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Effect of Surface Treatment on the Adhesion Forces between PVC Adhesives and PVC (Pipe - Fitting)

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ABSTRACT

This paper aims to improvement adhesion forces between (USA PVC adhesive , Commercial PVC adhesive and USA CPVC adhesive) and (PVC pipe – PVC fitting) by using surface treatment (mechanical and chemical treatment) for external surface of pipes and internal surface of fitting with depth (25 mm) . Before pipe adhesion test the samples put under some environmental conditions such as (at room temperature , at (80 ^{o}C) for (4 hr) , at (- 2.5 ^{o}C) for (4 hr) , at (tap water) for (48 hr) , at (3.5 % NaOH) for (48 hr) and at (3.5 % NaCl) for (48 hr)) .

Appearance of results of pipe adhesion testing for (PVC pipe – PVC fitting) with PVC adhesive, without surface treatment only (cleaning), under environmental conditions , the failure (pulling) happened in adhesion zone (adhesive adhesion failure) . As appearance of results of pipe adhesion testing for (PVC pipe – PVC fitting) with PVC adhesive by using surface treatment (surface roughness with abrasive paper and chemical treatment with alcohol), under environmental conditions, the failure happened in PVC pipe (pipe cohesion failure).

Keywords: Pipe Adhesion Testing, PVC adhesive, CPVC adhesive, PVC Pipe, VC Fitting, Chemical treatment and Mechanical treatment.

تأثير المعاملة السطحية على قوى الالتصاق بين لواصق بولي فانيل كلورايد و (انابيب – تأسيسات) بولي فانيل كلورايد

الخلاصة

يهدف هذا البحث لتحسين قوى الالتصاق بين (لواصق PVCالامريكية , لواصق PVC التجارية و لواصق CPVC الامريكية) وأنابيب - تأسيسات PVC باستخدام المعاملة السطحية (معاملة ميكانيكية وكيمياوية) للسطح الخارجي للانابيب والسطح الداخلي للتأسيسات بعمق (25 mm) . قبل اجراء اختبار لصق الانبوب توضع العينات تحت بعض الظروف الجوية في (درجة حرارة الغرفة , 80 ^{o}C لمدة (4 hr) , -2.5 ^{o}C لمدة (4 hr) , ماء حنفية لمدة (48 hr) , 3.5 % هيدروكسيد الصوديوم لمدة (48 hr) و 3.5 % كلوريد الصوديوم لمدة (48 hr) .

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أظهرت نتائج اختبار التصاق الأنبوب (للأنبوب – تأسيسات بولي فانيل كلورايد مع لاصق بولي فانيل كلورايد) , بدون معاملة سطحية فقط (تنظيف) , تحت ظروف جوية , الفشل يحدث في منطقة اللصق (فشل تلاصق اللاصق) . كما أظهرت نتائج اختبار التصاق الأنبوب (للأنبوب – تأسيسات بولي فانيل كلورايد مع لاصق بولي فانيل كلورايد) , باستخدام معاملة سطحية (خشونة سطحية باستخدام ورق حك ومعاملة كيميائية باستخدام الكحول), تحت ظروف جوية , الفشل يحدث في انبوب PVC (فشل تماسك الانبوب) .

INTRODUCTION

Poly vinyl chloride PVC is a commodity polymer used in a wide range of applications such as in profiles , pipes , tubes , adhesive , conduits and fittings . The mechanical properties, however of the UN plasticized polymer used in the above applications do present some issues [1]

The total length of PVC drinking water pipes in the Netherlands was about 55000 km in 2000 and is still increasing. The first PVC pipes were installed in the nineteen - fifties. About 2000 km of PVC water pipes were installed in 1960. [2, 3] .

Solvent welding and solevent cementing such as PVC adhesive are widely used techniques for the joining of thermoplastic polymers. A small amount of plasticizers and solvent along the joint promotes interdiffusion of polymer chains between the substrates. This creates a permanent weld, with no additional phases or potentially weak interfaces. A solvent cement is a solution of the polymer being joined. This also promotes interdiffusion, and leaves a single-phase joint when the solvent has evaporated .The solvent cementing (PVC) using for joints PVC pipes [4] .

The formation of a weld between two components during the PVC cement process relies on interdiffusion across the interface. As with other PVC pipe joining techniques, this interdiffusion depends on time, temperature and pressure. The Glass transition temperature,Tg, of the PVC is reduced by the introduction of solvent, allowing welds to form at lower temperatures than other techniques. Solvent is applied to the two substrates to be joined and it diffuses into the surfaces. This creates a softened layer where the mobility of the polymer chains is increased [4,5] .

Plasticization is achieved by incorporating a plasticizer into the PVC matrix through mixing and heat. Plasticizers may be classified as either monomeric or polymeric plasticizers, depending on their synthesis steps, which relates in part to their molecular weight. It is preferred to categorize plasticizers on the basis of their chemical structure and associated performance when employed in PVC [6].

DIDP (Diisodecyl Phthalate), DOP (Di-n-Octyl Phthalate) and DINP (Diisononyl Phthalate) as plasticizers get into between PVC polymer chains .As a result of this crystal properties of polymer decreases , becomes softer and shaped flexible named plastic . The reaction between the phthalates and terephthalates with heavy alcohols produce plasticizers. When PVC mixed this type of chemicals, it becomes plastic characteristic [5] CPVC is produced by reacting suspension PVC resin with chlorine. The reaction is initiated by decomposing diatomic chlorine dissolved in water into highly unstable and reactive chlorine atoms, with either high heat or ultraviolet

radiation. Once this initiation step has taken place, a chlorine atom attacks a PVC chain at a random location and replaces a hydrogen atom at the attack position [7].

Adhesion is defined as the adhesive force acting between the adhesive and the surface of the material. This force is the result of the mechanical interlocking between adhesive and the material surface roughness (mechanical adhesion) as well as the physical and/or chemical interaction between the adhesive and the material (specific adhesion) [8] .

Cohesion is the strength of the adhesive itself. This is a result of the mechanical entangling and interlocking of the adhesive molecules and their physical and/or chemical affinity for each other [8].

Numerous adhesives contain polar molecule groups (dipoles) such as PVC adhesives which have a strong polarising action on the PVC joining parts , form (dipole – dipole) bond between PVC adhesive and PVC pipe [8] .

The separation of adhesive joints occurs due to the failure of adhesion or cohesion or of both (i.e., mixed adhesion and cohesion failure) [8] .

In a previous study, the researchers used epoxy coating for coated PE and PP pipes, so they worked surface treatment (cleaning, flame, chemical and mechanical treatment) before using epoxy for pipe, and they tested coating adhesion testing [9]. And other researchers used (bonduit conduit) adhesive for adhesived PVC and HDPE pipe, so they worked surface treatment (without treatment , cleaning and sanding treatment)before used PVC adhesive for PVC pipe and fitting , and they tested (pipe adhesion , environmental , lap shear , weathering and other testing) [10] . Other researchers used various process techniques available to improve adhesion were discussed in this article. When the coater is satisfied that the surface is as clean as can be achieved, it requires, as we showed, a primer thin layer to make it work. Our analyses show clearly that thermal treatment of nanometric primer layer associated to a mecanical etching proved true very effective to consolidate adhesion properties [11] . Other researchers used to enhance surface polarity; surface treatments such as flame, corona or plasma can be applied to improve wettability and adhesion. Plasma can specifically be used as a preparatory treatment for the photografting approach recommended in this paper to achieve high stability in treatment and permanent changes to the surface [12]. Other researchers used several types of common polymers were deposited on glass slides sililated with organofunctional silanes. The extent of surface coverage, adsorbed layer thickness and topology were experimentally determined [13].

In this study aims to improvement adhesion forces between (USA PVC adhesive , Commercial PVC adhesive and USA CPVC adhesive) and (PVC pipe – PVC fitting) by using surface treatment (mechanical and chemical treatment) for external surface of pipe and internal surface of fitting with depth (25 mm) . Before pipe adhesion test the samples put under some environmental conditions such as (at room temperature , at (80 ^{o}C) for (4 hr) , at (- 2.5 ^{o}C) for (4 hr) , at (tap water) for (48 hr) , at (3.5 % NaOH) for (48 hr) , at (3.5 % NaCl) for (48 hr)) .

EXPERIMENTAL

Materials

PVC cementing

It contains from Flexible PVC (9002-86-2) , Tetrahydrofuran (109-99-9) , Methayl Ethyl Ketone (78-93-3) , Cyclohexanone (108-94-1) and Acetone (67-64-1) , made in USA .

PVC cementing

It contains from Flexible PVC (686-48-82-8) , Tetrahydrofuran (109-99-9) , Methayl Ethyl Ketone (78-93-3) and Cyclohexanone (108-94-1) Commercial making .

CPVC cementing

It contains from Flexible CPVC (7114-04) , Tetrahydrofuran (109-99-9) , Methayl Ethyl Ketone (78-93-3) , Cyclohexanone (108-94-1) and Acetone (67-64-1) , , made in USA .

PVC Pipe

It contains from Rigid UPVC, made in Egypt, size (1/2 in).

PVC Adapter of pipe bond (Fitting)

It contains from Rigid UPVC, made in Egypt, size (1/2 in).

Standard PVC

It contains from Rigid UPVC, without additives.

SAMPLE PREPARATION

Modified Surface Preparation

1- Cut pipes at length (125mm) and at right angles by using a pipe cutter or a saw .
2- Chamfer pipe ends with a chamfering tool.
3- Debur pipe ends .
4- Measure the full pipe insertion depth (25 mm).
5- Mark this depth at the end of the pipe.
6- Before use adhesive ensure that both the pipe and fitting are perfectly cleaned . Surface to be bonded must be perfectly dry before applying adhesive .
7- Surface roughness treatment by using abrasive paper size (60) for abrasion external surface of pipe and internal surface of fitting with depth (25 mm).
8- Chemical treatment by using immersion in ethanol alcohol for external surface of pipe and internal surface of fitting with depth (25 mm) about (1 min).
9- Using distilled water for washing of external surface of pipe and internal surface of fitting with depth (25 mm).
10- Drying the pipe and fitting by using hot air.
11- Stir adhesive and soak the brush well with adhesive. Apply a normal layer of adhesive on the inside of fitting in the direction towards the end of the pipe.
12- Cover the pipe end axially. Apply a thicker layer to the pipe end with firm brush pressure. The brush stokes should always be in an axial direction.
13- Immediately insert the pipe into the fitting to its full depth without twisting and bring them into the correct alignment. Remove excess adhesive with absorbent paper.
14- Repeat (1- 13) on another side of fitting.
15- Remain sample for (24 hr) before environmental and adhesion test.

Figure (1) (A, B, C) Appearance of stages of surface treatment for PVC pipe samples.

UNMODIFIED SURFACE PREPARATION

Repeat the points (1- 6) and (11-15).

Environmental Testing

Before pipe adhesion test the samples put under some environmental condition such as [14]:

1- At room temperature.
2- At (80 ^{o}C) for (4 hr).
3- At (- 2.5 ^{o}C) for (4 hr).
4- At (tap water) for (48 hr) .
5- At (3.5 % NaOH) for (48 hr) .
6- At (3.5 % NaCl) for (48 hr) .

PIPE ADHESION TESTING

The design of adhesion testing samples depends on using laboratory report of American Polywater Corporation [10] , and ASTM (D 2295 -96) [14] . after the samples put under environmental condition in previously testing , it fixed both sides by jaws of tensile test machining with form parallel for tension axial for tensile test . the maximum pulling force was recorded this test with (KN) , Figure (2) (A , B , C) Appearance of samples of PVC pipe adhesion testing .

RESULTS AND DISCUSSIONS

Results of Pipe Adhesion Testing

The Figures (3,4,5) show results of pipe adhesion testing for (PVC pipe – PVC fitting) with (USA PVC adhesive , Commercial PVC adhesive and USA CPVC adhesive) , without surface treatment only (cleaning) , under environmental conditions (At room temp., 80 ^{o}C , - 2.5 ^{o}C , tap Water , 3.5 % NaOH , 3.5 % NaCl) . appearance of results of pipe adhesion test the failure (pulling) happened in adhesion zone (adhesive adhesion failure) and for all types of adhesives and under all environmental conditions , excepting treatment under (80 ^{o}C) for all types of adhesives happened failure in (adhesive cohesion failure) . and the maximum adhesion force reaches less than (7 KN) for all types of adhesives .

Because the adhesion force between (PVC pipe – PVC fitting) and adhesive consistence weak for all types of adhesives and under environmental conditions(At room temp ., - 2.5 ^{o}C , tap Water , 3.5 % NaOH , 3.5 % NaCl) . and weak reason result smooth pipe surface for that mechanical interlocking theory consistence very weak , the bond depend on adsorption theory and electrostatic attraction theory , adhesive molecules adsorption inside pipe surface and formation dipole – dipole bond between surface of (PVC pipe – PVC fitting) and adhesive subsequently weak adhesion force result failure in adhesion zone . and excepting treatment under (80 ^{o}C) because all types of PVC adhesive from flexible type contains on plasticizers and solvent makes reduce Tg under Tg for rigid PVC (under 87 ^{o}C) subsequently failure happened (adhesive cohesion failure) for all types of adhesives under (80 ^{o}C) [5, 15] .

The Figure (6,7,8) show results of pipe adhesion testing for (PVC pipe – PVC fitting) with (USA PVC adhesive , Commercial PVC adhesive and USA CPVC adhesive) with surface treatment (surface roughness with abrasive paper and chemical treatment with alcohol) , under environmental condition (At room temp. , - 2.5 ^{o}C , tap Water , 3.5 % NaOH , 3.5 % NaCl) . appearance of results of pipe adhesion test the failure happened in PVC pipe (pipe cohesion failure) and for all types of adhesives and under all environmental conditions and the maximum adhesion forces reaches more than (9.1 KN) and minimum adhesion forces more than (7.8 KN) for all types of adhesives , excepting treatment under (80 ^{o}C) for all types of adhesives happened failure (adhesive cohesion failure) .

Because the adhesion force between (pipe – fitting) and adhesive consistence strong for all types of adhesives and under all environmental conditions excepting treatment under (80 ^{o}C) . and rising of adhesion force because surface treatment (surface roughness with abrasive paper and chemical treatment with ethanol alcohol) for external surface of pipe and internal surface of fitting , abrasive treatment increased surface roughness subsequently increasing mechanical interlocking between adhesive and pipe surface and fitting surface . as treatment with alcohol formation hydroxyl group on pipe and fitting surface form dipole – dipole bond between hydroxyl group and adhesive , subsequently increasing adhesion force between (pipe – fitting) and adhesive and resulting failure in pipe (pipe cohesion failure) , for all types of adhesives and under all environmental conditions, excepting treatment under (80 ^{o}C) , because all types of PVC adhesive from type flexible contains on plasticizers and solvent makes reduce Tg under Tg for rigid PVC (under 87 ^{o}C) subsequently failure happened (adhesive cohesion failure) for all types of adhesives under (80 ^{o}C) [5, 15] .

From Figure (3,4,5,6,7 and 8) adhesion force between adhesive and (pipe – fitting) increase because chemical and mechanical treatment for pipe and fitting before adhesived , adhesion force strong than cohesion force of pipe subsequently failure in pipe (pipe cohesion failure) under environmental condition (At room temp. ,- 2.5 ^{o}C , tap Water , 3.5 % NaOH and 3.5 % NaCl) .

CONCLUSIONS

The adhesion forces between PVC adhesive and (PVC pipe – PVC fitting) increase by using chemical and mechanical treatment for pipe and fitting before adhesived . adhesion forces strong than cohesion force of pipe subsequently failure in pipe (pipe cohesion failure) under environmental conditions (At room temp. ,- 2.5 ^{o}C , tap Water , 3.5 % NaOH and 3.5 % NaCl) and the maximum adhesion forces reaches more than (9.1 KN) and minimum adhesion forces more than (7.8 KN) for all types of adhesives , comparing with adhesion forces between PVC adhesive and unmodified (PVC pipe – PVC fitting) , it weak than cohesion force of pipe subsequently failure in adhesion (adhesive adhesion failure) under environmental conditions (At room temp. ,- 2.5 ^{o}C , tap Water , 3.5 % NaOH and 3.5 % NaCl) and the maximum adhesion forces reaches less than (7 KN) for all types of adhesives .

Excepting treatment under (80 ^{o}C) for all types of adhesives failure was happened in (adhesive cohesion failure) both samples surface modified and unmodified

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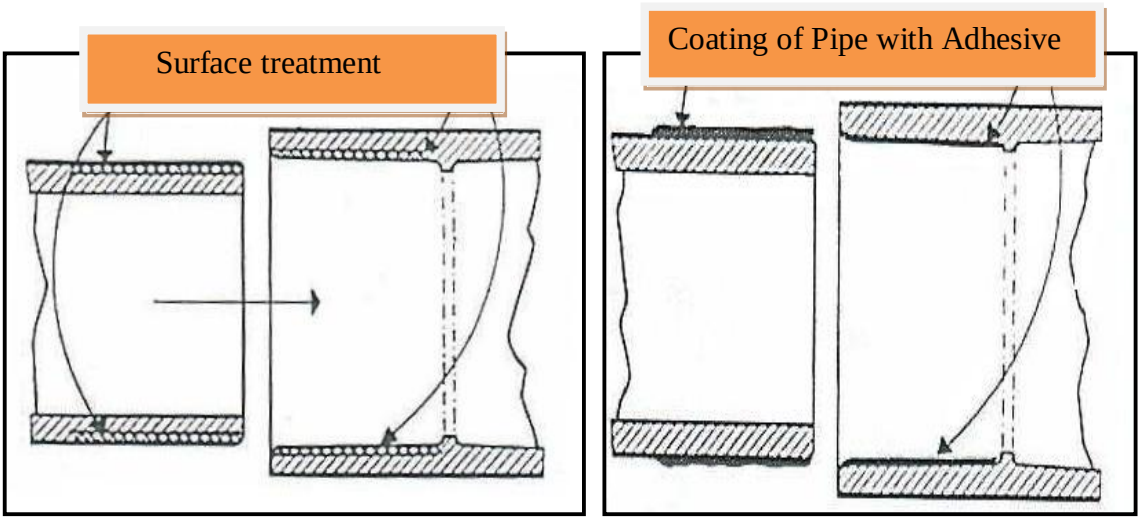
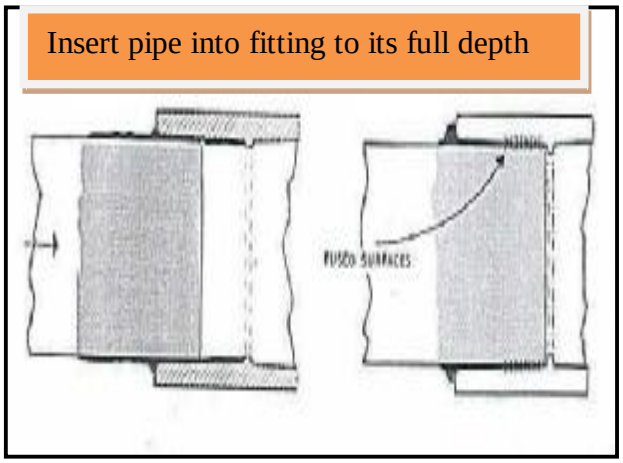


(A) (B)

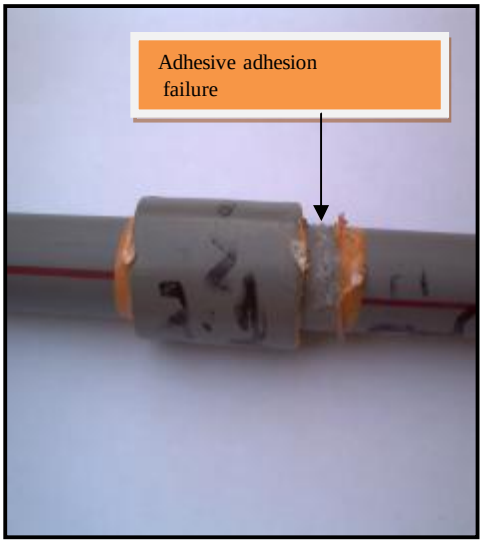


(C)

Figure (1) (A, B, C) Appearance of stages of surface Treatment for PVC pipe samples.

(C)

(A)



(B)

Figure (2) (A, B, C) Appearance of samples of PVC pipe adhesion testing.

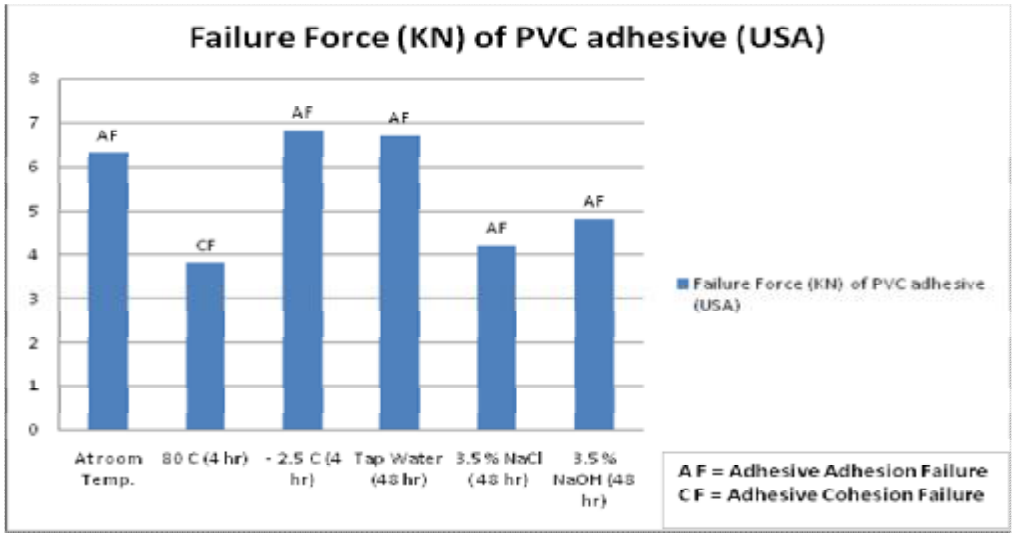


Figure (3) show results of pipe adhesion testing for PVC pipe with PVC adhesive (USA) without surface treatment, under environmental conditions.

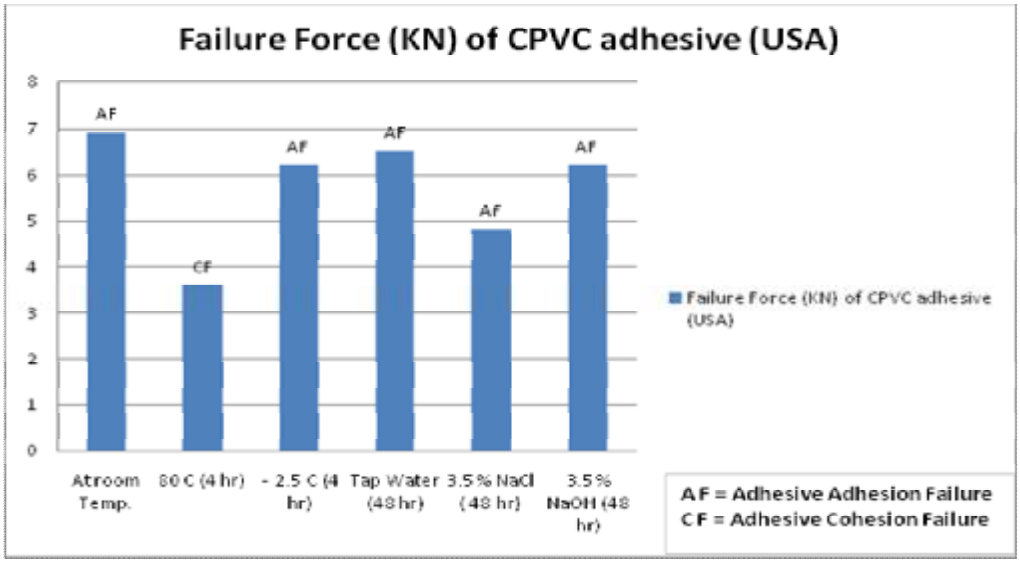


Figure (4) show results of pipe adhesion testing for PVC pipe with CPVC adhesive (USA) without surface treatment, under environmental conditions.

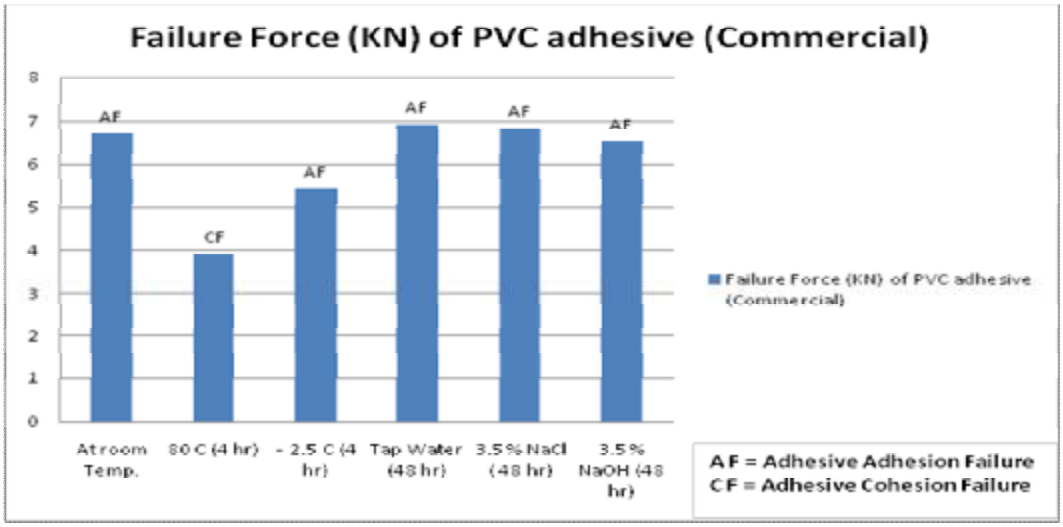


Figure (5) show results of pipe adhesion testing for PVC pipe with PVC adhesive (Commercial) without surface treatment, under environmental conditions.

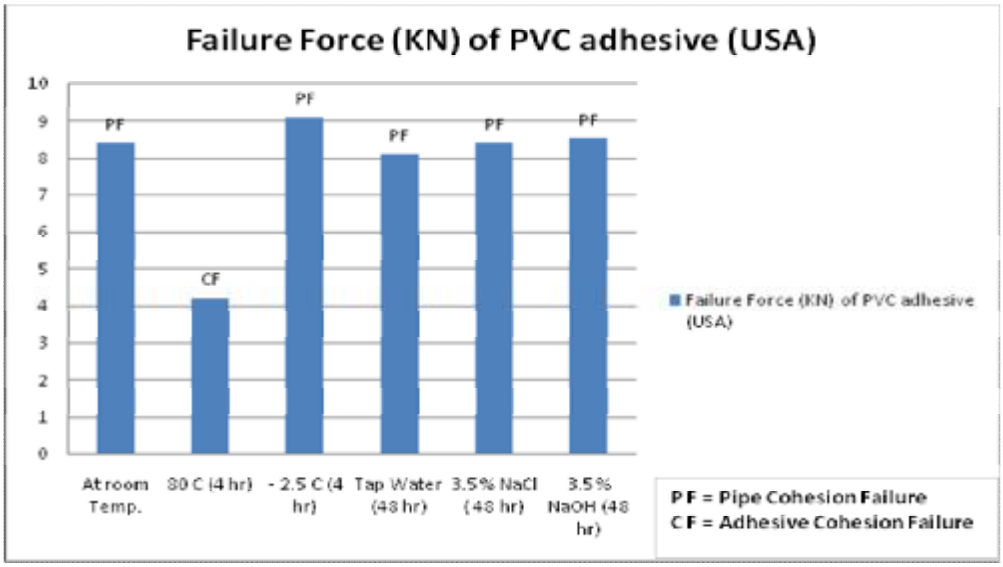


Figure (6) show results of pipe adhesion testing for PVC pipe with PVC adhesive (USA) with surface treatment, under environmental conditions.

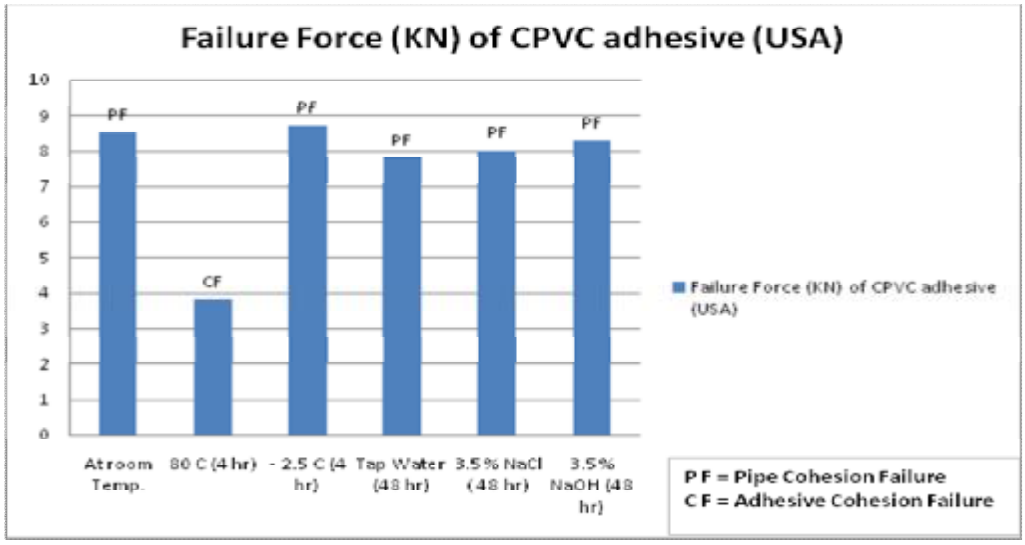


Figure (7) show results of pipe adhesion testing for PVC pipe with CPVC adhesive (USA) with surface treatment, under environmental conditions.

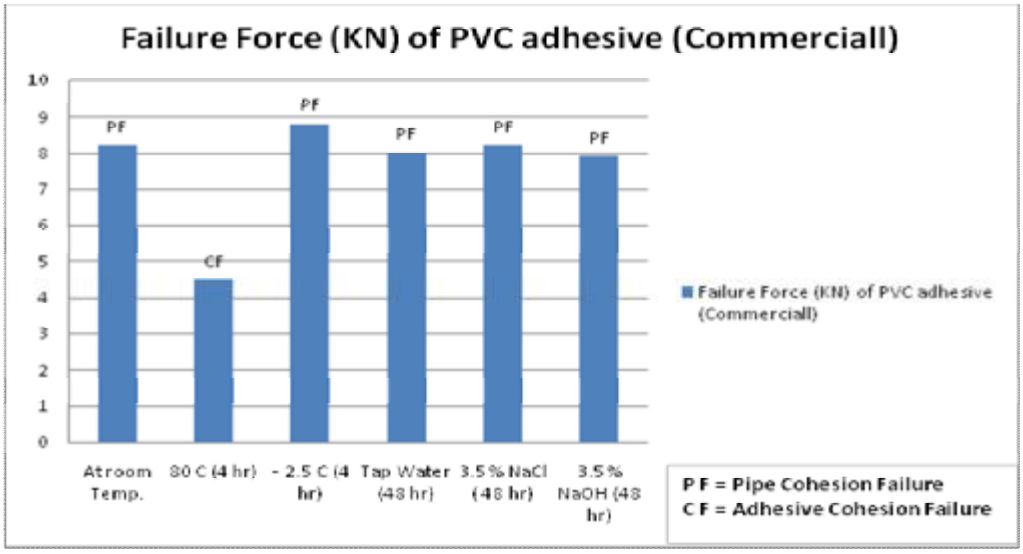


Figure (8) show results of pipe adhesion testing for PVC pipe with PVC adhesive (Commercial) with surface treatment, under environmental conditions.