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Risk Analysis Report of 178 years old Railway Bridge

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Abstract: **Transportation plays a most important role in our society from ancient periods. As now in modern society a special concern is given to the transportation department i.e. Roads, Railways and of course Bridges. Now a days a special committees are established to work on the old bridges which can serve for further more years by repairing and strengthening. There are several factors due to which a bridge losses it`s strength. Some of the reasons are Age, Accidents, increased service load, improper maintenance. An existing bridge needs to be repaired and strengthen to keep it in operation safely.**

1. **In this report we will work on repairing and mitigating the defects due to which the service life of the bridge is decreasing. The visible evidences of damages are collected and a brief detailing of these evidences are made to work on them. The common type of remedial measures are adopted and explained. There are two ways to tackle with the deficient bridges. Replacement of the bridge with new structure,**
2. **Upgrading the structure as per our needs.**

The replacement of the whole bridge structure comes to be un-economical as it includes traffic disturbance and time consuming. The second option includes repairing and strengthening of the elements which are damaged or structurally not able to serve. The second approach seems to be more economical and there will be less traffic disturbance. Whereas the adaptation of the option will depend on many factors i.e., Capital Available, the current condition of the structure, service providing by the structure.

We have already discussed, there are many bridges which needs to repair or strengthen it. The first step for this operation is to investigating the structure. The investigation process includes the risk analysis of the structure, to find out the elements which under high risk and can affect the serviceability.

Keywords —178Years old, Maintenance, Railway Bridge, Repair, Risk Analysis, Transportation

I. Introduction

1.1 What is Risk:-

The Combination of possibilities of an action to occur and the amount of the effect that the particular action can the structure.

1.2 Risks need to be:-

Identified–Considering uncertainties that would affect objectives of the project or of the organization, whilst ensuring there is a common understanding.

Assessed-Estimating the probability, impact and proximity of individual risks so that they can be prioritized.

Controlled–Planning appropriate res ponses to risks, appointing suitable risk owners and risk actioners, then implementing, monitoring and controlling these responses.

II. History of the Structure

The Barming Railway Bridge is located in South Street in the village of Barming, Maidstone, Kent. The bridge has a Network Rail designation of ELR-PWS1 Structure 958. The bridge is located between the railway stations of East Farleigh and Wateringbury. The railway line lies above an embankment and serves the Medway Valley Line rail services, linking Strood and the Medway Towns, with Maidstone West and onward to Paddock Wood and Tonbridge. The section of the railway, between Maidstone West and Tonbridge passes through the narrower sections of the River Medway on the outskirts of the village of Barming.

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The line was built by South Eastern Railway in two stages, with the first stage being opened in 1844.

Fig. 1. The Barming Railway Bridge

Structural Details: - The construction of this Railway Bridge was completed in 1844.This bridge form is a common type of design for railway bridges of this age. The structural form comprises of three I-girder beams, fabricated from wrought iron, riveted together with angle plates to form single girders.

The three I-girders bear down on six pad-stones which are used to distribute and transfer the vertical compressive loads to the abutment wall. The deck spans laterally between the I-girder beams and they are made from riveted cross girders fabricated from plates and metal troughs. The troughs are made from rolled steel and bear on an angle plate which is riveted to the corners of the main I-girder beam. The adjacent troughs are interconnected by a riveted joining plate. Angle cleats are riveted to the top of the connecting plate and also riveted to the web of the main I-girder beam. The troughs may be infilled with concrete with a ballasted track on top supporting railway line.

III. METHOD OF ANALYSIS

In this Project, we will analysis the existing structure of bridge and collect the visible evidences of damage and elements under high risk. After the collection, we will find out the best remedial measures by studying the possible reasons of those defects.

To determine the risk of the structural element, there are two attributes: - 1. Severity and 2. Likelihood.

The harm that an element may have on the service of the bridge is known as the severity. The degree of risk can be determine by the considering both severity and likelihood of the hazard. Therefore, to detect each hazard a study should be done on the seriousness and chances (probability) of the accident. A matrix is prepared to calculate the risk which will lead to the dangerous occurrence.

The probability will be classified as follows:

Extremely Unlikely	Very less Chance
Unlikely	In a period of 10 Years
Likely	In a period of 5 Years
Extremely Likely	In a period of 1 Year
Almost Certain	In a period of 6 Months

The amount and type of loss which may cause by a particular threat may classified as under:

Significant Harm	Devastating, Heavy destruction
Serious Harm	Serious destruction, Considerable loss
Moderate Harm	Moderate injury, Medium or Bearable loss
Insignificant Harm	Minor damage or loss no injury

After analyzing the whole structure, a matrix is prepared. The marking of a particular risk element in the matrix as discussed below:

1 to 5 is marked for the elements which shows low risk for the structure. For these risk no action is required.

Medium (6-12). In this stage, a proper remedial step is to be taken for the defect, otherwise the element will become a risk within one to two years. It will not be possible to mitigate by current remedial measures.

High (12-20). In this the risk is not bearable and can`t be ignored. Actions must be taken as soon as possible to avoid the risk.

The shown matrix is prepared, which provides knowledge about the seriousness of the risk. (R):-

Probability (P)		Seriousness (S)			
		a	b	c	d
		Un-Significant	Tolerable	Crucial	Significant
a.	Extremely Unlikely	1	2	3	4
b.	Unlikely	2	4	6	8
c.	Likely	3	6	9	12
d.	Extremely Likely	4	8	12	16
e.	Almost Certain	5	10	16	20

IV. RISK ASSESMENT OF ELEMENTS OF THE STRUCTURE

A. Defect No. 1:- Fatigue

Generally Fatigue refer to a damage occurred due to cyclic loading, in our cases the train movement. The structural element may fail under the elastic limit of the material. The cracks generated due to this effect will grow day by day with every passage of the load.

There are two stages in this cracking system:

- Beginning of Crack
- Crack Multiplication

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As the fatigue factor is not considered during designing structures, the structures having age of about 50-60 years and are subjected to cyclic loading needs special consideration.

The following are some simple remedial measures to lower the end result of fatigue:

1. By making reasonable reduction in the amount of loads and it`s Frequencies

2. By making cross sectional area of the structural member heavy.

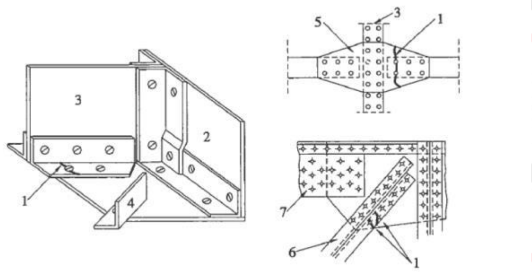
3. By redistribution of the loads by increasing numbers of members.

Structural Design elements which are more liable to Fatigue:-

- Structural Elements under the vibration and wind loads or traffic loads
- Holes for Rivet and bolt connections.

In suspension Bridges, the short hangers are the elements which are subjected to fatigue cracking.

Locations where fatigue cracking can be seen are shown in the fig below:



Possible location of fatigue cracks in riveted truss bridge. 1 — fatigue cracks, 2 — main girder, 3 — transversal beam, 4 — bracing, 5 — cover plate, 6 — diagonal, 7 — upper chord.

Fig. 2. Possible locations of fatigue cracks in riveted truss bridge

Due to age of the bridge, the probability of fatigue damage is very high. The load carrying capacity of the I-Girder may get reduced and could fail at any time. The repair on this part is very important to focus on.

Probability (P)		Seriousness (S)			
		a	b	c	d
		Un-Significant	Tolerable	Crucial	Significant
a.	Extremely Unlikely	1	2	3	4
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Repair:

Reinforcing of members

When a designed structure is seems to unable to take further loads, then the structure must be reinforced.

Followings are some reasons why reinforcing of the structure is required:

- The current structure is designed for the load which is less than that of the present one.
- Due to some wrong construction practices.
- Deteriorations e.g., corrosion or fatigue

Reinforcing the structure with help of additional material

This method is basically welding, jointing or pouring some extra material to the existing structure.

Adding plates is a common practice to reinforce the structure.

Some of the important points must make in count because the reinforcing process will depend on it are as follow:-

a). The type of load which the structural element have to bear? Whether it is the combination of Live load, Dead load or it is only live load?

b). Type of load in the structure have to bear in majority? Compression, tension, bending or torsion

c). Type of jointing technique in the structure used? Riveting, Welding

The common type of strengthening measure for the bottom and top flange of a girder is showed in Fig below.

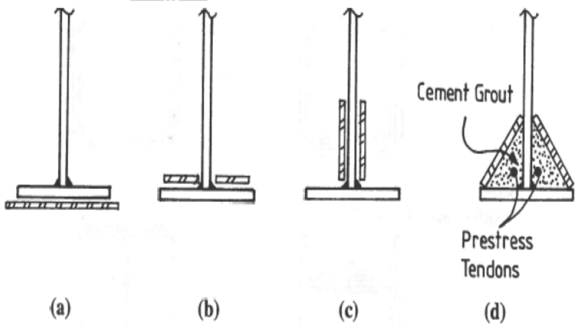

Fig. 3. Strengthening the bottom/top flange

B. Defect No. 2:- Cracks

1. Longitudinal cracks:-

Longitudinal cracks are likely to be on outgoing plane. These types of cracks can be happen shortly after the construction of bridge elements. There are two main reasons for the development of the cracks in bridge.

1. Cracks due to external load.

2. Cracks due to internal changes, which are free from the external loading conditions.

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The flexural and shear cracks are the cracks which develops due to external loads and occur after the concrete has hardened.

The cracks independent of the external loading conditions includes plastic shrinkage cracks, settlement, potholes, thermal cracks, and map or pattern cracks.

Cracks may also be defined by orientation Longitudinal, Transverse, Diagonal or Random.

Fig. 4. Longitudinal Cracks

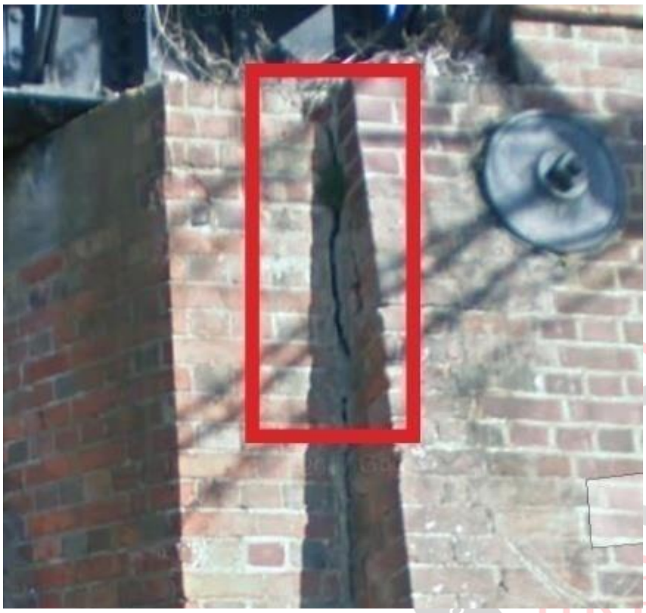

Fig. 5. Transverse Cracks

2. Stepped Cracks: - As the name defines these are the cracks which develops in the form of steps. These cracks looks like stairs going up and down these cracks usually seen in the foundation area which is sinking or settling due to any reason. Stair step cracks develop usually in brick masonry. In Brick masonry the main causes of these cracks is uneven moisture & relative settlement of the foundation. Evidences of routine maintenance can be detected, as there is color difference in the bricks and repointing of the cracks is detected.

According to the present condition, a regular inspection and repair is must be taken in account. If theses cracking will continue to expand risk of unstable settlement of the structure may arise. This settlement will further become a cause of derailment of the train passes through the bridge.

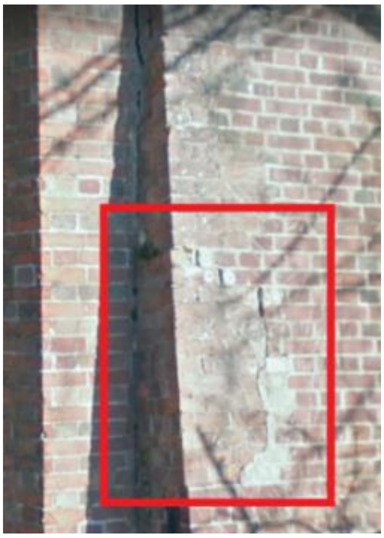

Fig. 6. Stepped Cracking & ongoing Maintenance

Probability (P)		Seriousness (S)			
		a	b	c	d
		Un-Significant	Tolerable	Crucial	Significant
a.	Extremely Unlikely	1	2	3	4
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C. Defect No. 3:- Pattress Plate Corrosion:

1. Pollutant contained air deteriorate the material. This process is called as Atmospheric corrosion. Rain due, humidity, melting snow are the major pollutants which lead to the atmospheric corrosion.

2. The area of Bridge location is humid area because of the River passes nearby. Due the River the atmosphere in this region contains significant moisture content. The Atmospheric corrosion initiates in the presence of electrolytes layer, by the reaction of anodic oxidation which includes the dissolution of the metal in the electrolyte whole. An assumption is made about the cathodic reaction, that it is an oxygen reducing reaction. They will reduce the level of humidity causes the foundation of film electrolyte and gently increase the duration of wetness on the canonic duration.

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Fig. 7. Pattress Plate Corrosion

Anode Reaction in the Atmosphere Reaction

$$2M + 2m2 + 4e^{-}$$

Cathode position in the atmospheric reaction

$$O_2 + 2H_2Co = 4OH^{-}$$

Measures should be taken to avoid Corrosion:-

1. Pipeline Cooling.

2. Soil Corrosively.

3. Potential for stray Current.

4. Stress corrosion cracking potential.

5. Inspection of redefies and interference bonds.

6. Close interval survey.

7. Use of interval inspection tools.

Predicted Risks: - Patress plate are recessed into brickwork to reinforce it. If these plates get deteriorate the strength of the brickwork get reduce and the wall will compromise with stability.

In the present conditions, the Patress plates failure of the structure due to these risks is Unlikely, that means these represents low risk to the members of the structure. However, a proper remedial step is to be taken for the defect, otherwise the element will become a risk within one to two years.

Probability (P)		Seriousness (S)			
		a	b	c	d
		Un-Significant	Tolerable	Crucial	Significant
a.	Extremely Unlikely	1	2	3	4
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D. Defect No. 4:- Water Strain / Wet Patching & Weeding

Water Patching:-

Dampness is the presence of unwanted moisture in the structure of the building. Water seeping through brickwork is the major cause of the dampness in this bridge. The moisture will also penetrates to the foundation by means of the brick masonry of the bridge abutments.

Drainage gullies also referred to as gullies drains are the drainage structures which carries rainwater or grey water discharge into it. Drainage gullies are designed to allow waste water and storm water to pass through easily.

In this bridge there are steel gully drains responsible for the carriage of the storm water through the bridge. Evidence are collected where there are damaged gullies which are also a factor due to which the corrosion of the material takes place.

Causes:-

1. Degraded Mortar: Due to continuous water seepage, combined acidic water dissolve calcium carbonate and mortar constituents, the degradation of the binding strength of the cement mortar initiates.

2. Soft Sapling Brickwork:- The combined effect of soft loose spalling brickwork together establish a freezing and thawing thermal cycle, which will result to the saturation of the bricks with water.

Risk: - Drainage system with gullies requires the regular maintenance and they should be in proper distance. If not so then excess would be track lead to serious hazards.

Fig. 8. Water Strains / Wet patches

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Fig. 9. Loose Brickwork

3. Loose Brickwork:- the Loose brickwork or spacing occurring the degradation of mortar which leaves to eventual loose through washout. (Fig. 9)

4. **Sulphate Attack**: - The ground water contains sulphate. Acidic substance comes in contact of tri-calcium aluminate. The evidence of powdery white residue left behind on the lead to problem for cracks. (Fig. 10)

Fig. 10. Sulphate Attack Effects

Weeding: - In brickwork the shrubs and algae growth will takes place in the brick joints. This will leads to loosen the joint. it`s strength reduces and looks bad on the bridge structure.

Fig. 11. Algea Growth

Fig. 12. Weeding

Predicted Risks:-

1. The pre-mature cracking in the abutments and some evidence of the same are already visible.

2. The meeting up of the penetrated moisture with ground water may arise the chances of differential deflections.

3. Due to the seepage of the moisture the risk of freezing and thawing action may also arises, which will leads to more cracking actions in it.

Probability (P)		Seriousness (S)			
		a	b	c	d
		Un-Significant	Tolerable	Crucial	Significant
a.	Extremely Unlikely	1	2	3	4
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d.	Extremely Likely	4	8	12	16
e.	Almost Certain	5	10	16	20

Remedies:-

1. Selection of material with similar corrosive potential.

2. Breaking the electrical connection.

3. Applying coating to the materials.

4. Inserting a suitable sized spacer between two materials to separate them.

Defect No. 5:- Erosion

Erosion is the natural process in which ground surface materials like soil & small stones are removed and taken away by the natural means which are generally wind or water. As similar process, widening breakdown or dissolved rocks but doesn`t involves moment. In the bridge it can be seen that there are the evidences of erosion at the base of the abutment which seems to be constantly well. The erosion in the bridge are increased to extend at which point it has exposed off some of the brickwork of the footing too, which is a serious point to be concern.

Cause of Erosion:-

1. Bridge Surrounds the removal of sediments such as sand and gravels from bridge abutments and piers. Swiftly moving

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water can seep out scour holes, which leads to Compromising with the weight of the structure.

2. Bridge water drainage directly connected to the main pipe line to the south direction is blocked. So, the flow of water is not passing through it.

3. There is a pipe at the south end of the bridge that carries water from the north side of the bridge (residential area drainage) and flow continuously along the base of the abutments.

4. Mismanagement of excess water: - The drainage pipe is connected to underside of the wall is pulled up and there is no provision for proper drainage from the excess water runoff.

Risk Raised: - Due to continue erosion of the bed the road under the bridge will get deteriorate and water will penetrate and met the soil under the bridge, the risk of settlement of the bridge may arise.

Probability (P)		Seriousness (S)			
		a	b	c	d
		Un-Significant	Tolerable	Crucial	Significant
a.	Extremely Unlikely	1	2	3	4
b.	Unlikely	2	4	6	8
c.	Likely	3	6	9	12
d.	Extremely Likely	4	8	12	16
e.	Almost Certain	5	10	16	20

Remedies:-

1. The flow bed around a typical span causes bed scour at spur strip and sediment deposit close to where amur adjoin the river/ streambank. A spur is useful for defining the local path of the flow as well as providing local bank protection.

E. Defect No.: 6: Crevice Pitting Corrosion

Crevice pitting corrosion is also called concentration call corrosion is most common type of corrosion damage to be found on many older aircraft which have not been adequately maintain.

The corrosion is most significant on one side of the girder. The other side is relatively clean. There is a discoloration of the trough and evidences of corrosion can be seen along the edge of the trough connection.

Mechanism of Crevice pitting corrosion:-

The corrosion resistance of a stainless steel is dependent on the presence of can ultra-thin protective oxide film (passive film) on its surface, but it possible under certain condition for the oxide film to breakdown.

Some of the phenomenon occurring within the crevice may be somewhat reminiscent of galvanic corrosion.

The major difference between Galvanic Corrosion and Crevice Corrosion is as under:-

The Galvanic Corrosion occurs when there are two different metals in same environment. That means the corrosion initiate with the internal reactions between two metals.

The Crevice Pitting Corrosion occurs when the metal undergoes two different environments. That means the corrosion initiates when a single metal undergoes different weather in cycle. i.e. wetting drying, freezing & thawing action.

Causes:-

The crevice Pitting Corrosion is localized in stainless steel generally occurs in presence of ions. Namely, coastal and dicing chloride salt sodium, calcium or magnesium chlorides, hydrochloric acid, calcium hypochlorite other chloride compounds.

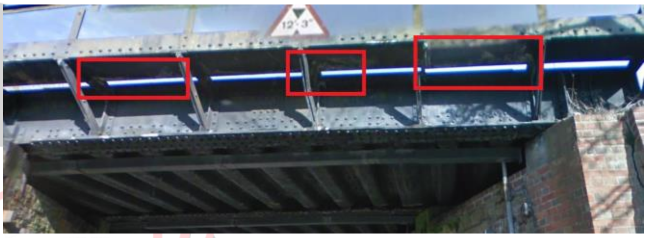

Fig. 13. Crevice Corrosion on South side of the bridge

Fig. 14. Crevice Corrosion

Therefore, this is a major point that must be focus on. The failure of the structure due to this defect is extremely Likely to be happen.

Probability (P)		Seriousness (S)			
		a	b	c	d
		Un-Significant	Tolerable	Crucial	Significant
a.	Extremely Unlikely	1	2	3	4
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Remedies:-

It requires two conditions:-

1. A gap metal surface and another metal or nonmetal surface and the presence of alagnant electrolyte.

Metal with strong resistance to pitting corrosion, often exhibit high crevice corrosion resistance as well.

2. Eliminating gap such as these found in weld and joint can help to reduce crevice corrosion risk.

3. Ensuring complete drainage of vessels and removing electrolytes from surface can further reduce risk.

4. Utilizing solid, non-absorbent, gasket can be reduce risk at connection and equipment.

F. Defect No. 9:- Parapet Structure

Bridge Parapet Detrition Mechanism:-

Bridge parapet subject to harsh condition including multiple cycles of freezing and thawing, melting and drying. The large scale use of salt and other deicing material contributes to the harshness of the environment exposure.

The effect of shrinkage and temperature, vibration, sonic waves causes non-structural reverting breakage from bridge parapet.

Risk:-

Steel parapet are generally are the weakest part of the bridge. The Riveted connected steel parapet is more likely to be damaged and due to the failure of parapet, the area become more liable to accident.

Probability (P)		Seriousness (S)			
		a	b	c	d
		Un-Significant	Tolerable	Crucial	Significant
a.	Extremely Unlikely	1	2	3	4
b.	Unlikely	2	4	6	8
c.	Likely	3	6	9	12
d.	Extremely Likely	4	8	12	16
e.	Almost Certain	5	10	16	20

Remedies:-

The adaptation of P6 Steel Parapet/ P1Steel Parapet will be more beneficial.

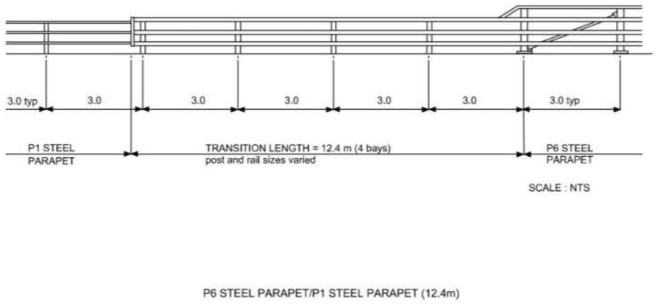

Fig. 15. Shows the P6 Steel parapet/P1 Steel parapet

V. CONCLUSION

The Railway bridges will naturally generate a variety of defects after serving for long duration. These defects will affect the durability of bridges and even safety issue may also arise.

The risk analysis has been completed on the elements identified as defects due to which the usage of Barming Railway Bridge is not suitable and have to undergo through some repairs or retrofitting.

The risk analysis has been completed based on the visual evidences on the structure.

In this analysis report the risk is classified into three categories low, medium and high.

1. A high risk cannot be neglected and an appropriate remedial measures must be taken into account to mitigate the risk. The probability of this risk very high.
2. A medium risk is a risk which is to be expected to be occur and action to eliminate them should be taken as, if no actions are carried on medium risk elements, it will convert into high-risk element within one to two years.
3. The low risk can be managed with the current inspection and no actions are required within the next one to two years.

The table below will show a brief result:-

Defect/ Element	Risk
Fatigue	High
Cracks	Low
Patress Plate Corrosion	Medium
Water Stain/ Wet Patches/ Weeding	Low
Erosion	Medium
Crevice Pitting Corrosion	High
Parapet Structure	Medium

Due to the present defects, the elements represents a High risk. Therefore, it is advisable to all the elements that represent or may represent a risk in future at the same time in order to save two mobilization.

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REFERENCES

[1] Design Manual for Roads and Bridges Volume1: Section 1 Approval Procedure BD2 – Technical Approval of Highway Structures on Motorways and Other Truck Roads Parts 1: General Procedures (DMRB 1.1) Volume1: section 3 General for highway Bridges (DMRB 1.3)

[2] Manual of contract Documents for Highway Works

Volume 1: Specification for Highway Works (December 1991)1: (HMSO (MCHw 1) Volume 3: Highway construction Details (December 1991/April 1992) HMSO (MCHW 3)

[3] British Standards

BS 729:1971 – Hot dip galvanized coating on iron and steel articles.

BS 4360:1986 – Specification for wieldable structural steels.

BS4482:1969 – hard drawn mild steel wire for the reinforcement of concrete.

BS 6779: Part 1:1992 – parapets for vehicle containment on highways – Specification for parapet of metal construction.

[4] Badoux M. and Jirsa J. O. “Steel bracing of RC frames for seismic retrofitting”, Proc. ASCE, J. Struct. Eng., 2000, 116 (1), 55-74

[5] Cope, G.H. (Ed.). (1993). British Railway Track: Design, Construction and Maintenance. Loughborough, UK: Permanent Way Institution.

[6] Bridges: Structures and Materials, Ancient and Modern, Arturo Gonzalez, Micheal Schorr, Benjamin Valdez and Valejandro Mungaray.

 DOI : 10.35291/2454-9150.2022.0097