American Journal of Civil Engineering
2015; 3(4): 125-128
Published online July 9, 2015 (http://www.sciencepublishinggroup.com/j/ajce)
doi: 10.11648/j.ajce.20150304.15
ISSN: 2330-8729 (Print); ISSN: 2330-8737 (Online)

Construction of Bridge Decks with Pre-Cast, Pre-Stressed Concrete Deck Planks

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To cite this article
Ashwin Maru. Construction of Bridge Decks with Pre-Cast, Pre-Stressed Concrete Deck Planks. *American Journal of Civil Engineering*. Vol. 3, No. 4, 2015, pp. 125-128. doi: 10.11648/j.ajce.20150304.15

Abstract: The research analyzes the use of precast prestressed concrete deck planks in the construction of bridge decks. Will the use of these precast prestressed styles PPC's aid in the durability of the construction, or will there be issues in the initial stages itself that has to be handled? And whether these constructions are in any way cost effective (as in lower number of rejection rates of the planks manufactured) are some the questions that are investigated here. A case study based research method has been adopted here. The case study is that of the bridge deck replacements that were carried out by the Illinois Department of transportation in 1999-2000. The bridge deck replacements were done by means of PPCs. The research also aims to find whether the bridge deck replacements that were carried out had early performance issues. It was established that there were indeed early performance issues, but these could be mitigated by means of load testing and the use of high-grade materials.

Keywords: Bridge Deck Replacement, Precast Prestresseddeck Planks, Design, Fabrication

1. Introduction

A plain concrete bridge deck obviously has more advantages in construction compared to the precast and pre-stressed bridge deck. However when it comes to advantages in the form of long lasting service to transportation agencies, and monetary allocation of the local government agencies it could be said that more planned for durable and long lasting concrete is more a requirement than a concern. The construction industry is one in which there are time and budget constraints and it also critical that the construction achieved is more durable. The immense magnitude of tasks in the construction industry necessitates that when the task is completed it should be as low maintenance as possible. Concrete bridge decks are susceptible to premature cracking and to corrosion of reinforcing steel. Properly constituted, placed and cured concrete bridge deck mixtures are essential to providing long-term performance.

The productivity and the efficiency of construction are measured not only by the requirements satisfied for the project, but also by the durability of the project [1]. Many researchers have argued both the wasteful efforts in the construction industry and also at the same time argue for the strategic efforts that although takes more time and money is seen to result in more durable constructions [3] [5] [15]

2. Research Background

Durable long lasting concrete is a basic requirement. Long lasting concrete like the precast and prestressed types are seen to be one way for transportation agencies to increase durability. Considering the case of the use of high strength concretes, and the pretreated variety, it can be said that they help reinforce with more strength. Secondly they also have very much reduced permeability, which is a requirement in a bridge deck. High strength and reduced permeability also means increased durability[4]. However high strength concretes might fail when compared to the precast and prestressed types because these are seen to show signs of early cracking. Early cracking is possible because of self-desiccation.

Self-desiccation is a process in which early age cracking is induced by means of autogenous shrinkage. While shrinkage processes are common, uncontrolled and unplanned for autogenous shrinkage will lead to cracking that reduces the durability of the construction [18] [17]. The cracks in concrete are also a problem extending beyond the structural element; these cracks are seen to be creating a preferential path. Chloride ions that reach the reinforcement steel could cause problems for the structure. These chloride ions are seen to be an aggressive species leading to deterioration and durability reduction of deck constructions. In such a context, it becomes necessary for the high strength concrete to be replaced by the prestressed and the precast type.

Given this context, prestressed concrete slab systems are more ideally suited for the floor and roof constuction attempts. Especially in the case of industrial buildings these are seen to be more desirable. They are of a more higherorder and can also be supported within short spans of construction times. Prestressed slabs in particular of a thickness of 660 mm are used for bridge deck constructions in the United States [2] [3]. These slabs are parabolic and are post tensioned. They can withstand high loads and are also suitable for use in any span ranges, from 3 to 8 km and more.

3. Research Aim and Objectives

Aim: The aim of the research is to analyze by means of a case study, the construction efficiencyand durability of bridge decks with pre-cast, pre-stressed concrete deck planks. The case study chosen has been paper is to discuss the bridge deck replacements that were carried out in 1999-2000 by the Illinois Department of transportation. The case study analysis considers the construction and early performance element for the two deck planks. These bridge deck reaplcements weredone by means of precast, prestressed concrete (PPC) deck planks.

Research Objectives:

- To identify by means of the case study the issues that had existed for the original deck planks so as to compare how prestressed and precast concrete deck planks outrate.
- To identify the early performance specifics of the precaset prestressed concrete deck planks
- To recommend based on case study analysis, the ways and mean that precast, prestressed deck planks can add to the durability of the deck planks

4. Literature Review

Precast and Prestressed Concrete Slabs:

Precast and prestressed concrete slabs are usually hollow core clabs, these either have topping and are importatn structural elements when it comes to indsutrialised building constructions [2]. Slabs are either prodcued by means of casting beds or by means of using pretenisoning elements. There are various forms of pre-tensioning available.

They will be cut to more shorter span lenghts to suit the construction that is being planned out. In some cases they would also be provided free support. Free support ensures that there are transverse walls and beams between the systems. There are different form of precast, pre tensioned cored slabs used in practice. Some of the more popular ones are that of the 2000 mm nominal width that has been used with a lenght of 3.6 to 6.4 meters [9]. Economical hollow cavities have been used as well alone with round cavity slabs.

Prestressed slabs have prestressed concrete ribbons in between that are used as riinforcements for the core whihc is hoolw in these slabs. They also have additional high grade tensioned wirers. The tensioned wires are quite rectangualr and are in the form of 40 to 80 mm dimension [7] [10]. However care has to be taken when using these pre-tensioned elements as previous research idnciates that the use of these elements might lead to apprent increase in loads and hence could result in cracking in situ.

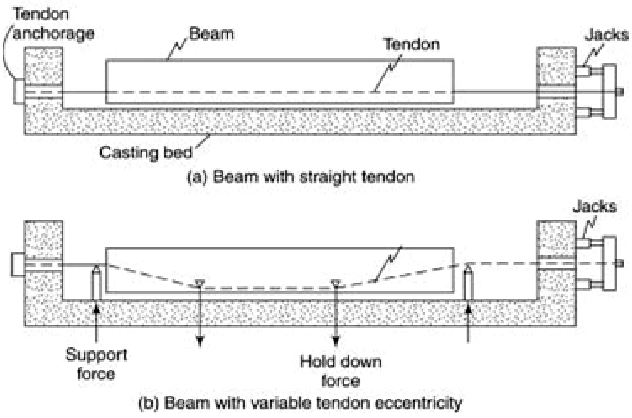

Figure 1. *Methods of Pretensioning.*

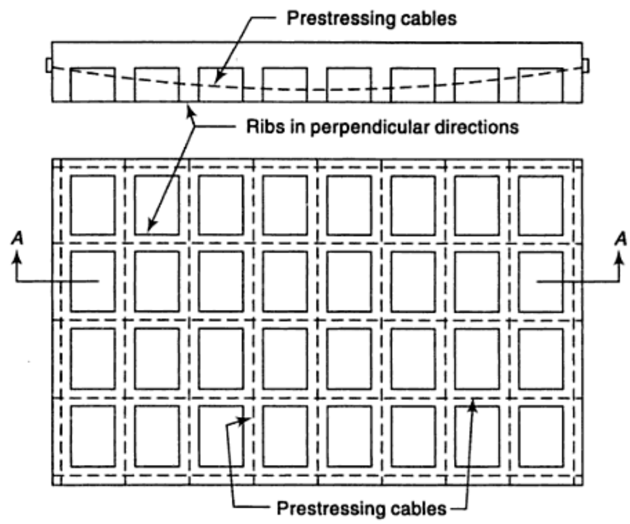

Figure 2. *Life Slab Construction: Prestressed Concrete Grid Floor.*

Lift Slab Contruction:

This is a accepted technique when it comes to useing cast and prestressed slabs in the groundlevel or for raising them from the ground level to mount levels. Two way continous slabs are often effective in reducing cracks as they control the thickness requireement and at the same time elimate cracks in the long run. In he use of prestressed slabs researchers such as Lin have commented that solid prestressed in the range of 6-10 m are often more economical than the rest [11] [13]. Prestressed also comes in different forms of coffered or grid floors in lift slab cosntructions. The grid floors are more slender in appearance and can also be used for artisitic treatments. They exhbit smaller deflections when compared to other prestressed variety and in fact are seen to be more beneficial when being used in te case of service loads such as bridges.

Prestressed Concrete One Way Slabs:

One way slabs are usually supported over the width of the entire slabs. In order to achieve this the design of such prestressed slabs should include for beams,piers and abutments as the case may be. The slab might be a continous one or might be angular for the prestressing force [12]. Mild steeel reinforcements would also be used, or the slabs might use continous force over several supports.Most experimental invetsigations on these forms of slabs seems to indicate that these slab designs are very safe within some prescribed limits and also support load factor above the theoreticallimits [17].

Prestressed Concrete Simple Flat and Continous Slabs:

A simple slap is usually supported by means of C columns netowrk. These are beams that are prestressed in perpendicular and are also used to resist forces in these directions. Slab is ususally proportioned using tendons housed in the context of column strips and the proportioning is also seen to be based on the total moment involved.

On the other hand a prestressed concrete continous slab will be involved with using continous over supports that would be in the form of a continous beam and would also use principle direction arrnagement of the slabs such that they do not conflict one another. The slabs in general are seen to be used with column and/ or middle strips.

The continous flat slabs are the ones that have been used extensively in the United States since 1955 [9].There are typically different adanatages towards using the prestressed concrete floor slabs and there different varieties and the types are usually vaired based on the construction section, the span and more [8] [15]

5. Case Study: Data Analysis and Discussion

The case study that has been chosen for analysis here is that of the replacement deck construction that took place in the years of 1999-2000 in Illinois. The deck replacement was to be done by using a precast, prestressed concrete (PPC) deck planks. These decks were seen to be part of an extensive bridge project that was carried out by the Illinois Transportation Department [9]. After preliminary analysis on the types of bridges that would require reinfrocement, it was decided that three bridges fit the category. These three bridges were then fitted with pre cast prestressed PPC deck planks. With a thickness of approximae 3.0 or 3.5 inches (this is in comparison with the 2.5 inch plank that was used earlier), these planks are seen to be constructed with a minimum maturity of about 60 days (the minimum amount of days for maturity is calculated from the time the deck pour is iniitated) [9]. The purpose of this case study is to report and critically investiagte on the techniques that have been used in the deck plank construction, the pre installations, the early performance evaluation and more.

Process:

The PPC Deck plan bridges for the project modifications were seen to be manufactured in strict adherence to theIllinois Department of Transportation Standard Specifications. The prestressed planks were seen to be placed in as headers and were also reinforced with wire meshing [9]. A vibratory screed was used to level off theplanks and the planks poured in between 10AM to 2PM were then stropped only after 6AM to 10PM when the release strenght was achieved for the planks. Steamcuring was allowedfor some of the pours and this was allowed for a time period of upto 42 hours after the pour.

A prelimianry field inspection was carried out in order to udnerstand how the deck planks thickeness could affect the durability and also on how concrete build up could lead to the planks to be wider than the projected estimate. Planks were also surveyed to ensure that the vertical and the horizontal locaitons were even for the strands. Deck planks had to be rehjected based on the excessive cracks that they showed initially. Some of the planks also had strand slippacge and others had other miscellaneous defects. Of the 384 planks that was manufactured, a total of 23 percent were rejected on an average whihc is about 90 out of the 384 planks. In the case of the 3.5 inches planks it was observed that there was a total rejection of 26 planks and that is an approximate 8 percent rejected and of the 3 inch planks there were a total of 95 planks rejected whihc was the highest percetage rejection at 28 percent.

Solution:

Based on the evaluation and the rejected planks it was decided that an open evaluation of rejected planks be done. Load tests were then conducted, it was estimated that the previously rejected planks were to be selected in the form of similarities in cracking patterns. They were cut flush at the ends and then a simulation of bearing structure was carried out. Deflection was measured an approximate of four times in these tests. In addition a visual inspection was also carried out, based on the same recommendations were made.

Discussion:

Some key elements of discussion that were driven into this state are that the load testing method must be employed when using deck plank bridges. The load testing method helps in weeding out the deformed or the damaged deck planks. In addition to this it is also recommended that the PPC deck plank fabrication makes use of pre installation of the leveling screws, this will ensure that the deck planks are aligned properly and hence do not contribute to additional stress in the construction. There is polystyrene used in deck plank constructions. It was seen that this could well be an issue and hence when it is necessary to use polystyrene then it has to be extruded polystyrene only and should also be of a grade type of 578 Type IV or higher.

6. Conclusion and Recommendations

Based on the case study it was observed by the researchers and engineers involved that the deck planks that were subject to the cracks came under stress that had to be studied. These deck planks were rejected even in the preliminary testing's, this is one area in which the users of prestressed, precast concrete deck plank users will have to focus on, as the apparent rejection rates for the number of planks made in this method is higher than the normal rates. Secondly it was seen that the load test was critical in determining the acceptance for the deck planks and their usages. A few modifications can then be created based on the load test and these modifications helped assess and also control the number of deck planks that would need to be recreated.

In the case of the PPC deck planks that were used, one more thing was noticed which was that the planks were seen to not hold up well under the pour and then the blow out stage, it was seen to be holding strong only when the steam process was also used as an additional element. This is hence one element in construction that the users of deck plank bridges of prestressed and precast types have to be aware of.

There is always an element of cost involved in construction. In construction, the cost element is often ratified as being one of the critical choices. However as per the case study it was noted that the PPC deck plank might not have in fact helped much in saving of the money. In fact it was noticed that the time and cost was more or less the same, and in addition it was also noticed that the cast in plan bridges could have been used just the same, as the deck plank bridges also demanded additional costing in terms of covering up of the transverse cracks in construction.

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