Design, detailing, fabrication of full-depth precast concrete deck panel bridge

Design, Architecture

Because of the phenomenon of deterioration of the aging structures and a high density of traffic, certain highway bridges need maintenance by replacement in United States. The projects that are done for the purpose of replacement cause troubles for the local traffic in form of non-convenient and possibly risky alternate routes. In order to reduce the time consumption of the construction works and reduce negative influence on the environment, and minimize quality control issues, a safer method against potential hazards is employed, that is incorporation of precast elements in the construction works, and this method is gaining popularity every next day.

This practice of using full depth pre-cast concrete decks in highway bridges started in 1965 AD in the United States. The idea behind usage of such method of construction is to accelerate the construction process in rehabilitation projects that leads to less inconvenience of local traffic, reduced costs of traffic closures especially in the areas where the traffic density is high. Through the experience of the design engineers over the years, they have realized that this method of construction has not only proven to be advantageous for rehabilitation projects but can also be equally beneficial for new construction projects. The quality of the precast decks is relatively higher and have a longer service life than others, that is why those precast elements require less future maintenance and thus reducing costs.

An economical and an effective design concept is made possible by the development of prefabricated, full depth precast concrete bridges, that can be employed for the rehabilitation of existing but also new construction of highway bridges. This solution if effective in case of reducing the reconstruction time and bridge closures. This practice minimizes the interference with the local traffic. The building of prefabricated decks can be achieved in short periods of time like days or even hours in contrast to the traditional methods that take months at least. This accelerated building method reduces the influence on environment and provides a safer construction and less life cycle costs by increased life spans.

The process is carried out in a controlled environment and is a combination of high strength prestressing cords with prefabricated full depth precast concrete panels of high performance. The resulted deck if high quality that is resistant to many environmental impacts. The connection among the beams and precast panels is provided by the shear studs aligned in shear pockets that provides full composition of action. In order to achieve a simpler framework of precast concrete panels and erection technique, no typical reinforcement in the transverse joints of adjacent precast panels is provided during design process, that is no steel runs through the joints. Keeping in consideration of concrete creep and shrinkage under different kinds of loads, it is advised to carry out post-tensioning of the precast concrete panels in longitudinal axis that results into continuous and tight transvers joints among the adjacent joints, and eliminating tensile stresses in the deck.

Previous Studies

Since the year 1970, the usage of full depth precast and precast concrete deck panels has significantly increased in the rehabilitation and construction of new bridges. For the purpose of documentation of application in various forms of deck panels in bridges in North America, a set of questions was sent to the departments of transportation (DOTs) of different states and a province. The requested information includes the construction types, dimensions of decks, the system employed to support the decks, type of reinforcement, the kinds of connecting systems among panels and supports, joints types among adjacent panels, the kinds of bonding materials used as filler for the joints, different issues with the joints, reasons for negative effects, and the protection system types. Table A shows the construction types in different states and Table B displays departments of transportation (DOTs) response summary.

The significant issues found through this survey were leakage, cracks and deterioration of the joints, behind which the main issue was the procedures implemented in construction practice. Following this survey another survey was conducted by Issa et al (1995b) focused on the investigation of the field performance of the bridge panels in different states. This investigation was focused on the field inspections of bridges and discussing the precast deck panels with the state engineers in ten states and the District of Columbia. As a result of the investigation it was found out that the main reason for lower performance was because of the poor connections among the panels and the supporting systems, configuration of adjacent joints, absence of post-tensioning in longitudinal axis, construction techniques, and the materials used.

Issa et al (2000) constructed a quarter scale (1/4) prototype of a bridge. This prototype consisted of full depth precast deck panels and two steel beams. The model was inspired heavily from a four continuous span bridge in

Virginia. Issa et al (2006) carried out about 11 tests on small scale on the connection of panel to concrete girder. The specimens used in the tests were combination of concrete girder sections having precast panels attached to either side. The tests were focused on the evaluation of the effects on the shear strength of the connection by the number of shear studs and their configuration per pocket including embedment depth of shear studs in the panel. The resultant information gave many findings. The primary results show that as the number of studs is increased the shear strength of the connection increased proportionally. This result was in contradiction with the results concluded by Issa et al.

In order to evaluate the constructability and behavior of precast bridge deck system, Issa et al (2007) conducted tests on a prototype of continuous two span bridge of full scale that they constructed as shown in (Figure 10). The length of bridge was 82 ft and with was 18 ft. The bridge was supported by three W shaped girders (W18x86). There were 11 precast deck panels in the deck and were constructed with mild steel. Ay the central support the deck was post tensioned to an approximate stress of 500 psi. Fig. 1 Full -scale precast deck panel Menkulasi and Roberts Wollmann (2005) studied the behavior of horizontal shear connections on prestressed I-Girders studied for full depth precast concrete bridge decks.

Badie et al. (2006) reported in this document that the study was performed under NCHRP Project 12-65 by the Civil and Environmental Engineering Department, The George Washington University, Washington DC, Tadros Associates, LLC, Omaha Nebraska, and the Department of Civil Engineering, University of Nebraska-Lincoln. The contractor for this study was George Washington University. The work undertaken at Tadros Associates, LLC, and the University of Nebraska-Lincoln was under individual subcontracts with The George Washington University.

The studies conducted previously were focused on the procedures for construction and structural aspects for the design of full depth precast systems. But there is no concentration on the economic aspects in constructing full depth precast units. Focusing on the factors which contribute to the implementing and constructing of a suitable system, things like alternative routes construction equipment, time of process, and safety of the process with some other factors need to be considered.

Guidelines for Design, Detailing, Fabrication of Full-Depth Precast Concrete DeckPanel

The full-depth precast concrete bridge deck system includes:

1. The shear studs inside shear pockets are used to connect the precast panels to the beams to supply a stable action.
2. In order to achieve a simpler framework of precast concrete panels and erection technique, no typical reinforcement in the transverse joints of adjacent precast panels is provided during design process, that is no steel runs through the joints.
3. The post tensioning should be carried out of precast concrete panels in the longitudinal axis which provides continuous tight transverse joints among adjacent panels prior to the combining all components.

A system was designed of a bridge as a prototype. It had two continuous spans and two lanes. It was a full depth bridge system. It had 11 prefabricated full depth precast panels which were supported by three W18x86 steel beams. Shear studs and shear connectors were provided for full composition.

1. Full-depth deck panel precast concrete systems.
2. Panel fabrication and reinforcement details.
3. Placement of panels and longitudinal post-tensioning.
4. Design and installation of shear stud connectors.

The important components of construction and design of this system are:

1. The kind of materials used for filling the joints, and the transverse joints among the precast concrete panels.
2. The kind of connection provided among the decks and the supporting systems, as well as the kind of grouting.
3. Longitudinally post-tensioning.
4. Haunches between the top flanges of the girders and the slab deck.
5. The systems of waterproofing membrane and the overlaying mechanism.

Rapid bridge deck replacement technique

Following is the section that combines the techniques employed for the bridge decks full replacement. The implication of closures at the weekends are possibly the best. This aids to less interruptions in the traffic flow while completion of the construction work. This type of construction has the following procedures:

1. Shutting down and switching traffic: Alternate routes are provided to which traffic is switched and thus motorists are accommodated.
2. Saw cutting: The slabs that already exist are cut using a machine saw closer to the shear connectors from the top flange of beams at about 0. 5 inch or about 13mm.
3. Demolition: Then the existing deck is removed using demolition technique.
4. Formwork: Then the carpenters start working on the formwork leaving the haunch pockets after removing the panels.
5. Preparation for panel placement: Before the placement of the precast panels the top flanges of the beams are carefully cleaned.
6. Placing of precast panels: Cranes are used to lift the precast panels and carefully place them on the supports, carefully aligning it with the deck grade. The precast panels are prepared in the precast yards.
7. Leveling: Leveling screws are used to perfectly position the panels; the crews are adjustable and thus slab us= nits are placed in alignment next to each other.
8. Haunches: Minimum 1 inch or 25 mm haunches are provided and then tied.
9. Post-tensioning ducts: taking from the live end till the dead end, a set of post tensioning cords run. The cords are passed in sheath ducts. The

number of tendons or cords provided for post tensioning is one count less than the counts of shear pocket lines.