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Repairing of Reinforced Concrete Beam

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Abstract
Strengthening of reinforced concrete beams is required due to design errors, deficient concrete production, bad execution processes, damage due to earthquakes, accidents such as collisions, fire, explosions, and situations involving changes in the functionality of the structure, etc. In the present paper, there is a reinforced concrete bridge and a reinforced concrete dam built interconnecting each other. All the frame structures are in a good condition except for the beam of the dam part in front of the bridge. The beam members are cracked and deflected from the structure due to the soil pressure under the bridge and the vibration load comes from the vehicles. There are several repair methods for a reinforced concrete structure. One of the repairing methods is a beam-jacketing method, and for this study have found this method is suitable and has been able to repair the cracked and deflected beam. Jacketing of the reinforced concrete beam has been done by enlarging the existing cross-section with a new layer of concrete that have reinforced with both longitudinal and transverse reinforcement. Four different methods have been employed for jacketing of reinforced concrete beams. According to this study, have removed the soil between the concrete bridge and the reinforced concrete dam structure and have built a retaining wall to solve the problem by the sudden load coming from the traffic and to block the soil pressure from under the bridge. To repair the cracked and deflected beam using this method, the structure is first partially have removed and Thoroughly cleaned, and then the structure has restored using a bonding agent to allow the new concrete to blend well with the old concrete.
Keywords: Reinforced concrete beam, Repairing, Jacketing, Shear wall, Soil pressure.
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1 Introduction

There are large numbers of concrete structures that cracked or become unsafe due to, Inadequacy of design detailing, construction and quality of maintenance, improper construction management system during construction, Overloading, chemical attacks, corrosion of rebar, Foundation settlement. Abrasion, High water-cement ratio to make them workable, the improper cover provided during concreting, insufficient vibration at the time of laying the concrete, Due to loss of water from concrete surface shrinkage occurs, Fatigue effect Atmospheric effects, abnormal floods, Changes in configuration and natural disaster (accidental load), etc. All of these factors affect the durability of concrete structures. In general, reinforced concrete has proved to be a highly successful material in terms of both structural performance and durability. Achieving good durability in reinforced concrete is a major factor in enabling a structure to perform its designed function for its expected lifetime. Structural rehabilitation brings a structure or a structural member to a specified safety and performance level. Depending on state of a structure or structural members, rehabilitation can be divide into two categories: Repair and Strengthening. Repair is the rehabilitation of a damaged structure or a structural member, on the other hand strengthening is upgrading an undamaged structure or the member. One popular solution to the problem of strengthening old reinforced concrete (RC) structures is to place jackets around the structural elements. Jackets have been constructing using concrete jacketing, steel jacketing, precast concrete jacketing, external prestressing and FRP wrapping. Ghobarah, Aziz, and Biddah and Biddah, Ghobarah, and Aziz proposed the use of corrugated steel shapes to provide high out-of-plane stiffness. The grouted corrugated steel jacket was intending to provide an early lateral confinement effect in the elastic range of the RC column as well as additional shear resistance in the column, beam, and joint. The cross-section of the corrugated steel plates and of the two-part jackets before and after installation is shown in Fig. 1. In addition to the in-place welding, the joint jacket was also anchoring to the concrete using two steel angles and anchor bolts. A 20 mm (0.79 in.) gap was providing between the end of the beam jacket and the column face to minimize the flexural strength enhancement. Tests on four one-way exterior joints showed that the proposed system could change the joint shear failure mode to a ductile flexural mode in the beam when both the column and the beam were jacketed. Effective confinement was achieving up to a 5% drift by increasing the ultimate compressive strain of concrete. Biddah, Ghobarah, and Aziz added to this study by testing two exterior joint specimens with discontinuous beam bottom bars. One of them was a reference specimen, and the second was strengthening with a corrugated steel jacket around the column only in addition to two steel plates bolted to the beam and to the joint to prevent pullout of beam bottom bars. This strengthening system could not resist the bottom bar pullout observed in the reference specimen, and the bolts failed in shear; however, the system did provide an increase of approximately 38% in strength and 180% in energy dissipation capacity. A design methodology for calculating the required thicknesses of the corrugated steel jackets and the grout was also proposing. The authors believe that, when compared with concrete and masonry jackets, the use of steel jackets can significantly reduce the construction time due to prefabrication. Disadvantages, however, such as the potential for corrosion, difficulty in handling the heavy steel plates, objectionable aesthetics in the case of corrugated steel shapes, and loss of floor space in the case of grouted steel tubes, cannot be over looked. Steel jackets may result in excessive capacity increases, even where only confinement effect is intended, and create unexpected. There are several ways to repair a cracked beam. One of them is the beam jacking method, which have found suitable for this study. As we have seen, they used the jacket method to repair damaged structures due to various problems. There are fundamental issues that can cause a structure to break down or cracked. They have some similarities with the above study, but in this study, a specific problem was observing that damaged the structure. These problems have caused by high pressure from the lower part of the bridge, which pushes the structure. Repair of concrete structures are essential not only to use them for their intended service life but also to assure the safety, serviceability and economy of the associated components so that they meet the same requirements of the structures built today and in future. A good repair improves the function and performance of structures, restore and increase safety (strength and stiffness), enhances the appearance of the concrete surface, provide water tightness, preventing ingress of the aggressive species to the steel surface durability. Types of Cracks in Concrete Beams Cracks in beams due to increased shear stress. Cracks in concrete beams due to increase in shear stress appears near the support such as wall or column. These cracks are also called as shear crack and are inclined at 45 degrees with the horizontal. These cracks in beams can avoided by providing additional shear reinforcements near the support where the shear stress is maximum. Shear stress is maximum at a distance of d/2 from the support where d is the effective depth of beam.

2 Methods of Repairing of Cracked Beam

Strengthening of a reinforced concrete cracked beam is required due to design errors and deficient concrete production. Based on our project analysis jacketing and form and pump modified concrete repair methods are free flowing, self-leveling, self-compacting and high early strength material which are being effectively used for strengthening of deteriorated reinforced concrete members of beams in an aggressive environment.

2.1 Jacketing methods

Method I Jacketing of beams using dowel connectors and micro-concrete: Dimension of the dowel connectors selected is 120 mm x 50 mm. These connectors have fixed on the surface of the beam up to 80 mm. Therefore, out of 120 mm length, 80mm length of the connectors are adjusted inside the concrete and the remaining 40 mm length is extended up to stirrups for the jacketed beam. Dowel connectors are fixed on 150 mm width side and 300 mm depth side surfaces of the beam throughout the span of 2100 mm at 300 mm c/c spacing in staggered pattern using bonding chemical.

Method II Jacketing of beams with bonding agent and micro-concrete: The bonding agent is applied on the beam using brush on its surface. After application of the bonding agent, the jacketing is done.

Method III Jacketing of beams with combined use of dowel connectors, bonding agent and microconcrete: First, the dowel connectors are fixed on the concrete surface of the beam. After that, the bonding agent is applied on the beam surface. Jacketing of the beam with smooth surface using dowel connectors, bonding agent and micro-concrete. Method IV Jacketing of beams using micro-concrete without dowel connectors and bonding agent, only micro-concrete has been used. The jacketing of the beam with chipped surface without using dowel connectors, bonding agent and using only micro-concrete.

3 Repair methodology

Steps

1. Support the reinforced concrete beam members around the column and the retaining wall around the bridge and the dam that have connected to the cracked beam with timber posts or steel support at suitable intervals before chipping the loose concrete, this supports are adequate to provide sufficient structural support to the load carrying members.
2. All the spelled cracked concrete should be have removed by stripping the concrete cover of the beam to expose the reinforcing bars to know the number of reinforcement and stirrups. The chipping of concrete depends on the crack depth. The concrete should be have chipped to a minimum depth behind the reinforcing bars and the areas to be repaired can be shaped in the inward tapering edges.
3. The exposed reinforcing bars should be have cleaned thoroughly to remove all traces of rust by using wire brush or emery paper. The stirrups should also be have cleaned in the same way.
4. Since the beam joint reinforcing is not in accordance with the seismic resistant requirements, additional anchoring from column to beam must be have placed. In our case, some part of the beam concrete must be have removed for anchoring.

5. The nature of the beam it shows that it is not adequate so we can implement two different choices, either remove the entire beam concrete and install the additional reinforcement or additional reinforcement is installed outside the beam and concreted (in this case we can use different repairing methods like jacketing, form and pump method.
6. For the joints, the beam concrete must be removed and install the necessary anchoring. For additional column stirrups, strip the beam concrete cover and subsequently place the stirrups with suitable size and spacing.
7. Slurry tight strong form work in position and fixed such that the micro concrete can be poured into the formwork within the overlay time of bonding agent and care should be taken to ensure leak proof shuttering.
8. Use form and pump method by using its repair material, which is (pump able, good flow characteristics, self-bonding, and aggregate size compatible with the size of cavity) by mixing it, and pump via concrete line connected to the formwork until the cravity have filled and pressurized. The internal form pressure provides consolidation and bonding. This method is a twostep process of constructing formwork and pumping repair material into the cavity confined by formwork and existing concrete. When the cravity is full, pump pressure have exerted into the form causing the repair material to consolidate and make contact with existing concrete surface.
9. Provide polymer based bonding coat or rich cement bonding between old and new concrete
10. Place the concrete of required thickness and grade and workability admixed with plasticizers.
11. After 24 hours, the formwork can be removed and the protruding concrete part can be chipped.

4 Results and Discussion

Jacketing of the reinforced concrete beam have done by enlarging the existing cross section with a new layer of concrete that is reinforced with both longitudinal and transversal reinforcement. Remaining two reinforced concrete beams have considered as control beams. The surface of old concrete are cleaned by air jetting. Expanded wire mesh have fixed on the two sides and bottom of the beam. To ensure a good bond between old concrete and new polymer modified concrete, an epoxy bon cote is applied to the old concrete surface. The polymer modified mortar is applied, while the bond cote is still fresh. Sometimes 2 or 3 coats of polymer modified mortar are applied to achieve desired thickness. The mortar is cured for approximate period in water. Epoxy resin grout have injected in the cracks along top of beam. Jacketing of beam is recommend for several purposes as it gives continuity to the columns and increases the strength and stiffness of the structure. While jacketing a beam, its flexural resistance must be carefully compute to avoid the creation of a strong beam weak columns system. Jacketing of beam may be carried out under different ways the most common are one side’s jacket it.

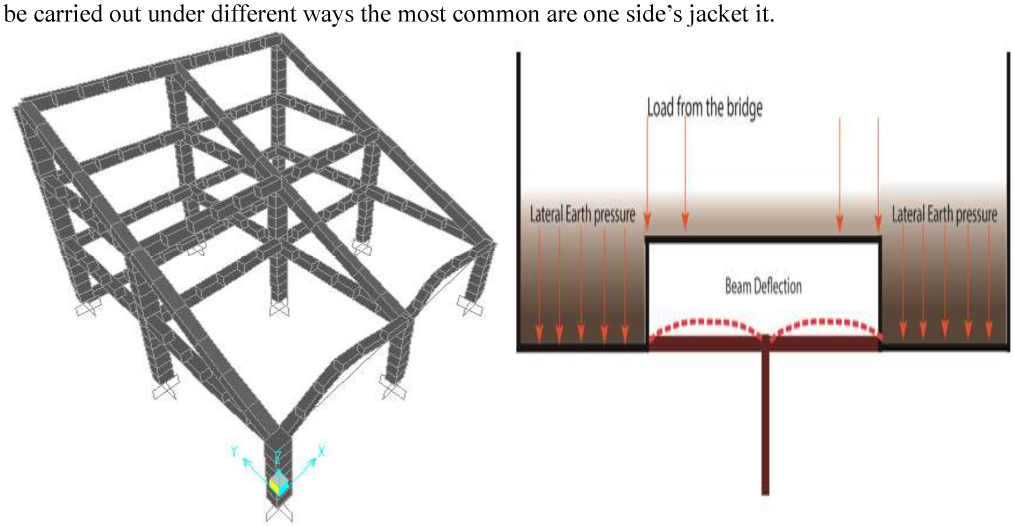

Figure: 1 Section and three dimensional of deflected beam

Earth pressure is the pressure that soil exerts in the horizontal direction. The lateral earth pressure is important because it affects the consolidation behavior and strength of the soil and because it is considered in the design of geotechnical engineering structures. Retaining walls are relatively rigid walls used for supporting soil laterally so that they can be retained at different levels on the two sides. Retaining walls are structures designed to restrain soil to a slope that it would not naturally keep to (typically a steep, near-vertical, or vertical slope). They are used to bound soils between two different elevations often in areas of terrain possessing undesirable slopes or in areas where the landscape needs to be shaped severely and engineered for more specific purposes like hillside farming or roadway overpasses. A retaining wall that retains soil on the backside and water on the front side is called a seawall or a bulkhead. A wall for holding in place a mass of earth or the like, as at the edge of a terrace or excavation. A retaining wall is a structure designed and constructed to resist the lateral pressure of soil when there is a desired change in ground elevation that exceeds the angle of repose of the soil. A basement wall is thus one kind of retaining wall. However, the term usually refers to a cantilever retaining wall, which is a freestanding structure without lateral support at its top. These have cantilevered from a footing and rise above the grade on one side to retain a higher-level grade on the opposite side. The walls must resist the lateral pressures generated by loose soils or, in some cases, water pressures.

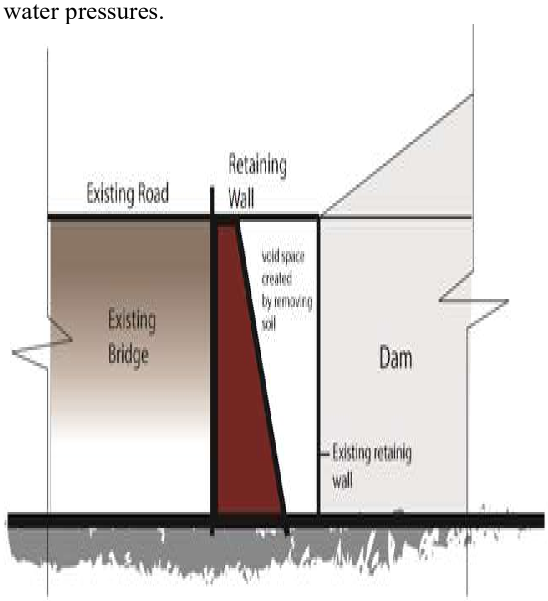

Figure 2: Section of retaining wall

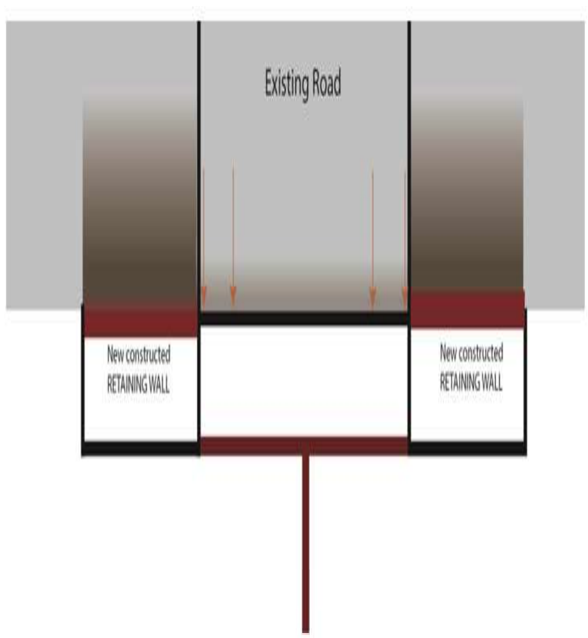

Figure 3: Section of existing road

The most important consideration in the proper design and installation of retaining walls is to recognize and counteract the tendency of the retained material to move downslope due to gravity. This creates lateral earth pressure behind the wall which depends on the angle of internal friction (phi) and the cohesive strength (c) of the retained material, as well as the direction and magnitude of movement the retaining structure undergoes. Lateral earth pressures are zero at the top of the wall and – inhomogeneous ground – increase proportionally to a maximum value at the lowest depth. Earth pressures will push the wall forward or overturn it if not properly addressed. In addition, any groundwater behind the wall that is not dissipated by a drainage system causes hydrostatic pressure on the wall. The total pressure or thrust may be assumed to act at one-third from the lowest depth for lengthwise stretches of uniform height. To prevent the effect of soil pressure we have provided a small retaining wall at the edge of the bridge. Before providing retaining walls, we have removed the existing soil on the left and right sides of the bridge and built a gravity retaining wall. Finally, after providing the retaining wall we have repaired the deflected and cracked beam by using one of the above repairing methods, which is a jacketing method.

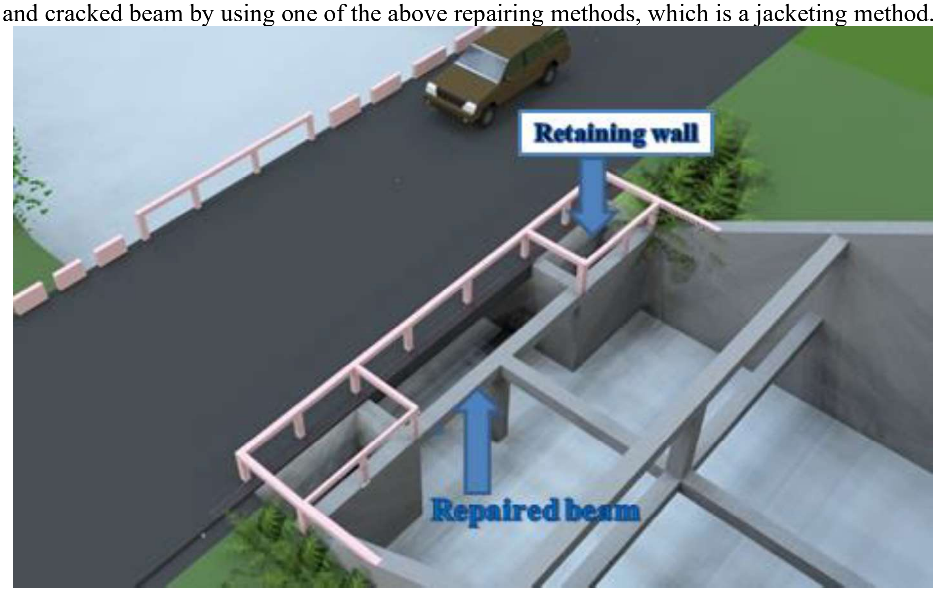

Figure 4: New model providing retaining wall

A good repair improves the function and performance of structures, restores and increases their strength and stiffness, enhances the appearance of the concrete surface, provides water tightness, preventing ingress of the aggressive species to the steel surface durability. Of course, the repairing methods rather than replacement structures should become both environmentally and economically preferable. Summery There are different types of reinforced concrete beam repairing methods. Cracks may occur due to various reasons, as discussed above depending on the above reasons we have provided a small retaining wall at the edge of the bridge to prevent the effect of soil pressure and vehicles loads coming from the bridge on the member of the frame of the structure. The occurrence of cracks cannot be stopped but particular measures can be taken to restrict them to reduce the level and degree of consequences. The jacketing of RC beams were done by using additional reinforcement and for connection between lateral and longitudinal reinforcement bar of old and new beam Z bars were introduced before concreting. Surface preparation plays important role before jacketing for superior performance of RC jacketed beam. Difference in the behavior of jacketed beams were observed whose interfaces have been fully roughened or partially roughened. These methods include use of dowel connectors and micro-concrete, bonding agent and micro-concrete, combined use of dowel connectors, bonding agent and micro-concrete and use of only micro-concrete without dowel connectors and bonding agent, respectively.

Conclusion

Recently repairing is gradually increasing with the increase of age of concrete structures. In some instances, it may be more economical to accept the need for maintenance or repair at suitable intervals than to attempt to build a structure that will be maintenance-free under severe conditions for a long period. Several types of materials and techniques are available for repairing of exiting deteriorated reinforced concrete beams. In this paper, causes of deterioration of concrete as well as repairing by using jacketing and the technique of applying of these materials and also some resin based materials for bonding agent between interface of old concrete and new concrete are reported. Any lack of attentiveness can lead to a cause for damage in the structure in its future, which can also lead to the failure of the structure. Finally, as we can see, we can use one of the above repairing methods for repairing reinforced concrete beams. The cause of the beam crack and deflect is lateral soil pressure comes from the edge of the bridge and traffic loads come from the bridge to prevent this pressure provide a retaining wall and used jacketing method. Jacketing methods are the most popular methods for beam crack repairing method and we select this method to repair cracked and deflected beams. For causes and prevention of cracks in a particular case, it is necessary to make careful observations. In the case of existing cracks, after detailed study and analysis of crack parameters, the most appropriate method of correction should be adopted for effective and efficient repair of crack jacketing methods are the most popular methods for beam crack repairing method we select this method to repair that cracked and deflected beam. Jacketing the beam have highly recommended for several purposes as it gives continuity to the columns and increases the strength and stiffness of the structure. While jacketing a beam, its flexural resistance must have be carefully computed to avoid the creation of a strong beam weak columns system.

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