Third Party Audit of ROB's and FOB's of SCR

INSPECTION OF FOB AT FALAKNUMA RAILWAY STATION

Final Report

SEPTEMBER | 2020

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1. VISUAL INSPECTION

Name of the Project	:	VISUAL INSPECTION OF FOB AT FALAKNUMA RAILWAY STATION
Location	:	FALAKNUMA RAILWAY STATION
Location Co-ordinates	:	**17.3327330 N, 78.4746585 E**
Date of Inspection	:	3rd March 2020

Visual inspection Summary:

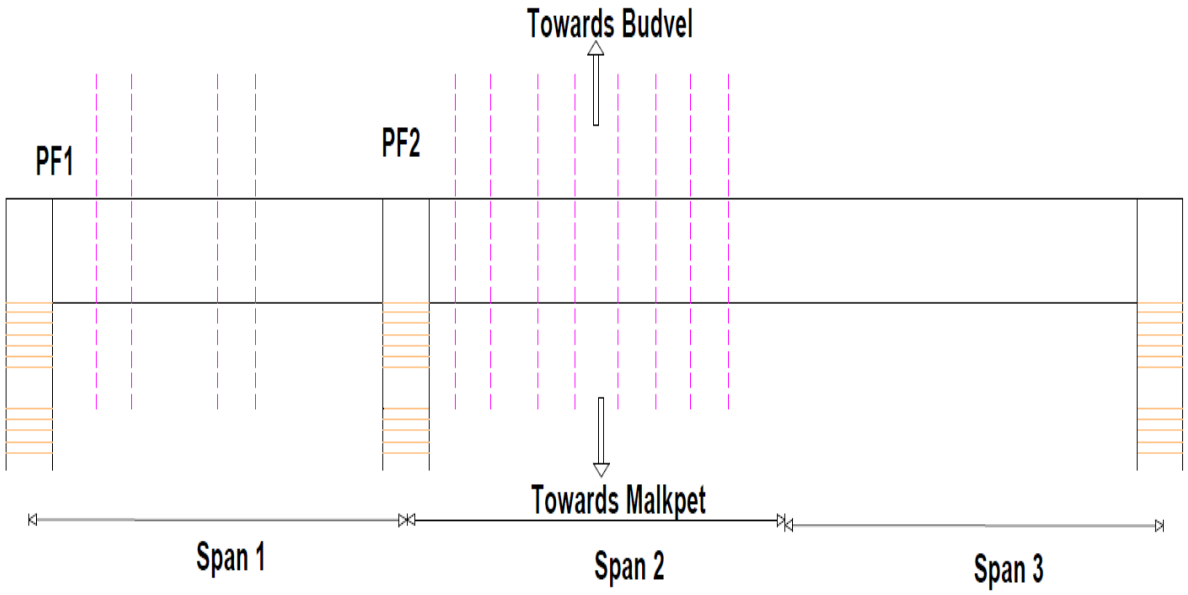
a) Spalling and reinforcement exposed observed in floor slab at slab and steel joint along the 1st span.

b) Corrosion is observed at joints connecting Floor beams and bottom main chord member and slight rusting is observed at bottom chord member along the length of FOB.

c) Slight corrosion is observed at stringer beams and concrete joint.

1.1 GENERAL INFORMATION AND OBSERVATION		
a.	Name of the Bridge	Falaknuma FOB
b.	Location of Bridge	Falaknuma Railway Station
c.	Type of truss Structure	N-Truss.
d.	Year of Construction	Not available
e.	Description of the main use of the bridge	Pedestrians Crossing
f.	Major Materials used in different parts of bridge	Structural Steel, RCC Slab
g.	Width of the pathway (m)	1.6 m
h.	Length of the pathway (m)	74.9 m
i.	No of Railway Lines Crossings	6 no's tracks Span 1 = 2 Span 2 = 4 Span 3 = -
j.	Span arrangement (no x Span in meters)	1x15.96 + 1x33.55 +1x16.25 m = 65.76 m **(Clear span)**
k.	Vertical Clearance (from rail top to girder bottom)	6.78 m
l.	Head Room	3 m
m.	Damages due to accidental hitting, Grazing Marks	No Visible signs appear
n.	History of Repair/ maintenance	Not available
o.	Existing structural drawings	Not available

Key Plan



1.2 IDENTIFICATION OF LOADS ON BRIDGE			
		Yes/No	**Photo ID**
a.	**Dead Loads at Roof level**		
	a) Pipeline - Utilities	No	Not observed at site
	b) Cables	Yes	Cables are protected with 1-inch and 2-inch dia HDPE pipe of 2 nos. and 1-inch PVC pipes of 6 no's and (Refer ***fig :1.1)*** King post supported with 65 x 65 x 8 mm angles are used (Refer ***fig: 1.1).*** Steel Metal Sheet is used for Roof (Refer ***fig :1.1***)
	c) Roof Truss	Yes	
	d) Roof Sheet	Yes	
	e) load of advertising hoarding	No	No Advertising boards are provided
	f) load of train/coach display boards	No	No train coach display boards are provided
	g) Electrical equipment (OHE), signal	No	No electrical equipment and signal are provided
b.	**Dead Loads at Floor level**		
	a) Additional wearing coat on Floor	Yes	Chequered tiles are used for flooring.
	b) Provision of protective screen for passengers	Yes	Chain link fence made of galvanized wire of 2 mm gauge and 2mm galvanized sheet is used above OHE line on both side of gangway is used for protection. (Refer ***fig :1.1)***
	c) Type of Material used for mesh	Galvanized wire mesh	

	1.3 STRUCTURAL SYSTEM OF THE BRIDGE		
			Photo ID
a.	**Foundation Details**		Not visible at site
b.	**Trestles details**		
	Trestles Connection Details		Trapezoidal Concrete encasement is observed below vertical supports (Refer ***fig :1.2)***
	a) No of Bolts and size	Not visible, filled with concrete	
	b) Thickness of Base Plate	Not visible, filled with concrete	
c.	**Roof Truss**		
	Element of roof truss section	Angle sections	Span of roof truss is supported with 65 x 65 x 8 mm double angle sections which are rested on Top chord members. (Refer ***fig :1.1)***
	Size of roof truss	2.0 X 0.7m	
	Connection of Roof elements	Bolted	
d.	**Steel Truss**		
	Shape of Truss Section	Double angle sections	a. Top and bottom chord members 150 x150 x12 mm of double angle sections. b. 90 x 90 x 10 mm double angle sections are used as bracing members c. ISMC 150 Double Channels are used as Floor beams supported by 65 x 65 x 8 mm angle sections
	Height of Truss (H)	3 m	
	Girder/Truss Support Condition	Ridged connection	
	Type/Shape of Secondary Girder /Bracings	Double Channel sections and angle sections	
	No of Secondary Girders/bracings for span	7, 13, 7 no's	
	Arrangement of Bracings	Diagonal	

	Type of Beam-Column Joint (shape of gusset plate if any)	Cleat angles	to transfer load from slab to roof truss. (Refer ***fig :1.3***)
e.	**COLUMN**		
	Type/Shape of Column section	I – Section	FOB is supported on vertical column of Four - ISMB 300. (Refer ***fig :1.2***)
	No of Columns/support	4	
	Dimensions of Column	300x150 mm	
	BEAM-Column joint (bolted, welded, riveted)	Bolted connection	
f.	**FLOOR SLAB OF THE PATHWAY**		
	Material of Slab	RCC	RCC slab panels is used for floor slab of 125 mm thick, RCC slab panels is supported with Floor beams and bracings from bottom
	Thickness of Slab	125 mm	
	Condition of Slab from Bottom	Spalling and Reinforcement exposed slab panels	
	Condition of Slab from Top	Not visible as covered with Chequered tiles	
g.	**Staircase Details**		
	Number of Staircase	3 no's	Staircase steps are observed as RCC slab, Steps are supported on stringer beams of ISMB 250 section, horizontal members of ISMB 150 and diagonal bracings with 65 x 65 x 8mm angle sections. (Refer ***fig :1.6***)
	Number of Steps from PF – 1	31 no's	
	Number of Steps from PF – 2	31 no's	
	Number of Steps from CA	42 no's	
	Material used for steps	RCC	
h.	**Staircase Railing**		
	Type of Parapet Railing	Steel railing	Staircase is provided with railing on both sides of one-meter height using 65 x 65 x 8 mm double angle sections and 35 mm dia MS pipes are used. (Refer ***fig :1.6***)
	Height of Railing	0.9 m	

1.4 SIGNS OF DISTRESS, DEFORMATION IN BRIDGES

a. ✓ Spalling and Reinforcement exposure of RCC slab observed along the 1st span of FOB

Spalling and reinforcement exposure

b. ✓ Corrosion is observed in joints of Floor beams and bottom main chord member and slight corrosion is observed at stringer beam joints

Corrosion observed in Floor beams joints of span 2

Corrosion of floor beam joints of span 3

Corrosion at mid landing beam column joint.

corrosion observed at Stringer beam (steel concrete joint)

SIGNS OF DISTRESS, DEFORMATION IN BRIDGES			
	Defects	**Location**	**Comments**
	Cracking in Steel Members		No cracks are observed in Steel during visual inspection
	Cracking in RCC components		No cracks are observed
	Spalling	RCC slab	Spalling and exposed reinforcement is observed at the bottom of slab in span 1 and at stair case slab. (Refer ***Part 1.4 – 1.4(a)***)
	Rust straining	Bottom chord members	Rusting is observed at all over the bottom chord members of FOB. (Refer ***Part 1.4 – 1.4(b), Fig 1.4)***
	Extent of Corrosion	Joints	corrosion is observed at bolted joint connecting Floor beams, bracings and bottom chord members(Refer ***Part 1.4 – 1.4(b)***

***Rust:** Rust is a part of corrosion and is a chemical process which results in the formation of red or orange coating on the surface of metals.

***Corrosion:** it is the process of deterioration of materials as a result of chemical, electrochemical or other reactions.

Fig 1.1: Cables, Roof truss, Flooring and Protective screen

Fig 1.2: Trestles details

Fig 1.3: Front view and bottom view of span 1

Fig 1.4: Front view and bottom view of span 2

Fig 1.5: Front view and bottom view of span 3

Fig 1.6: Staircase details

Fig 1.7: Inspection team at Falaknuma FOB

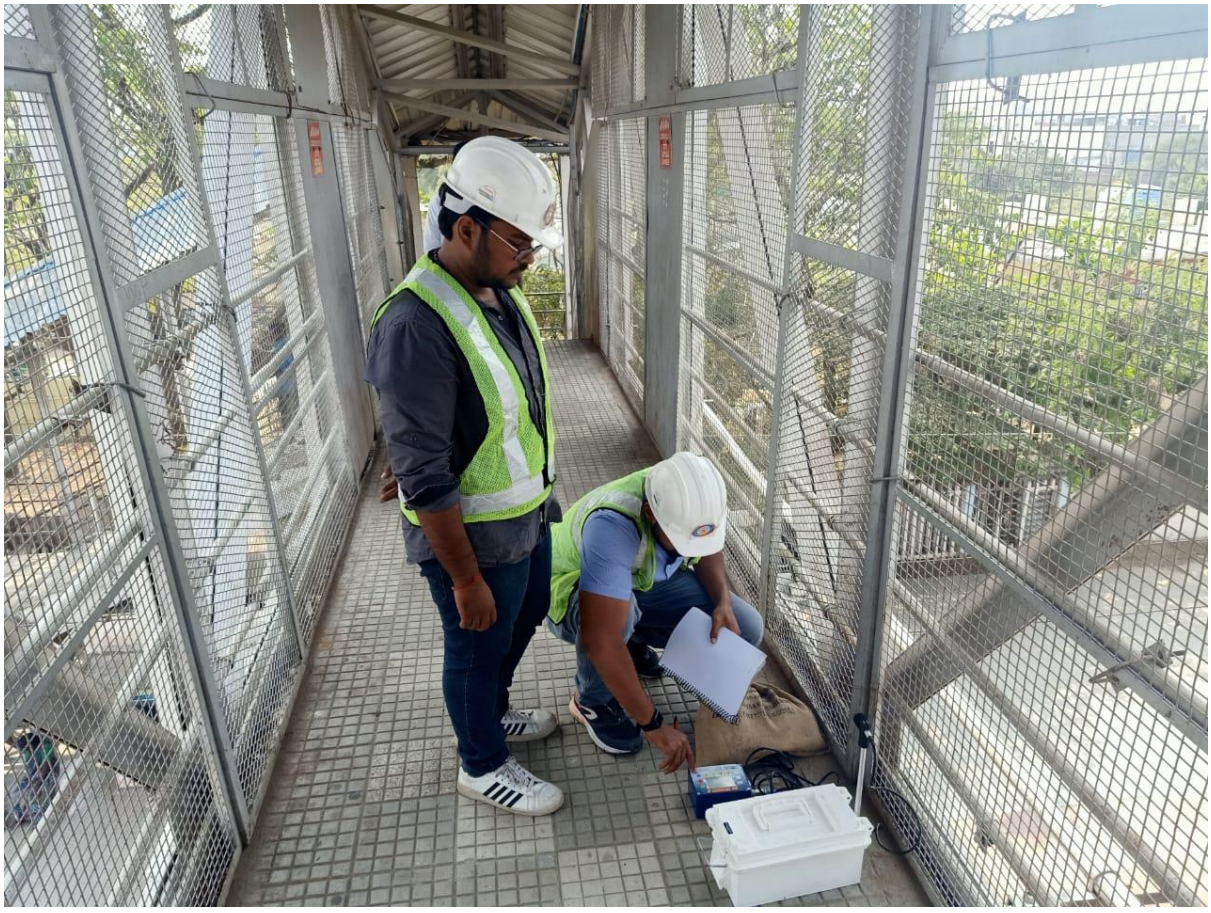


Fig 1.8: Vibration Test at Falaknuma FOB

2. Vibration Analysis

Version 2.0.1.8 (06Mar2019(m))

File: Evt94.ns8

Nomis Seismographs]

Telephone: 205-592-2488

Nomis Seismographs, Inc.

Company: KDMEIPL

Unit #: 21047

03-03-2020 at 11:10 Event # 94

Location: Falaknama FOB

Operator: J.Ram

Notes:

Record Duration: 1.0 sec
Sample Rate: 1024/sec
Last Calibration: 17-12-2019

Distance: N | *Wgt. Per Delay: N* | *Scaled Distance: N*

No GPS Data

Seismic

Gain: 1 | Seismic Trigger: 0.508mm | Vector Sum: 5.79 mm/s @ 9.31 Hz

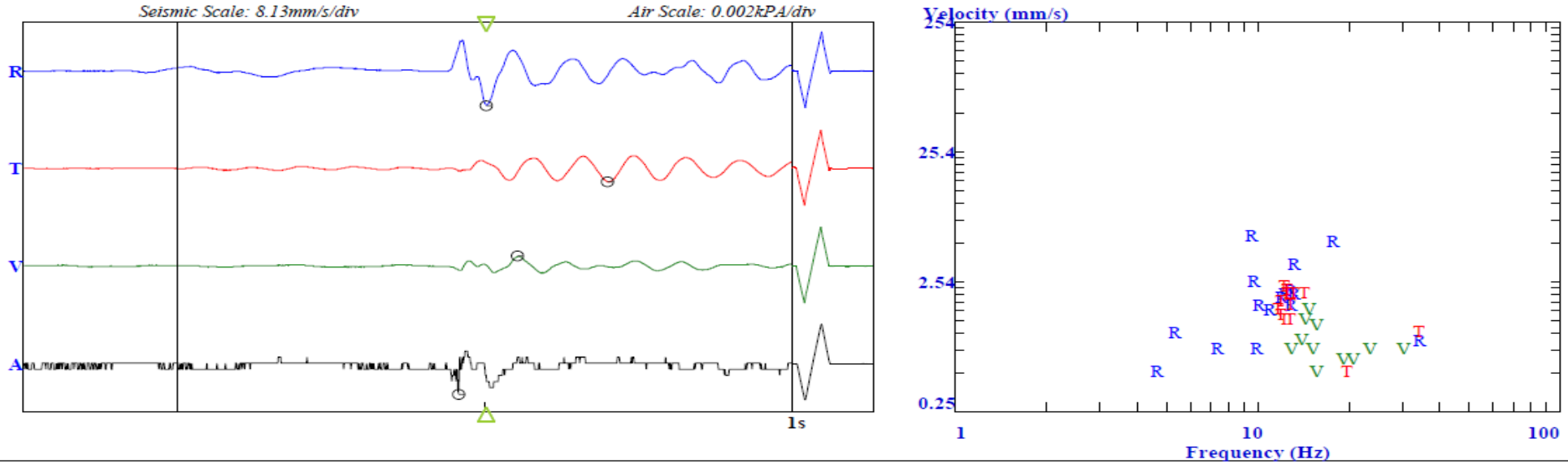
Channel	Radial	Transverse	Vertical
Velocity (mm/s)	5.715	2.286	1.524
Frequency (Hz)	9.4	12.1	14.6
Displacement (mm)	0.0968	0.0301	0.0166
Acceleration (g's)	0.034	0.018	0.014
Trigger >>> Peak	502.0	699.2	552.7

Air

Gain: 1 | Air Trigger: N

Measurement	Value	Trigger >>> Peak	
		457.0	
kPA	0.001249		
dBL	95.9		
Hz	170.6		

Waveform Analysis / Frequency Plot



Ref: Handbook of Machine Foundations by P Srinivasulu and CV Vaidyanathan

The permissible amplitudes of vibration are generally specified during analysis and design of the structure. Below fig. suggested by Richart may be adopted during design or operation of the structure

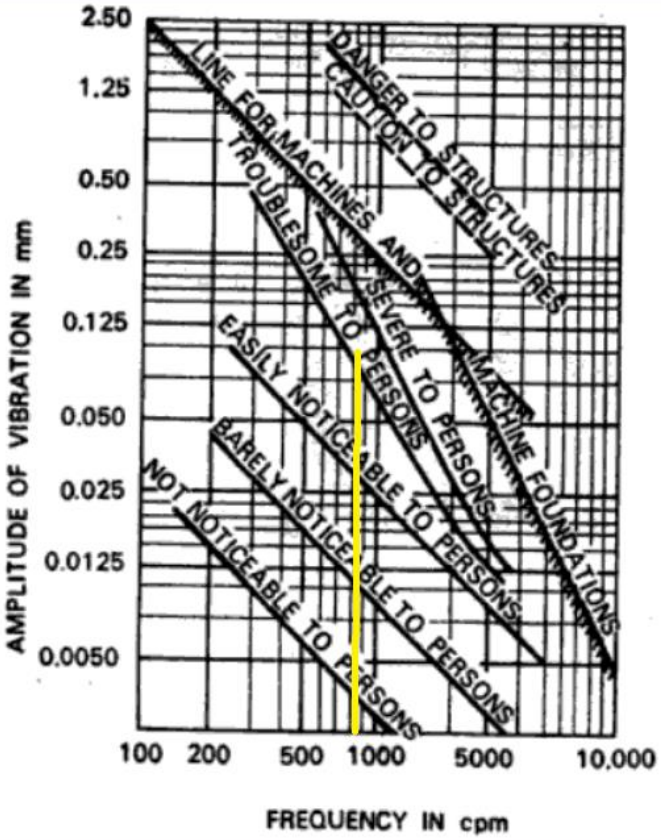


Fig. 1.4: Allowable Limits for Vertical Vibration Amplitudes (After Richart, F. E., Jr. *et al., Vibration of Soils and Foundations*, Prentice-Hall Inc., New Jersey, USA, 1970; with permission).

Based on the vibration analysis carried out the structure is undergoing more vibrations than permissible limit of vibrations. (Frequency observed is 876 cpm and maximum amplitude observed during the test time of complete 3hrs is 0.0968 mm)

3. Repair and Retrofitting Recommendations

3.1 Repairs/Maintenance

a. Cleaning

- **Methodology for cleaning:** Generally foreign material is deposited or accumulated on bridge deck and in several bridge components which can deteriorate the bridge if proper action is not taken, so we support cleaning.
- **Debris removal:** The surface areas of a FOB should be cleaned and washed by brushing with fresh water or using high-pressure water blasting, including Deck slab top, sides along steel concrete joint on either side of deck, Supporting Railing and connecting staircase.

b. Patchwork (spalling, honey comb, voids)

Reinforced cement concrete Slab at Deck level and some precast panels in staircase are observed with exposed rebar in many locations. *(Photographs of the same can be see in **fig 3.4**)*

Methodology for patching: Hand applied Mortar (Patching) repair is performed to restore small areas where sound concrete is damaged by spalling, scaling and/or impact. This method of repair is generally applied using trowel and require minimum or formworks. The patch thickness is limited to a maximum of 100 mm depth of hollow surface. Hand applied Mortar repair is classified into two types considering defective area and surface. Hand applied Mortar

a) **Type - A** is applicable to surfaces without exposed rebar is having defective widths of up to 300mm and depths of up to 50 mm.
b) **Type - B** is for surfaces with exposed rebar, with defective widths between 300 mm and 600 mm, and up to 100 mm depths.

Hand applied Mortar repairs may be composed of Polymer cement mortars or non-shrinkage cement mortars depending on the type of patching, location and extent of damage. To keep good bond ability to the existing concrete.

c. Corrosion:

Based on Steel Surface area effected by corrosion on steel member are classified into three grades as follows

i. **Grade 1**- Mild Corrosion: 10 – 20 % of Surface area is affected with and peeled-off coating film is partially visible.
ii. **Grade 2**- Moderate Corrosion: 20 – 30 % of Surface area is affected with corrosion and coating film is almost visible but partially deteriorated due to corrosion.
iii. **Grade 3**- Severe Corrosion: 30% and more of Surface, area is affected by Corrosion and coating film is almost gone.

Methodology for Corrosion:

- If the paint condition is identified as Grade-1, aluminum paint shall be applied with a similar shade.
- Where condition of paint is evaluated as Grade-2 special anticorrosion paint shall be applied to restrict corrosion from progressing further.

- When the condition of the member is observed to be in Grade – 3, which might have occurred due to environmental conditions or age of the structure. In such cases section loss is calculated by using caliper where it is accessible and UPV at one accessible location. The first step in dealing with corrosion is to measure the section loss in the member. The member may be measured using calipers or other appropriate methods for totally exposed sections.
  a. Section Loss < 15% - Clean the Surface and Apply the anticorrosion protective coat.
  b. Section Loss 15% - 40% Repair the member as per design.
  c. Section Loss > 40% - Replace the member.

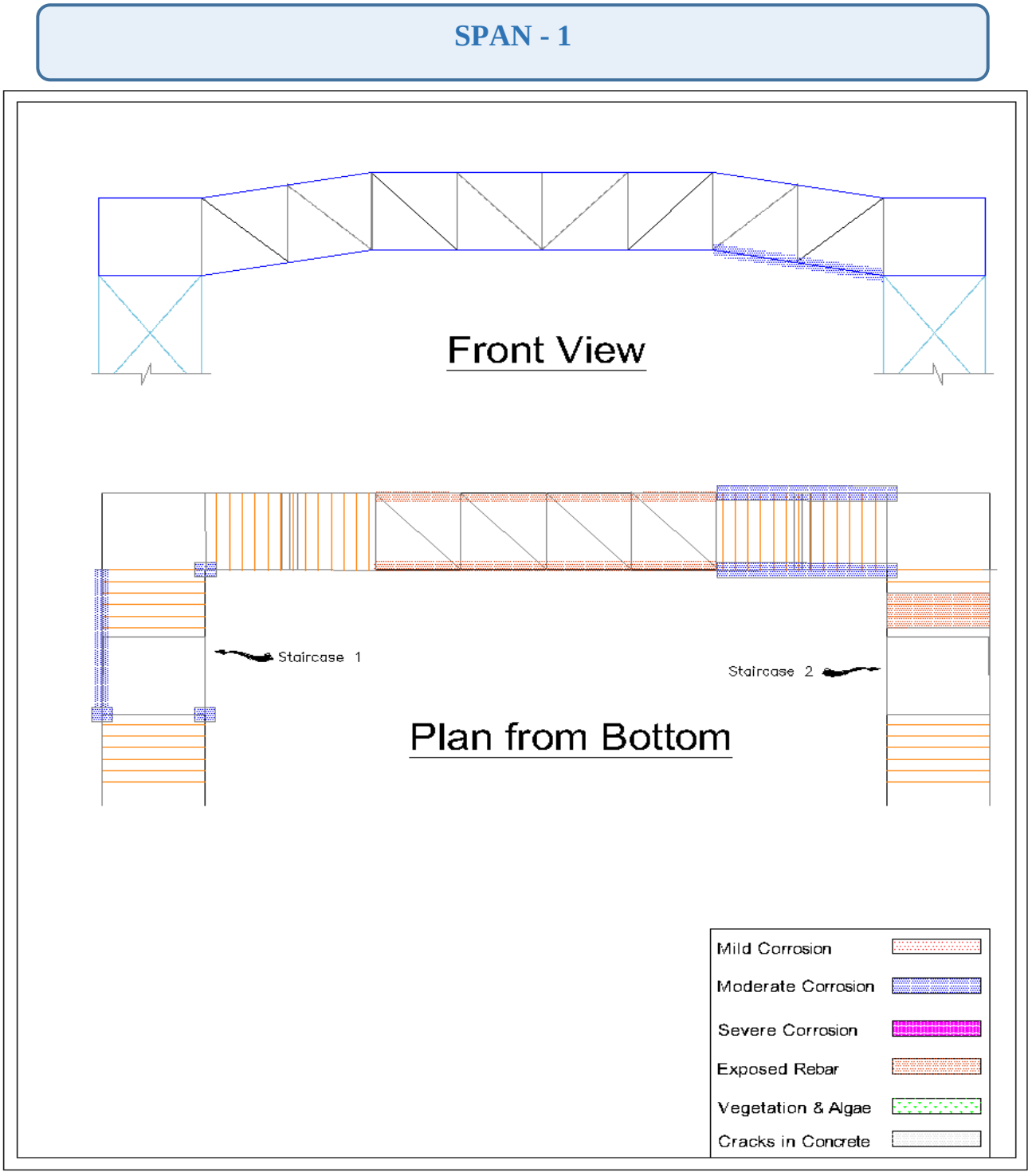


Fig: 3.1 Locations of deteriorations and bottom view of span-1

Span one recommendations

- Structural members are in fair condition, displaying mild corrosion for top chord members, verticals, floor beams, diagonals and bottom chord members, moderate corrosion for stinger beams. Moderate corrosion of joints near stinger beam and column connection (locations are marked in figures below).
- Exposed reinforcement in pathway slab near at deck level. *(Photographs of the same can be see in **fig3.2-3.4**)*

Table 3.1: Grading of corrosion in span 1

Span 1	Mild Corrosion	Moderate Corrosion	Sever Corrosion	Remark
Floor Beams/ Cross Girders	✓			
Bottom Chord		✓		
Top Chord	✓			
Bottom Lateral Bracings	✓			
Diagonals	✓			
Vertical	✓			
Bolts		✓		

Fig: 3.2 Exposed reinforcement in slab at pathway of span-1

Fig: 3.3 Corrosion of bolts near beam column joint at span-1

Fig: 3.4 spalling and exposed reinforcement at staircase-2

SPAN - 2

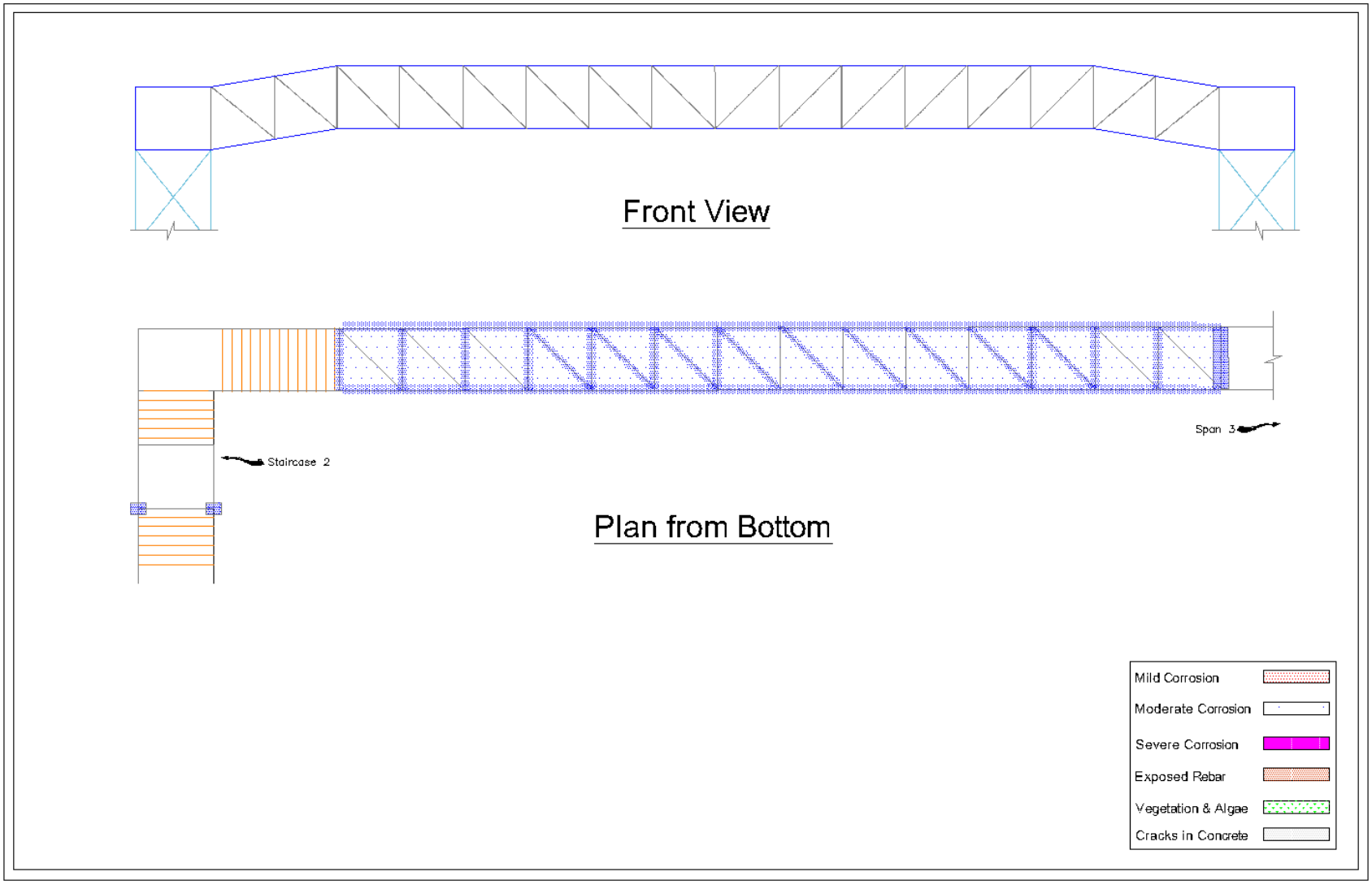


Fig: 3.5 Locations of deteriorations and bottom view of span-2

Span two recommendations

- Structural members are in fair condition, displaying mild corrosion for top chord members, verticals and moderate corrosion for floor beams, diagonals and bottom chord members. Moderate corrosion of joints connecting diagonals to bottom chord. (Locations are marked in figures below).
- Moderate corrosion of sacrificial plate is observed all over the pathway of span-2. *(Photographs of the same can be see in **fig3.6-3.8**)*

Table 3.2: Grading of corrosion in span 2

Span 2	Mild Corrosion	Moderate Corrosion	Sever Corrosion	Remark
Floor Beams/ Cross Girders		✓		
Bottom Chord		✓		
Top Chord	✓			
Bottom Lateral Bracings	✓			
Diagonals		✓		
Vertical		✓		
Bolts		✓		

Fig: 3.6 corrosion of bottom chord and sacrificial plate at span-2

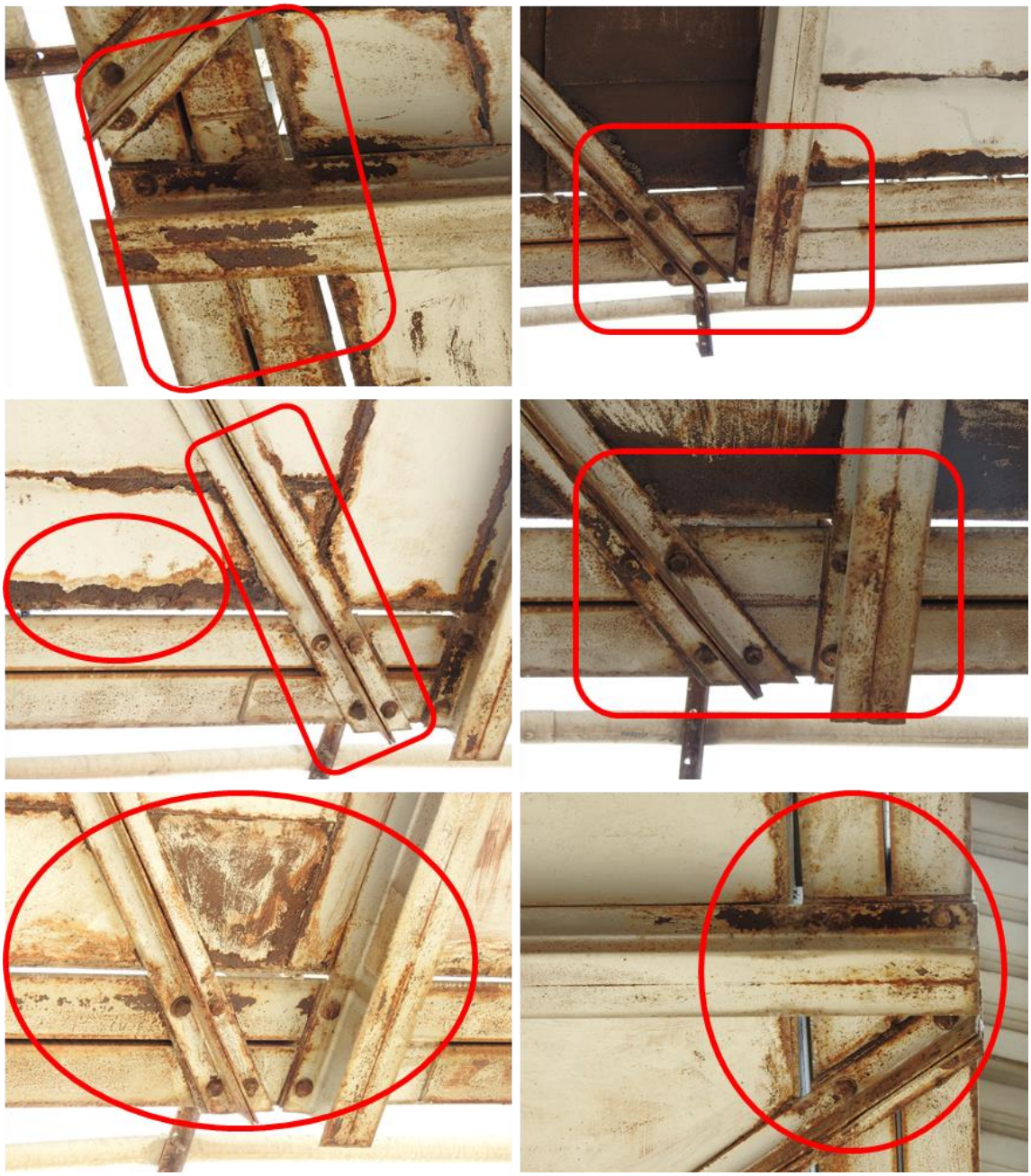


Fig: 3.7 corrosion of diagonals, floor beams at span-2

Fig: 3.8 corrosion of bolts at span 2

SPAN - 3

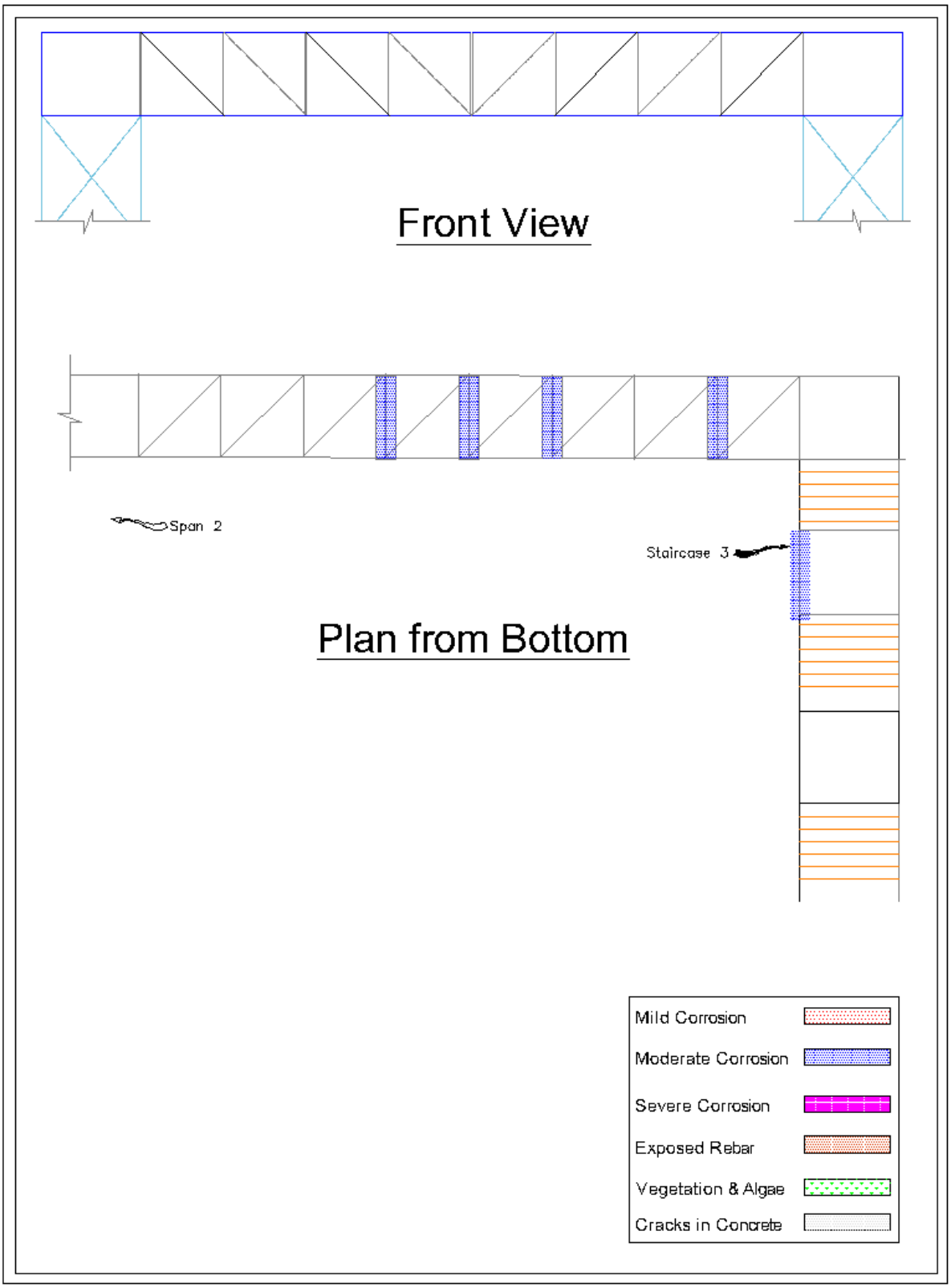


Fig: 3.9 Locations of deteriorations and bottom view of span 3

Span three recommendations

- Structural members are in fair condition, displaying mild corrosion for top chord members, verticals and moderate of bottom chord members, diagonals, and floor beams. (locations are marked in figures below).
- Moderate corrosion of sacrificial plate in span-2 *(Photographs of the same can be see in **fig 3.10-3.11**)*

Table 3.3: Grading of corrosion in span 3

Span 3	Mild Corrosion	Moderate Corrosion	Sever Corrosion	Remark
Floor Beams/ Cross Girders		✓		
Bottom Chord		✓		
Top Chord	✓			
Bottom Lateral Bracings	✓			
Diagonals		✓		
Vertical	✓			
Sacrificial plate		✓		
Bolts		✓		

Fig: 3.10 Corrosion of floor beams, diagonals and bolts at span-3

Fig: 3.11 Corrosion of diagonal and sacrificial plate at span-3

ANNEXURE

Annexure-1a: Repair methods

Defects/Deficiency	**Debris accumulation**
Remedial Measures	**Cleaning**

During the Bridge service life, several components of bridges get unclean due to deposition of foreign materials. Materials that collect on the deck surface flow with the rain water towards the drainage spouts which may choke the outlets and affect drainage. Also, the materials that collect on the deck and carried by the rainwater towards edges of the gangway and accumulate in the gaps or on the steel members. Such debris accumulation can cause acceleration of the corrosion in metal since debris tend to hold water. Also, growth of vegetation such as grass, shrubs, and other plants on the components of bridges is very common. But, they should be thoroughly cleaned of accumulated dust, debris and other foreign materials at regular intervals. This is to prevent deterioration of the bridge, which will therefore preserve the bridge components in their intended conditions resulting in increased service life of the bridge as well as provide safety and comfort to the users.

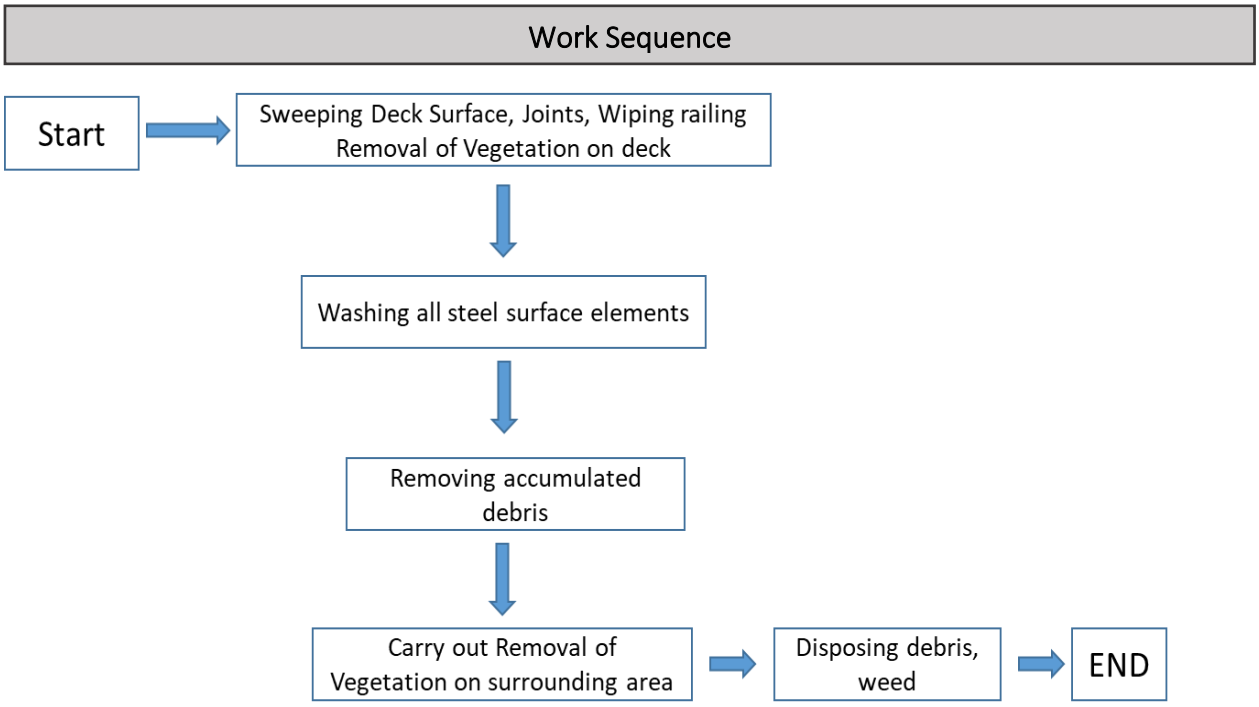


Figure:1.1 Work sequence of removal of vegetation and accumulated debris

1. Material Requirement

Requirement and Specification

Water to be used for cleaning of the bridge components shall be clean and free from unwanted foreign materials such as sediments, salt contaminants, chemicals, grease, oil, rubbish and other substances which are harmful to the bridge components.

All necessary tests shall be performed on water samples at laboratories to be specified by the Engineer, and test certificates shall be provided as required.

2. Work Requirement

1) General

All accumulated foreign materials shall be removed from gangway, its sides and check at beam flanges, gusset plates, truss joints, deck drain systems, and other locations specified and as directed by the Engineer, prior to cleaning with water pressure. Removal shall be performed using hand brooms, hand shovels, scrapers, vacuum cleaners or other methods acceptable to the Engineer. The removed materials shall be collected and disposed at an approved waste area in accordance with railway regulations. At no time shall these materials be allowed to be disposed within the vicinity of the bridge or on the tracks.

2) High pressure water

Salt contaminants, dirt, and other detrimental foreign matters shall be removed without damaging or peeling the paint from any structural steel. If high-pressure water is used, the maximum water pressure shall not be so high that any paint is damaged. The cleaning operation shall be discontinued if the foreign materials have not been easily removed or if cleaning operation is causing damage to existing paint coating. In this situation, the high-pressure water shall be adjusted to clean the surface without damaging the paint coating.

All deck drains or gangways and its accessories shall be flushed with high-pressure water after the accumulated foreign material has been properly removed. Drain systems may have to be disassembled to remove large blockages of accumulated foreign material. Should this be necessary, these shall be returned to their original configuration immediately after cleaning. Drainage systems shall drain properly after cleaning.

The Contractor shall flush out the interior surfaces of all truss members using high-pressure water. This flushing shall continue until such time that clear water is being draining out. The exterior surfaces of all truss members, miscellaneous structural steel connecting the truss members, and floor beam-ends projecting outwardly from the row of exterior stringers shall be thoroughly washed down using high-pressure water.

The Contractor shall obtain approval of the source of water used. They shall use fresh water, which is free of sediments and salt contaminants, and be responsible for all expenses involved in securing the approved water.

3) Power block

During this activity power block is mandatory and has to be carried in the presence of BRI.

Annexure-1b: Repair methods

Defects/Deficiency	**Spalling, Honey comb**
Remedial Measures	**Patching**

Spalling of concrete requiring patching, which is usually caused by corrosion of steel reinforcement. Honeycomb is the effect of inadequate compaction of concrete while being cast. Patching is a temporary repair measure unless all the chloride-contaminated concrete is removed before the concrete deck or stair case is patched. If only the spalled and delaminated concrete is removed, the corrosion process continues and additional spalling can soon appear.

Studies of deck-sealing practice suggest that while sealing or overlaying of chloride contaminated concrete cannot stop the process of corrosion and deterioration of steel and concrete, it can slow the process, which may be acceptable depending upon the schedule of future major rehabilitation. Further, moving passengers increases the impact

Work Sequence

loading, which can result in increased damage**.**

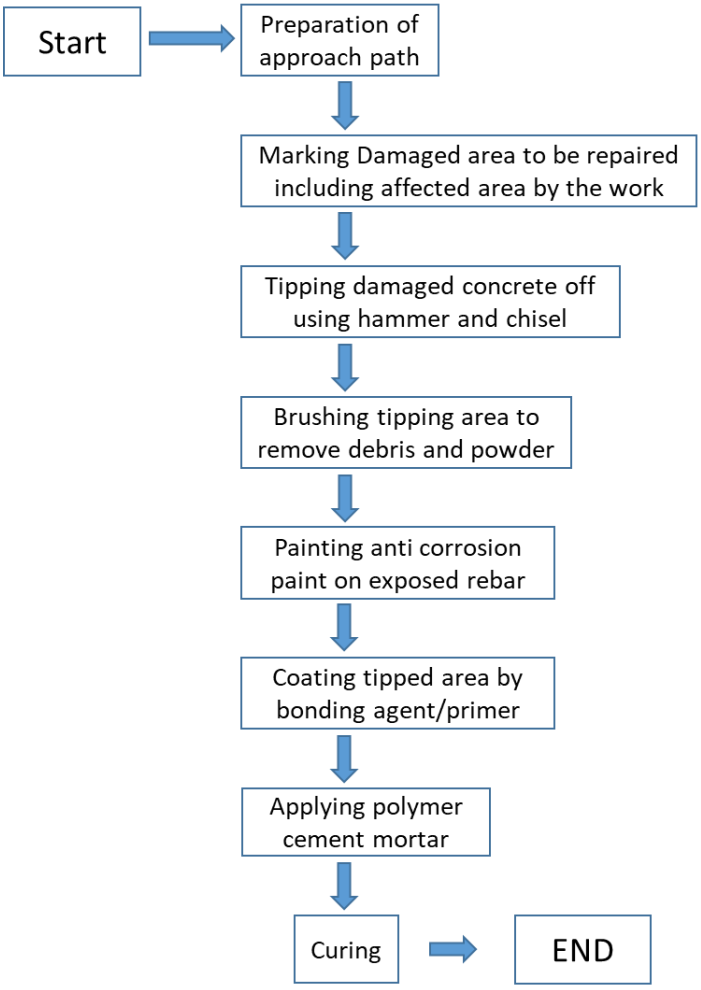


Figure: 1.2 Work sequence of Epoxy Coating

Required equipment / Tool and material

Material List –

- Polymer Cement Mortar
- Portland Cement
- Epoxy Bonding
- Zinc rich primer

Tool/Equipment List –

- Chisel
- Portable Generator
- Wire Brush

Requirement and Specification

Material Specifications

1) Polymer Cement

Polymer cement mortar shall conform to the requirements of the specifications shown in Table 1.1 or equivalent ASTM Specifications.

Table:1.1 Specification of Polymer Cement for Patching

Property	Test Method	Specification
Initial setting time	-	above 60 minutes
Shrinkage	ASTM D2566	below 0.05 %
Thermal expansion	ASTM C531	$2.0x10^{-5}$ mm/mm/ ^{o} C
Slant shear bond to concrete	ASTM C882	Concrete failure above 15 N/mm^2
Compressive strength	ASTM D695M	above 20 N/mm^2

2) Epoxy bonding agent

The epoxy-bonding agent to concrete surface shall conform to the requirements of the specification indicated in Table 1.2 (Anti-corrosion zinc rich primer shall be applied to exposed rebar).

Table 1.2 Specification of Epoxy Bonding Agent to Concrete Surface

Property	Test Method	Specification
Compressive strength	ASTM D695M	70 N/mm^2
Flexural strength	ASTM D790M	40 N/mm^2
Tensile strength	ASTM D638M	30 N/mm^2
Tensile shear bond to steel	ASTM 1002	15 N/mm^2
Slant shear bond to mortar	ASTM C882	15 N/mm^2
Bond Strength of Cured Concrete to Fresh Concrete	ASTM D7274	15 N/mm^2

3) **Zinc Rich Primer**: The zinc rich primer to rebar shall be in accordance with the requirements of the specifications in Table 1.3

Table 1.3 Specification of Zinc Rich Primer for Rebar

Property	Test Method	Units	Specification
Gloss @ 60°Angle	ASTM D 523	-	Flat
Adhesion	ASTM D 3359	-	Minimum 3A
Salt Spray Resistance	ASTM D3-37	-	Excellent
%Zinc by Weight in Dried Film Test		%	87.5±2

Work requirement

1) **General**

Patching repair works using Portland cement mortar shall be carried out in accordance with provisions of relevant standards and manufacturer's specifications. Patching, as a minor repair work, should be carried out using an appropriate means to access the repair area, before the defect worsens. Patching repair work method using polymer cement mortar shall be carried out as follows:

2) **Marking of patching area**

Evaluate surface area to be patched using hammer for hollow sounding delaminated area (or by using instruments to detect unsound concrete). Mark the area to be patch-repaired with paint or marker. Ensure complete coverage of the damage.

3) **Tipping damaged concrete off**

Using a small sledge hammer and chisel, remove all damaged concrete at the edges and corners of area to be repaired. Use a wire brush to remove loose debris. Care should be taken to ensure that no reinforcement is damaged. **Surface** shall be cut to expose the reinforcement and to reach the sound concrete substrate, without breaking the concrete behind the reinforcement. If rebar is exposed, anticorrosion agent coating should be applied on the bar surface prior to patching. All works shall be subjected to the approval of the designated Engineer. **Patch areas** that are within 600 mm of each other should be combined into a single large patch. If necessary, provide formwork around the damaged concrete to straighten the edges of the damaged section.

4) **Coating tipping area**

Concrete surfaces to receive repair mortar shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss. The clean and dust free surface shall then be coated by a bonding primer. Care shall be taken to ensure that vibration associated with the repair works does not cause delamination of existing adjacent plaster or concrete.

5) **Applying bonding agent and anti-corrosion paint**

Apply bonding agent to the damaged area in order for the patch material to adhere. Additionally, concrete nails/bids may be set to reinforce the repair. If rebar is

exposed, anticorrosion coating should be applied on the bar surface prior to patching.

6) **Patching mortal**

Prepare the mortar mix in a bucket using equipment approved by the Engineer. Use a trowel to spread fresh mortar over the area, covering the concrete nails driven halfway in the old concrete. Smoothen and level the mortar with a trowel. Polymer cement mortar is suitable for both vertical and horizontal surface applications, with a thin coating of up to 15 mm.

7) **Finishing**

As may be required, the mortar surface can be smoothened using a trowel or broom finished. The texture of the finish of the final repair mortar layer shall match the finish of the existing surface. The repair mortar application shall be built up to the original surface profile in layers not exceeding 20 mm with the final layer not exceeding 15 mm, unless otherwise recommended by the manufacturer and approved by the Engineer. The Engineer may approve repair mortar application thickness of up to 50 mm for lightweight mortars, provided the mortar manufacturer furnishes technical data to justify a layer thickness of greater than 20 mm.

8) **Curing**

All types of concrete repair with repair mortar need thorough and continuous curing to develop strength and impermeability. Curing also minimizes drying shrinkage while bond strength is developing. Curing of the repair mortar shall be in accordance with the manufacturer's instructions related to the polymer modified additive. Where curing agents are specified by the manufacturer, they shall be applied immediately after the surfaces have been scarified for the next repair mortar layer, or troweled to a finish.

Annexure-1c: Repair methods

Defects/Deficiency	**Minor corrosion of steel element**
Remedial Measures	**Touchup painting**

Due to thin paint coverage on steel surfaces or formation of pin-holes in paint, the steel surface may get exposed to atmosphere resulting in initiation of corrosion. Touch up painting at the early stages prevents progress of corrosion. Work included in this section comprises field touchup painting on steel members at localized areas including surface preparation and other associated works. This section covers only painting on relatively small affected areas which can be carried out with the use of small power tools / hand tools. Painting of larger areas requiring sand blast cleaning should be carried out in accordance with the specifications covered under major repairs.

Work Sequence

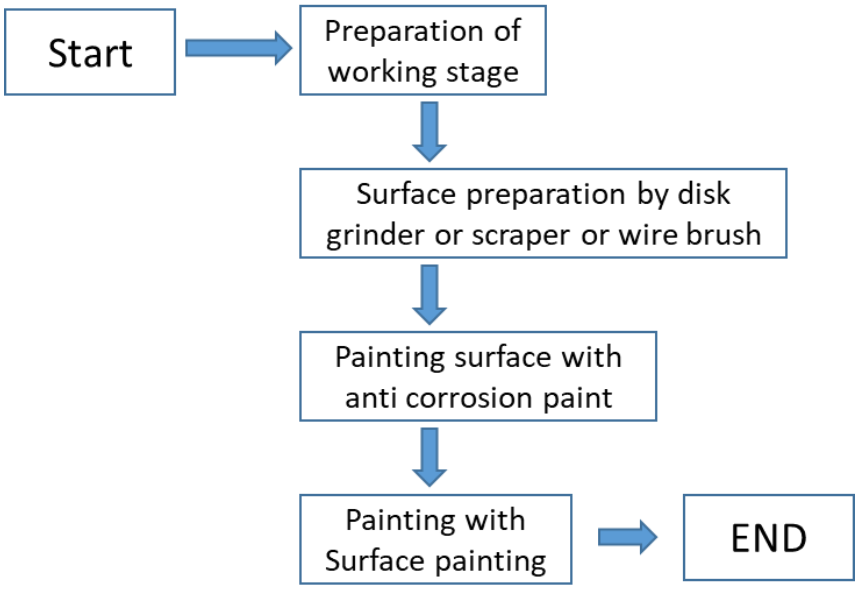


Figure: 1.2 Work sequence of Painting with anti-corrosion paint

i. Materials

Required Equipment / Tool and Material

- Aluminum paint / special anticorrosion paint as required
- Thinner
- Epoxy resin filler

ii. Tools/Equipment

- Scaffolding, inspection vehicle
- Portable generator (3 kVA)
- High pressure water blaster (8.0Mpa, 10.0 liters/min.)
- Sandpaper, portable power disk grinder
- Paint brush, roller

i. Material

Aluminum paint material shall be in accordance with the manufacturer's specifications and as approved by the Engineer.

For special anticorrosion paint, the materials shall satisfy the test requirements indicated in the relevant ASTM specifications as follows:

Table 1.4 Specification of Aluminum paint

Test	Test reference	Specification
Adhesive test	ASTM D7234	7days 1.0 N/mm^2, 28days 1.5 N/mm^2
Elongation	ASTM C190	7days 0.40 %, 28days 0.40 %
Saltwater test	ASTM D6943	No defection

ii. Work requirement

1) **Scaffolding**

Scaffolding shall be installed for close access to the corrosion-affected surfaces of the steel members to be repaired. Standard scaffoldings may be used however mobile scaffolding/inspection vehicle may be found suitable as it allows for free movement in most cases and provides access with convenience to various parts of a bridge.

2) **Preparation of Steel Surface**

Surface preparation shall conform to the paint manufacturer's specifications. Hand or power tools shall be applied for cleaning the surface. Groves and ridges formed on the affected surface shall be removed with power grinder. Where appropriate, as an alternative, epoxy resin filler may be used to fill the surface to a smooth and even finish. Where depth of roughness is within 0.5 mm, paint adequacy and durability can be achieved without application of multiple coats of surface leveling paints. Thickness of each coat shall not exceed the limiting value recommended in the paint manufacturer's specifications. Application of aluminum paint material shall be in accordance with the manufacturer's specifications and as approved by the Engineer.

3) **Application of Touchup Paint**

Paint shall be applied with brush or roller. The paint shall be applied in such a way that a uniform and smooth surface is formed without wrinkles, runs, streaks, sags, or any other defects. Components of the paint shall be mixed in accordance with the manufacturer's instructions and the application shall also conform to such instructions and specifications. Paint shall be applied immediately after the surface preparation, preferably within 4 hours. Total dry film thickness for special anticorrosive paint shall be 500 µm (equivalent 1.5kg/m^2) consisting of two layers of coating as follows: -
Layer-1: 250 µm and Layer-2: 250 µm
Anticorrosion paint shall be applied in accordance with the stipulations of paint manufacturer's specifications. Minimum total film thickness for aluminum paint shall be not less than 125 µm. Roval paint is recommended for galvanized member touchup

painting. Total dry film thickness for Roval paint shall be 80 m (equivalent 0.5kg/m2) consisting of two layers of coating as follows: -

Layer-1: 40 µm and Layer-2: 40 µm

Roval paint shall be applied in accordance with the stipulations of paint manufacturer's specifications.

Annexure-1d: Repair methods

Defects/Deficiency	Spalling, Abnormal Anchorage
Remedial Measures	Hand applied Mortar (A) & (B)

Hand applied Mortar (Patching) repair is performed to restore small areas where sound concrete is damaged by spalling, scaling and/or impact. This method of repair is generally applied using trowel and require minimum or formworks. The patch thickness is limited to a maximum of 100 mm depth of hollow surface.

Hand applied Mortar repair is classified into two types considering defective area and surface. Hand applied Mortar (A) is for defects without exposed rebars while Hand applied Mortar (B) is applied to surfaces with exposed rebars. Hand applied Mortar repairs may be composed of Polymer cement mortars or non-shrinkage cement mortars depending on the type of patching, location and extent of damage.

Work Sequence

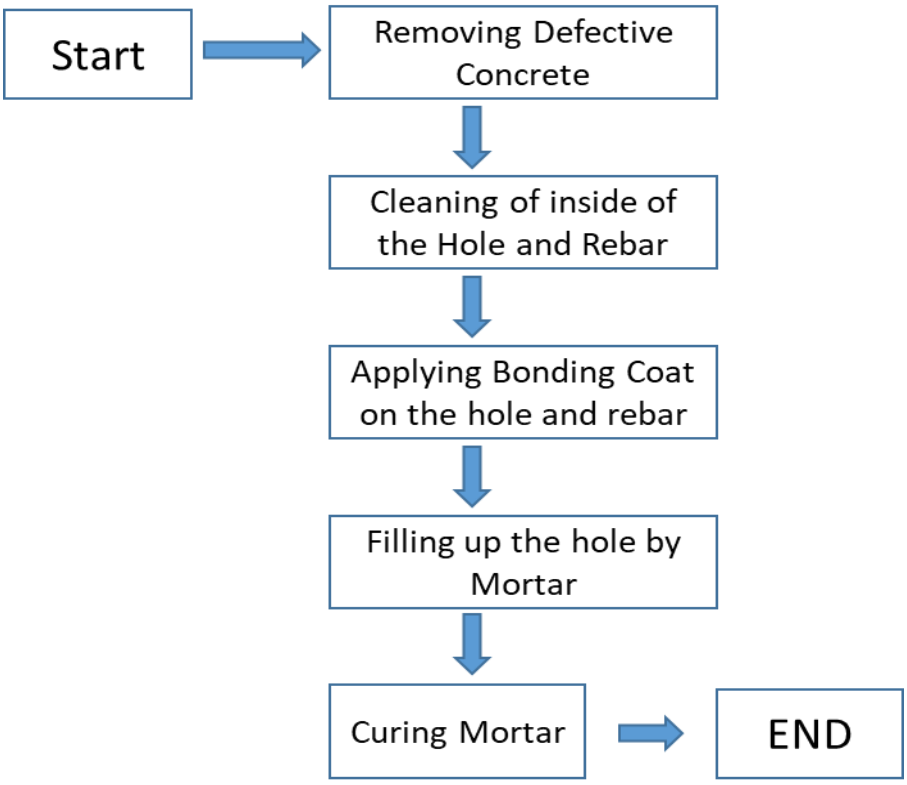


Figure: 1.3 Work sequence of Hand applied mortar

Required tools / Equipment and Material

1) Tools/Equipment

For Hand applied Mortar (A) and Hand applied Mortar (B): -

- Power Disc Grinder
- Portable Generator
- Brush

2) Material

Hand applied Mortar (A): -

- Polymer Cement
- Epoxy Bonding Coat

Hand applied Mortar (B) –

- Polymer Cement
- Epoxy Bonding Coat
- Zinc Rich Primer

Requirements and Specifications

i. **Material**

1) Polymer Cement

Polymer cement mortar shall conform to the requirements of the specifications shown in Table 1.5 or equivalent ASTM Specifications.

Table 1.5 Specifications of Polymer Cement

Property	Test Method	Units	Specification
Thermal Expansion	ASTM C531	mm/mm^{o}C	2.0 x 10^{-5}
Slant Shear Bond to Concrete	ASTM C882	N/mm^2	1.5 /above
Compressive Strength (7days x 20)^{o}C	ASTM C579	N/mm^2	20 /above

2) Corrosion Protective Coating

The Protective Coating of rebar shall conform to the requirements of the specifications in Table 1.6.

Table 1.6 Specifications of Corrosion Protective Coating to Rebar

Property	Test Method	Units	Specification
Compressive Strength	ASTM D695M	N/mm^2	75
Flexural Strength	ASTM D790M	N/mm^2	40
Tensile Strength	ASTM D638M	N/mm^2	30
Tensile Shear Bond to Steel	ASTM D1002	N/mm^2	10
Slant Shear Bond to Mortar	ASTM C882	N/mm^2	15

3) Zinc Rich Primer

The zinc rich primer to rebar shall be in accordance with the requirements of the specifications in Table 1.7.

Table 1.7 Specifications of Zinc Rich Primer to Rebar

Property	Test Method	Units	Specification
Gloss @ 60 Angle	ASTM D 523	-	Flat
Adhesion	ASTM D 3359	-	Minimum 3A
Salt Spray Resistance	ASTM D3-37	-	Excellent
%Zinc by Weight in Dried Film Test	-	%	87.5 ±2

ii. Work requirement

The Contractor shall submit the Methodology (Procedures) to the Engineer-in-Charge for his review and approval before commencement of the work.

1) Remove of defective concrete

Remove all defective, unsound and contaminated concrete and prepare the edges for the patch area based on the visual inspection. If local corrosion in reinforcement with section loss is found, which would require additional bars, remove only the damaged concrete including the length needed to bond the new reinforcement.

Concrete within marked out areas shall be removed using light mechanical breakers or hammer and chisel, the exposed reinforcement shall be cut and the sound of concrete substrate shall be determined to the satisfaction of the Engineer-in-Charge, without breaking out behind the reinforcement.

2) Cleaning of Concrete and Rebar

Remove loose particles and dust using high pressure water or vacuum cleaner. Concrete surfaces to be bonded must be free from dirt, oil, grease, asphalt etc. Corrosion must be removed before placing the new concrete. If deterioration is due to chloride contamination or if the reinforcement is covered with loose corrosion elements having pits, use water abrasive blasting until all the rust is removed

The concrete surfaces selected for repair shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss, and then coated by bonding primer. Utmost care shall be taken to ensure that vibration generated during the process does not cause delamination of adjacent render or concrete.

3) Additional concrete breakout

Where the breakout indicates that the exposed reinforcement is further corroded or the surrounding concrete is not sound, an enlarged area shall be agreed to be broken to the satisfaction of the Engineer-in-Charge. The Contractor shall test the concrete for extent of carbonation at the reinforcement depth. The depth of breakout in clearly defined areas can be increased based on written instructions from the Engineer-in-Charge, in order to remove all carbonated concrete. The additional concrete breakout shall not extend more than 20 mm behind the bottom layer main reinforcement. During breakout, utmost care shall be undertaken to minimize damage to the existing reinforcement.

4) Additional or replacement rebar

The Contractor shall report to the Engineer any rebar which has 10% or more section loss as a result of corrosion. Additional or replacement rebar shall be provided as instructed by the Engineer. Replacement rebar shall be cleaned to the same standard as the existing rebar. This replacement rebar shall be lapped on the side of the existing bars and be spot welded on one side. It shall be fixed along its length at suitable intervals to prevent sagging. The corroded rebars shall be cleaned and applied with zinc rich primer to prevent further corrosion. The Contractor shall obtain Engineer's approval for the rebar coating prior to proceeding with repair mortar application.

5) Bonding coating to concrete and rebar

Epoxy bonding coats are applied to dry and clean concrete surfaces in order to bond firmly. Specially formulated resins are also available for damp surfaces. Apply the selected bonding coat to steel bars as shown in the photo; with a brush working vigorously to ensure that they are evenly covered all around.

6) Filling up repair material

The mortar should be placed in layers of about 20 mm thickness. Compact each layer thoroughly over the entire surface using a wooden trowel or hammer. Generally, there should be no time delays between the placing and compacting of layers. The patching to the surrounding concrete is performed using a form material, and then hammered using a mallet, wood float or steel trowel. The mortar shall be mixed using equipment (normally a force action mixer) approved by the Engineer. The mixing liquid shall be added to the dry components and thoroughly mixed to achieve a uniform consistency, unless otherwise approved by the Engineer. The mortar shall then be applied to the bonding agent using hand packing and trowel to the satisfaction of the Engineer-in-Charge. The textured finish of the final repair mortar layer shall match the finish on the existing interior surface. The repair mortar application shall be built up to the original surface profile in layers not exceeding 20 mm and the final layer shall not exceed 15 mm, unless otherwise recommended by the manufacturer and approved by the Engineer-in-Charge. The Engineer may approve repair mortar application thickness of up to 50 mm for lightweight mortars, provided the repair mortar manufacturer can furnish a technical data to justify a layer thickness of greater than 20 mm.

7) Curing

All types of cement repairs need thorough and continuous curing to develop strength and impermeability, and to minimize drying shrinkage while bond strength is developing. Curing of the repair mortar shall be in accordance with the polymer modified additive manufacturer's instructions. Where curing agents are specified by the manufacturer, they shall be applied immediately after the surfaces have been scarified for the next repair mortar layer or troweled to a finish.

Summary

- **Visual inspection of Falaknuma railway station fob has been conducted on 3rd March 2020, following observations were made**
    i. Spalling and reinforcement exposed observed in floor slab at slab and steel joint along the 1st span.
    ii. Corrosion is observed at joints connecting Floor beams and bottom main chord member and slight rusting is observed at bottom chord member along the length of FOB.
    iii. Slight corrosion is observed at stringer beams and concrete joint.

- **Based on visual inspections and its interpretations following recommendations were made:**

a) Cleaning of debris immediately to avoid deterioration of concrete and steel members.
b) Anti-corrosion treatment for Grade-1 and Grade-2 highlighted corrosive members for floor beams and diagonals in span-2 and span-3.
c) Replacement of damaged or severely corroded bolts connecting diagonals to bottom chord member in span 2 and span 3.
d) Replacement of bolts in stinger beam and column joint at staircase -1.
e) Patch work for exposed rebar in span -1 along the pathway of fob.

Note: Provided step wise procedure for each recommendation are detailed out in annexure based on requirements