Evaluation of Coating Degradation on Truss of Maubin Bridge, Myanmar

Khin Khin Thaw

***Abstract*—**Paper presents the existing coating deterioration on truss of Maubin Bridge, Ayeyarwady Region, Myanmar. The purpose of this study is to conduct a preliminary assessment of the bridge truss coating for pilot repainting. The assessment includes evaluation of degradation of coating, cross-cut test and measuring coating thickness. According to evaluation of degradation of coating, maximum degree of rusting is Ri 3 and the maximum degree of flaking is flaking without preferential direction (panels of area 1dm^2 to 2dm^2): Quantity (density) 3. And then, cross-cut test results showed classification 5 for outer face of outside flange and classification 3 for outer face of inside flange of truss diagonal member. The existing coating thickness is in the range of 160µm - 450µm for all diagonals of truss.

***Keywords*—**Cross-cut, coating deterioration, coating thickness, evaluation, repainting.

I. Introduction

Corrosion problems of steel bridges due to coating deterioration are much severe in Myanmar, one of tropical countries with vast coastline. Therefore, periodic maintenance of the coating is the major concerns for anticorrosion. Most of the bridges in Myanmar were constructed over last two decades and used two coats system.

The environmental conditions at bridge site can raise the corrosive attack of steel and significantly reduce the functional life of steel bridge components. Some atmospherically exposed steel in bridges is subjected to very slight environments, whereas other steel is exposed to very extreme environments and has a higher risk of corroding. The application of anticorrosive coatings is one of the most common ways of mitigating corrosion of atmospherically exposed steel in structures. This corrosion mitigation technique provides additional service life to the steel, but periodic maintenance of the coatings is required given its exposure to the surrounding environment.

Bridge coating systems can be complex. The composition of coating liquids can differ depending on the type of solvent, resin, and pigment used. Further, bridge coating systems are typically composed of different layers, each serving a particular function. Therefore, care must be taken during the selection of the appropriate coating for a new structure. With existing structures, however, determining the best approach for maintaining the coating system and protecting the structural steel becomes even more complex. First, the condition of the existing coating must be evaluated, including factors such as coating type, percentage of coating failure on the structure, adherence of the existing coating, coating thickness, and coating age. It is also important to assess the condition of the steel substrate. Depending on when the structure was put into service, the steel may contain mill scale or have an existing profile.

Based on the evaluation, a determination is made as to whether the structure should be spot coated (i.e., localized or isolated coating repair); zone coated (i.e., selective coating of a steel area that requires additional protection from corrosion); over coated (i.e., application of a new coating over an existing coated surface); or recoated (i.e., removal of old coating and application of new coating) [1].

II. Evaluation Procedures

A. Location of Maubin Bridge and test regions

Maubin Bridge was opened on 10th February, 1998 and constructed across Myitmaka River in a region of soft soil within the Ayeyarwady delta belt, Ayeyarwady Region, Myanmar. It is located between the latitude 16 ° 44′ 27″ N and the longitudes 95 ° 39′ 55″ E. The type of the truss is Warren Type and the total length of the bridge is 2604ft. The original coating system is two coats system. The location of Maubin Bridge is shown in Fig. 1[2] [3].

Fig. 1 Location of Maubin Bridge

In Fig. 2a and Fig. 2b, the red diagonals indicate evaluation of degradation of coating diagonals (D6 and D7) and coating

Khin Khin Thaw, Department of Civil Engineering, Yangon Technological University, Myanmar,

thickness measuring diagonals (D1-D5). The blue diagonals (TD1-TD5) indicate pilot tested region for repainting. The sketch of the evaluation faces of diagonal members are described in Fig. 2c. Detailed coating thickness measured area in test region is shown in Fig. 3.

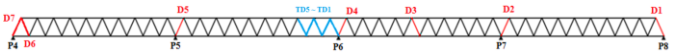


Fig. 2a Sketch of upstream side truss diagonal members

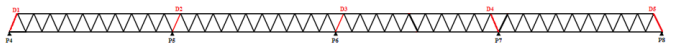


Fig. 2b Sketch of downstream side truss diagonal members

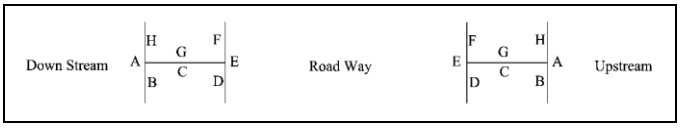


Fig. 2c Sketch of faces of diagonal members

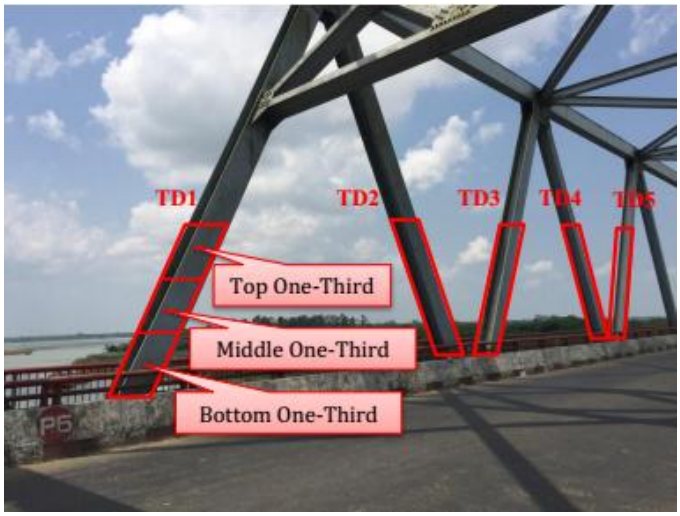


Fig. 3 Coating thickness measured area in test regions

B. Evaluation of Degradation of Existing Coating [ISO 4628:2003]

ISO 4628 defines a system for designating the quantity and size of defects and the intensity of changes in appearance of coatings. This system is intended to be used, in particular, for defects caused by ageing and weathering, and for uniform changes such as colour changes, for example yellowing. ISO 4628 also provides pictorial standards or other means of evaluating particular types of defect.

A uniform convention has been adopted for designating the quantity and size of defects and the intensity of changes by means of ratings on a numerical scale ranging from 0 to 5, 0 denoting no defects or changes, and 5 denoting defects or changes so severe that further discrimination is not reasonable. The other ratings, corresponding to the numbers 1, 2, 3 and 4, are so defined that they give optimum discrimination over the whole range of the scale.

The degrees of assessment in this designation are blistering, rusting, cracking, flaking, chalking by tape method, chalking by velvet method, delamination and corrosion around a scribe and filiform corrosion [4].

C. Cross-Cut Test [ISO 2409:2007]

This International Standard describes a test method for assessing the resistance of paint coatings to separation from substrates when a right-angle lattice pattern is cut into the coating, penetrating through to the substrate. The property measured by this empirical test procedure depends, among other factors, on the adhesion of the coating to either the preceding coat or the substrate.

The cutting is performed manually by the following specified procedure. The cutting tool with the blade is held normal to the test panel surface. With uniform pressure on the cutting tool and using the appropriate spacing guide, the agreed number of cuts is made in the coating at a uniform cutting rate. All the cuts shall penetrate to the substrate surface. This operation is repeated, making further parallel cuts of equal number, crossing the original cuts at 90° to them so that a lattice pattern is formed. Brush the panel lightly with the soft brush several times backwards and several times forwards along each of the diagonals of the lattice pattern.

For steel substrates, additionally adhesive tape is applied. For the beginning a new series of tests, two complete laps are removed from a reel of the adhesive tape and are discarded. An additional length is removed at a steady rate and a piece is cut approximately 75 mm long. The center of the tape is placed over the lattice in a direction parallel to one set of cuts and the tape is smooth into place over the area of the lattice and for a distance of at least 20 mm beyond with a finger. To ensure good contact with the coating, the tape is rubbed firmly with a fingertip or fingernail. Within 5 min of applying the tape, the tape is removed by grasping the free end and pulling it off steadily in 0.5 s to 1.0 s at an angle which is as close as possible to 60°. In evaluation and expression of results, there is a six-step classification. The first three steps are satisfactory for general purposes and are to be used when a pass/fail assessment is required [5].

D. Coating Thickness [ISO 2808:2007]

The ultrasonic thickness gauge has an ultrasonic transmitter and a receiver for determining the film thickness from the sound propagation time. A couplant is applied to the coating whose thickness is to be measured. The instrument with the probe face flat is placed on the coating. The instrument is operated and the results are determined in accordance with the manufacturer's instructions [6].

III. Investigation Results

The evaluation and tests were carried out on both upstream and downstream diagonal members of truss on 10th March, 2018.

A. Evaluation of Degradation of Existing Coating on Truss

The evaluation of degradation of existing coating on truss had been done by ISO 4628-3:2003(E). This evaluation was carried out on upstream diagonals D7 and D6, and the results

are shown in Table I.

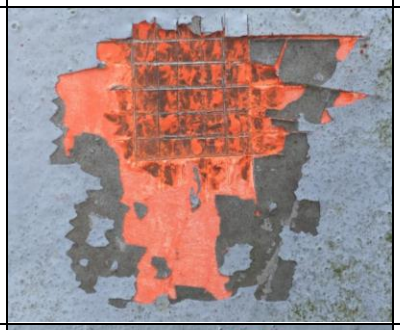
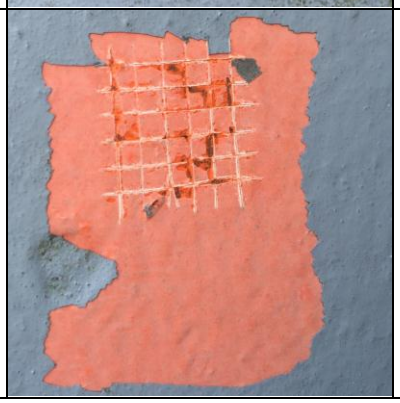
TABLE I
EVALUATION OF DEGRADATION OF COATING ON D7 AND D6 (UPSTREAM)

No.	Diagonal No.	Face	Evaluation of Degradation [ISO 4628-3:2003(E)]			
			Blistering	*Rusting*	*Cracking*	*Flaking*
1.	D7	A	5(S3)	Ri 0 ~ Ri 1	-	WPD: 1
		B	4(S3)	Ri 0 ~ Ri 1	-	-
		C	4(S3)	Ri 0 ~ Ri 1	-	WPD: 1
		D	4(S3)	Ri 0 ~ Ri 1	-	-
		E	4(S3)	Ri 0 ~ Ri 1	Switch Cracking: ASTM 2 – TNO 8	WPD: 1
		F	2(S3)	-	-	-
		G	2(S3)	-	-	-
		H	2(S3)	-	-	-
2.	D6	A	4(S3)	Ri 0 ~ Ri 1	-	WPD: 3
		B	3(S3)	-	-	-
		C	3(S3)	-	Shrinkage Cracking: ASTM 4 – TNO 6	PD: 2
		D	3(S3)	-	-	-
		E	5(S2)	-	WPD: 1	-
		F	4(S3)	Ri 2 ~ Ri 3	-	WPD: 1
		G	4(S3)	-	-	-
		H	4(S3)	-	-	-

B. Cross-Cut Test on Test Region - TD4

Cross-cut tests were done on Face A and Face D of test diagonal TD4. The existing coating thickness is in the range of 160µm - 450µm and the type of the substrate is steel. Therefore, the cuts are spaced 3mm in each direction and the number of cuts in each direction of the lattice pattern is six. The classifications of test results are shown in Table II.

TABLE II
CLASSIFICATION OF CROSS-CUT TEST RESULTS (IS0 2409:2007)

Diagonal No.	Test Face	Appearance of surface of cross-cut area	Classification
TD4	A		5
	D		3

C. Existing Coating Thickness on Truss

The existing coating thickness was measured on both sides of truss diagonals (D1-D5) and test diagonals (TD1-TD5) by coating thickness gauge [PosiTector 6000]. Coating thicknesses were measured 5 points on each face of the diagonals (D1-D5) and took the average value as a result. For test diagonals (TD1-TD5), there were measured 15 points on each face and also took the average value as a result.

The original paint system is two layers system but there are three layers in existing coating. Therefore, the top layer may be over coated (i.e., application of a new coating over an existing coated surface) in maintenance operation.

D. Coating Thickness Comparison for Test Diagonals

Coating thicknesses were measured more detailed in test region by dividing measured 1m length into three portions. There were measured 5 points on each portion of the faces. The comparison of coating thickness for test diagonals (TD1-TD5) are shown in Fig. 4, Fig. 5, and Fig.6.

For top one-third, the minimum coating thickness is 173µm on TD1-Face H and the maximum coating thickness is 423µm on TD3-Face G.

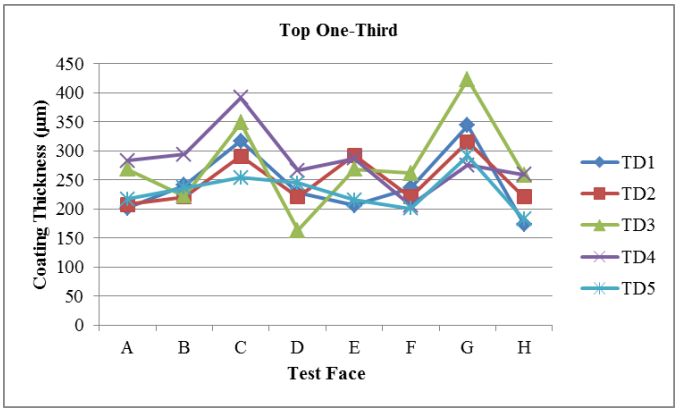


Fig. 4 Coating thickness comparison for top one-third of test diagonals

The minimum coating thickness is 162µm on TD3-Face D and the maximum coating thickness is 456µm on TD3-Face G for middle one-third.

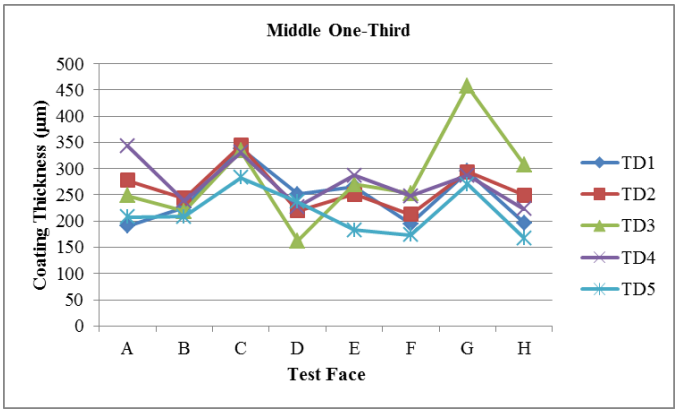


Fig. 5 Coating thickness comparison for middle one-third of test diagonals

For bottom one-third, the minimum coating thickness is 160µm on TD3-Face D and the maximum coating thickness is 406µm on TD4-Face C.

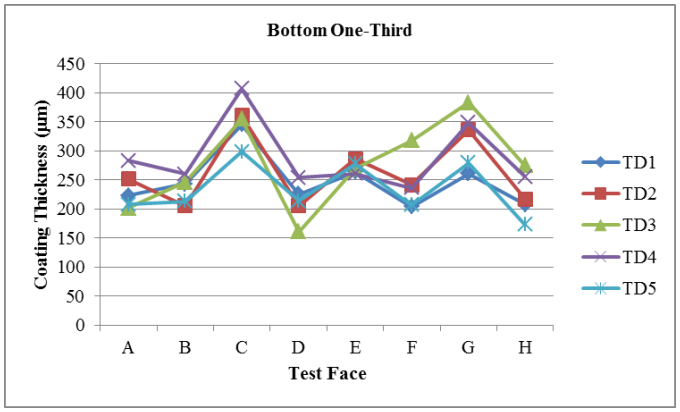


Fig. 6 Coating thickness comparison for bottom one-third of test diagonals

The comparison of coating thickness for faces of test diagonals are shown in Fig. 7, Fig. 8, and Fig.9.

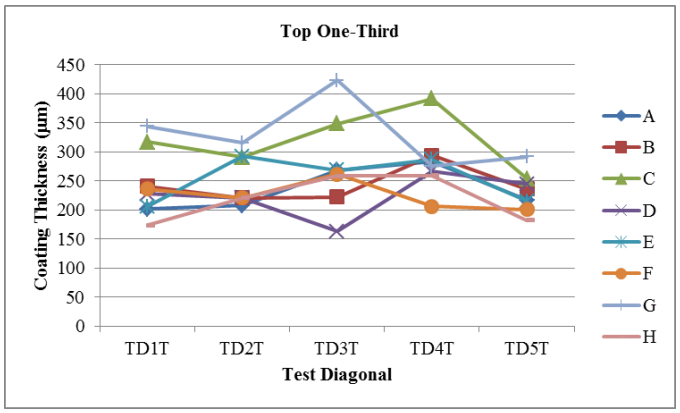


Fig. 7 Coating thickness comparison for faces of top one-third

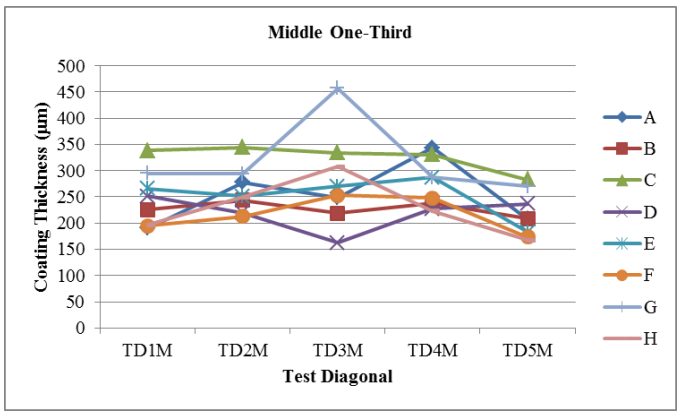


Fig. 8 Coating thickness comparison for faces of middle one-third

In coating thickness comparison for faces of test diagonals, the minimum coating thickness is 160µm on TD3-Face D and the maximum coating thickness is 456µm on TD3-Face G. According to the investigation results in test region, coating thicknesses are the same for the faces along each diagonal.

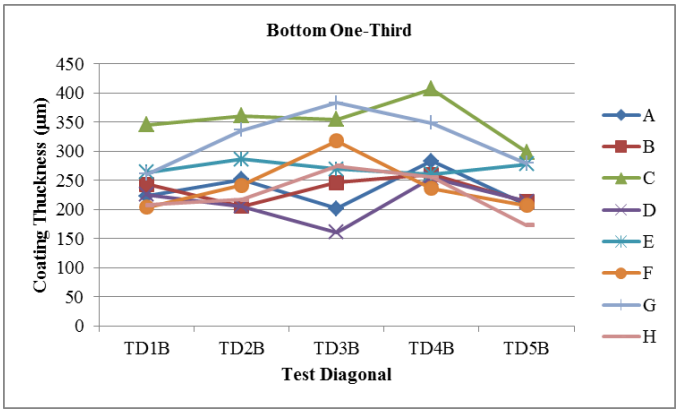


Fig. 9 Coating thickness comparison for faces of bottom one-third

E. Comparison of Coating Thickness on Upstream Truss

For upstream truss diagonals, the minimum coating thickness is 176µm on D5-Face H and the maximum coating thickness is 388µm on D2-Face C.

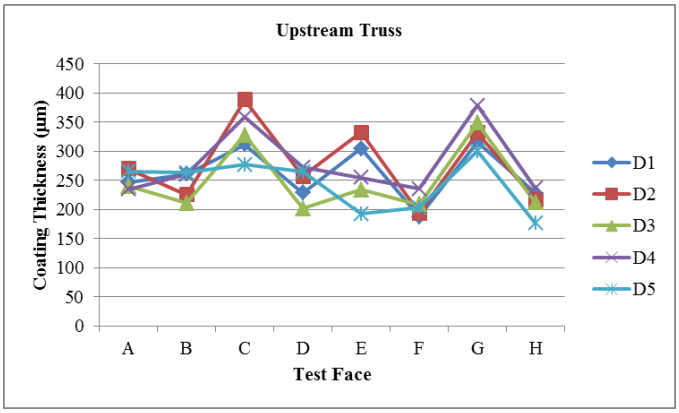


Fig. 10 Coating thickness comparison for upstream truss diagonals

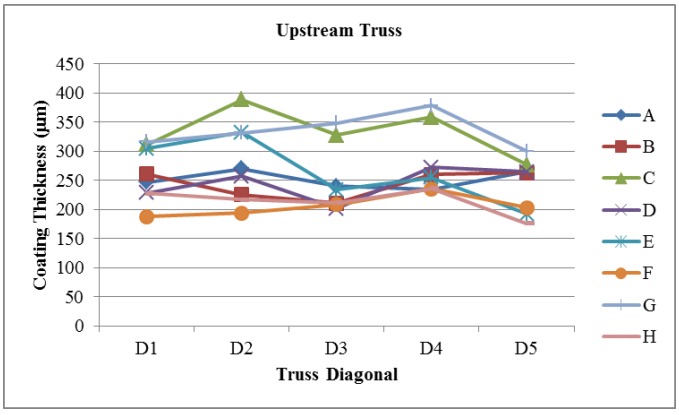


Fig. 11 Coating thickness comparison for faces

The comparison of coating thickness for upstream truss diagonals (D1-D5) are shown in Fig. 10, and Fig.11.

F. Comparison of Coating Thickness on Down Stream Truss

For downstream truss diagonals, the minimum coating thickness is 167µm on D2-Face H and the maximum coating thickness is 458µm on D2-Face C.

The comparison of coating thickness for downstream truss diagonals (D1-D5) are shown in Fig. 12, and Fig.13.

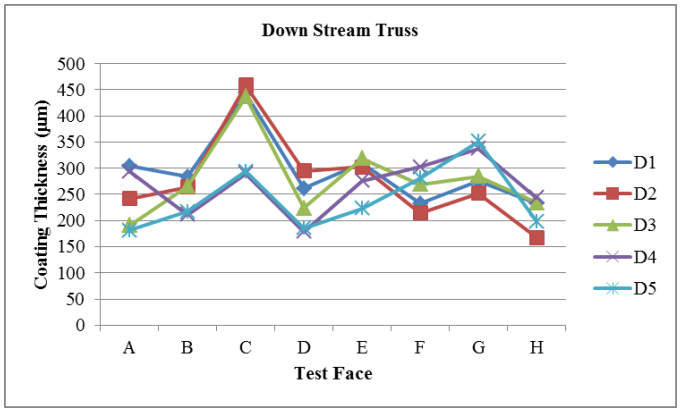


Fig. 12 Coating thickness comparison for downstream truss diagonals

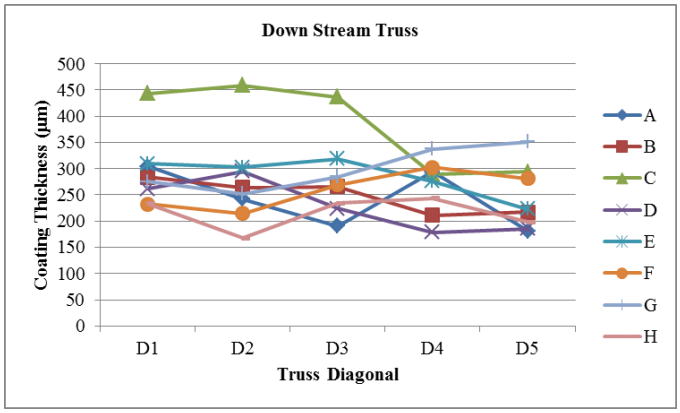


Fig. 13 Coating thickness comparison for faces

G. Comparison of Coating Thickness between September, 2016 and March, 2018 (1.5 yr. Interval) for Down Stream Diagonals

The existing coating thickness measured on March, 2018 is compared with the thickness measured on September, 2016. The comparison of coating thickness between September, 2016 and March, 2018 (1.5 yr. interval) for downstream diagonals (D1-D5) are shown in Fig. 14, Fig. 15, Fig. 16, Fig. 17, and Fig. 18.

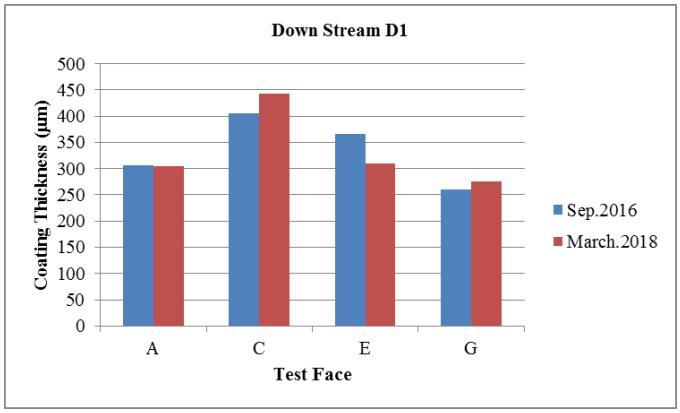


Fig. 14 Comparison of coating thickness for downstream D1

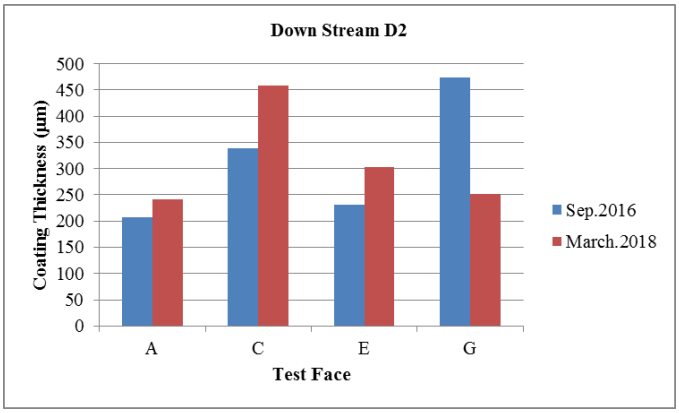


Fig. 15 Comparison of coating thickness for downstream D2

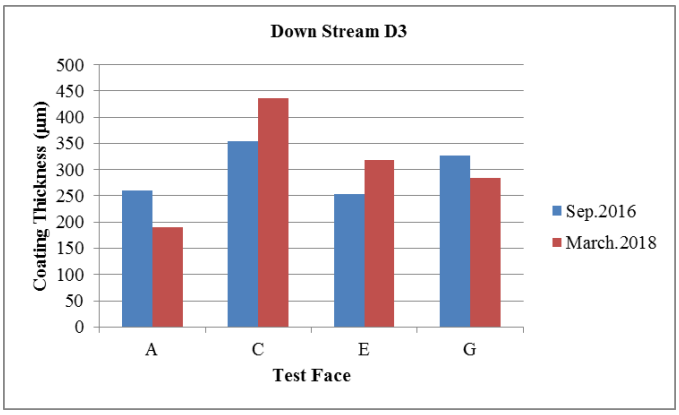


Fig. 16 Comparison of coating thickness for downstream D3

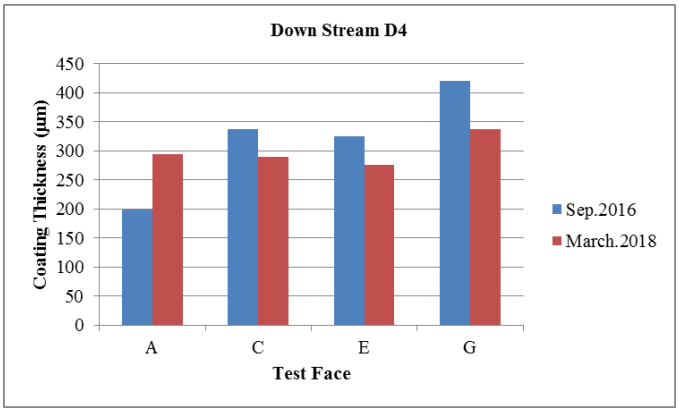


Fig. 17 Comparison of coating thickness for downstream D4

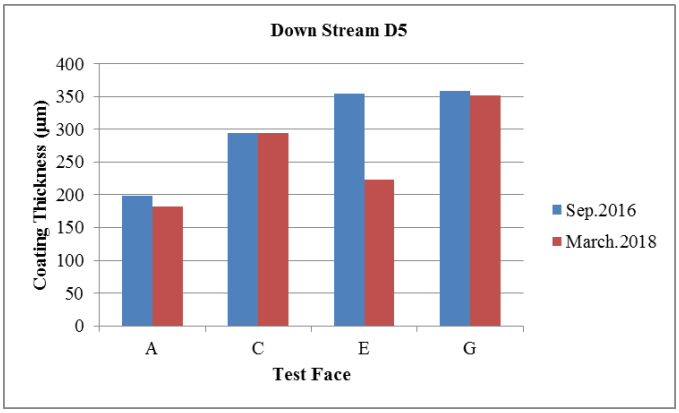


Fig. 18 Comparison of coating thickness for downstream D5

IV. Discussions on Investigation Results

The evaluation of degradation of coating on truss at Maubin Bridge is discussed as follows:

1. The degradation of coatings on D7 and D6 are nearly the same for the degradation on all diagonal members of truss at Maubin Bridge. Therefore, this evaluation covers for coating degradation on all diagonal members of truss.

2. The maximum degree of rusting is Ri 3 and the maximum degree of flaking is flaking without preferential direction (panels of area $1dm^2$ to $2dm^2$): Quantity (density) 3. From this evaluation, damage of paints on truss is overall so repainting should be done as soon as possible.

Cross-cut tests were carried out on Face A and Face D of TD4 (Middle One-Third) in test region. The test results are discussed as follows:

1) For Face A, the result showed Classification 5 and all three layers do not work well. The primer layer do not adhesive on substrate so all layers should be removed out for repainting.
2) The result described Classification 3 for Face D. In this case, top coat and intermediate coat do not perform well definitely and primer layer does not work probably about 35%. Therefore, all layers should be also removed out for repainting.

Coating Thickness was measured within 1m in height of diagonals and results are discussed as follows:

1) The existing coating thickness is in the range of 160μm-450μm for all diagonals of truss.
2) According to the comparison of coating thickness for diagonal members, coating thickness on all faces is not so different for all diagonals.
3) Web coating thickness (Face C and Face G) is more than flange coating thickness (Face A, B, D, E, F and H). Among flange coating thicknesses, flange inside (Face E) coating thickness is the most.

Comparison of coating thickness between September, 2016 and March, 2018 (1.5 year exposure interval) for downstream D1-D5 is discussed as follows:

1) The coating thickness has risen about 14μm-120μm for web and 34μm - 95μm for flange.
2) For web, the coating thickness has reduced in the range of 0.4μm-222μm and 1.6μm-131μm in thickness reduction for flange.

V. Conclusion

According to evaluation results, the truss of Maubin Bridge should be repainted. In this case, all three layers should be removed because there is no adhesion between top coat intermediate coat and primer, and less adhesion between primer and substrate. The new anticorrosive coating system which is long-lasting and economical should be selected before actual repainting.

Acknowledgment

The author would like to express my very great appreciation to Dr. Nyan Myint Kyaw, Professor and Head of Department of Civil Engineering, Yangon Technological University, for his valuable and constructive suggestions during the planning and development of this study. The author would also like to extend my thanks to Supervisor and Co-supervisor, Department of Civil Engineering, Y.T.U for their helps in this study. My grateful thanks is also extended to the research group of "Corrosion and Deterioration of Construction Materials and Strategic Maintenance of Infrastructures on Southeast Asia" for supporting me to evaluate the coating deterioration.

References

[1] Virginia Center for Transportation Innovation and Research, "Preliminary Assessment of Procedures for Coating Steel Components on Virginia Bridges".
[2] Government of the Republic of the Union of Myanmar, Ministry of Construction, Public Works, "Current Situation of Road Networks and Bridges," 26th March, 2014.
[3] Japan Infrastructure Partners (JIP), "Current Situation and Issues of Myanmar's Bridge Work," September, 2012.
[4] "ISO 4628: Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance," [*Third edition 2003-09-01*].
[5] "ISO 2409: Paints and varnishes – Cross-cut test," [*Third edition 2007-05-15*].
[6] "ISO 2808: Paints and varnishes – Determination of film thickness," [*Fourth edition 2007-02-01*].
[7] Alexandros N. Kallias, Boulent Imam and Marios K. Chryssanthopoulos, "Performance profiles of Metallic Bridges Subject to Coating Degradation and Atmospheric Corrosion," Department of Civil and Environmental Engineering, University of Surrey, Guildford, Surrey, GU2 7XH, UK.
[8] K. M. Davis, "Surface Coating Deterioration Studies," University of Aston, Birmingham, September 1952.
[9] Philip A. Schweitzer, P.E., "Paint and Coatings_ Application and Corrosion Resistance," Taylor & Francis Group, Boca Raton, London, New York.
[10] NACE International, The Corrosion Society, "Corrosion Control Plan for Bridges," 1440 South Creek Drive, Houston, TX,USA.
[11] "Johnson Street Bridge Rehabilitation, Victoria, British, Columbia," MMM Group Limited, Vancouver, BC, May, 2010.

About Author:

[Corrosive attacks of steel bridges due to coating deterioration are much severe in Myanmar.]