CHAPTER 2

LITERATURE REVIEW

2.1 General

Carbon fibre reinforced polymers and glass fibre reinforced polymers are extensively used worldwide to strengthen the common building structures and complex domes, bridges, and tall chimneys. In the early twenty century, steel plates were also used for strengthening the girders and other structures of importance. The behavior of composite polymer used in all types of concrete structures has been investigated thoroughly since the late seventies, both experimentally and practically.

In this chapter history damage of the brides is reviewed along with the remedies to retrofitting out serviced bridges. Uses of steel plate as a strengthening material, corban fibre reinforced polymer and glass fibre reinforced polymer to strengthen the old bridges have been reviewed chronologically. Numerical and experimental analysis of several structures for FRP have been studied. This literature review is categorized in three parts;

1. Damage analysis of girders
2. Strengthening technique of girders
3. FRP retrofitting

2.1 Damages analysis of girders

History tells the story of several deteriorated bridges due to many reasons and different stages of its service period. Some bridges deteriorated due to acidic water flowing down, whether some were due to low construction material/techniques, whereas the majority due to increased traffic volume and hiked live load. Rusting of steel cover, forming of voids during construction (honeycombing), nearby saline water, poor design or material, and increase load than designed one are the significant causes of dilapidation of bridges.

Imad et. (2020) reviewed the girder failures and their prevention using fibre reinforced polymers. The author investigated that how the FRP can be an alternate option for Steel reinforcement. The author explores the mechanical properties and matrix of fibre which helps the structure to strengthen the Concrete structure. The author explained that due to resistance to chemical, low density, high elastic module. Low Conductivity, low water absorption, and good creep level FRP are the most suitable material for preventing the girders from collapsing.

Biezma et al. (2017) studied the dilapidation reason of RC bridge girders. The author finds that the ultimate common reason for dilapidation in the RC girders are rusting, overload, a mistake in inspection, Sudden impact. To eliminate these problems from time to time, strengthening of bridges required in between the service life of bridges. Choate and Walter (1983) analyzed the deterioration behavior of bridges in the USA and Japan. The acute deterioration and damages in the bridges toy become a severe economic and technical concern for the entire world. The bridges constructed in the America from 1920 to 1940 went in severe dilapidation by the 1980 and the deterioration in Japan in 2010 of the bridge built in 1950 to 1980. This period of time is known as the economic growth period in Japan. The graph shows that the aging problem in bridges built in this period deteriorated. This trend is scary for all the developed and developing countries. Considering the bridges more than 50 years old, which is the service life of bridge design of Japan as a case study, the ratio unprecedented increased from 6% in 2006 to 20% in 2016, and it is vaticinated that it will reach 47 % in 2026. Robert et al. (2016) - The author researched the suitability of fibre in place of steel reinforcement beers in his study. The author found that corrosion in reinforcement is the main reason for the failure of bridges and other structures.

The work represents the mechanical durability of the fibre reinforced polymer. The author concluded that fibre reinforced polymer could be easily used at the place of steel reinforcement to avoid the failure of bridges due to the corrosion effort. Attari et al. (2012) investigate the use of hybrid FRP to strengthen the bridge. A four-point bending device has been used to test the strengthened beam. The author analyses the strength and ductility of the beam. In the research, the author concluded that the model predicts the actual result as in the laboratory. The hybrid fibre is also cost-effective. The study also suggested that U-type anchorage increase flexural strength and contribute to stiffness of the structure.

2.1 Strengthening techniques of girders

To improve the load Carrying capacity bridge beam steel plate have been widely used in Japan, Europe and Africa since 1904. The procedure of Application of steel plate is straightforward. In the tension flange of the beam the steel plates were fixed with the help of epoxy to improve the stiffness and load-carrying capacity of the beam the benefits of using this strengthening system consists the easier application procedure, absence of special anchorage, Repairing of girder can be performed while bridge in use.

Klaiber et. al and Saadamanesh (1989) Initially, in 1982, the external strengthening was started by Klaiber et al.: and Saadamanesh in 1989. In the early days the prestressing was started using an epoxy bonded steel plate in the tension flange. In this research, the engineers found steel epoxy plate to be safe, Economical, and efficient in increasing the stiffness and Strength of the girder, but there are several difficulties in using it like corrosion in steel plate and stability of beam at the time of post-tensioning in the lateral direction. Klaiber et al. (1987) researched the corrosion in steel plate and invented a new type of material. Corrosion in the steel plate will adversely affect the band strength between epoxy and plates. To rectify the corrosion in steel plate strengthening, the plate was replaced by anti-corrosive fibre composites. When the researchers started exploring a different types of fibre for strengthening of the beam then they find that some fibre which has more fatigue and tensile capacity than steel plate also the corrosion-resistant was too high.

Swamy et al. (1987) analyzed the impression of steel plate on the initial crack load, behavior of cracking, level of deformation, girder's serviceability and ultimate strength of RC girder. The author tested 24 girders with the rectangular dimension of 0. 115 m X 0. 255m and length was 2500 mm. Three steel reinforcements of diameter 20 mm were used. There, such combinations were made for plate and 3 glue thickness; 1. 5mm, 3mm, and 6mm comprises each plate. The width of each was kept constant to 125mm. The test output shows that the amplification of plate and glue with RC beam equally contributed to flexure, stiffness, minimizing crack width, deformation reduction in girders, and increasing the ultimate flexure strength. The total efficacy of deformation in the girder was equal to the stiffness increment due to glued plate. Gernert and Boseh (1985) both studied about the long-term effect of corrosion on the epoxy steel band Strength. They conducted the durability test on RC beam externally bonded with the composite epoxy plate. They measured the impact of prolonged exposure, loading, temperature and fatigue. The researcher Concluded that meteoric corrosion depends on the three factors- Concrete quality, the surface of steel plate, and efficiency of rehabilitation members. So it was concluded that the technically Sound artistry and careful preparation of work are essential in improving the resistance of structure and plates not to corrode.

VanGemert et al. (1985) studied the bond strength of steel plates with concrete. The author had taken the 0.3 meter × 0.25 meter Size girder and bonded it with a steel plate of 5 mm thick X 250mm wide. The four-point load were applied cyclically on the beam with 30 cycles (min and of total 500,000 cycles on each beam and the beam undergone up to the maximum stress of 40 N/mm Donald and colder (1982) analysed the bending of Steel plate to the concrete beam in their tension flange. The authors investigated the series of 4980mm and 3250mm girders in bending at 4 points. The researcher concluded that full composite support was preserved by adhesive. The critical performance in the form of ultimate load Stiffness and Controlled crack had shown a remarkable improvement. To analyze the long-term effect due to corrosion, an exposure test was carried out on the girder, and it was found that a considerable quantity of rusting in the steel plate had taken place because of natural exposure and other factors. It was also noticed that den to corrosion, the bend Strength of epoxy steel also weakened. Dussek (1980) Author reported the strengthening behavior of RC beam. This was the first reported incident of using epoxy bonded steel in the RC beam in 1964 at South Africa's Durban. Here with the help of these plates a concrete beam of an apartment was strengthened. This strengthening was done because during the casting of this beam accidentally the primary reinforcement came out of the beam. This incident was reported by Dusek in 1980. At Quinten junction, four bridge structure on the MS highway in 1975 and atswanley Kunt 1125- M 20 highway two bridge in England was retrofitting by using ghee and Plate in 1977. In Quinton's case, at the time of inspection,, the crack appeared in the the main span and at the soffit of the end. The Quinton's bridge was a RC box girder type bridge with a span of 16.75 meter, 27.4 meter and, 16.75 meter.

Araldit (1979) To strengthen the several building in Zurich, Switzerland, the epoxy banded steel plates were used. In a residential building, some extra live load was added so to accommodate these loads the plating of slabs and beam was done. By the use of these strengthening method, the flexural strength was in hand. To bear the shear and live load same plate were glued in the side of beam. This scheme used to in hance base of these structure also. Another corporate building in Zurich was strengthened utilizing this method in the same year.

Hamid sadatmanesh (1978), six different beams are analyzed in which five were rectangular and one was T beam for static strength. All the beam was strengthen using glass fibre reinforced plastic. In this study, the FRPs were used in the tension flange of the beam and tested under four-point bending. In this study, it was concluded that glass fibre is beneficial in increasing the flexural strength if fibre was applied in the tension flange of the RC beam. The author also concluded in this study that using epoxy with plates the cracking width at any load can be minimized, and evident crack formation can be reduced.

According to a survey, more than forty-five percent of bridges worldwide need immediate attention for rehabilitation and strengthening to avoid possible failure. The designed load of existing Bridges is much lower than they are experiencing now. So only rehabilitation or retrofitting would not be sufficient, it need to strengthen them immediately.

2.1 FRP retrofitting of bridges

Saleh z et al. (2019), in this study, unstressed CFRP was laminate over 70 girders, span ranging from 2000 mm to 7000 mm. Shear way observed in the girder and due to that decortication of the fibre is quite possible. Cracks were also sprayed throughout the laminates and no such effect on loading capacity. In the case of temperature change, the laminate epoxy resin is stressed due to the differ volume of coefficient of thermal expansion. The author tested the 100 cycles of loading with unstressed laminates and the temperature of structure was kept from 20°C to 25^{o} C, the following conclusion by the study-

1. Regular decorting of fibre laminate on the raw surface of the beam impacts the peeling speed of laminates. Like where the structure was more uneven, then the peeling of the laminate was higher at that particular place, and where the structure was lesser, then there was slower decortication.
2. The shear effect in the tensile zone was observed. It Causes the secondary failure of the structure.
3. Failure of the beam observed in the compression zone.

4. Sudden failure of laminates with intense fulminative cracks.
5. A fatigue test reinforcement failed in the tension area.

All the beam was strengthened using the glass fibre reinforced plastic. In this study, the fiber-reinforced plastic was used in the beam's tension flange and tested under four points bending. The author concluded that glass fibre is beneficial in increasing the flexural strength if used in the tension flange. Numerical analysis of the beam performed using ANSYS to determine the efficiency of fibre composite varying in layers and length. The most efficient was suggested to be implemented on the field.

J Michels et al. (2016) The author tested the CFRP repaired reinforced concrete beam tested under a beam load and obtained the load-strain graph, which represents the local behavior at selected points when the beam was analyzed using linear finite element method. Numerical data shown similar stiffness than in experimental while nonlinear ranged finite element models shows more stiffness values than the lab results. 30-50% transient traffic (Varying with 1 Hz) load of unstrengthened beam can be allowed at the time of retrofitting, and a reasonably good bonding were observed between CFRP sheet and concrete during the strain development in FRP sheet at above said load.

Dias and Barros (2013) The author studied fiber bonding techniques to the concrete surface. There are mainly two techniques are using to laminate carbon fibre reinforced polymer (CFRP) in concrete - Externally bonded reinforcing (EBR) and Near Surface mounted (NSM). Several research have been proved that near-surface mounted techniques are better than externally bonded reinforcing (EBR) because NSM has better contact ratio to the concrete with high confinement provided to concrete, So NSM shows good behaviour in shear and flexure than EBR. Four flexure mode is mainly researched for failure of RC beam strengthened by CFRP with NSM and EBR technique- Tension failure of CFRP, Compression failure of concrete, delamination of concrete cover and CFRP de-bonding. The service life of CFRP retrofitted bridge is approximately 50 years with deflection of 25 $\mu\dot{\varepsilon}$ after 1 million load cycle.

Julien et al. (2016) - The author discusses the efficiency and suitability of anchorage gradient. Author has chosen a bridge in Poland for strengthening using gradient anchorage. Two 18.4 meter span were taken in the experiment. One bridge was set up as a reference white other way strengthen by two pre-stressed CFRP Strip. Both girders were loaded up to failure. the carbon fibre reinforced polymer strengthen girder shows the ductile failure by 16 % more than the other one. Service load was increased by 25% than the unstrengthened girder. The author suggested dry shotcrete in case of the cambering beam.

Bai et al. (2012) studied the linear and nonlinear behavior of the FRP retrofitted structures. Modeling of a beam strengthening with FRP using 3D finite element simulation, compared to experimental analysis of beam in both linear and nonlinear, showed that final failure load from finite element analysis is lesser than the practical load by 6–18%. By the full-scale load test of strengthened T-type bridge girder using concrete weight block as loading system, it is found that this method is safe and convenient and for strengthening with this method the FRP materials carbon, glass and aramid fibre were found effective in improving flexure capacity. The design code ACI 440.1R, which is refer to strengthen the concrete structure and it is assumed that ACI 440.1R can be used for full-scale bridge strengthening. The beam and slabs which contain pre-stressed CFRP tendons show much lower deflection and better serviceability control than the steel-reinforced structures.

Noi and Souduki (2011) The author studied the ultimate scaled load that can be applied without any retrofitting and FRP strengthen the bridge. His studies explain that capacity of strengthening bridges were increased by 28 % in comparison of unstrengthen bridge. Also, the deflection in un strengthen bridge was higher than that of the strengthening beam at the same truck load. The flexure strength of the RC beam is limited because of the occurrence of concrete cover delamination, but it can be increased by CFRP reinforcement. So in many cases, it has been observed that concrete cover delamination occurs in the externally bonded reinforced CFRP strengthen beam due to the formation and propagation of fracture surface.

Alfarabi et al. (2010) conducted a study on the humidity and temperature test of laminates. o understand the behavior of laminate in high humidity and increased temperature the loading was continued in raised temperature to 50^0 C and humidity of 98 % after 12.36×10^7 loading cycle the first steel bar cracks because of temperature and fatigue. Another steel bar breaks at 14.78×10^7 Cycle where load was constant, and stress increased in the laminates. After failing second bar, the crack caused by laminate propagating rapidly and fibre laminate also sheared.

Xue and Tan (2010) extensively studies about the structural changes after retrofitting by the fibre reinforced polymer. According to the author, with the application of pre-stressed CFRP flexure strength of girder was increased by 16% in cracking, 19% in yielding and 24% in ultimate load-carrying capacity than without retrofitted girder while ductility increment recorded in every case of CFRP lamination. Also the ultimate load of CFRP applied girder reached by tensile failure of CFRP strip. When the Road over bridge girder repaired through FRP laminates with EBR technique, the deflection of damaged girder reduced from 2 to 12 % for static loading and 7 to 12 % for dynamic loading. And also the reduction in steel reinforcement stress was also recorded. It has been reduced to 4 to 12% for static loading and 4 to 9% for dynamic loading.

G. Williams (2007) According to the author's studies, the design moment capacity of the bridge girder receives a considerable change of approximately 25% after CFRP retrofit. After retrofitting with CFRP beam completely regains its virgin flexural strength. Serviceability and crack control have also shown good recovery after strengthening due to the application of CFRP on girder the chloride-induced corrosion of steel reinforcement reduced by at least 5% if measured in the long term and the reduction in the frequency of beam were decreased by 3% with application of CFRP. Also in the flexure it records 6% more stiffness than without CFRP retrofitted girder if corrosion recorded for long duration. The residual flexure rigidity of steel reinforcement of beam girder after 100 years of chloride-induced corrosion was recorded approximately 70% of original girder strength.

Saidi et al (2006) author studies about the new fibre composite material for reinforcing concrete (NEFMAC) grid, a type of FRP invented in Tokyo, can be a replacement for steel reinforcement, but several parameters like modulus of elasticity, brittleness of FRP and cross section area of NEFMAC FRP have higher values than steel which will need to be anchored. With the help of CFRP plate, the stiffness in corroded and damaged steel girder can be restored up to 10–37%, and to prevent the galvanic corrosion a glass fabric layer can be used. After strengthening of girder with carbon and glass fibre, the global flexural of girder was improved by 11.6% compared to strengthened girder. This strength can be verified by the case study of Horsetail Creek Bridge. After FRP strengthening of Horsetail Creek Bridge, the capacities on mass proportion and scaled truck loading improved by 28 and 37%, respectively. Yield of steel bars and crack length are reduced in FRP-strengthened bridge, and the mode of failure of bridge changed from shear failure to flexure failure.

Chang (2004) explored the types of anchors used in the plates. Author uses the three different kind of anchoring for the beams: (a) discontinuous mechanical anchorage system (DMA), (b) sandwich discontinuous mechanical anchorage system (SDMA) and (c) additional horizontal strip (HS). The studied result explains that SDMA system is more successful than DMA and HS systems, respectively. The sandwich discontinuous mechanical anchorage system improves the shear strength by 59–91% altering the failure by deboning of FRP. The externally bonded FRP performed well under transient loading. CFRP and concrete showed the properties of a suitable composite material together. It is also noticed that transient loading affects the final ultimate performance if loaded during curing period. Flexural strengthening by CFRP strip gave 16, 19 and 24% additional strength than un strengthened structure in case of cracking, yielding and on ultimate load capacity, respectively, and failure of structure occurs as tensile failure which means bonding of epoxy with concrete and CFRP was adequate.

Teng (2003) the author explores the total fibre area in the concrete structures. The reinforced concrete structure fails in the brittle manner if the GFRP is below 0.5% of total reinforcement area, while increasing the area of GFRP from 0.5 to 1.0% results in the increment of ultimate load taking capacity with 67% and energy absorption capacity with 48 and 27% decrement in the mid-span deflection. When the GFRP sheet layers are placed at the bottom of the slab, the slab's displacement got reduced. It has been experimentally verified that the use of GFRP sheet at the spalling area of concrete improve the ultimate load capacity of infected area and also decrease the deflection at that point. The analytical analysis of repaired bridge with jacketing at bottom of the slab reduces the stress in the tension zone of slab with better vibration absorption capacity. The combination of the steel cage and GFRP in repairing RC structures gives confinement to the damaged members and prevents the joints of structures from excessive distortion.

El-Hacha et al. (2001) analyzed the location of fibre rods around the concrete structure. Near-surface mounted GFRP rods reduce the changes in the values of frequencies of the structures, and the failure of RC beam strengthen using this technique depends on the bonding of RC beam and GFRP. RC beams strengthened with FRPs suffer failure in three ways, i.e., flexure, shear and de-bonding with the de-bonding of the FRP sheet being the dominant failure mechanism. The plates can be provided on the tension side of the beams to enhance flexural strength and on the lateral sides to enhance its shear resisting properties Studies have shown that FRP confined concrete behaves differently from steel confinement due to the linear elastic properties of FRP up to failure. Steel plates and FRP sheets together have been used to increase the efficiency of retrofitting. Comparatively, FRP materials are more expensive but advantageous in overall economy, speed of retrofitting and ease of installation especially in places difficult to reach. In addition to that FRP sheets can be employed over a wide range of structural entities like beams, columns, connections, floors, girders, etc. The use of CFRP layers on columns has been found to increase the maximum load it can sustain by about 27%. While using it with GFRP bars has increased these numbers to 51%. The use of these techniques has also affected the method of failure, from flexure-shear failure to plastic hinging in some cases. Another study conducted on low-strength concrete beams has shown an increase of 19–27(%) in strength depending on the configuration of CFRP pile sheets used in retrofitting.

Yost (2001) the author explored the contribution of CFRP in the strength of concrete. A very important characteristic which degrades the quality of the strengthened structure is reduction in ductility caused by gluing of plate, because it is inevitable that plates reduced the elasticity of structure. And it brings the reason of failure of concrete layer between longitudinal reinforcement and GFRP plate at limiting load. The least vital element in the sandwich of concrete and fibre plate determines the shear strength of CFRP and adhesive interface. In this study, it is proved that the CFRP contribution is much more effective in stiffness of beam rather than the strength. Vertical deflection and steel reinforcement stress were significantly reduced by the use of GFRP, and the moment of inertia also improved in the concrete structures by using glass sheet.

Miller et al (2001) the researcher analysed about the restrainer made by FRP. The restrainer made by FRP of glass carbon and combining glass and fibre has reduced the impact at hinge, so it may be used as a device for earthquake restrainer in bridges. When these carbon and fibre FRP restrainers were compared with steel, they showed least movement than steel restrainer. The impact factor of FRP Bridge based on deflection is much lesser than of concrete bridge which explains that dynamic impact factor suggested in AASHTO can also be applied to FRP Bridge and in its strength design, while the acceleration of fibre-reinforced bridge is higher comparatively to concrete bridge.

Alfarabi (1994) worked on the rehabilitation of old bridges. Author found in his studies that to rehabilitate the old or damaged structures, the fibre-reinforced polymers (FRP) are very favourable material due to its qualities like light in weight, easy in installation, high strength and high stiffness and high durability. Several studies have been done on both undamaged and damaged girder with FRP laminates and found effective in a reduction in deflection of girder and stress reduction in the steel reinforcement.

Kaiser (1993) A 300 mm wide, 2000 mm long-and of depth of 250 mm, girder investigated under fatigue. The girder was laminated by glass and fibre of size 0. 3×200. Initial failure at fatigue loading was occurred at 480000 Cycles in one of tension reinforcement and second steel rod failed at 560000 loading cycle. When loading reaches 610000 cycle another split-observed in first reinforcement anal at 7,20,000 cycle a new break occurred in the second rod. The laminate experiences its first crack after the 7120,000 Cycle a new break happened in the second rod. The laminates experience its first cracks after the 7,50,000 cycle of loading and when load reach to 805000 Cycle then laminate failed. It was great to observe that even after complete failure of steel rod the laminates remain intact and safe with cement.

The author investigated a 6000 mm long girder. The ultimate load capacity of unstrengthen girder was 600 KN and after the strengthening of a girder with composite laminates the strength increased up to 805 KN. The total increment in strength is approx. 34% to 805 KN. The author loaded the girder up to 10.32×107 cycle of loading for same load without any visible damage.

Hamid Saadatmanesh et. al. (1991) Hamid researched about the role of GFRP plate in structural strengthening. He found that flexural strength of the reinforced concrete beam can be increased if GFRP plate anchored in tension flange of beam. The beam which has lower cement-reinforcement ratio they shown good improvement in strength than with the higher steel RC beams. In this study researcher found that the glued plates minimize the crack width at all applied load during the testing. The high amount of epoxy suggested to avoid the delamination of plates from beam. Fibre composite reduces the ductility of girder at some extent and reduction in ductility is found to directly proportional to the ductility of original girder. Behaviour of retrofitted girder can be accurately predicted with the help of analytial and experimental data. The researcher suggested to further study about estimating the limiting load that allows the failure of concrete existence between longitudinal reinforcement and composite fibre. It can be noticed in this study that cambering of girder decrease the crack width during loading but it need sufficient data need to explore regarding cambering effect on the reduction of crack width. The role of epoxy for causing the cambering stress is also need to investigate. The hamid and Ehsan (1992) found that no any environmental factor effects the fibre composite directly like steel plate but the role of extreme moisture and temperature on the epoxy joint need further investigation and newly -retrofitted beam must go on under fatigue loading.

Eui- Seung Hwang 1991 tries to find the method to numerate the total of dynamic load. Author tries to develop a statically formula for dynamic load calculation which can be use in reliability driven Code for bridge design. Author also find that dynamic load factor inversely proportional to vehicle weight (gross). And to establish the correlation between static live load and dynamic live load was ambiguous except for 30 meter span where very negligible amount were observed.

Pleimann (1987) the most famous type of fibre composite is glass fibre because of its low cost. The Ultimate strength of glass fibre reinforced is nearly equal to the steel plate but it logs in it modulus of elasticity which is much lower than steel. This may be the reason that GFRP is less explored material in Composite fraternity. The glam fibre reinforced plastic has lesser modular of elasticity but when it is mixed with conventional material it performed very well. In this research it has been noted that if graphite or Kevlar were added with glass thin the modulus of elasticity increased 3 to 4 times than of original which leads equal to modulus of elasticity of steel. In the structural engineering the research and use of fibre are very limited as compared to other field of Engineering like aerospace, automobile, ship engineering, chemical Engineering.

Haskin and Baker (1986) the composite fibre reinforced plastic is the safest material in the term of environmental pollution. No any key issue have detected due to external weather to fibre composite or no any fatigue issue have reported in aviation ports during their service life. Haskin and Balar researched about the manufacturing and, performance of different type of composite with reference of resin and fibres. Author discussed about benefits and harms of using composites. Uses of monolithic metal alloy introduced by Hoskin and Baker. Water residence capacity of resin and occurrence of corrosion due to that was discussed by author. The effect of absorbed moisture on the epoxy band on production as well as during working period has been discussed briefly. To avoid the defacement the use of silicon rubber was discussed.

Dang (1991**)** Author analyses the data of several bridge and adduced that if the span of the bridge is larger than the impact value will be smaller and if the bridge's span will be shorter than the impact factor will be more significant. So for shorter span it is recommended that in spite of finding the average for whole bridge the impact factor of every girder should be investigated. It is also helpful in the long span too.

Fennes et-al (1962) studied the deflection of bridge and suggested the impact value I for strain about 0.03 to 0.25 and for deflation. He suggested the value of I as 0.02 to 0.42 Leonard et. al. (1974) the researcher worked on impact over 30 bridges and suggested the value of I from 0.09 to 0.75. Shepherd and aves (1973) they had investigated 14 bridges in New Zealand and recommended the impact value as 0.1- 0.7 O 'Connor and Pritchard (1985) the impact factor for continuous bridge had found between 0.1 to 0.87 while for other type of bridge it was suggested 0.7 to 0.75. Mile Creek Bridge have been investigated in Australia by Author and concluded the value of I between 0.19 to 1.25. After studying the method of all researchers it may concluded that impact on the bridges depends on following factors-

1. Type of bridge

2. Natural frequency of the bridge
3. characteristic of passing vehicle
4. speed of vehicle on the bridge
5. Approach road profile and deck of bridge
6. damping nature of bridge and motor
7. Weight of vehicle.

2.1 Critical observations

The first invention of fibre reinforced polymer was happened around middle of twentieth century. Till now a lot of studies across has been done for retrofitting work of different structures. However, some of unexplored area is yet to investigate. The author finds some gap during his literature review.

1- The stress, deformation and natural frequency of deteriorated and retrofitted girder of different shape is not well focused.
2- The effect variation of FRP layers with large variation of span of actual bridge girders are not appropriately addressed.
3- The effect of varying the percentage of steel in the girder with different layers of laminate composite needs to be explored.
4- Design parameters with FRP laminated retrofitting is required attention.
5- Real-time studies on the rail bridge girder or vehicle actual loading condition need more attention.
6- Field study on real bridges with FRP and its strengthening scheme should be focused.

2.1 Scope of the present study

To keep in the mind the research gap, the following studies are carried out.

1. Deformation and stress analysis of FRP laminated simply supported prismatic and I-girder numerically.
2. Parametric study of the girder laminated with:

(i) One layer, two layer and three layer of GFRP in Shear zone.

(ii) One layer, two layer and three layer of CFRP in Tension tone.

(iii) One layer, two layer and three layer CFRP in tension zone and one layer, two layer and three layer GFRP in shear zone on the same girder.

(iv) All above combination of studies for different spans of real and for few hypothetical girders with regression analysis.

3. Field study of a RC bridge girder at Pusa (Bihar) and its strengthening scheme with FRP layer for IRC vehicle loading.
4. Modelling of severely damaged RC bridge girder with IRC loading using Finite Element Method for different length of girder and its field verification.
5. Field study of two out serviced rail bridges (No 114 and 54) of western railway at Ratlam (M.P.) and its modeling and retrofitting with field verification.
6. Modeling of rail bridge girder using RDSO specified rail load using Finite Element Method for different lengths of girder.