EUROPEAN JOURNAL OF MATERIALS SCIENCE AND ENGINEERING
Volume 7, Issue 2, 2022: 143-149 | www.ejmse.ro | ISSN: 2537-4338

DOI: 10.36868/ejmse.2022.07.02.143

INTEGRITY ASSESSMENT OF 3LPE COATED PIPES STORED IN OPEN ENVIRONMENT FOR SEVERAL YEARS

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Abstract

In present study integrity assessment of 3 layer PE coated pipes is discussed. Pipes were 3LPE coated several years ago and stored in open yard with direct exposure to environmental conditions. Several inspection and testing including visual inspection, Peel adhesion test, Impact test and continuity tests as specified for 3 layer PE coating in DIN 30670 has been performed to assess the integrity of coating. Inspection and testing results performed after several years of storage were found satisfactory however loss of gloss of coating is observed moreover it is recommended to perform UV degradation test to assess degradation percentage due to UV exposure by sun.

Keywords*:* *Three layer Polyethylene coating, DIN German institute for standardization, Integrity Assessment, Peel Adhesion Test, Visual Inspection, Impact Test, Continuity Test, Melt Flow Rate.*

Introduction

Since all materials get heat up while exposure to sunlight this is because of the radiation received. While the effect of sunlight is least beyond just simple heating in many materials, some other materials are in fact degraded by sunlight. In the latter group most plastics exist. Related studies (degradation of plastics by sunlight) have revealed that spectrum of frequencies exist in the sunlight and that the most damaging frequencies for plastics are at the higher energy end of sunlight i.e., in the ultraviolet range of the spectrum. The absorbed UV light breakdown, or splits, the weak molecular chains or chemical bonds of the polymer material. This leads to shorter chains, which causes the plastic material to become more brittle. The process is called, photo degradation, and it eventually leads to loss in mechanical properties and/or loss of gloss (discoloration) and cracking. In short words photo degradation causes weathering of plastics [1].

To protect outdoor plastic products from the damaging UV light, shielding of plastics to protect from harmful rays need to be done. Obviously shielding to protect from sunlight by means of some umbrella-like shading system is impractical in most the cases and it could not be cost effective too. Consequently, a simple, economical method is needed and that has been found with internal stabilizers. These stabilizers, (an example of which is carbon black) are added to the plastic before molding. The stabilizers screen out or absorb the destructive UV light and transform the energy of the rays (the UV light) into heat, which is then dissipated safely throughout the product [2].

3LPE coatings have been in service for not only giving protection from corrosion to the pipelines but also increasing the service life of pipelines. Three Layer PE coating systems comprises of a Fusion Bonded Epoxy, an anticorrosion layer, second layer a copolymer adhesive which forms bond between the first layer (FBE) and the top layer (polyethylene)

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and third (i.e the outer layer) layer of high density polyethylene which gives strong and durable protection. 3LPE coating systems are considered the most effective corrosion protection for small and large diameter pipelines with operating temperature ranges -40ºC up to 80ºC which is relatively higher range [1].

In the present study, top layer of 3 layer PE coating consists of High Density Polyethylene with 2% carbon black content. The change in mechanical properties is found to be the best at a carbon black filler loading rate of 2% in the HDPE matrix. Also, properties are found not affected when the UV environment is exposed to samples [3].

In field storage where the majority of stored pipe are stacked on top of each other in yards there is unlikely to have significant exposure to UV radiation except for the outermost pipes placed on top layer. According to the management study related to corrosion protection, which found that coated pipes (specific to coating) open to sunlight exposure for around 10 years was considered no longer appropriate for in service use [9].

In present study, the pipes were coated as per DIN 30670 standard [7], inspection and testing performed during the initial coating process were compared with the testing performed after several years as tabulated in table 5.

Methodology and Testing

Bare pipes were visually inspected for surface defects dents, pits, bevel and root damage, straightness, surface contamination etc., QC cleared pipes sent for surface cleaning process while rejected pipes sent for re-working or replacement. Detailed coating process steps are presented in flow diagram below (Fig. 1).

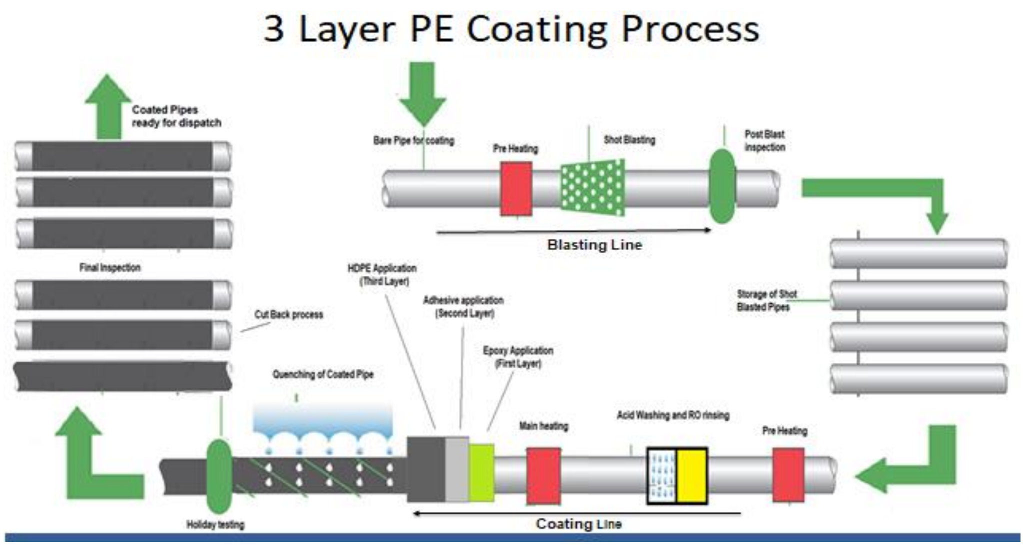

Fig. 1. Three layer polyethylene coating process utilized

After several years of storage of the 3LPE coated pipes in open yards in single layers, visual inspection and some destructive and Non-destructive testing is performed. Table 1 below shows coating year, pipe dimension data, coating thickness distribution and coating material types.

Table 1. Coating year, pipe dimension data, coating thickness distribution and coating material types

Pipe Size	Coating Month-Year	3LPE Thickness Distribution	FBE Manufacturer-Type	COA Manufacturer-Type	HDPE Manufacturer-Type
OD 168.2 mm x WT 4.7 mm	Jan-2010	FBE: 0.2 mm COA: 0.25 mm HDPE: 1.75 mm Total 3LPE: 2.2 mm	Jotun- Jotapipe AC 1003	Dupont-EMB158H	Borouge-HE 3450
OD 508 mm x WT 9.5 mm	Feb-2010	FBE: 0.2 mm COA: 0.25 mm HDPE: 2 mm Total 3LPE: 2.45 mm	Jotun- Jotapipe AC 1003	Dupont-EMB158H	Borouge-HE 3450
OD 457.2 mm x WT 6.4 mm	Mar-2014	FBE: 0.15 mm COA: 0.20 mm HDPE: 1.85 mm Total 3LPE: 2.2 mm	Jotun- Jotapipe AC 1003	Hyundai LLDPE-LE 149V	Borouge-HE 3450
OD 609.6 mm x WT 11.13 mm	Nov-2016	FBE: 0.2 mm COA: 0.35 mm HDPE: 3.2 mm Total 3LPE: 3.75 mm	Jotun- Jotapipe AC 1003	Dupont – E 158H	Borouge-HE 3450
OD 914.4 mm x WT 14.3 mm	Apr-2017	FBE: 0.2 mm COA: 0.2 mm HDPE: 2.6 mm Total 3LPE: 3 mm	Jotun- Jotapipe AC 1003	Dupont – E 158H	Borouge-HE 3450

Table 2. Information of pipe size, coating year, 3 layer thickness distribution and coating raw material type

Pipe Size	Temperature Range before Epoxy Application °C	Coating Speed (m/min)	1st Layer (FBE) Thickness (mm)	2nd Layer (COA) Thickness (mm)	Top Layer (HDPE) Thickness (mm)	3LPE Thickness (mm)
OD 168.2 mm x WT 4.7 mm	228-250	3 – 4	0.2	0.25	1.75	2.2
OD 508 mm x WT 9.5 mm	195-230	2.0 – 2.4	0.2	0.25	2	2.45
OD 457.2 mm x WT 6.4 mm	181-202	2.4 – 2.5	0.15	0.20	1.85	2.2
OD 609.6 mm x WT 11.13 mm	184-211	2.0 – 2.1	0.2	0.35	3.2	3.75
OD 914.4 mm x WT 14.3 mm	190-222	1.2 – 1.3	0.2	0.2	2.6	3

Table 3. Production parameters utilized during coating process

Pipe Size	Peel Adhesion (N/cm) @ 25 °C	Peel Adhesion (N/cm) @ 50 °C	Melt flow Rate Test (g/10 min)	Impact Test Energy Absorbed (J)
OD 168.2 mm x WT 4.7 mm	200 – 220	180 – 190	0.5	11
OD 508 mm x WT 9.5 mm	200- 250	150 – 180	0.5	12.25
OD 457.2 mm x WT 6.4 mm	270–310	170 -200	0.45	11
OD 609.6 mm x WT 11.13 mm	140-150	70-90	0.49	18.75
OD 914.4 mm x WT 14.3 mm	230-270	160-170	0.43	15

Table 4. Original inspection and testing results during coating process

Pipe Size	Geographical Location	Storage Years (No.)	Typical Air Temperature Range during Summer (March to Nov.) ºC	Typical Air Temperature Range during Winter (Dec. to Feb.) ºC	Actual Coated Pipe Surface Temp. during Summer ºC	Actual Coated Pipe Surface Temp. during Winter ºC
OD 168.2 mm x WT 4.7 mm		12				
OD 508 mm x WT 9.5 mm		12				
OD 457.2 mm x WT 6.4 mm	Nooriabad, Sindh, Pakistan 25.18°N 67.8°E,	8	25 to 46	18 to 25	35 to 56	18 to 35
OD 609.6 mm x WT 11.13 mm		5				
OD 914.4 mm x WT 14.3 mm		5				

Table 4 shows environmental conditions in which 3LPE coated pipes were stored openly [4, 5].

Fig. 2. Temperature of 3LPE coated pipe surface during summer season (Picture taken in May 2022)

Fig. 3. Peel Adhesion test at higher temperature (Pipe temperature increased to 70 ºC prior to peel test at 50 ºC)

Results and Discussion

Shop floor inspection and testing was performed on pipes in as it is condition, first through visual inspection and holiday detection at 25 KV was performed after getting satisfactory results, two region of interests were marked on different pipes, in the first region following testing were performed peel adhesion test of 3 layer PE coating and Melt Flow rate test of top layer HDPE, in the second region of interest holiday detection subsequent to impact test were performed. Originally during coating process impact test was performed considering N-type coating which requires minimum impact energy 5 joules per millimeter of coating thickness whereas the same test after several years of open storage was performed at 7 joules per millimeter coating thickness to detect any sign of brittleness in top layer due to long time exposure to sun light (UV exposure).

Table 5. above shows inspection and testing results after several years of storage in open environment

Pipe Size	Coating Month-Year	Peel Adhesion (N/cm) @ 25 °C	Peel Adhesion (N/cm) @ 50 °C	Melt flow Rate Test (g/10 min)	Impact Test Energy Absorbed (J)
OD 168.2 mm x WT 4.7 mm	Jan-2010	140-150	50-55	0.52	15.4
OD 508 mm x WT 9.5 mm	Feb-2010	300-330	220-240	0.51	17.15
OD 457.2 mm x WT 6.4 mm	Mar-2014	200-210	170-190	0.36	15.4
OD 609.6 mm x WT 11.13 mm	Nov-2016	230-250	90-100	0.53	26.25
OD 914.4 mm x WT 14.3 mm	Apr-2017	150-180	50-70	0.497	21

Fig. 3. Impact test at ambient temperature (25 +/- 3°C) with drop weight from certain height method

Fig. 4. Holiday detection at 25 KV after impact test

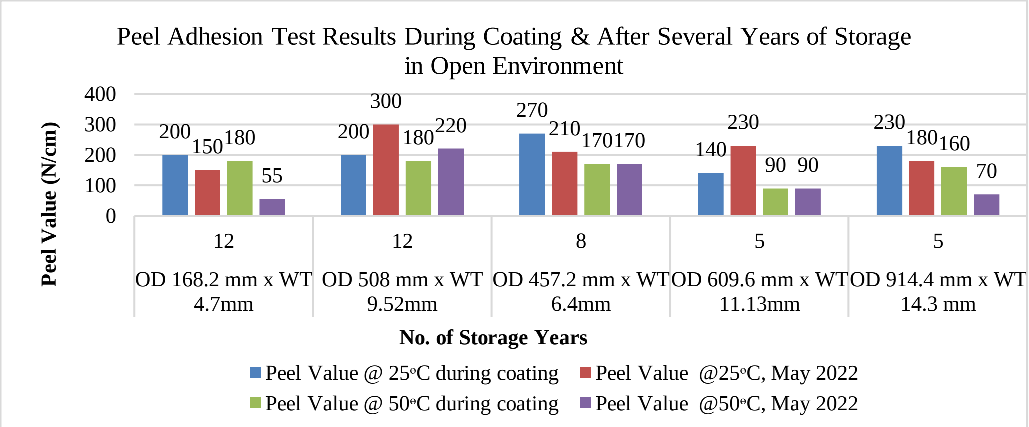

Fig. 5. Comparison of Peel adhesion test values during coating process and after several years of storage

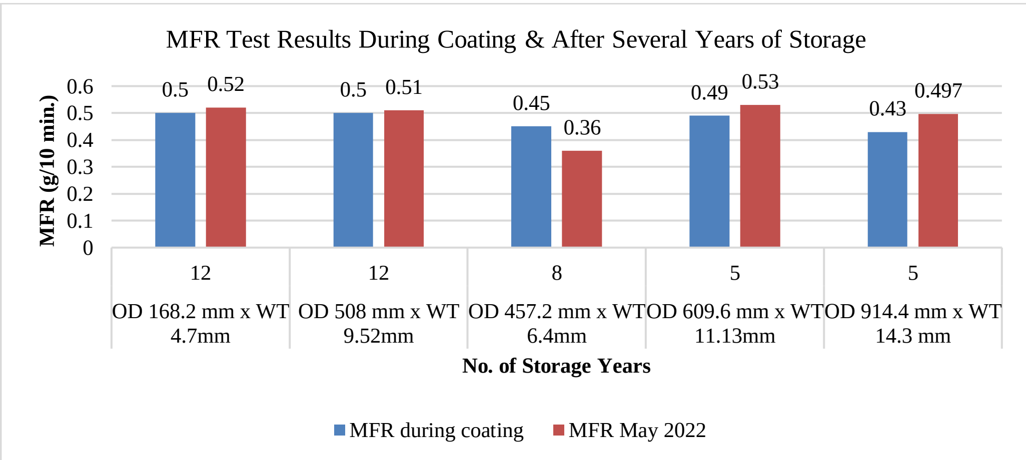

Fig. 6. Comparison of MFR test values during coating process and after several years of storage

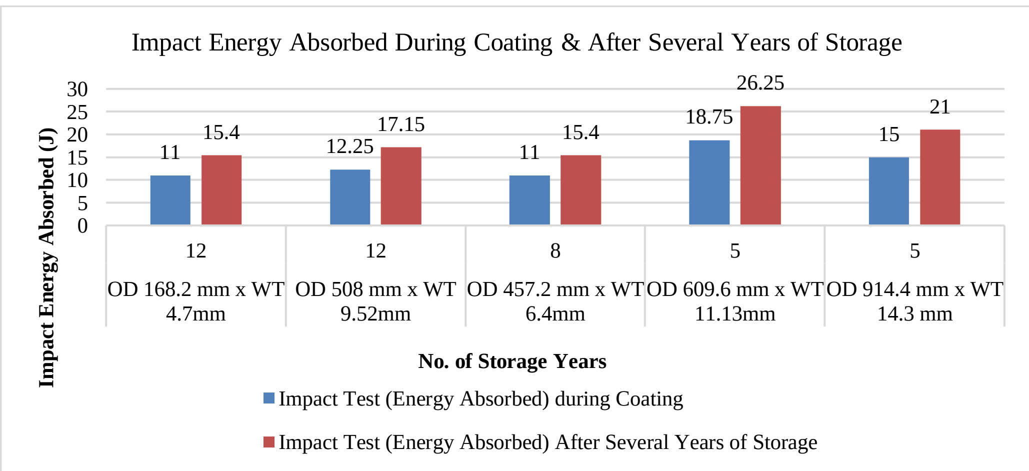

Fig. 7. Comparison of impact test values during coating process and after several years of storage

Based on above results the top layer of 3LPE coating which is of HDPE was exposed to open environment (several years exposure to UV radiation of sun and temperature) however no significant degradation (except decrease of gloss of top layer i.e. HDPE material) in the mentioned properties of coating was due to some precautionary measures taken during long time storage which are:- Rotating the pipes in quadrants after every month so as to avoid long time sun exposure to particular area of pipe moreover corrosion protection on pipe ends in the form of epoxy based liquid paint was applied to avoid corrosion on bare ends of pipe (cut back portion). Further investigation for measuring the actual degradation of top layer (HDPE) in terms of percentage can be performed by first irradiating the HDPE sample (can be taken from 3 layer PE coating free from adhesive layer) with xenon lamp under specified conditions as per DIN 30670 [7] and ISO 4892-2 [8] and thereafter performing melt flow rate test.

Conclusion

Based on technical data sheets of top layer HDPE of different manufacturer, long time exposure in temperatures above 50°C and direct exposure of sun light to avoid UV rays is not recommended [9]. However, for large volume of pipes and on field storage where there is not feasible to provide storage of coated pipes in sheds it is critical to select the top layer HDPE with minimum 2 % carbon black content as UV absorber and to re-position pipes time to time to avoid long time exposure to single specific surface only.

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Received: May 01, 2022
Accepted: June 10, 2022