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Review on studies and research on widening of existing concrete bridges

Mitaali Jayant Gilbile[1], Vivek Sangramsingh Ghatage[2], Gaurav Sampat Patil[3], Pradip Hindurao Patil[4], Shweta Shivaji Nikam[5]

[1] Assistant Professor, Department of Civil Engineering, D. Y. Patil Technical Campus, Talsande, Kolhapur
[2,3,4,5] UG Students, Department of Civil Engineering, D. Y. Patil Technical Campus, Talsande, Kolhapur

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Abstract - *An ever-increasing population and economic growth of India escalating in traffic volume. For this increase in volume of traffic, infrastructures such as roads and bridges are becoming inadequate to fulfill the current traffic demand. To solve this problem infrastructures are need to be upgrade. Modernizing or upgrading infrastructure helps to mitigate traffic problems, provide safety for the traffic stream. Many existing bridges cannot meet their current traffic demand. To cope up with traffic problem bridge widening becomes necessary. Widening of existing bridges saves lot of time and money instead of constructing a new bridge. This paper summarizes studies and research carried out on widening of existing concrete bridges in various countries.*

Key Words: Traffic volume, Modernizing, Existing bridge, Stitching

1.INTRODUCTION

Bridges are used to cross an obstacle like a river or a valley for the safe movement of vehicles or pedestrians over it. Existing bridges are becoming inadequate to cope up with current traffic demand. Engineers have two options for bridge modernization either they can construct a new bridge by demolishing old one or they can widen an existing bridge. Due to many reasons such as time, money and traffic disruption during construction it becomes more economical to widen an existing bridge rather than constructing a new bridge. Widening of an existing bridge can be easily done when it is functionally obsolete. If it is structurally deficient then it can be either retrofitted and then widened or it can be required to demolish. Various techniques can be used for widening an existing bridge. Some of the studies across the globe are summarized below,

Yue Yang et al. (2015) presented a detailed study on Bridge widening technique with a composite steel-concrete girder. This technique of widening has been used in various bridge widening projects in China and one of from those projects was selected for the study. The selected bridge was the Niuerhe Bridge located in Chongqing, China. The bridge was an 11-span simply supported multi-girder (6) highway bridge with 4 lanes made of prestressed concrete. The widening is only done for one side of superstructure of the bridge which consist of steel girders, concrete slab, transverse diaphragms, and parapets. Composite steel-concrete girder has high flexural strength and torsional stiffness and it has low self-weight. This superstructure widening solution provide a safeguard for bridge widening work and traffic flow.

In this study they have developed methods for estimating live load distribution factors of a widened bridge with different types of girders. First, the field test was conducted on widened bridge for the assessment of deflections and longitudinal strains at mid-span of girders. As per the design code of China the field test was conducted with 5 different loading cases using 6 fully loaded three-axle dump trucks. Then live distribution factors were calculated from measured displacements and longitudinal strains using various expressions. The distribution factors obtained from the expressions were nearly equal for each girder where it is larger for the composite girder and getting smaller towards the last concrete girder. Proposed analytical methods which are Rigid jointed method and Flexible jointed method were used to determine live load distribution factors. Also, finite element analysis using MSC Marc program was used to validate results obtained from the proposed analytical methods. After evaluating distribution factors obtained from field test and theoretical analysis, they were compared with each other. From this study they have concluded that the proposed analytical methods provide a better result for determining load distribution factors. Also result from two detailed finite element models gave accurately same result as obtained from field test. It would be more effective in decreasing the distribution factors for intermediate girders if bridge widened on both sides rather than that widened on a single side. (1)

Mohammad M. Hamdan (2023) carried a detailed study on widening of an existing bridge structure in the UAE. They have given various challenges encountered and their implemented solutions during the process of widening. The widening of the bridge was executed by constructing a new bridge beside the existing bridge and connected by stitching with each other to form a new bridge. The existing and new bridge were made from post-tensioned voided concrete. The main challenges they faced were replacing existing bridge bearing, stitching work, adjusting levels in old and new structures and matching expansion joint gaps. First, they carried condition survey which involved the assessing the condition of the existing bridge by visual inspection and conducting various tests. The condition survey of the bridge under consideration was found no severe defects. They have given solutions for each challenge faced during the construction stage. (2)

Paul W. Corbett et al. (2014) provided constructible solutions for widening of two existing bridges on state highway 16, Auckland. Two existing motorway bridges namely Whau River Bridge and Causeway Bridge were need to widen in order to provide additional capacity for vehicular, pedestrian and cyclic traffic. These two bridges are a mix of structural forms. The original bridges were 3 lanes in both directions. They were need to upgrade to 4 lanes with cycleway having a minimum width of 3m.

For Whau River Bridge additional deck width on both outer edges were provided to accommodate the fourth traffic lane in each direction with widened pedestrian/cycleway on one bridge only. The deck widened using new 1.2m deep, precast, pretensioned concrete super-T beams and reinforced concrete deck slab which is casted monolithically on reinforced concrete headstocks sitting on top of new 1.5m dia. Permanently cased, bored, cast-in-situ piles. Then new deck is connected to the existing structure's outer deck edge by way of reinforced concrete stitch pours.

Proposed widening works to the Causeway Bridge comprise the construction of a new independent bridge structure to carry one side traffic with 4-lane. Existing bridges were decided to connect with each other to accommodate the 5-lane traffic with widened pedestrian for other side traffic. The new bridge consists of 1.2m deep, precast, pretensioned concrete super-T beams and reinforced concrete deck slab, supported monolithically on reinforced concrete headstocks and permanently cased, bored, cast-in-situ piles of 1.2m dia. Piles. The gap between two existing bridges were connected by stitching.

For constructability and safety in design precast/prefabricated elements were used wherever possible. Permanent tubular steel casing for piles were used in order to provide permanent formwork solution for the piers and to reduce in situ works. They also carried assessments of existing structural elements for durability, live load and seismic. Assessment of the bridges in their proposed modified form showed the adequacy of structural performance including under traffic loading and earthquake conditions. (3)

Mark Treacy et al. (2023) outlines the safety measures and the challenges of strengthening and widening a structurally deficient road bridge under live traffic. Also, they have demonstrated the ultra-high-performance fiber-reinforced cementitious composite (UHPFRC) strengthening concept by means of a design example. The historic Port Weir Bridge is located over the Nidau-Buren Canal in the Canton of bern, Switzerland. The bridge serves multipurpose functions such as an important road bridge, a mechanized weir, a lock for canal boats as well as a hydroelectric power station. The road bridge comprises an orthogonal grillage of monolithic T-beams with cantilevering slabs. At each axis, the longitudinal T-beams are supported on reinforced concrete cross frames and cross beams sitting atop limestone clad concrete columns.

They did investigation work such as hammer tapping tests to identify delaminated concrete surfaces, potential measurements, concrete cover measurements, opening 'windows' in asphalt, local removal of cover concrete to inspect reinforcement, concrete cores for chemical analysis and rebar samples for yield strength tests. Lab testing was done using sample concrete cores of 50mm and 100mm diameter were taken from non-critical locations for the determination of the compressive strength, density and pull-out capacity. Also, the chloride content, carbonation depth and potential field measurements were determined to find out material properties. The structural conformity factors at numerous locations were found out below the minimum requirements of the code. It was clear that renovation works would be required so for this as a precaution immediate measures were taken. To allow heavier traffic to use the bridge in the months before it could be fully renovated it was decided to do temporary strengthening using temporary prop all beams using steel supports. Due to the severe reinforcement corrosion in the outer longitudinal T-beams on the footway side, it was decided to replace these beams on the older part of the bridge and use the opportunity to widen the roadway in line with modern standards. As the existing T-beams could not meet the full requirements of the load model, it was decided to strengthen them using a thin layer of reinforced UHPFRC. The use of UHPFRC as an efficient strengthening solution was well proven with more than 300 applications were carried out over the past 18 years in Switzerland. A modern expansion joint system of high-performance polymer was used at all movement joints. Replacement of all roller bearings were done with modern spherical bearings. A new 176m long pedestrian footbridge was constructed with four of the six support points located on the existing bridge piers which met the client's requirements of avoiding supports in the canal and adequately responded to the conservation requirements regarding materials and aesthetics. (4)

Lucio F. Torricelli et.al. described the most representative interventions realized to widen the existing bridges and viaducts belonging to the A1 Milan-Naples highway, Italy. The aim was to enlarge the highway carriageway by inserting the third traffic lane. Widening criteria in correspondence of bridges and viaducts, the widening intervention consisted of an enlargement of both superstructure and bents in continuity with the existing parts. Three bridges were selected for the study namely Morignano viaduct, Foglia bridge and Pesaro Station

Underpass. The existing bridge deck was composed by a grillage of prestressed concrete girders and widening requires the use of additional beams. With reference to the bents, the basic design criteria were to widen by providing new columns characterized by almost the same ultimate flexural resistance of the existing ones. In order to avoid significant deficiencies of various components due to seismic action, a system of seismic restrainers has been provided. With reference to the structural behavior under seismic conditions, the three selected bridges had revealed different deficiencies which had required different retrofitting strategies. In the first case, an inadequate level of deformation ductility in plastic hinge regions of the piers had needed the use of fiber reinforced polymer materials; in the second case, the deficiency of the foundation in resisting bending moment due to an over-dimensioning of the pier cross-section has been solved by a rational weakening of the pier base; in the last case, the unsuitability of the abutments in contrasting seismic horizontal forces has been solved by providing a system of passive anchors.

Widening of Morignano Viaduct consist of deck made of steel-concrete composite structure formed by three new steel beams and a concrete slab linked to the existing one. To support the new deck, all the bents have been widened by constructing three new columns, identical to the existing ones, linked to those by means of the cap beam and the plinth. In order to assure the continuity between new and old parts, a system of doweled bars has been used. To verify the seismic suitability of the widened bridge, a pushover analysis has been carried out. To meet the seismic suitability, existing bearings have been replaced by elastomeric pads and new expansion joints have been provided. To prevent deck jumping, longitudinal and transversal seismic restrainers have been introduced by means of reinforced concrete elements doweled to the existing cap beams. The retrofitting solution has consisted of the enhancement of the ductility of the weak members by FRP wrapping. The weak members were columns have rectangular cross-section. In order to reduce any detrimental effect of the sharp corners of column on the tensile strength of the FRP, the corners have been rounded and an elliptical-shaped external cover surrounding the old rectangular section has been realized by using cement grout. Finally, a multilayer Carbon FRP jacket made by unidirectional fiber epoxy-impregnated sheets has been around the elliptical-shaped region. Widening of Foglia bridge is same as above bridge. Nevertheless, during the construction phases, the building firm has proposed to substitute the three steel beams with the two V-shaped prestressed concrete girders. In addition, the type of connection at the slab level has been modified instead of cutting the existing slab, it has been decided to hydro-demolish it preserving existing steel reinforcement. The results of the structural seismic analysis performed in the final widened configuration have highlighted that existing pier elevations had been overdesigned and the old foundation were not able to sustain the resistant bending moment of the cross-section at the wall base. The chosen retrofitting strategy has been focused on strengthening the footing as well as reducing the bending capacity of the pier wall. The reduction of the bending capacity of the pier wall has been obtained by means of a local weakening of the base cross section by cutting circular openings with diameter of 1.20m. After the intervention, the concrete cover has been completely restored, and the effectiveness of the reinforcing bars in correspondence of the circular openings has been restored by closing all the provisional openings. For Pesaro station underpass, a strengthening intervention has been needed to assure an adequate safety level against horizontal seismic forces. To this aim, a system of passive anchors has been realized by using micropiles inclined of 15 degrees with respect to the horizontal line and disposed at two different levels. (5)

Kenneth W. Shushkewich (2003) introduced the strutted box widening method (SBWM). This system allows a two-lane segmental bridge to be designed and constructed so that it can be easily widened into three or four lane bridge at any time in the future. Two examples are demonstrated to how the SBWM can be used to widen a variable-depth cast in place segmental bridge and a constant depth precast segmental bridge. Design and construction considerations of the SBWM are addressed, and the advantages and disadvantages of the SBWM are outlined. The author believes that this method should be given serious consideration by government agencies and design-build consortia starting at the planning stage on any project.

Kenneth W. Shushkewich (2005) presented how a two-lane prestressed concrete bridge can be designed and constructed so that in future it can be widened easily into a three or four lane bridge. The methods presented are the strutted box widening method (SBWM) which applies to concrete box girder bridges and the strutted girder widening method (SGWM) which applies to precast concrete girder bridges. The first is a detailed example that demonstrates how the SBWM can be applied to the span-by-span precast segmental bridge. The second example shows how the SGWM can be used to double the traffic capacity of an existing bridge.

The SBWM is quite simple. Stage 1 includes two lanes plus shoulders, Stage 2 includes three lanes plus shoulders and Stage 3 includes four lanes plus shoulders. During stage 2 construction, exterior compression structs are installed and the deck slab is widened. Additional transverse internal prestressed tendons are installed and stressed. Widening from stage 2 to stage 3 construction is similar. The deck slab is again extended and additional transverse internal prestressing tendons and longitudinal external prestressing tendons are installed and stressed. The SBWM offers a number of attractive advantages over a conventional box girder scheme. Widening an AASHTO-PCI precast girder bridge using the strutted girder widening method (SGWM) is similar to widening a precast segmental box widening method (SBWM). Exterior compression struts are installed and an additional deck is formed and placed. Both transverse internal prestressing tendons and longitudinal external prestressing tendons are installed and stressed. The major advantage of using the SGWM to widen an existing bridge is that no additional substructure work has to be done. A precast segmental extradosed bridge that is constructed and widened using the strutted box widening method has been proposed by the author for the new Fraser River Crossing in Vancouver, Canada. (7)

3. CONCLUSION

Widening of an existing bridge by constructing new piers and deck beside existing bridge and connecting each other deck by stitching would be more feasible, safer and economical as compared to other methods. Because it provides an opportunity to use remaining service life of an existing bridge and after the end of service life of an existing bridge it can be easily demolished without affecting widened structure. Also, traffic disruption will not be occurred if this method is used.

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