the study is useful for the construction site engineers and contractors in order to implement it for bridge construction in different sites, 2. Executive administrators in the ministry of way of different countries can use the findings of the current study in order to make useful changes in the bridge construction of their countries. 3. Students in the field of civil engineering can use the results of the current study in order to know different methods of bridge construction especially cast in-situ balanced cantilever type of the bridge.

The remainder of the paper has been organized as follows: in section two different types of bridges will be presented, in section three bridge construction methods including pre-cast and cast in-situ method will be explained, in section four segmental concrete bridge will be presented, and in section five cast in-place balanced cantilever segmental bridge construction will be discussed and finally in section six conclusion of the study have will be mentioned. There are many ways to classify the bridges such as flexibility of superstructure and also situation of bridge floor that is related to the highest flood discharge and level of formation, inter-span, type of super structure, materials which are used to construct super structure, clearance for navigation, expected productivity period, function, method of connection between steels, length of span, level of highway crossing, degree of redundancy, alignment, loading and road level related to highest level flood of the river(Ettlie, J. E., et al., 1984).

2. Different types of bridges

Common types of bridge are divided to five parts such as Beam Bridge, Truss bridge, Arch, Suspension bridge and Cable stayed.

Beam Bridge has been considered as the oldest and simplest type of the bridges for designing and building in the construction sites. Generally half of the total bridges all around the world are beam bridges. This kind of bridge consists of horizontal beams and vertical piers. The strength of the beam depends on the road way and piers addition. When the beam length is small, piers would have nearer distances to each other.

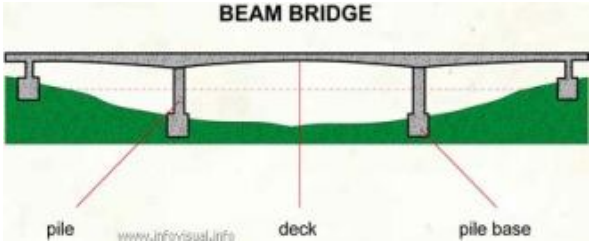

Figure 1. The structure of Beam Bridge

Arch bridge is the other types of common bridges which have been built by the Romans for the first time. Two main factors should be focused in designing arch bridges namely appearance and strength. The shape of the arch may give strength to the bridge and based on the arch different supports can be placed to reinforce the bridge. Different kinds of materials such as wood, stone, concrete and steel can be used for making this type of bridge.

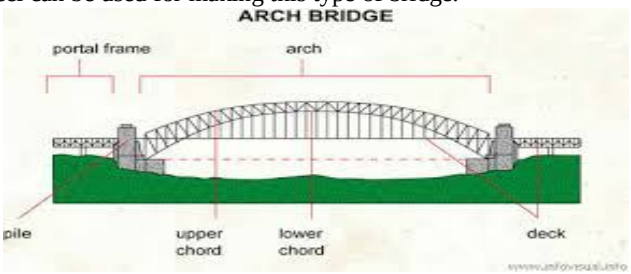

Figure 2. The structure of Arch Bridge

The third type of bridges is Truss bridge that its wooden type was built in the early 1500s and its metal type has been completed in 1841. This kind of bridge is very strong and normally used for railroad as it can support heavy loads. Truss is usually set between two piers and it has been widely used for holding up the roadbed, additionally due to the triangle shapes inside of the Truss bridges inside, they are too rigid.

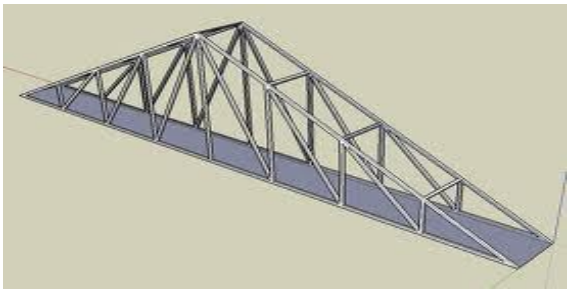

Figure3. The structure of Truss bridge

The fourth kind of bridges is suspension bridge which is strong and generally they have long length. The earliest bridge of this type was designed and built in 1801 in Pennsylvania, United States. This type of bridge is very expensive as it requires spending long time for execution and high amount of material for construction. One of the most important materials for building this kind of bridge is pair of cables that should be suspended from the towers and should be attached to the both ends of an anchor.

The fifth kind of bridge refers to cable-stayed bridge that its modern type of has been completed in Sweden in 1956. It is has been considered as an economical way for building a bridge with long distance between the piers and in order to build this kind of bridge it is required to use new materials as well as several construction new techniques. It consists of one or more than one towers with a set of cables which are usually attached to the road way.

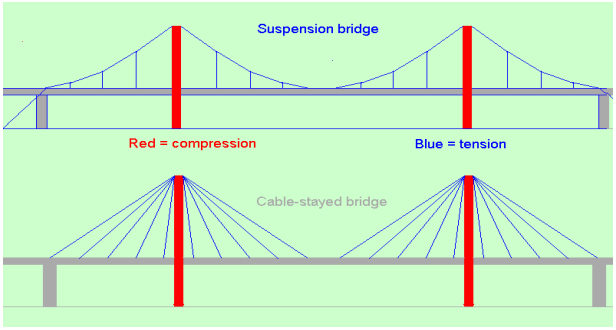

Figure 4. The structure of Suspension and Cable stayed bridges

During this study, researcher aimed to introduce different kind of method for bridge construction, to this aim researcher has been focused on in-situ balanced cantilever method and evaluated the proportions of balanced cantilevered built bridges.

3. Bridge construction methods

Bridge construction methods have been divided into two parts included pre-cast and cast in-situ methods.

3.1 Pre-cast bridge construction method

Pre-cast bridge construction method has been divided into three parts namely I beams and super Tee, Segmental and full span.

Figure 5. Precast component to be installed in precast type of bridge

I beam and super Tee have been considered as one kind of pre-cast bridge in which standard beams have been usually used that can be pre or post tensioned and it can be produced both on sites or in other places. This type of bridge has two main advantages namely its cheap cost and its simplicity of erection. This kind of bridge usually has four different disadvantages namely their low efficiency and logistics, limited in length and Aesthetics.

Segmental refers to the second part of pre-cast bridge building process which completes deck cast which can be delivered and erected in a specific location. All of the segments have been pre-stressed together by using internal or external tendons. The advantages of segmental bridge refer to the fact that it can be completed during the deck erections, its aesthetic and it is structurally efficient and can be fabricated during substructure works. It has only one disadvantage that relates to its logistics and setup process to the casting yard.

Full pre-cast span refers to the complete construction of the span in another place and transporting to the site for erection. The main benefits of this method refer to its high quality and high speed of casting.

3.2 Cast in-situ bridge construction method

This method of bridge construction method has been divided into three parts including cast in-situ post tensioned, balanced cantilever and incrementally launched.

Figure 6. The structure of in-situbalanced cantilever

Post tensioning is a technique in which it pre-loads the concrete that can reduce tensile stresses including dead or live loads. In this method strength concrete as well as high strength materials such as wires, bars and steel strands should be used. After concrete hardening, the strands which have been passed through the concrete, have been pulled by a special jack and after receiving pre-determined force, the strands would be locked. This method has several advantages namely reducing direct cost, reducing the required material, labor cost, rebar, and transportation costs and increasing the speed of formwork. The second and third advantages of this method are increasing construction efficiency and better structure performance (Sulina, V. 2011).

Balanced cantilever method is the second part of the cast in-situ classification which has been considered a most effective method for bridge construction. The most advantage of using this method especially in urban areas refers to its characteristic that it does not need any temporary shoring and it can disrupt traffics over water channels and in deep gorges which is very dangerous for construction workers. Additionally it can be used for irregular and long span lengths with few repetitions. Normally the length of each segment in this method should be considered between 3-6 meters. This method

usually starts by piers construction followed by building both segments simultaneously that would be continued at both sides of piers and each segment would be tied to previous segment by post-tensioning tendons.

Incrementally launched method has been recognized as the third category of cast in-situ bridge construction which has been considered as a highly mechanized erection method. This method has been considered as an effective method for bridge construction when the site meets its particular alignments requirements. In this method, different units of the bridge with dimensions of 15 to 30 meters have been prefabricated in the factory and it doesn't need any scaffolding that can be launched horizontally and enhances the bridge by sliding it on Teflon bearing. The most advantage of this method is that, it does not need heavy erection equipment like cranes and it does not need to use epoxy at the segment joint. The most important thing is that alignment should be straight or the curve should be constant that both of them should be considered by the designer. (Chen, W. &Duan, L., 2000)

Figure 7.The structure of Incrementally launched type of bridge

4. Segmental Concrete Bridge

A segmental bridge is a bridge which is built in several short section types. Usually segmental bridges have two types namely pre-cast and in-situ segmental concrete bridge. This kind of bridge is suitable for long spans which have more than 100 meters length when there is restriction for accessing to the site in land and also it is very economic. The first type of precast segmental bridge has been built in 1962 over the Seine River in France and the first in-situ segmental bridge has been built in 1950 across the Lahn River in Germany. Basic developments of bridge engineering design have been improved through segmental bridge construction. In bridge construction mostly designers are concerned with different calculations and also planning the project but in segmental concrete bridge it has been solved completely. In each project both designers and contractors should have information about available methods for segmental construction which can be improved by innovations of both contractors and design engineers. In-situ balanced cantilevered is a kind of in-situ segmental concrete bridge and pre-stressed concrete bridge that can solve several construction problems such as environmental restrictions, existing traffic problem, etc. (Muller, J. M., & Barker, J. M. (1985).

5. Cast in-place balanced cantilever segmental bridge construction

This method can be applied on spans up to 200 meters length or more and by using cable-stayed; this method could be employed on spans of 500 meters or longer. Each pair segment should be built on both side of a pier at the same time. To control the negative moment in cantilever, pre-stressing the segments during the casting should be focused more. In this method two segments should be cast which will follow post-tensioned. It is very important to analyze each step of casting to control dead load of the segment plus and also the weight of the next segment during the casting. Casting two segments together on oneside of the pier is not possible due to deviate pier shaft. In some parts of bridge temporary bending is recommended for making it balanced.

The initial step of this method refers to building pier shaft and pier cap that both of them should be locked together by vertical post-tensioned bar. Small kid derricks should be installed over a pier cap when small skid derrick is erected but before erection some strong steel bar should be installed in the pier cap to save skid derrick from deviation pier shaft. The derrick can lift up all of the required material for building each segment such as steel bar, ducks and etc. Upon placing all of the required materials, the segment is ready for concreting. The properties of concrete mix design like its strength is very important because it should have adequate strength for pre-stressing within 1 to 3 days. Post tensioning will be the next step of the pier cap segment and after getting the specification result of post tensioning, skip derrick will be moved and temporarily bolted to the deck. This process can continue for each pair of segments normally between 4 to 7 days.

This method is demanded by the contractors therefore accuracy and quality control pay important role in its application. All of the ducts for pre stressing should be placed accurately and to be fixed during concreting and vibrating procedures. At

the end of each segment, all of the ducts should be located in its specific places and it should be ensured that each duct has been continued across the joint. Using pipe piston is very essential to ensure that all of the ducts are open for tendon passage. In order to prevent deformation of ducts, another pipe with good quality which has little smaller size of duct should be located inside the duct during concreting process. Concreting should start from outer side of each segment toward the segment which has been completed before. Normally each segment has been congested a lot due to conventional reinforcement and post tensioning tendons, and therefore pouring concrete would be very difficult and it is recommended to use plasticizer or super plasticizer to have better workability. Before and after concreting, the level of formwork for each segment should be checked by surveyor engineers. The collected results can help designers and contractors for the implementation of the next segment. After post tensioning each duck should be filled by Grout to prevent the tendons from chemical attacks. (Nawy, E. G. 2008)

The internal forces and continuous system are very essential for in-situ balanced cantilever method which should be focused more in the application of this method. Internal forces are usually produced by different factors namely pre stressing the balanced cantilever system and the effects of long time girder weight, forces which have been caused by continuity tendons, superimposed dead load, forces which have been caused movement of the foundation after continuity, live loads and forces that have been caused through environmental effects such as wind. Girder weight and cantilevers pre-stressing have been caused original internal forces and both of them are changed after achieving continuity. (Bishara, A. G., & Papakonstantinou, N. G.,1990)

The depth of the deck directly depends on the different factors like appearance, price of materials and also eases of construction which has been classified into different types. For spans less than 100 meters, the depth of the deck should be approximately span/ 14. At this depth the webs do not need to be thickened in order carry shear and also in this condition the pre-stress is economical. Although in some bridges the road alignment is higher than the specification depth and its consequences will appear in bridge appearance. Normally support depth for large bridges is about span/20 in order to dominate the great structural depths disadvantages. Loading code used is another factor that should be considered for economical mid span depth. According to British code, when we have dominant load of 180 ton vehicle load for the bridges with 80 meters span the depth of mid span should not be less than approximately span/35. According to British code with the most other codes, it is economical to adjust depth around span/45 or less. Due to economic considerations the economy constant depth of cantilever bridge rarely exceeds a span of 100 meters and generally span/depth ratio for this kind of bridge could be greater than 1/18. (Bishara, A. G., & Papakonstantinou, N. G.,1990)

6. Conclusion

The review of this research is performed in order to clarify about different type of bridges, classification of bridges, bridge construction methods and proportions of balanced cantilevered built bridges.This study has different types in the introduction of the study some advantages of cast in-situ balanced cantilever type of bridge comparing to other methods has been discussed, in the second section of the paper different types of bridges in the construction industry have been reviewed, in the third section of this paper different bridge construction methods in the construction sites like pre-cast and cast in-situ method has been presented, in the fourth section of the study segmental concrete bridge has been discussed, and finally in the fifth section of the paper cast in-place balanced cantilever segmental bridge constructionhas been reviewed in detail. In this paper researchers attempted to introduce in-situ balanced cantilevered method for building a bridge. Several related sources have been used to write this paper namely reports, journal articles, published papers, books and Internet databases. In the situations where pre-casting bridge construction is not applicable, in-situ balanced cantilever method to build a bridge for medium or long span will be suitable. The most important advantage of this method is being economical where access of below is impossible or very expensive. The most important problem regarding this method is controlling deflection. In this method consideration to constructability has been considered essential for all steps of building a bridge from foundation until finishing the bridge. (Chen, W., Duan, L., 2000)

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