STUDY ON RESPONSE OF CONCRETE BRIDGE DUE TO CONSTRUCTION DEFECTS

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF DEGREE
OF
MASTER OF TECHNOLOGY
IN

STRUCTURAL ENGINEERING

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CANDIDATE'S DECLARATION

I, Surendra Kumar Verma, Roll No. 2K/20/STE/24 student of M.Tech. (Structural Engineering), hereby declare that the project dissertation titled "**STUDY ON RESPONSE O, CONCRETE BRIDGE DUE TO CONSTRUCTION DEFECTS**" which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship or other similar title or recognition.

SURENDRA KUMAR VERMA

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<u>CERTIFICATE</u>

I, hereby certificate that the Project titled "**STUDY ON RESPONSE OF CONCRETE BRIDGE DUE TO CONSTRUCTION DEFECTS**" which is submitted by Surendra Kumar Verma, Roll No. 2K/20/STE/24, Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any degree or diploma to this university or elsewhere.

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ACKNOWLEDGEMENT

At the outset, I would like to express my sincere and deep gratitude to my supervisor, Dr. Shilpa Pal, Associate Professor for her enlightening and inspiring guidance to complete my project work under her valuable guidance and supervision. His guidance has taught me valuable lesson for my career.

I also pay my sincere thanks to Sh. Durgaprasad Golla, Scientist, BES Division, CSIR-Central Road Research Institute-New Delhi for his immense support and guidance in the completion of my project work as a co-supervisor. I came to know about so many new things during my project work with his experience& knowledge.

I also grateful to all the faculty members of Department of Civil Engineering, DTU for their help and teaching me the fundamental during the course work.

I would like to sincere thanks to Director, CSIR- Central Road Research Institute who has granted the permission to enhance my qualification and also thanks to my HoD, Dr. Rajeev Goel who encourage me to pursue my master degree.

Apart from this, I would like to extend a token of thanks to my family with whose support and love enabled me complete my course.

SURENDRA KUMAR VERMA

ABSTRACT

Different types of defects in a bridge structure can be cracking, delamination, honeycombing, improper casting of pedestal, poor drainage system, inappropriate placing of bearing, improper seating of girder etc. It is well documented that the bridges constructed in the last couple of decades are showing considerable signs of distress in the early stages of their design life and lead to collapse without serving the intended designed service period of 100 years. To maintain the structure, it is necessary to conduct a systematic inspection in accordance with the structure and the available guidelines in order to detect defects at an early stage. It is also significant to accumulate the data collected during the field inspection and maintenance activities without ignoring any distress. During bridge construction, skilled supervision is crucial to make sure that the structure is structurally sound so that it can avoid structurally deficient bridges. Periodical inspection after the construction will make the structure more efficient and long-lasting.

In this study, the field survey has been done to identify the defects and elaborate on the codal provisions. The method used for assessing the behaviour of the structure due to defect is modelling and analysis of the bridge in STAAD pro software. With the consideration of defect, additional unexpected moments are generated in the girder and diaphragm for which the structure was not originally designed. In general, steel reinforcement is provided for required moments in the structures. If additional unexpected moments are generated, then damage can occur in the structure and affect the service life of the structure. The present study highlights that the collection of data can provide information about the possible defects with their causes for a meaningful conclusion about the service life of the structure.

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CHAPTER 1

INTRODUCTION

1.1 BRIDGE

A bridge is a structure providing passage over an obstacle without closing the way beneath. The required passage may be for a road, railway, pedestrian, river or a pipe line. Bridge can be in multilevel also.

A symbolic or natural bridge is shown in Fig 1.1 which is in Andaman but never used just for tourist purpose.

Fig 1.1 View of a natural bridge

In the transportation system bridge is a key element because of three reasons:

- It likely controls the capacity.
- Highest cost per km.
- If the bridge fails, the system fails.

In general the cost of road per lane per km is less if no bridge structure is there. If any bridge structure is necessary to build on roads then cost of roads per lane per km will rise obviously. So, to maintain this bridge structure is necessary in our transport system.

As bridges are the integral part of a transportation system, in the view of the bridge importance and some of the bridges are designed in India as the inspiration for engineering skill. In the view of all theses the department of Indian Post released the stamp of rupees 5 for four bridges in India as "Landmark Bridges in India" namely Mahatama Gandhi Setu , Patna in Bihar, Vidyasagar Setu, Kolkata in West Bengal, Howrah Bridge, Kolkata in West Bengal and Pamban Bridge, Rameswaram in Tamilnadu.

A commemorative postage on Mahatma Gandi setu shown in Fig 1.2 This bridge is located in Patna, Bihar. It is also known as Ganga Bridge. This bridge is opened to traffic in March, 1982. This bridge having a total length 5565 meters.

Fig 1.2 View of A commemorative postage on Mahatma Gandi Setu

A commemorative postage on Vidyasagar Setu shown in Fig 1.3 This bridge is located in Kolkata, West Bengal. This bridge is opened to traffic in October, 1992. This bridge having a total length 828 meters. This bridge is locally known as “Second Hooghly Bridge”.

Fig 1.3 View of A commemorative postage on Vidyasagar Setu

A commemorative postage on Howrah Bridge shown in Fig 1.4. This bridge is located in Kolkata, West Bengal. This bridge is opened to traffic in February, 1943. This bridge having a total length 705 meters. It was renamed in June, 1965 as “Rabindra Setu”.

Fig 1.4 View of A commemorative postage on Howrah Bridge [10]

A commemorative postage on Pamban Bridge shown in Fig 1.5. This bridge is located in Rameshwaram, Tamil Nadu. This bridge is opened to traffic in February, 1914. This bridge having a total length 2060 meters.

Fig 1.5 View of A commemorative postage on Pamban Bridge [10]

1.2 CONFIGURATION OF BRIDGE

Configuration of bridge is shown in Fig 1.6 which comprises with superstructure, substructure & foundation. Superstructure is a main part of the bridge comprises deck slab, expansion joints, girder and bearing. Substructure support to superstructure and transmit its load to ground floor, it comprises to pier cap, pier and foundation.

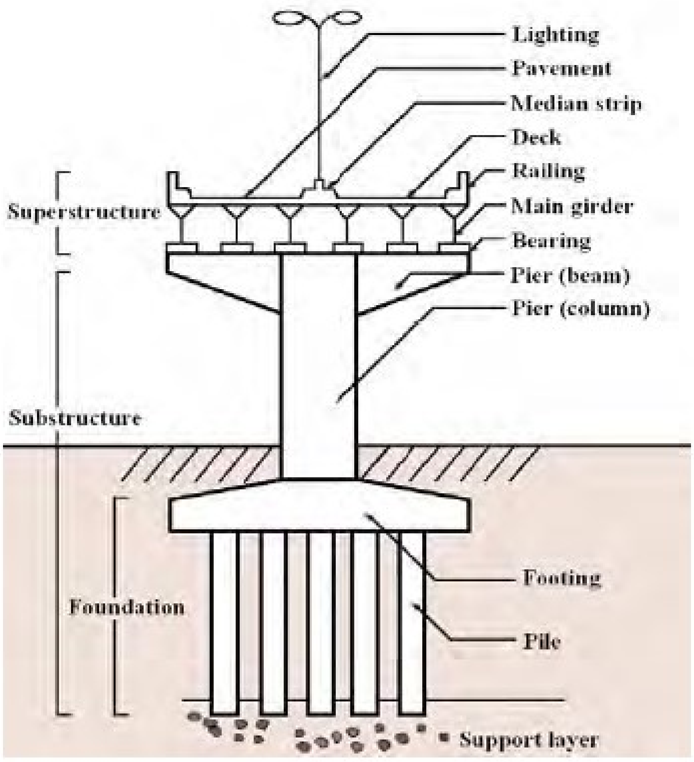


Fig 1.6 Configuration of bridge (source: manual of JICA)

1.3 DEFECTS IN CONCRETE BRIDGE

It is very important that to note that if any problem occurs in the bridges, it creates lot problem in the road transport system. Though bridges are a small part in road system but it has significant importance. With the massive transportation development in our country is going on in faster mode, therefore sometimes ignorance in the work can be happened by which so many problems initiated and intended service life of bridge compromised. Therefore, a proper system or awareness to avoid such type problem is required. In the recent years, it has been observed in the many documents and media news that there is lot of defects in bridge structures and failure or collapse. This cannot be attributed to only one reason, there may be many reasons behind it but ignorance, poor construction practices, lack of knowledge, using substandard material, ignorance in the periodic inspection of bridges after construction are also the reasons. In this report it is tried to explain the defects and damages in concrete road bridges which are observed during the field survey with their causes and affect on the bridge structure. Bridges are vital part of road infrastructure. Actually without bridges life cannot be sustained. Damage or collapsing of such types of vital structures leads to a lot of risk for human lives & results in monetary loss.

Construction defects in concrete bridge have raised the major concern about the safety and probability of the failure or collapsing of the structure. Construction defects can affect the overall safety of new or old bridge structures. Due to the lack of knowledge and ignorance of the codal provisions results in distresses in the form of cracks etc. Improper quality control and low quality aggregate leads to distress such as spalling, honeycombing, exposed reinforcement etc. Table 3.1 gives a list of few common defects which are observed in different bridges in India. 14 bridges have been inspected for this study, which are elaborated in subsequent chapters. All the bridges inspected as of the reinforced concrete bridges.

1.2 OBJECTIVE OF THE STUDY

The objectives of this study are as follows:

- To educate and familiarize field engineers to avoid possible construction defects on the basis of field observations.
- This study gives a general idea for the possible construction defects and their causes in field.
- With the study of this report, field engineers can minimize the construction defective work in the field due to which certain types of losses can be prevented.
- If pay little attention while working then can make the structure good without any extra cost.

1.3 SCOPE OF THE STUDY

This study has been done on the basis of collected data during the inspection of bridges. In this study total 14 bridges are considered with their defects in different components. These defects have been elaborated with the given guidelines in Indian standards. A study also done to know the response of bridge component due to the defect as observed in the field.

1.4 LIMITATION OF THE STUDY

This study is limited up to 14 concrete bridges. For further study more number of bridges can be consider, more data to include more distresses in the field. In this study few distress are consider and analysis of the distress structure to know the global response of the structure. Inspection of more numbers of bridges of common distresses can be part of future study.

1.5 ORGANIZATION OF THESIS

The Dissertation titled **"STUDY ON RESPONSE OF CONCRETE BRIDGE DUE TO CONSTRUCTION DEFECTS"** is composed of five chapters.

Following are the chapters included in this dissertation.

Chapter 1 consists of the Introduction of the defects in the concrete bridges, in which objective, scope and limitation of thesis is also given.

Chapter 2 comprises of literature survey.

Chapter 3 Discussed about the defects in bridges which has been observed in the field and elaborated with the given guidelines.

Chapter 4 Analysis of distressed bridge to know the response of bridge component with the defects as observed in the field.

Chapter 5 Conclusion and recommendations

References of the literatures which have been referred in the study are also provided.

CHAPTER 2

LITERATURE REVIEW

R.K.Garg et al. (2020) studied related to the failure of bridges during 1977-2017 in India. In this study described a statistical data which have been classified under various categorised based on material, cause of failure and others. There are many documents/articles are available in India related to the failure of bridges. More than 2130 bridges (excluding pedestrian and culverts) have failed in last 40 years (1977 to 2017) to provide their intended service. In this study reasons for failure of bridges have been analysed during their service life. This study highlighted and described the study on the causes of failures of bridges during their service of the bridges. Natural disaster is the main dominating (80.30%) in which flood, scouring, earthquake; storm, landslide & snow are considered [4]. Secondly cause of failure is the material deterioration is 10.10%. Design and construction is the 4.13% of cause. Overloading and human-made disasters are 3.28 % and 2.19% respectively. Component's failure of bridge identified and presented. The failure of superstructure is 72%, substructure 10% and foundation 6% of all failures, 7% failures of abutment, earth retaining walls and expansion joints. Remaining 5% are for the demolished condition [4].

Philipp Huthwohl, Ruodan Lu & Ioannis Brilakis (2019) proposed concrete defects classifier with three staged which can classify the unhealthy bridge areas into their specific defects type with conformity with the existing bridge inspection guidelines [6]. Deterioration of the bridge structures having drastic implications on road users satisfaction and country's economic success. Common defects classified and classes as exposed reinforcement, abrasion/wear, cracks & efflorescence etc. In this paper author classified the defects in three manners; (i) multiple defects (ii) defects combination and (iii) scale independence [6].

As per first requirement detect multiple defects and noted. After analysing the defects observed that some defects can appear as a combination at same location on structure. For example cracks and spalling can be appearing at the same location. On the other combination exposed reinforcement and spalling can also occur together at same location. As per the third requirement defect classifier is the ability to classify defects independently from the defect scale. Different defects appear at different scales. In this some defects such as scaling or spalling affect a considerable, typically twodimensional area in a surface texture. For example, taking an inner part of high-resolution spalling defect could be appear as a healthy concrete. On the other hand cracks are represented as a one-dimensional formation on the surface texture. As per author's observation defect classifier has to be able to detect defects invariantly from the scale.

Author described six steps of condition assessment namely (i) Texture mapping (ii) Unhealthy detection (iii) classification (iv) semantic segmentation (v) property extraction and (vi) condition rating.

Step 1 (Texture mapping) is a high frequency computer graphics method in which defect can be represent in multidimensional. Step 2 (unhealthy detection) is a method developed to identify the unhealthy area in bridge defects surface texture. A method suggested identifying the healthy and unhealthy concrete area. Step 3 (classification) as the process of assigning one or multiple levels for an image on the basis of image content. Step 4 (semantic segmentation) indicates the location of a defect at a pixel level and would include a definition of which parts of a defect are actually part of a defect. Step 5 (Property extraction) measures the defect type dependent properties such as width and orientation for a crack. Step 6 (condition rating) is a complete assessment by assigning a condition rating.

Here presented a multi-classifier that can assign, none one, or multiple classification labels to a defect image.

M.Y. Al-Mandil et al. (1990) studied on the 21 defective bridge decks around the Saudi Arabia. To the deck system, damage has been classified into structural damage and material damage. Structural damage to girder slab bridges as localized failure in the form of potholes in the deck slab, it may be resulting from punching shear. Such failure leading due to the cyclic loading under heavy loads.

Material damages in the form of corrosion of deck slab. Hypothesized to have transpired either due to lack of control on raw material or some others factors.

For depth of evaluation after selecting the bridges crack mapping done for know the behaviour of cracks as length of cracks, width of cracks and orientation of crack etc. To know the concrete quality non destructive testing (NDT) also done by using the ultrasonic pulse-velocity (UPV) tester. Other test by rebound hammer (RH) done to know the in situ concrete compressive strength. At several location during the study author observed the less strength and quality of concrete than the specified values, primarily due to the improper mix, poor construction practices and lack of quality control. Damages for deck distresses are classified as (i) Load-Induced damage and (ii) Environmentally Induced Damage. Load induced damaged includes distress primarily caused by the overloading of the structure due to the passage of nonregulatory vehicular loading by which most common damages includes;

- Localised slab failure in the form of potholes and
- Grid pattern cracking on the soffit slab

Secondly environmental induced category structural harm due to a variety of factors arising from poor construction practices, lack of quality control and aggressive environment etc. Author summarised to avoid failure in the structure that strictly quality control over the new bridges constituent materials and techniques of construction need to be imposed and carefully implemented.

Japan International Cooperation Agency Library (Ministry of Public work and transport) bridge repair manual (2018) introduced a bridge repair manual. Bridges are the vital part of the road network. To survive the life is very difficult without connecting with the other places or peoples. Bridge is not only a structural part it is also connecting to the people and communities. It is really a life line of those inhabitants who were deprived with this facility. As per bridge repair manual-2018, Japan International Cooperation Agency Library (Ministry of Public work and transport) compared road network with vascular network in a human-body (refer Fig 2.1). To maintain the healthy human body, people may check their body daily or a regular interval and have some advice with their doctors periodically and then keep their body condition well and fit. In the same way structure's life span is also depends on quality of construction, regular inspection of structure to avoid major damage or defects in the structure.

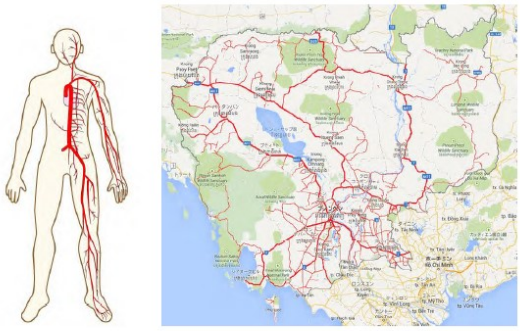


Fig.2.1: Road network is equivalent to blood vessels

A preventive maintenance concept mentioned in Fig 2.2. Soundness of the structure goes down with the time but their condition can be recovered by repair work. If the current condition of the structures and progress of deterioration can be monitored and identified in early age, the recovery of structure can be made with minor repair. If the defects in the structure neglected due to any kind of reason then the structure got major repair or sometimes structure fail. This manual prepared for the better awareness on the basis of commonly defects found in the bridges.

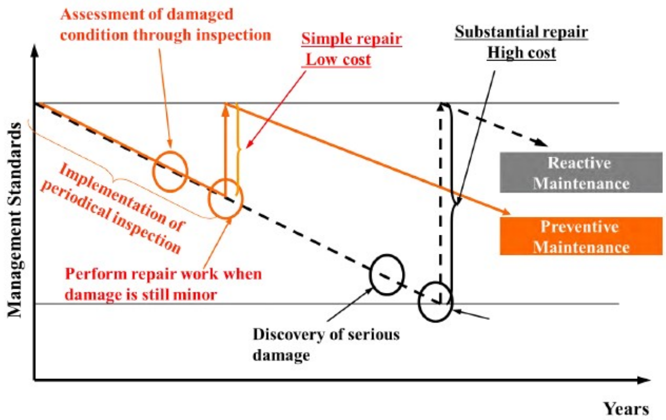


Fig.2.2: Concept of preventive maintenance

IRC: SP: 69-2011 deals the provisions for the expansion joints of all types bridges. This document serves the guidance to the design and construction engineers for a better understanding. Expansion joints provided in the bridges to accommodate the expansion/contraction to the span. Expansion joint should be water tight. Different types of expansion joints for bridges are discussed in this code. Main functional requirement for expansion joint is the longitudinal movement of deck. Different type's expansion joints are discussed below:

- **Joints for movement upto 25mm (for small opening):** Brief descriptions are given for such type expansion joints with their limitation.

  i. **Buried joint (upto 10mm movement):** Such type bridge joint consists of laid bituminous layer over the expansion joint. A steel plate resting freely over the top surface of concrete deck. This joint is suitable for short span structure.

  ii. **Filler joint (upto 10mm movement):** Life of such type joint is short because compressibility of filler gets reduced with age.

  iii. **Asphaltic plug joint (upto 25 mm movement):** This type joints are suitable for rehabilitation work.

- **Joints for movement over 25mm and upto 80mm (medium opening):** Such type expansion joint consists of a sealing element, edge elements and fixing elements.

i. Compression seal joint (upto 40 mm movement)
ii. Single strip/ box seal joint (upto 80mm movement)
iii. Reinforced elastomeric joint (upto 80mm movement)

- **Joints for movement over 80mm (large opening):**

i. **Modular strip/box seal joint:** Such type joint divides the total movement into several smaller gaps. In this joint of the individual gaps are blocked by debris or stone pieces then the functioning of joint lead to poor functioning.
ii. **Finger Joint:** It can be accommodate small vertical deformation without any hazard.
iii. **Reinforced coupled elastomeric joint:** Such type expansion joint can take up upto 230 mm movements.

IRC: SP:42-2014 code is for the guidelines of road drainage. Drainage system in the bridge is the important from two aspect (i) Drainage and (ii) Road safety**.** To avoid flooding over the deck, it is important to provide effective drainage. If water flow over the deck is uncontrolled, it will lead the corrosion of concrete. In this code it is also recommended that all drainage inlets frequently to see that they are not clogged or chocked. The down take pipe of drainage spouts should be in proper length to avoid the water spread over the concrete surface. A proper down take pipe arrangement is given in this document.

IRC: SP:18-1978 deals about the guidelines and provision for the inspection of highway bridges. Bridge inspection is not only a routine, it is also an art wherein techniques and knowledge have to be applied to ascertain the physical condition of the bridge structure and avoid the adverse affect. By the inspection of the structure can be recommend the suitable remedial measures. All bridges shall be inspected by a competent engineer. This code is having the guidelines for inspection the different components (piers, abutment, wing walls expansion joints & bearings etc) of bridges within a prescribed format for better understanding.

IRC: SP:35-1990 given the guidelines for inspection and maintenance of the bridges. A large numbers of concrete bridges are constructed over the roads in India. Bridge structures are deteriorated due to inadequate maintenance of bridges. Main purpose of the inspection is to ensure the structure is safe and fit for their designed use. Secondly can be identify the actual problems if any in the structure at the earliest stages and preventive measures can be taken timely without any failure. Three type maintenance inspections are suggested in this document:

- **Routine Inspection:** Such type inspection shall be at least once a year but preferably twice a year is recommended before and after the mansoon. Purpose of the routine inspection is to report the actual deficiencies which might lead to severe damage in the structures.
- **Principal Inspection:** This is a detailed and more intensive inspection and close examination will involve for the components of the structures. Principal inspection should be intervals of maximum three years. This inspection may be more frequently if any distress observed during the routine inspection. This type inspection shall be done with the standard instrumentation.
- **Special Inspection:** Such type inspection carried out in the condition of unusual occurrences such as accidents, earthquake, passage of unusual loads, major weakness noticed during routine/principal inspection, any settlement in the foundation etc. If any bridge of similar design and constructed almost at the same time and showing any distresses, all such bridges may be subjected to the special inspection.

CHAPTER 3

STUDY OF COMMON DEFECTS IN BRIDGE STRUCTURE

3.1 GENERAL

Defects as observed in the field as shown in Table 3.1. Various components of the bridge are such as Deck slab, Expansion joints, Drainage spout, Bearings, Pedestals, Girders, Pier cap & Pier. Apart from these components, there is also the possibility that defects can be occurred in other parts also. If taken care of these components it can prevent deterioration of the bridge resulting in increase of service life of the bridge and provide safety and comfort to the road users.

Construction defects and their negligence is major factor in the failure of concrete bridge structures. Each component having own significance in the bridge structures. If any component gets construction defects, this will affect the whole structure with their design life. Some defects are discussed here.

3.2 DECK SLAB

Deck slab is a part of superstructure which may be solid slab, T-beam slab, voided slab and box girder that facilitates the flow to traffic on the superstructure. In the field, several defects are observed in the deck slab but at the most of locations, Reinforcement exposed in the soffit of deck slab are observed (refer Fig 3.1 to 3.4). As observed reinforcement exposed is a major problem at many locations, resulting in corrosion. Honecombing and leaching also observed in the deck slab as shown in Fig 3.5 to 3.6 respectively.

3.2 EXPANSION JOINT

Expansion joints are provided in the bridge to permit the movement of the span. It should offer good riding comfort to road users. Expansion joints should be free from water leakage or watertight and be capable of expelling debris without clogging [1]. In the field, it was observed that at most of the locations debris was accumulated in the expansion joint (refer Fig 3.7 to 3.8). This may be happened due to the improper periodic inspection or cleaning. In the strip seal type expansion joint, neoprene seal was damaged/missing at most of the locations as seen in Fig 3.9 to 3.10. Due to this seepage observed at pier cap level and lead to corrosion initiation in the reinforcement.

Table 3.1 Summary of defects identified

Bridge Location → Component ↓	Location-1	Location -2	Location -3	Location -4	Location -5	Location -6	Location -7	Location -8	Location -9	Location -10	Location -11	Location -12	Location -13	Location -14
Deck Slab	ER, SP	ER, SP	CR, PH	-	-	-	-	-	ER, LC	ER, HC, CR	-	-	ER	-
Expansion joint	CL	CL	CL	CL	CL, SM, ER	CL, SM	CL, SM, EN	CL, SM,	CL, SM,	-	CL	CL, SM	CL, SM	CL
Drainage spout	CL	CL	CL	CL	CL	CL	CL	-	-	CL	CL	CL	CL	CL
Girder	HC, ER	HC, ER	-	-	PCE	-	-	-	-	ER, HC	-	PCE	CR, SP	-
Bearing	MD	NC	-	-	-	-	-	-	-	-	-	NC	NC, IP	NC
Diaphragm	HC, ER,CR	HC, ER,CR	-	-	-	-	-	-	-	HC	-	HC	HC, CR	-
Pedestal	SP	SP, CR	-	-	CR	-	-	-	-	-	-	CR, SP	SP, CR	-
Pier cap	VG	VG, SP	-	DB	DB	-	-	-	ER	-	DB	DB, SP, LC	SP	DB
Pier	ER	ER	-	-		-	-	-	-	-	-	-	LC, ER	-

Note: HC=Honeycombing ER=Exposed Reinforcement, SM=Strip Seal Missing, CL=Clogged, SP=Seepage, LC=Leaching, CR=Cracks, PH=Pothole, NC=Not Clean, DB= Debris, ER=Erosion, IP=Improper placing, PCE= End portion prestress cables exposed in girders, EJ=Expansion Joint, EN=excessive noise during traffic passing over the EJ

Fig 3.1 Exposed Reinforcement and also seen unwanted material in deck slab

Fig 3.2 Exposed Reinforcement Observed in deck slab

Fig 3.3 Exposed Reinforcement Observed in deck slab

Fig 3.4 Exposed Reinforcement Observed in cantilever portion

Fig 3.5 Honeycombing observed in soffit Slab

Fig 3.6 Leaching observed in soffit slab

It has been also observed that during the laying of wearing course, expansion joint gap filled with the wearing course material (refer Fig 3.11) leading to restriction in movement and causing additional stresses in the structure. Edge beam of expansion joint is also damaged as shown in Fig 3.12. Due to the strip seal missing water leakage through expansion joints observed at several locations (refer Fig 3.13 to 3.14). Underside portion of expansion joint is also observed damaged (refer Fig 3.15)

Fig 3.7 Debris accumulated in expansion joint

Fig 3.8 Debris accumulated in expansion Joint

Fig 3.9 Neoprene seal missing in expansion joint due to movement affected

Fig 3.10 Neoprene seal missing in expansion joint due to movement affected

Fig 3.11 wearing course material filled in expansion joint

Fig 3.12 Exposed reinforcement in edge beam of expansion joint

Fig 3.13 Neoprene seal missing in expansion joint and water leakage observed

Fig 3.14 Underside portion of expansion joint damaged

Fig 3.15 Underside portion of expansion joint severely damaged

3.3 PEDESTAL

Pedestal is a monolithic component with Pier cap in the bridge which provides the base to placing the bearing. Pedestal should be cast appropriately for resting the bearing for functioning properly, while in the field it is observed that pedestal are not casted as per standard and honeycombing are observed at many locations as seen in Fig 3.16. Negligence in proper concreting of pedestals are observed as shown in Fig 3.17, there is a cavity observed in the pedestal while it should be properly compacted concrete. Due to the debris accumulated at the pier cap, moisture retention and water seepage are observed near the pedestal. If seepage continues it will lead to initiating the corrosion in the structure.

Fig 3.16 Pedestal not casted properly

Fig 3.17 Cavity observed under the bearing plate at pedestal

3.4 PIER CAP

Pier cap is a horizontal component over the pier which transfers the superstructure load to the substructure. Dampness is major problem which has been observed at many locations during the field observations. One of the main reasons of dampness was due to poor installation practice & maintenance of expansion joint which leads to leakage from the expansion joint (refer Fig 3.18 to 3.19). If the dampness continues then the chances of reinforcement corrosion increase and the structure begin to corrode severely. Another common defect observed in the field is the vegetation growth over the pier cap (refer Fig 3.20 to 3.21) Due to the vegetation growth cracks are initiated in individual component. Debris accumulation over the pier cap (Fig 3.22 to 3.23). It is also observed that hardened concrete was accumulated around the bearing at pier cap which was a sign of poor workmanship negligence (Fig 3.24 to 3.25).

Fig 3.18 Seepage on pier cap

Fig 3.19 Seepage on pier cap

Fig 3.20 Vegetation growth on pier cap

Fig 3.21 Vegetation growth on pier cap

Fig 3.22 Debris accumulated over the pier cap

Fig 3.23 Debris accumulated over the pier cap

Fig 3.24 Concrete accumulated at pier cap due to negligence during the construction

Fig 3.25 Concrete accumulated at pier cap due to negligence during the construction

3.5 BEARING

Bearing is a structure device that transfers the load from superstructure to substructure while allowing rotation & translation. If bearing does not function properly, leads to change in structural behavior.

In the field, it is observed that elastomeric bearings are not placed properly as seen in Fig 3.26 to 3.27. The surface on which elastomeric bearing are placed shall be accurately level but at many locations ignored often. In the steel bearings, it has been observed that bolts were not properly tight and even missing at few locations. Bolts for fixing bearing shall be checked carefully by not doing so, performance of bearings can be affected (refer Fig 3.28 to 3.30). Bearing plates also got damaged at several locations as shown in Fig 3.31.

As shown in Fig 3.32 to 3.33 bearing's lock sleeves not opened before the traffic movement is allowed over the bridge. Due to this ignorance functioning of bearing will affected and distresses in the structure will be initiated in the form of crack etc.

Due to lack of maintenance debris get accumulated around the bearing and affect the functioning of bearing. While IRC standard recommends that, *"After Installation, bearing and their surrounding area shall be left clean [2]" and "Bearings shall be made available for purpose of inspection and maintenance"*

At few locations it is observed that MS binding wire is seen around the elastomeric bearing leading cuts on bearing rubber as shown in Fig 3.36 to 3.37.

Fig 3.26 Bearings not placed properly

Fig 3.27 Bearings not placed properly

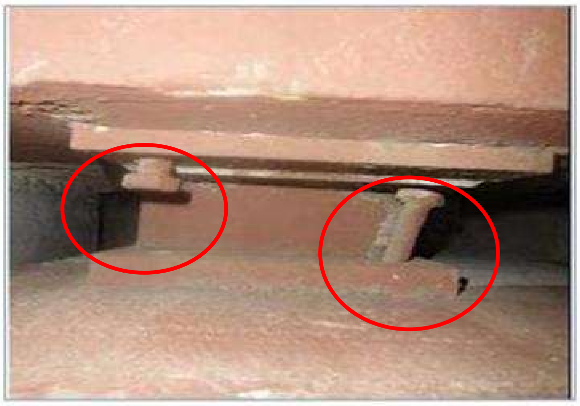


Fig 3.28 Bolts are not tight in the bearing plate

Fig 3.29 bolts are missing in bearing plate

Fig 3.30 bolts are missing in bearing plate

Fig 3.31 Bearing steel plate damaged

Fig 3.32 Locked bearing is observed as sleeves are not opened for free movement

Fig 3.33 Locked bearing is observed as sleeves are not opened for free movement

Fig 3.34 Unwanted R/F bar exposed

Fig 3.35 Debris accumulated around the bearing, affected the performance of bearings.

Fig 3.36 MS wire binding around the bearing

Fig 3.37cuts on bearing is observed

3.6 GIRDER

Girder is a component of bridge structure which used to support the deck slab and takes load. In the field it is observed that girder not seated on the bearing appropriately, at few locations, it is even observed that Bearings are missing end the girders are seated directly on pier cap (refer Fig 3.38). As shown in Fig 3.39 to 3.40 the end portion of prestressing cables are exposed, it can be a cause to initiation of corrosion in the structure. Such type of problems occurs due to the negligence of field engineer. As per the standards, after completion of stressing activity, the wire shall be cut and two coats of epoxy paint shall be applied and entire portion filled with the non-shrink epoxy mortar [3] In Fig 3.41 to 3.42 shown that all prestressing cables are corroded and damaged. It seems that it is due to the improper drainage system and water continues to seep over the girder surface. Exposed sheathing as seen from the bottom of flange as shown in Fig 3.43and exposed reinforcement also seen at the bottom of flange (refer Fig 3.44). A poor repair work also observed in the field as shown in Fig 3.45. In Fig 3.46 honeycombing observed at the bottom of flange.

Fig 3.38 Girder resting on pier cap without bearing

Fig 3.39 Prestressing cables exposed at end girder

Fig 3.40 Prestressing cables exposed at end girder

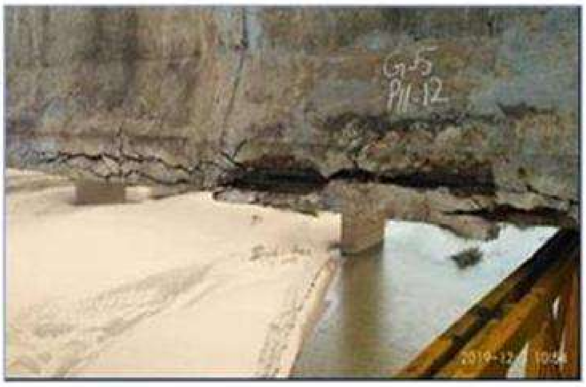


Fig 3.41 Prestressing cables corroded

Fig 3.42 Prestressing cables corroded

Fig 3.43 Exposed sheathing as seen from the bottom in the bottom flange of girder

Fig 3.44 Exposed reinforcement as seen from the bottom in the bottom flange of girder.

Fig 3.45 Poor repair work

Fig 3.46 Honeycombing as seen at the bottom of the flange of girder

3.7 PIER

Bridge pier support the span and they transfer the load from superstructure to foundation. The problem of Leaching was observed on the surface of pier as shown in Fig 3.47 and localized exposed reinforcement was also observed as shown in Fig 3.48.

Fig 3.47 Leaching observed on pier

Fig 3.48 Exposed reinforcement observed on pier

3.8 DRAINAGE

Drainage over the bridge deck is important from two aspects one is to keep structure safe from corrosion and second is safety for road users. If the drainage system is not maintained uncontrolled flow of water over the bridge deck then will lead to corrosion and deterioration of the concrete structure. It has been observed in the field that drainage system found in poor condition at many locations leading to structure deterioration in the early age. Though guidelines are available on the drainage and its maintenance, but the same are not followed in the field religiously. Improper down take pipe observed in the field (refer Fig 3.49 to 3.51). Seepage was observed on the structure surface due to improper fixing of down take pipe as shown in Fig 3.52. IRC: SP: 42-2014 guidelines are laid for appropriate decision making in drainage the water shown in Fig 3.53. Drainage system should be maintain properly and regularly and ensure that all inlet should not be chocked or clogged. In Fig 3.54 shown the proper down take pipe arrangement, it is a good construction practice. Both Fig. 3.55 & 3.56 are of the same structure but right work has been done on one pier (by providing the proper down take pipe) while not done on the other pier. It is called a negligence or careless. It has been observed that drainage pipe provided properly but got damaged and it has not been noticed due to lacking of inspection (refer Fig 3.57). Due to the chocking / clogged the drainage spout water logging observed at road level (refer Fig 3.58)

Fig 3.49 Improper down take pipe

Fig 3.50 Improper down take pipe

Fig 3.51 Improper down take pipe

Fig 3.52 Seepage observed on structure surface due to improper drainage system

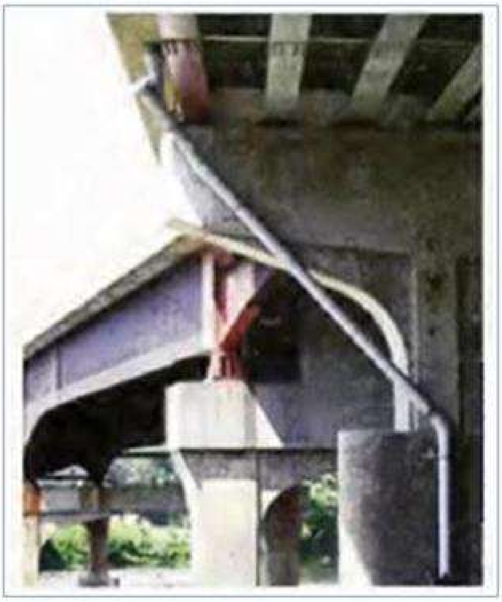


Fig 3.53 Provision for water channelization given in IRC:SP:42

Fig 3.54 Proper down take pipe provided.

Fig 3.55 Proper down take pipe provided.

Fig 3.56 Improper down take pipe provided

Fig 3.57It shows Drainage pipe provided properly but got damaged and it has not been noticed due to lacking of inspection.

Fig 3.58 Water logging observed at road level

3.9 DIAPHRAGM

Diaphragm is a structural part of the bridge and it resists the lateral load in bridge. A general view of the arrangement of diaphragm shown in Fig 3.59. A cavity was observed at the bottom of diaphragm as shown in Fig 3.60. Honeycombing and exposed reinforcement also observed in diaphragm (refer Fig 3.61). Cracks also observed at the bottom face of diaphragm as shown in Fig 3.62.

Fig 3.59 Typical view of diaphragms

Fig 3.60 Exposed reinforcement at bottom of diaphragm

Fig 3.61 Exposed reinforcement in the face of diaphragm

Fig 3.62 cracks observed at the bottom of diaphragm

CHAPTER 4

RESPONSE OF BRIDGE COMPONENT DUE TO CONSTRUCTION DEFECT

4.1 INTRODUCTION

Many defects observed in the field such as Exposed reinforcement, honeycombing, spalling of concrete, drainage system not provided properly, girder not seated on the bearing appropriately. Five girders seated on pier cap as shown in fig. but out this one girder seated directly over the pier cap, while available guidelines recommended that bottom of girder to be seated on the bearing. To know the affect on bridge due to this defect a model prepared in STAAD and incorporates the same defect and analysis and compared with the results. A typical view of diaphragm shown in Fig.4.1

Fig.4.1 Out of five Girders one girder resting on pier cap without bearing

4.2 ANALYSIS OF SIMPLE SUPPORTED BRIDGE IN STAAD SOFTWARE:

4.2.1 Data Assumed

Total Length of Superstructure (EJ to EJ)	:	20.00	m	
Length of Girder (C/C of Bearing)	:	18.70	m	
Spacing of girder in transverse direction	:	3.00	m	
Width of crash barrier	:	0.45	m	as per IRC:5
Height of Crash Barrier	:	1.10	m	as per IRC:5
Depth of Girder	:	1.45	m	
Depth of Bearing & Bearing Pedestal	:	0.45	m	
Depth of Diaphragm	:	1.25	m	
Depth of Diaphragm including deck slab	:	1.48	m	(1.25+.230)
Width of End Diaphragm	:	0.40	m	
Total nos. of main girders	:	5	no	
Total width of deck slab	:	14.50	m	

Total thickness of deck slab	:	0.230 m
Thickness of haunch	:	0.060 m
Density of concrete	:	25 kN/m^3 as per IRC:6-2017 (clause 203)
Density of wearing coat	:	22 kN/m^3 as per IRC:6-2017 (clause 203)

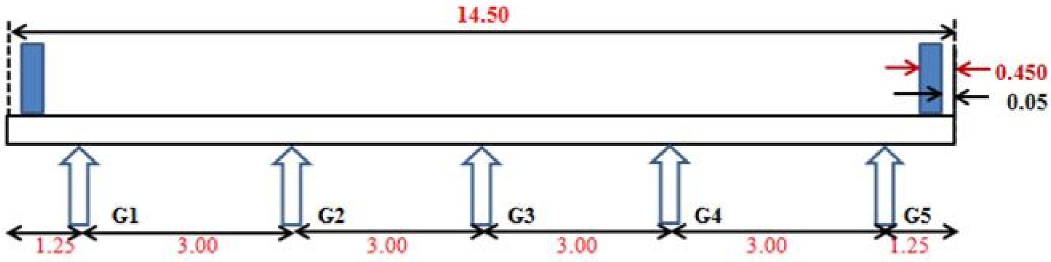


Fig 4.2 Typical view of cross section of superstructure

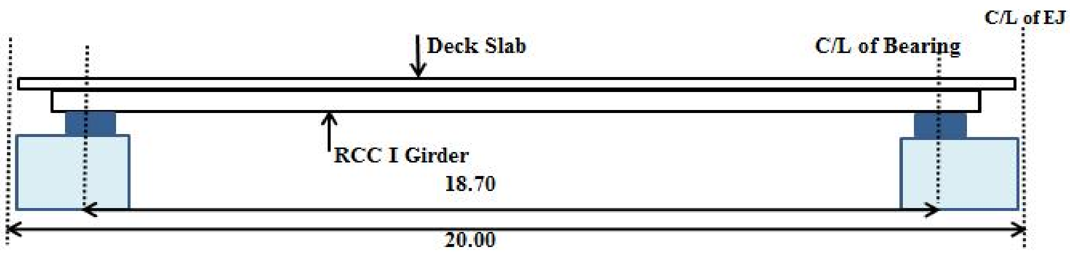


Fig 4.3 Typical view of elevation of superstructure

4.2.2 Sectional Properties

Sectional properties of a I-Girder are the area of section, centre of gravity, moment of inertia and section modulus which have been calculated

4.2.2.1: Sectional properties of girder at mid span

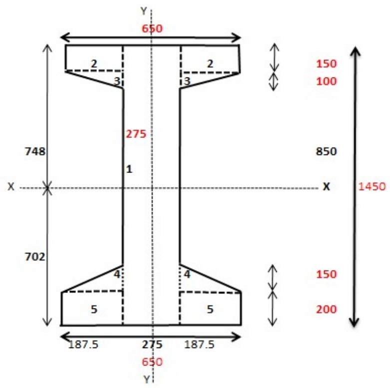


Fig 4.4 Cross section of girder at mid section

Table 4.1 Area of Section

Sr.	Section area	Total section	Sectional dimensions (mm)		Area, mm^2	Sec. shape
1	Area of section-1 (a_1)	1	275	1450	398750	Rect.
2	Area of section-2 (a_2)	2	187.5	150	56250	Rect.
3	Area of section-3 (a_3)	2	187.5	100	18750	Triangle
4	Area of section-4 (a_4)	2	187.5	150	28125	Triangle
5	Area of section-5 (a_5)	2	187.5	200	75000	Rect.
				Total Area=	**576875**	

Distance of Centroid of each section from top:

y_1= 275 mm

y_2= 75 mm (150/2)

y_3= 183.3 mm (150+100/3)

y_4= 1200 mm (1450-200-150/3)

y_5= 1350 mm (1450-200/2)

Table 4.2 Properties about X-X (Mid section straight portion)

Sr.	Section area, mm^2	y^{top} mm	$A * y^{top}$ mm^3	Distance from Y-Y axis ,h mm	$A*h^2$ mm^3	I_{self} or I_{xx} mm^4	I_{NA} or I_z mm^4
1	398750	725	289093750	23.43	2.19E+08	6.986E+10	7.008E+10
2	56250	75	4218750	673.43	2.55E+10	52734375	2.556E+10
3	18750	183.3	3437500	565.10	5.99E+09	5208333.3	5.993E+09
4	28125	1200	33750000	451.57	5.74E+09	17578125	5.753E+09
5	75000	1350	101250000	601.57	2.71E+10	125000000	2.727E+10
Total=	**576875**		**4.318E+08**		**6.46E+10**	**7.006E+10**	**1.347E+11**

Total area = 576875 mm^2

MOI about NA (I_{NA}) = 1.347E+11 mm^4

C.G. of the section from the top = 748.43 mm (4.318E+08/576875)

C.G. of the section from the bottom = 701.57 mm (1450-748.43)

Section Modulus at top, Z^{top} = 1.80E+08 mm^3 (1.347E+11/748.43)

Section Modulus at bottom, Z_{bottom} = 1.92E+08 mm^3 (1.347E+11/701.57)

Table 4.3 Properties about Y-Y (Mid section straight portion)

Sr. No.	Section area, mm^2	Distance from Y-Y axis h, mm	I_{self} or I_{xx} mm^4	$A*h^2$ mm^3	I_{NA} or I_z mm^4
1	398750	0	2.51E+09	0	2.51E+09
2	56250	231.25	8.24E+07	3.01E+09	3.09E+09
3	18750	200	1.83E+07	7.50E+08	7.68E+08
4	28125	200	2.75E+07	1.13E+09	1.15E+09
5	75000	231.25	1.10E+08	4.01E+09	4.12E+09
Total=	**576875**		**2.75E+09**	**8.89E+09**	**1.16E+10**

4.2.2.2: Composite Sectional properties

Composite sectional properties are calculated with the deck slab.

4.2.2.3 for end girder (G-1 & G-5) at mid section

Cantilever projection = 1.25 m

Effective flange width for the composite section is computed as per clause 7.6.1.2 of IRC:112-2019 as below:

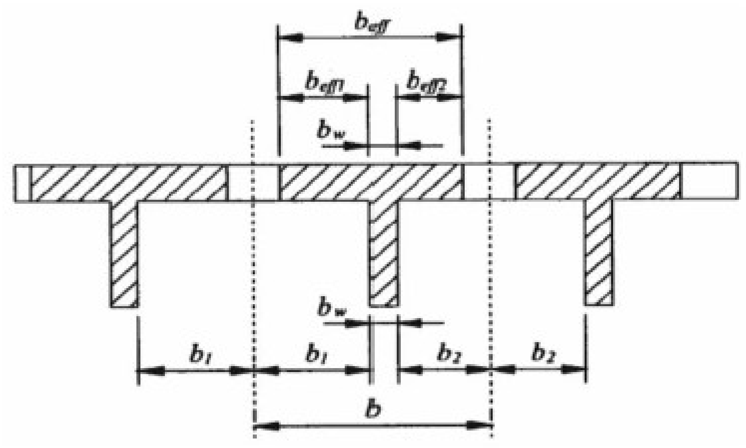


Fig 4.5 Definition of parameters to determine effective flange width 9as per IRC: 112-2019)

l_0 = 18.70 m

b = 2.750 m (1.25+3/2)

D = 0.230 m

b1 = 1.1125 m (1.25-.275/2)

b1 = 1.3625 m (1.50-.275/2)

b_{eff1} = 1.1125 m

b_{eff2} = 1.3625 m

b_{eff} = 2.750 m

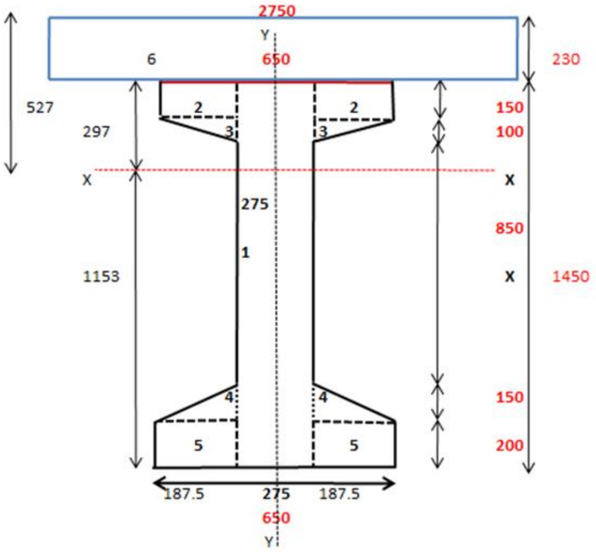


Fig 4.6 Cross section of girder (outer girders)

Table 4.4 Area of Section

Sr.	**Section area**	**Total section**	**Sectional dimensions (mm)**		**Area, mm^2**	**Sec. shape**
1	Area of section-1 (a_1)	1	275	1450	398750	Rect.
2	Area of section-2 (a_2)	2	187.5	150	56250	Rect.
3	Area of section-3 (a_3)	2	187.5	100	18750	Triangle
4	Area of section-4 (a_4)	2	187.5	150	28125	Triangle
5	Area of section-5 (a_5)	2	187.5	200	75000	Rect.
6	Area of section-6 (a_6)	1	2750	230	632500	Rect.
				Total Area, A=	**1209375**	

Table 4.5 Properties about X-X (Mid section straight portion)

Sr.	Section area, mm^2	y^{top} mm	A* y^{top} mm^3	Distance from Y-Y axis ,h mm	A*h^2 mm^3	I_{self} or I_{xx} mm^4	I_{NA} or I_z mm^4
1	398750	955	3.81E+08	428	7.30E+10	6.99E+10	1.43E+11
2	56250	305	1.72E+07	222	2.77E+09	5.27E+07	2.82E+09
3	18750	413.3	7.75E+06	114	2.42E+08	5.21E+06	2.47E+08
4	28125	1430	4.02E+07	903	2.29E+10	1.76E+07	2.30E+10
5	75000	1580	1.19E+08	1053	8.32E+10	1.25E+08	8.33E+10
6	632500	115	7.27E+07	412	1.076E+11	2.79E+09	1.10E+11
Total=	**1209375**		**6.37E+08**		**2.895E+11**	**7.285E+10**	**3.624E+11**

Total area = 1209375 mm^2

Depth of NA from the top of slab, $y_{top\text{-}slab}$ = 527 mm (6.37E+08 / 1209375)

Depth of NA from the top of Girder, $y_{top\text{-}girder}$= 297 mm (527-230)

Depth of NA from the Bottom = 1153 mm (1450+230-527)

Moment of Inertia, I_{NA} = 3.624E+11 mm^4

Section of modulus from top of slab, $Z_{top\text{-}slab}$ = 6.88E+08 mm^3 (3.6237E+11 / 527)

Section of modulus from top of girder, $Z_{top\text{-}girder}$ = 1.22E+09 mm^3 (3.624E+11 / 297)

Section modulus from bottom, Z_{bottom}= 3.14E+08 mm^3 (3.624E+11 / 1153)

Table 4.6 Properties about Y-Y (Mid section straight portion)

Sr.	Section area, mm^2	Distance from Y-Y axis h, mm	I_{self} or I_{xx} mm^4	A*h^2 mm^3	I_{NA} or I_z mm^4
1	398750	0	2.51E+09	0	2.51E+09
2	56250	231	8.24E+07	3.01E+09	3.09E+09
3	18750	200	1.83E+07	7.50E+08	7.68E+08
4	28125	200	2.75E+07	1.13E+09	1.15E+09
5	75000	231	1.10E+08	4.0E+09	4.12E+09
6	632500	0	3.99E+11	0	3.99E+11
Total	**1209375**		**4.01E+11**		**4.10E+11**

4.2.2.4 For inner girders (G-2 &, G-3 & G-4) at mid section

l_0 = 18.70 m

b = 3.000 m (3/2+3/2)

D = 0.230 m

b1 = 1.3625 m (3-.275)/2

b1 = 1.3625 m

b_{eff1} = 1.3625 m

b_{eff2} = 1.3625 m

b_{eff} = 3.000 m

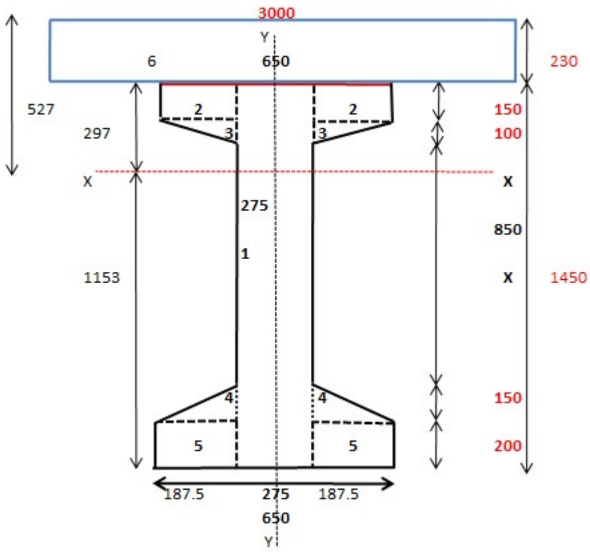


Fig 4.7 Cross section of girder (inner girders)

Table 4.7 Area of Section

Sr.	Section area	Total section	Sectional dimensions (mm)		Area, mm^2	Sec. shape
1	Area of section-1 (a_1)	1	275	1450	398750	Rect.
2	Area of section-2 (a_2)	2	187.5	150	56250	Rect.
3	Area of section-3 (a_3)	2	187.5	100	18750	Triangle
4	Area of section-4 (a_4)	2	187.5	150	28125	Triangle
5	Area of section-5 (a_5)	2	187.5	200	75000	Rect.
6	Area of section-6 (a_6)	1	3000	230	690000	Rect.
				Total Area=	**1266875**	

Table 4.8 Properties about X-X (Mid section straight portion)

Sr.	Section area, mm^2	y^{top} mm	A * y^{top} mm^3	Distance from Y-Y axis ,h mm	$A*h^2$ mm^3	I_{self} or I_{xx} mm^4	I_{NA} or I_z mm^4
1	398750	955	3.81E+08	447	7.97E+10	6.99E+10	1.50E+11
2	56250	305	1.72E+07	203	2.32E+09	5.27E+07	2.37E+09
3	18750	413.3	7.75E+06	95	1.68E+08	5.21E+06	1.73E+08
4	28125	1430	4.02E+07	922	2.39E+10	1.76E+07	2.39E+10
5	75000	1580	1.19E+08	1072	8.62E+10	1.25E+08	8.63E+10
6	690000	115	7.94E+07	393	1.07E+11	3.04E+09	1.10E+11
Total =	**1266875**		**6.44E+08**		**2.99E+11**	**7.31E+10**	**3.72E+11**

Total area = 1266875 mm^2

Depth of NA from the top of slab, $y_{top\text{-}slab}$ = 508 mm (6.44E+08 / 1266875)

Depth of NA from the top of Girder, $y_{top\text{-}girder}$=278 mm (508 - 230)

Depth of NA from the Bottom = 1172 mm (1450+230-508)

Moment of Inertia, I_{NA} = 3.71937E+11 mm^4

Section of modulus from top of slab, $Z_{top\text{-}slab}$ = 7.32E+08 mm^3 (3.7193E+11 / 508)

Section of modulus from top of girder, $Z_{top\text{-}girder}$ = 1.34E+09 mm^3 (3.7193E+11 / 278)

Section modulus from bottom, Z_{bottom}= 3.17 E+08 mm^3 (3.7193E+11 / 1172)

Table 4.9 Properties about Y-Y (Mid section straight portion)

Sr.	Section area, mm^2	Distance from Y-Y axis h, mm	I_{self} or I_{xx} mm^4	$A*h^2$ mm^3	I_{NA} or I_z mm^4
1	398750	0	2.51E+09	0	2.51E+09
2	56250	231	8.24E+07	3.01E+09	3.09E+09
3	18750	200	1.83E+07	7.50E+08	7.68E+08
4	28125	200	2.75E+07	1.13E+09	1.15E+09
5	75000	231	1.10E+08	4.01E+09	4.12E+09
6	690000	0	5.18E+11	0	5.18E+11
Total=	**1266875**		**5.20E+11**		**5.29E+11**

4.2.2.5 For Outer Girder (G-1 &G-5) at support

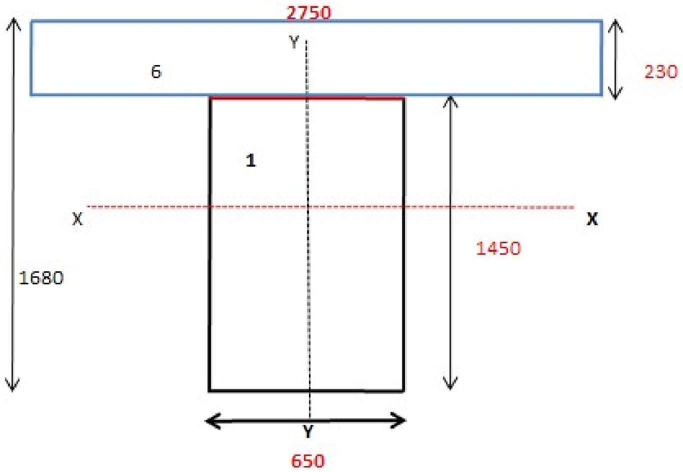


Fig 4.8 Cross section of girder at support (outer girder)

Table 4.10 Properties about X-X axis (at support section)

Sr.	Section area, mm^2	y^{top} mm	A * y^{top} mm^3	Distance from Y-Y axis ,h mm	$A*h^2$ mm^3	I_{self} or I_{xx} mm^4	I_{NA} or I_z mm^4
1	650* 1450= 942500	955	9.00E+08	337	1.07E+11	1.65E+11	2.72E+11
2	2750*230 =632500	115	7.27E+07	503	1.6E+09	2.79E+09	1.63E+11
Total=	**157500**		**9.73E+08**		**2.67E+11**	**1.68E+11**	**4.35E+11**

Total area = 157500 mm^2

Depth of NA from the top of slab, $y_{top\text{-}slab}$ = 618 mm (9.73E+08/1.58E+06)

Depth of NA from the top of Girder, $y_{top\text{-}girder}$=388 mm (618-230)

Depth of NA from the Bottom = 1062 mm (1450+230-618)

Moment of Inertia, I_{NA} = 4.35E+11 mm^4

Section of modulus from top of slab, $Z_{top\text{-}slab}$ = 7.04E+08 mm^3 (4.35E+11 / 618)

Section of modulus from top of girder, $Z_{top\text{-}girder}$ = 1.12E+09 mm^3 (4.35E+11 / 388)

Section modulus from bottom, Z_{bottom}= 4.09 E+08 mm^3 (4.35E+11 / 1062)

Table.4.11 Properties about Y-Y axis (at support section)

Sr.	Section area, mm^2	Y^{left} Mm	$A * y^{left}$ mm^3	Distance from Y-Y axis ,h mm	$A*h^2$ mm^3	I_{self} or I_{xx} mm^4	I_{NA} or I_z mm^4
1	650* 1450= 942500	1375	1.3E+09	0	0	3.32E+10	3.32E+10
2	2750*230 =632500	1375	8.7 E+08	0	0	3.99E+11	3.99E+11
Total=	**1.58E+06**		**2.17E+09**			**4.32E+11**	**4.31E+11**

Total area, A = 1.58E+06 mm^2

Depth of NA from Left, Y_L = 1375 mm (2.17E+09 / 1.58E+06)

Depth of NA from the right, Y_R= 1375 mm (2750-1375)

Moment of Inertia, I_{NA} = Iyy= 4.32E+11 mm^4

Section of modulus Z_L= 3.14E+08 (4.32E+11/1375)

Section of modulus Z_R=3.14E+08

4.2.2.6 For Inner Girder (G-2, G-3 &G-4) at support

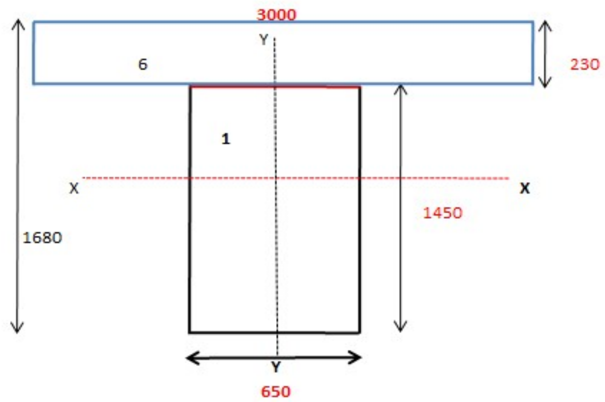


Fig 4.9 Cross section of girder at support (inner girders)

Table 4.12 Properties about X-X axis (at support section)

Sr.	Section area, mm^2	y^{top} mm	$A * y^{top}$ mm^3	Distance from Y-Y axis ,h mm	$A*h^2$ mm^3	I_{self} or I_{xx} mm^4	I_{NA} or I_z mm^4
1	650* 1450= 942500	955	9.00E+08	355	1.19E+11	1.65E+11	2.839E+11
2	2000*230=690000	115	7.94E+07	485	1.623E+11	3.04E+09	1.653E+11
Total	**1.63E+06**		**9.79E+08**		**2.81E+11**	**1.68E+11**	**4.49E+11**

Total area, A = 1.63E+06 mm^2

Depth of NA from top of slab, $Y^{top\text{-}slab}$ = 600 mm (9.79E+08 / 1.63E+06)

Depth of NA from top of girder, $Y^{top\text{-}girder}$= 370 mm (600-230)

Depth of NA from bottom, Y_b = 1080 mm (1450+230-600)

Moment of Inertia, I_{NA} = Ixx= 4.49E+11 mm^4

Section of modulus from top of slab , $Z^{top\text{-}slab}$= 7.49E+08 (4.49E+11/600)

Section of modulus from top of girder, $Z^{top\text{-}girder}$=1.21E+08 (4.49E+11/ 370)

Section of modulus from bottom, Z_{bottom}=4.16E+08 (4.49E+11/ 1080)

Table 4.13 Properties about Y-Y axis (at support section)

Sr.	Section area, mm^2	Y^{left} Mm	A * y^{left} mm^3	Distance from Y-Y axis ,h mm	$A*h^2$ mm^3	I_{self} or I_{xx} mm^4	I_{NA} or I_z mm^4
1	650* 1450= 942500	1500	1.41E+09	0	0	3.32E+10	3.318E+10
2	3000*230 =690000	1500	1.04E+08	0	0	5.18E+11	5.175E+11
Total=	**1.63E+06**		**2.45E+09**			**5.51E+11**	**5.51E+11**

Total area, A = 1.63E+06 mm^2

Depth of NA from Left, Y_L = 1500 mm (2.45E+09 / 1.63E+06)

Depth of NA from the right, Y_R= 1500 mm (3000-1500)

Moment of Inertia, I_{NA} = Iyy= 5.51E+11 mm^4

Section of modulus Z_L= 3.67E+08 (5.51E+11 / 1500)

Section of modulus Z_R=3.67E+08 (5.51E+11 / 1500)

4.2.2.7 Sectional properties for Diaphragm

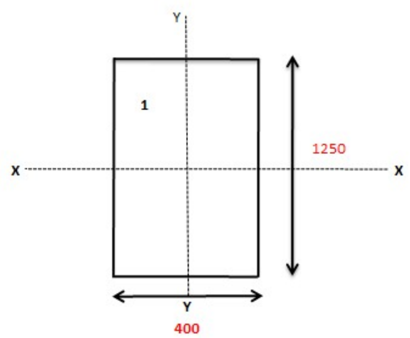


Fig 4.10 Cross section of Diaphragm

Table 4.14 Properties about X-X axis

Sr.	Section area, mm^2	y^{top} mm	A * y^{top} mm^3	Distance from X-X axis ,h mm	$A*h^2$ mm^3	I_{self} mm^4	I_{NA} mm^4
1	400* 1250= 500000	625	3.13E+08	0	0	6.51E+10	6.51E+10

Ixx= 6.51E+10 mm^4

Table 4.15 Properties about Y-Y axis

Sr.	Section area, mm^2	y^{left} mm	A * y^{left} mm^3	Distance from X-X axis ,h mm	$A*h^2$ mm^3	I_{self} mm^4	I_{NA} mm^4
1	400* 1250= 500000	200	1.00E+08	0	0	6.67E+09	6.67E+09

Iyy= 6.67E+09 mm

4.2.3 LOADING ON BRIDGE: Generally three types load are operated on the bridges.

- Dead Load (it is the weight of the bridge itself)
- Live Load (it is the traffic moving load)

In general it can be divided into two types of loading on bridge (i) Permanent and (ii) Transient load. A transient load means they are not permanent loads. Which type loads comes under permanent and transient are given below:

- Permanent Loads: Such type loads and forces are assumed constant upon the the completion of the structure or varying over a long period. Example: Dead Load (DL) , Superimposed Loads (SIDL), Time dependent as creep and shrinkage loads (TD-CR and SH), Earth pressure & earth Surcharge load (EP & ES) , Prestressed load (PS).
- Transient loads: Such type loads and forces can vary over a short period of time. These loads come due to (i) Environment (ii) Traffic and (iii) construction.

For the study purpose DL and SIDL are considered as calculations are given below.

4.2.3.1 DEAD LOAD: Dead load on the structure (superstructure) is the aggregate of the entire superstructure elements such as crash barrier, wearing coat, railing, deck slab, girder etc.

SELF WEIGHT OF GIRDER

Cross sectional area of girder, A = 0.5768 m^2 (as calculated above)

RCC Density = 25 kN/m^3 (as per IRC: 6-2017)

Self weight of girder = 0.5768 * 25 = **14.422** kN/m

C/S area of haunch over girder for cross slope (60mm) = 0.06 * 0.5 *1.5 = 0.045 m^2

Wt of haunch = 0.045 *25 = **1.125** kN/m

Total load per running meter = 14.42+1.125 = **15.55** kN/m

SELF WEIGHT OF DIAPHRAGM:

C/S area = 1.25*.400=0.500 m^2

Load per running meter = 0.500*25=**12.5** kN/m

SELF WEIGHT OF GIRDER AT END SECTION FOR INNER AND OUTER GIRDERS:

C/S area = 1.450*0.650= 0.9425 m^2

Load per running meter = 0*.9425* 25=**23.56** kN/m

SELF WEIGHT OF DECK SLAB:

FOR END GIRDER (G-1 & G-5):

Cantilever portion width = 1.250 m

c/s area = (1.25+1.50) *0 .230 = 0.633 m^2

Load per running meter = 0.633*25= 15.81 kN/m say **15.90** kN/m

FOR END INNER GIRDER (G-2 , G-3 & G-4):

c/s area = (1.50+1.50) *0 .230 = 0.0.690 m^2

Load per running meter = 0.690*25= 17.25 kN/m say **17.30** kN/m

SUPERIMPOSED DEAD LOAD: Crash barrier and wearing coat load is SIDL
Due to Crash Barrier

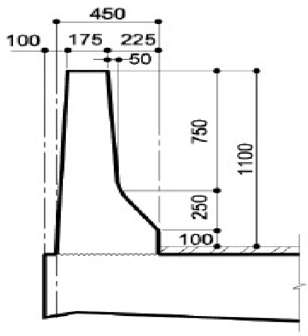


Fig 4.11 Typical details for crash barrier (IRC: 5-2015)

Cross sectional area = 0.201+0.029+0.034+0.028 = 0.292 m^2

Weight per running meter = 0.292 * 25 = 7.30 kN/m

Assumed service load = 1 kn/m

Total load due to crash barrier = 7.30+1= **8.30** kN/m

Due to wearing coat

Assumed wearing coat thickness = 0.100 m

For end girder

Cantilever portion width = 1.25 m

C/s sectional area = 0.225 m^2 (1.25-0.05-0.450+3/2)*0.100

Density of wearing coat = 22kN/m^3 (as per IRC: 6-2017)

Load per running meter = 0.225*22= **4.95** kN/m

For inner girder:

C/s sectional area = 0.300 m^2 (3/2 + 3/2)*0.100

Density of wearing coat = 22kN/m^3 (as per IRC: 6-2017)

Load per running meter = 0.300*22= **6.6** kN/m

4.2.3.2 LIVE LOAD: Live loads are the vehicle moving loads. For live loads IRC loading details are given below (as per IRC:6-2017).

i. **IRC 70R Loading (Wheeled vehicle):** IRC 70R loading is to be adopted for on all roads bridges and culverts which are the permanent structures. In this loading we are having total load 100t. In the vehicle direction having the load arrangement such as 8t, 12t, 12t, 17t, 17t, 17t, 17t with the respective distance as shown in Fig 4.12. From the centre of the front wheel to edge of the vehicle is 610mm and centre of back wheel to edge of the vehicle is 910mm. Nose to tail distance between successive vehicles shall not be less than 90m.

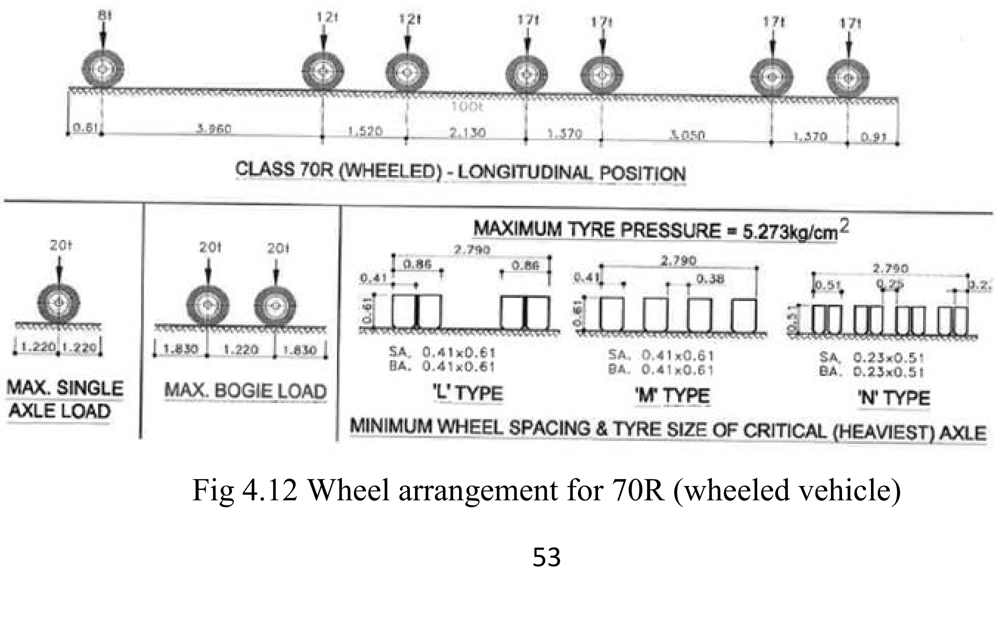


Fig 4.12 Wheel arrangement for 70R (wheeled vehicle)

ii. **IRC 70 Loading (Tracked vehicle):** This is also having the same way of loading 35t and 35t of each wheels with the 840mm width.

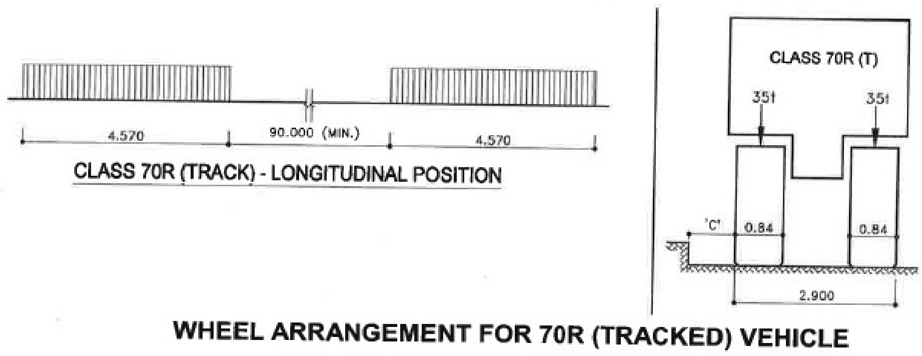
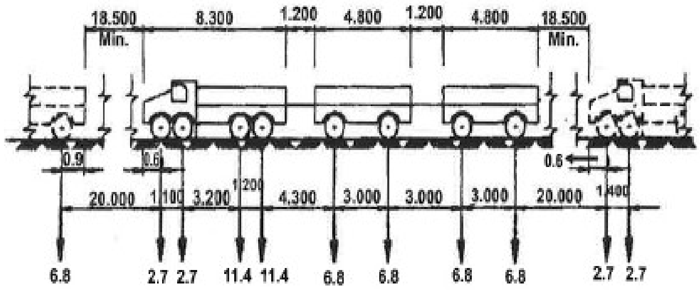
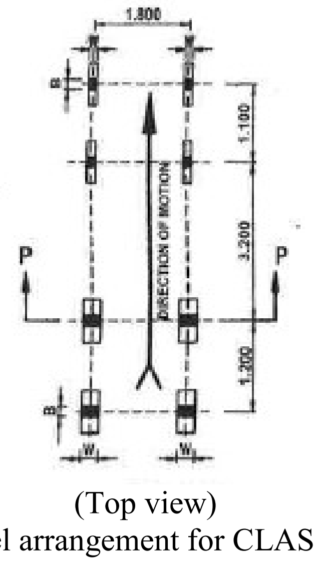


Fig 4.13 Wheel arrangement for 70R (tracked vehicle)

iii. **IRC CLASS A Loading:** CLASS A loading is to be adopted for on all roads bridges and culverts which are the permanent structures. In this loading having total load 55.4t. In the vehicle direction having the load arrangement such as 2.7t, 2.7t, 11.4t, 11.4t, 6.8t, 6.8t, 6.8t & 6.8t with the respective distance as shown in Fig 4.14. Nose to tail distance between successive trains shall not be less than 18.5 as shown in Fig 4.14.



(Side View)



(Top view)

Fig 4.14 Wheel arrangement for CLASS A Loading

LIVE LOAD COMBINATION: Live load combinations are given in IRC: 6-2017 Live load combinations are given on the basis of carriageway width.

Table 4.16 Live Load Combination as per IRC:6-2017

Sr. No.	Carriageway width (CW)	Number of Lanes for design purpose	Load combination
1	Less than 5.3m	1	One Lane of Class A considered to occupy 2.3m. The remaining width of carriageway shall be loaded with 500kg/m^2
2	5.3 m and above but less than 9.6m	2	One lane of Class 70R or two lanes for Class A
3	9.6 m and above but less than 13.1m	3	One lane of Class 70R for every two lanes with one lanes of Class A on the remaining lane or 3 lanes of Class A
4	**13.1 m and above but less than 16.6 m**	**4**	**One lane of Class 70R for every two lanes with one lane of Class A for the remaining lanes, if any or one lane of Class A for each lane**
5	16.6 m and above but less than 20.1 m	5	
6	20.1 m and above but less than 23.6 m	6	

A diagrammatic representation is given (refer Fig 4.15) for 4 lanes carriageway as per IRC:6-2017 which has been followed for this study.

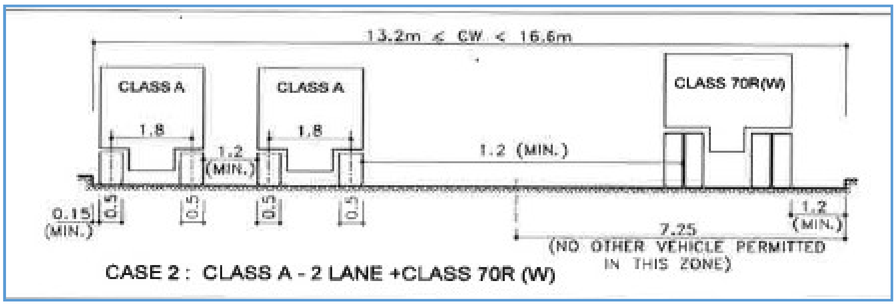


Fig 4.15 Diagrammatic representation for 4 lanes carriageway

4.3 PROBLEM STATEMENT:

4.3.1 GEOMETRY: A simple supported bridge deck model with total span length 20m (expansion joint to expansion join) is considered with total carriageway width 14.50m as 4-Lane (refer Table 4.16). At both ends diaphragms are considered (D1 to D4 as shown in Fig 4.16). Total five I-Girders are considered (G1 to G5). Crash barrier considered as per IRC-5 (refer Fig 4.16). Wearing coat over deck slab is considered with 60mm thick.

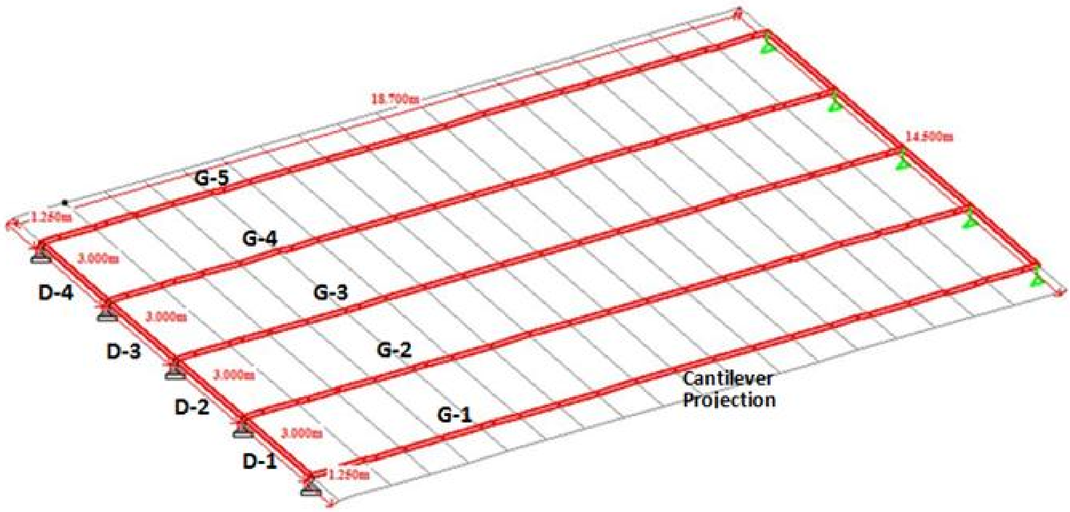


Fig 4.16 Grid model of deck slab with STAAD-Pro

4.3.2 END SUPPORTS: Only main girders will be sitting on the bearings. In this study prepared a model with one support on a pin, and the other on a roller.

4.3.2 LOAD CONSIDERED: Following load case considered for the analysis of bridge.

- Dead Load (DL)-Self weight of girder and end diaphragm
- Superimposed Dead Load (SIDL)-Self weight of crash barrier and wearing coat
- IRC CLASS A Load
- IRC 70R (wheeled) Load

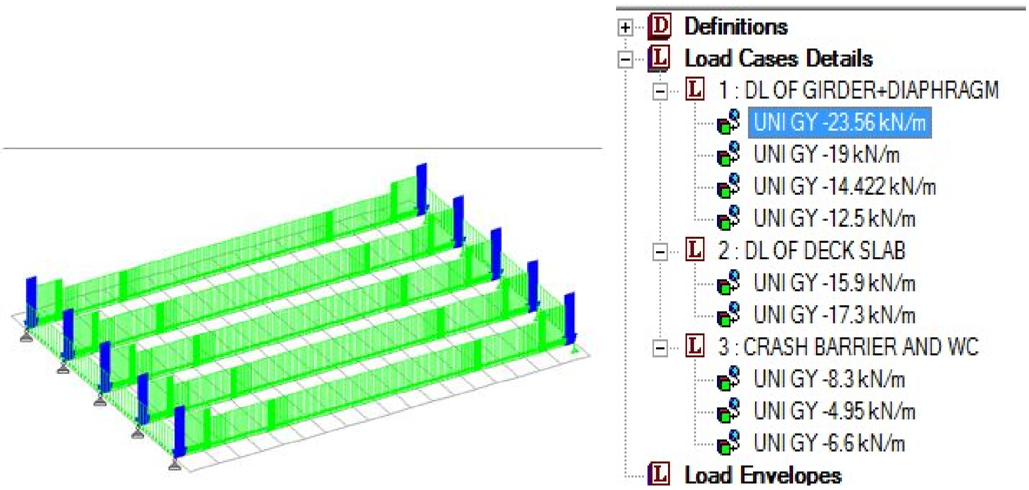


Fig 4.17 General view of Loading (Dead Load) on girder in STAAD

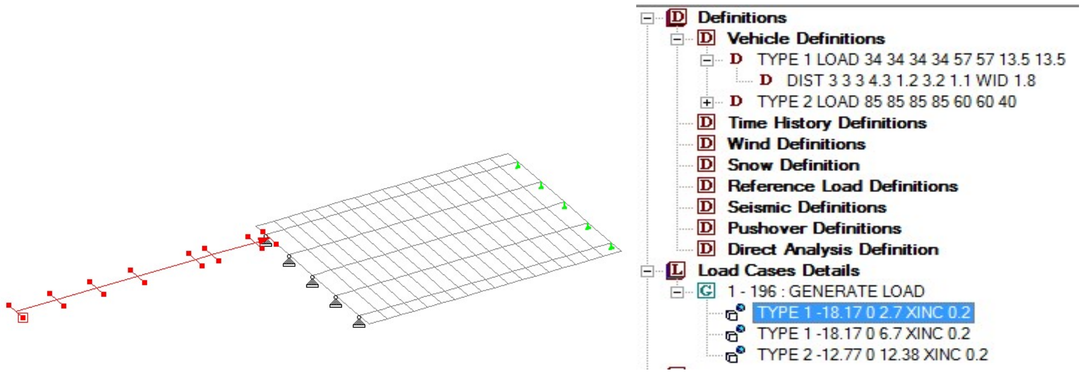


Fig 4.18 General view of loading (Live Load CLASS A) on girder in STAAD

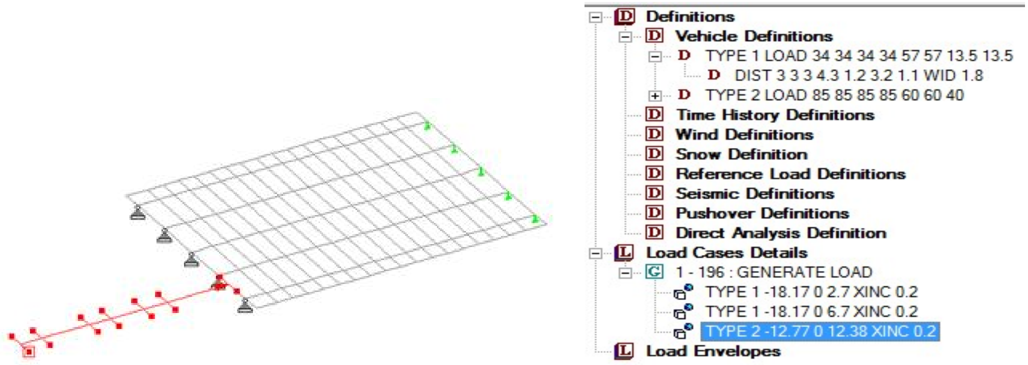
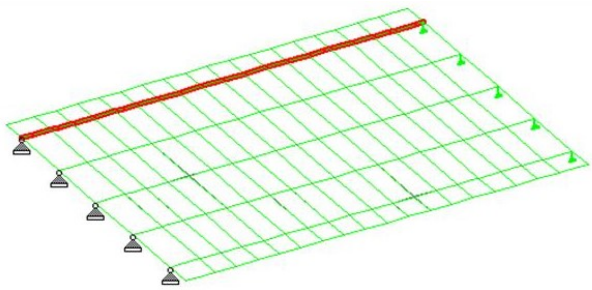


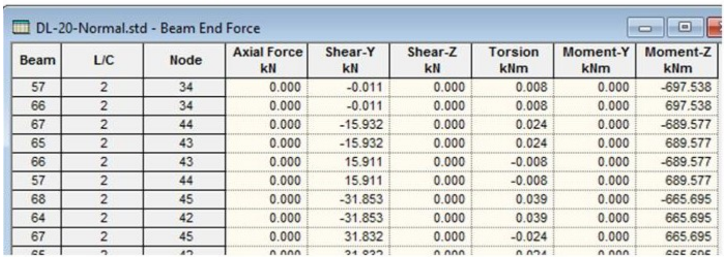
Fig 4.19 General view of loading (Live Load 70R) on girder in STAAD

4.3.3 ANALYSIS AND RESULTS

The Bridge model is analysed in two cases. In the normal case, there is no defect; in the other case, one of the five girders (G-5) is 300 mm down at one end. Results are shown for both cases due to dead load and live load. G-5 varies by 300 mm from one end to the other end.

4.3.1 STADD RESULTS DUE TO DEAD LOAD IN NORMAL CASE:





DL-20-Normal.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
57	2	34	0.000	-0.011	0.000	0.008	0.000	-697.538
66	2	34	0.000	-0.011	0.000	0.008	0.000	697.538
67	2	44	0.000	-15.932	0.000	0.024	0.000	-689.577
65	2	43	0.000	-15.932	0.000	0.024	0.000	689.577
66	2	43	0.000	15.911	0.000	-0.008	0.000	-689.577
57	2	44	0.000	15.911	0.000	-0.008	0.000	689.577
68	2	45	0.000	-31.853	0.000	0.039	0.000	-665.695
64	2	42	0.000	-31.853	0.000	0.039	0.000	665.695
67	2	45	0.000	31.832	0.000	-0.024	0.000	665.695

Fig 4.20 General view of results in STADD

4.3.2 STADD RESULTS DUE TO DEAD LOAD IN SECOND CASE (when defect incorporated):

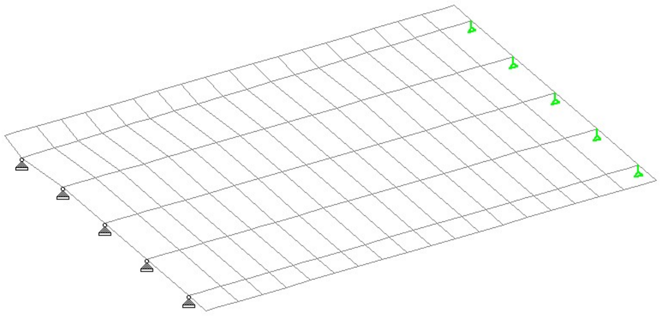
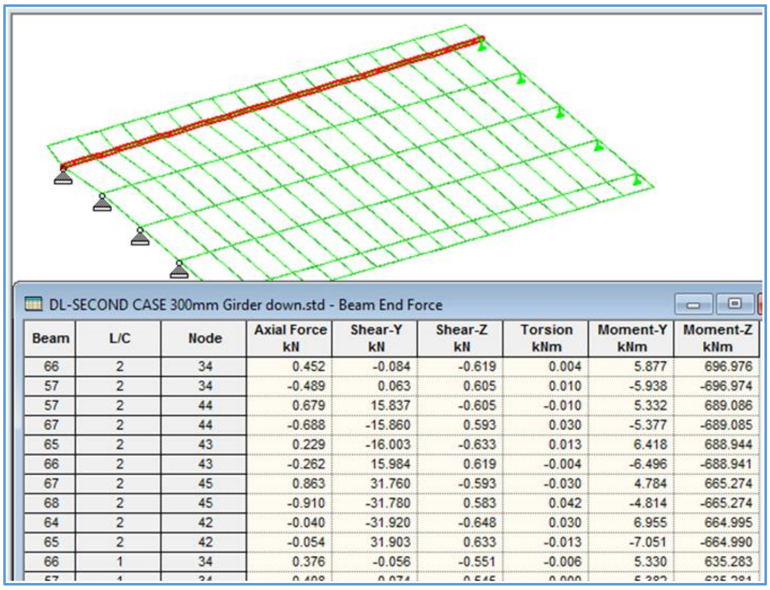


Fig 4.21 View of Model in STAAD with G-5 down 300mm

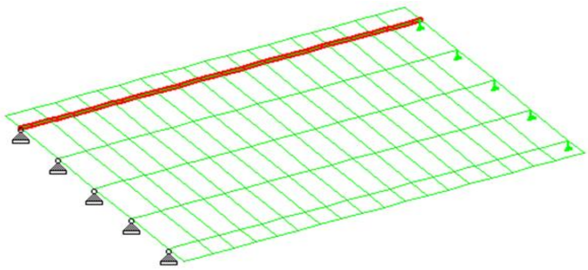


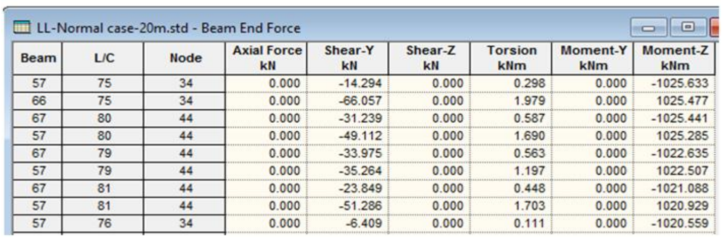
DL-SECOND CASE 300mm Girder down.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
66	2	34	0.452	-0.084	-0.619	0.004	5.877	696.976
57	2	34	-0.489	0.063	0.605	0.010	-5.938	-696.974
57	2	44	0.679	15.837	-0.605	-0.010	5.332	689.086
67	2	44	-0.688	-15.860	0.593	0.030	-5.377	-689.085
65	2	43	0.229	-16.003	-0.633	0.013	6.418	688.944
66	2	43	-0.262	15.984	0.619	-0.004	-6.496	-688.941
67	2	45	0.863	31.760	-0.593	-0.030	4.784	665.274
68	2	45	-0.910	-31.780	0.583	0.042	-4.814	-665.274
64	2	42	-0.040	-31.920	-0.648	0.030	6.955	664.995
65	2	42	-0.054	31.903	0.633	-0.013	-7.051	-664.990
66	1	34	0.376	-0.056	-0.551	-0.006	5.330	635.283

Fig 4.22 General view of results in STADD

1.3.3 STADD RESULTS DUE TO LIVE LOAD IN NORMAL CASE:



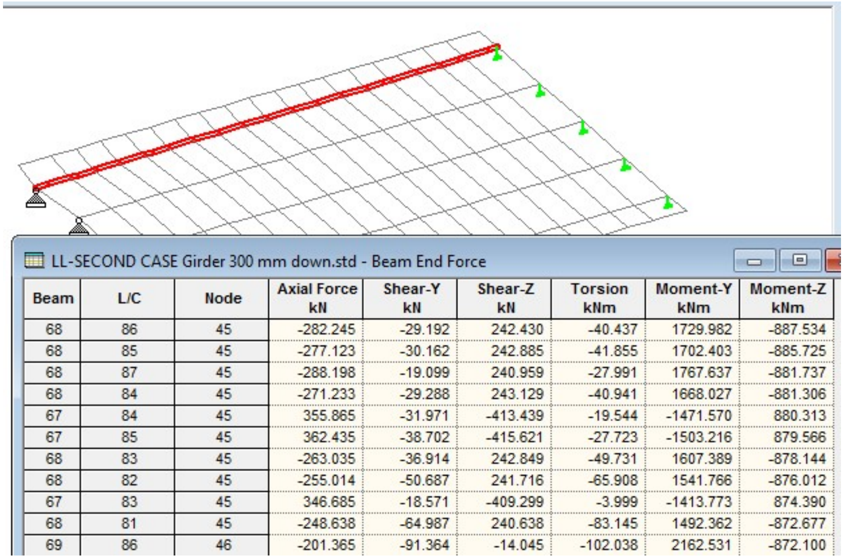


LL-Normal case-20m.std - Beam End Force

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
57	75	34	0.000	-14.294	0.000	0.298	0.000	-1025.633
66	75	34	0.000	-66.057	0.000	1.979	0.000	1025.477
67	80	44	0.000	-31.239	0.000	0.587	0.000	-1025.441
57	80	44	0.000	-49.112	0.000	1.690	0.000	1025.285
67	79	44	0.000	-33.975	0.000	0.563	0.000	-1022.635
57	79	44	0.000	-35.264	0.000	1.197	0.000	1022.507
67	81	44	0.000	-23.849	0.000	0.448	0.000	-1021.088
57	81	44	0.000	-51.286	0.000	1.703	0.000	1020.929
57	76	34	0.000	-6.409	0.000	0.111	0.000	-1020.559

Fig 4.23 General view of Maximum Bending moment in G-5

4.3.4 STADD RESULTS DUE TO LIVE LOAD IN SECOND CASE (when defect incorporated)



Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
68	86	45	-282.245	-29.192	242.430	-40.437	1729.982	-887.534
68	85	45	-277.123	-30.162	242.885	-41.855	1702.403	-885.725
68	87	45	-288.198	-19.099	240.959	-27.991	1767.637	-881.737
68	84	45	-271.233	-29.288	243.129	-40.941	1668.027	-881.306
67	84	45	355.865	-31.971	-413.439	-19.544	-1471.570	880.313
67	85	45	362.435	-38.702	-415.621	-27.723	-1503.216	879.566
68	83	45	-263.035	-36.914	242.849	-49.731	1607.389	-878.144
68	82	45	-255.014	-50.687	241.716	-65.908	1541.766	-876.012
67	83	45	346.685	-18.571	-409.299	-3.999	-1413.773	874.390
68	81	45	-248.638	-64.987	240.638	-83.145	1492.362	-872.677
69	86	46	-201.365	-91.364	-14.045	-102.038	2162.531	-872.100

Fig 4.24 General view of Bending moments in G-5

Results for the normal case and with the consideration of defect are summarised as per Table 4.17

Table 4.17 Results due to dead load & Live load

Sr. No.	Component	**case-1 (Normal case)**				**Case-2 (with consideration defect)**				Load Case
		Max BM, kN-m		Def. mm	SF, kN	Max BM, kN-m		Def. mm	SF, kN	
		M_y	M_z			M_y	M_z			
1	Girder	0	698	0.007	149	11	697	0.007	149	DL
2	Diaphragm	0	11	0.003	22	10	11	0.003	22	DL
3	Girder	0	1025	0.022	236	1730	888	0.018	238	LL
4	Diaphragm	0	35	0.003	33	16	175	0.101	56	LL

4.3.6 RESULTS

In this study two bridge models have been analyzed in STADD pro software. One model analyzed as a normal case in ideal condition and another one analyzed with the consideration defect which has been observed in the field out of five girders one girder was seated directly on the pier cap while the code recommended that it should be ensured that bottom of girder to be seated on the bearing. Both models analyzed for the dead load and live load separately. Initially bridge designed for the normal case and reinforcement provided accordingly on the basis of bending moment and shear force. In the main girder with the consideration of defect it is observed that additional moment in y direction (M_{y}) about 1.6 % of M_z value is generated with the dead load consideration.Whereas, under the live load consideration, the moment of z direction was reduced but in y direction moments increased so high which are not acceptable. The diaphragm D-4 (D4 is the end diaphragm which is laterally connected with Girder 5 – Girder 4) is also affected with this defect. Additional moments are generated in y direction (M_{y}) about 10% of M_z value with the live load consideration.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 GENERAL

In this report, studies on the common defects in bridge structures and response of the structure due to the defect reported. Study is done on the basis of field observation of 14 bridges. Table 3.1 gives a list of few common defects which are observed. It is observed that about 90% Expansion joints were filled with debris and strip seals are missing which is the main cause for seepage through the expansion joint on the pier cap and it was the main reason of corrosion , 90% drainage spout were chocked or not provided with proper down take pipe as mention in IRC code as discussed above which lead to continue seepage on the structure's surface and which causes to lead the corrosion in structure and due to this initiation of structures starts in the early age, 50% structure having the exposed reinforcement problem which causes due to the less concrete cover or poor workmanship in the field, 60% structures are affects with honeycombing due to lack of quality control on concrete and lead to reduction in the strength of concrete as well as the decreases durability of concrete. Some of observed defects with their possible causes are given below:

- **Spalling & exposed reinforcement:** due to less concrete cover, improper drain leads to early initiation of common subsequently leading to spalling and exposed reinforcement.
- **Debris in Expansion joints & neoprene seal missing:** Due to lacking of regular inspection of the expansion joint and not clean joint regularly.
- **Cavity at pedestal:** Negligence or improper concreting.
- **Improper Bearings placed bolts not tight and sleeves locked:** Bearing pads have not been placed properly at several locations, in steel bearing bolts have not been tight and locked bearing observed as sleeves are not for free movement. Possible cause for such type defects attribute to negligence at work.
- **Girder seated on pier cap directly without bearing:** Out of five one girder rested without bearing at same location, later on the bearing is more to theft. To avoid such incidents frequent inspection are needed.

- **Corrosion of the pre-stressed cables:** poor grouting of prestressing duct and poor maintenance of the bridge.
- **Seepage:** water leakage through expansion joint is the main cause of seepage over the pier cap and improper down take pipe of drain is also the cause of seepage on the structure's surface.
- **Cracks:** Cracks can be attributed to many reasons, based on location of the cracks, width of the cracks. Cracks are classified into 4 types: (i) Hair line cracks (ii) Shrinkage cracks (iii) Structural cracks (iv) Settlement cracks.
- **Vegetation:** Improper inspection and maintenance of the bridge.
- **Honeycombing:** lack of quality control during construction.

5.2 CONCLUSIONS

In this study two bridge models have been analyzed in STADD pro software. One model analyzed as a normal case in ideal condition and another one analyzed with the consideration defect which has been observed in the field out of five girders one girder was seated directly on the pier cap while the code recommended that it should be ensured that bottom of girder to be seated on the bearing. Both models analyzed for the dead load and live load separately. Initially bridge designed for the normal case and reinforcement provided accordingly on the basis of bending moment and shear force.

Following conclusions have been made:

1. In the main girder with the consideration of defect it is observed that additional moment in y direction ($M_{y)}$ about 1.6 % of M_z value is generated with the dead load consideration.
2. Whereas, under the live load consideration, the moment of z direction was reduced but y direction moments increased so high which are not acceptable
3. The diaphragm D-4 (D4 is the end diaphragm which is laterally connected with Girder 5 – Girder 4) is also affected with this defect. Additional moments are generated in y direction ($M_{y)}$ about 10% of M_z value with the live load consideration.

Hence, it is revealed that reinforcement could not be provided for such conditions. If additional moments are generated, then damage can occur in the structure and affect the service life of the structure.

5.3 OBSERVATIONS AND RECOMMENDATION

Based on the study presented in this project report, following observations are drawn:

1. With the little attention while working, can make the bridge structurally sound without any extra cost and minimize the damages in the structures.
2. The reinforcement and the pre-stressing cables were exposed at several locations leadings to initiation to corrosion in the structure.
3. During the construction by following the guidelines of relevant standards are can minimize the defects in the structure.
4. By looking at some of the existing bridges in India, it is seen that vegetation growth on the bridge components initiates the cracks. Therefore, there is a need to vegetation growth shall be removed to enhance structure efficiency.

On the basis of the study recommendations are given below:

Table 5.1 Study of defects and their recommendation proposed

Defects observed in the field	Recommendations
1. Expansion Joint: i. Due to Debris accumulated in the expansion joints movement of expansion joint is found to be restricted. ii. Seepage through expansion joints at several locations indicating that a neoprene seal of the expansion joints was in poor condition iii. Bituminous wearing coat is found laid over the expansion joint. iv. Edge beam of expansion joint found damaged. v. Underside portion of expansion joint is found damaged.	i. Should be capable to expelling debris without clogging and should be watertight[1] ii. Inspection shall be carefully to remove the debris accumulation and also removed foreign objects to provide free movement [1]. iii. Expansion joint should permit the expansion/contraction to the span without causing any distress or vibration[1] iv. If any Wear and tear in the vicinity of the expansion joints at road level shall be inspected at a regular interval and shall be rectifying at the earliest. v. Expansion joint should be offer good riding comfort without any cause of hazard/inconvenience [1]. vi. Gap of expansion joint should be maintained properly excluding the laying of wearing coat i.e. covering the gap of expansion joint [1]. vii. If any defects appear in expansion joint, remedial action should be taken accordingly.
2. Bearing: i. Locked bearing is observed as sleeves are not removed for free movement.	i. Locked bearing shall be free for movement before opening the traffic. ii. Bolts for fixing bearing shall be checked carefully [3].

ii. Bolts are not tight and also missing of the bearing plates at several locations. iii. It has been observed that MS wire binding around the elastomeric bearing due to bearing got damaged. iv. It has been observed that debris accumulated around the bearing.	iii. After installing the bearings, their surrounding area shall be left clean [2]. iv. If any bearing got damaged shall be replaced immediately to avoid the difference in level at same location [2]. v. Bearing shall be made available for inspection & maintenance [3].
3. Pedestal i. Cavity observed under the bearing plate at pedestal. ii. Honeycombing observed in pedestal concrete. iii. At many locations in bearing pedestals, seepage marks are observed.	i. Surface of pedestal where bearings are to be placed shall be cast horizontally [3]. ii. It should be ensured that concreting of pedestal should be compacted properly without any honeycombing and cavity etc. iii. It should be ensured that surface of pedestal to be dampness free to avoid any initiation of corrosion.
4. Girder: i. Girder direct seated on the pier cap. ii. Honeycombing also observed in the girders.	i. It should be ensured that bottoms of girder to be seated on the bearing [3]. ii. It should be ensured that bearing to be placed in position [3].
5. Pier cap i. At many locations in pier caps, seepage marks are observed. ii. Vegetation growth observed over the pier cap. iii. Major debris accumulated over the pier cap at many locations.	i. Vegetation growth shall be removed to enhance structure efficiency. ii. Pier cap should be clean easy the movement over the pier cap to check the bearing etc.
6. Drainage: i. Drainage pipes are found damaged and insufficient at many locations due to seepage observed on the surface of bridge component and lead to corrosion initiation in the reinforcement.	i. The water spouts shall be cleaned regularly to avoid clogging. ii. Down take pipe should be provided properly to avoid water fall on the structure's surface.

5.4 FUTURE SCOPE OF WORK

Present study has deals with the limited defects in the bridges with different ages of the structures. One defects considered for the analysis to know the behavior of the structure. However, the future scope of the work deals with the detailed of more defects in the structure with their causes and with the incorporate the defects and analysis the structure to know the behavior of the structure for a better understanding to the field engineers.

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