17th World Conference on Earthquake Engineering, 17WCEE
Sendai, Japan - September 13th to 18th 2020

STUDY ON MOISTURE EFFECTS ON MASONRY RETROFITTED WITH FIBER REINFORCED PAINT

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Abstract

Seismic retrofitting of masonry structures has been of research interest for past many years, due to the vulnerability of this type of buildings against earthquakes and also due to the existence of a large number of buildings belonging to this type in seismically vulnerable regions worldwide.

By the previous studies, it has become clear that retrofitting of masonry structures with special fiber reinforced paint drastically improved the structure's seismic capacity and also reduces the effort involved in retrofitting structures. However, such retrofitting method where the outer surface of the masonry wall is covered tends to influence the natural evaporative properties of the masonry, delaying its drying off period. Moisture ingress in masonry walls either through rising damp or wind driven rains, when retained, leads to adverse effects such as reduction of load bearing capacity of the masonry structure and increase in efflorescence on the masonry surface. This is a serious problem is non-engineered or old masonry structures with improper foundation damp-proofing.

When retrofitting using fiber reinforced paint, it is usually recommended to apply a coat of primer on the masonry wall. But the effects of the addition of primer on the water transmission capacity and the seismic performance of the paint need to be investigated.

The current study aims to (i) study the effects on the water vapor transmission rates of masonry due to the addition of the fiber reinforced paint layer, and to (ii) study the effects on paint-mortar adhesive properties due to moisture and efflorescence.

In the first part of the study a series of pull out tests to understand the effects of moisture on the fiber reinforced paint peel-off property. The adhesion of the brick and paint interface of dry brick specimen and fully saturated brick specimen are compared. The effect of introducing primer coating is also investigated. The next part of the study involves the water vapor transmission rates are studied by slightly modifying the testing standard ASTM E 96-80 in order to test conventional bricks. The influence on the water transmissivity due to the introduction of fiber reinforced paint as well as primer is investigated.

Although other moisture related problems in masonry retrofitted with fiber reinforced paint like shrinkage, swelling, thermal expansion/contraction and permanent irreversible moisture expansion are not discussed in the current study, the two major aspects namely, the effects on evaporation rate and effects on the paint-brick adhesion, are addressed. Based on the experiments performed in this study, recommendations are made on the usage of the fiber reinforced paint for retrofitting of existing masonry structures that are susceptible to rising damp.

Keywords: fiber reinforced paint, masonry building, masonry retrofitting, water vapor transmission rate, pull-out test

1. Introduction

Seismic retrofitting techniques of masonry structure have been one of the most significant research topics in the earthquake engineering internationally because of the typical cause of the casualties in the past earthquakes around the world is the collapse of masonry houses. In the major earthquakes that exceeds 6 in its magnitude from 1915 to 2015 around 1.36 million out of 1.72 million were fatalities caused by the collapse of masonry structures [1].

Previously various retrofitting techniques have been developed but most of them can be applied only for new structures. So, Meguro's research team has developed many methods which can be used for both new and existing structures including the Polypropylene band (PP-band) mesh retrofit method エラー! 参照元が見つかりません。[2][3]. A technique using coating of fiber reinforced resin is one of such methods and it improved the seismic capacity of masonry house increasing its strength and deformation capacity エラー! 参照元が見つかりません。. The advantage of this method realizing seismic retrofitting only with coating is its simplicity of implementation so that it enables labor and time reduction for the application. The material of this method is the composite composed of water based acrylic silicon resin and glass fiber. The basic resin acrylic silicon resin has been used for several decades in Japanese market as paint, and it is considered to be waterproof. In the Japanese market a kind of paint is necessary to pass the JIS (Japanese Industrial Standard) A6909 [5], and this acrylic silicon based resin has passed in several tests including waterproof and at the same time this has been confirmed that it has the capacity of water vapor transmission with the testing of JIS A0208 [7].

This method is suggested to have a coating on entire surface of masonry wall and also the coating of both sides of the wall is necessary so that it prevents the wall from producing the dust or dropping bricks. However, since the entire surface of the masonry wall is covered with the coating this method has a possibility of affecting the masonry wall's natural water evaporation system especially if the house does not have enough waterproofing at its base. Masonry wall has a tendency to become wet mainly because of capillary rise by touching the water on the surface of masonry wall such as rain or underground water. This tendency has the possibility of having the problems degrading both the coating and wall itself. The retaining of the water causes the reduction of structural strength of the masonry wall, and affects the adhesive property of the material coated on the wall, which is critical for coating based retrofitting materials [8][9][10].

In surface based retrofitting technology or general paints, the masonry wall surface is generally made smooth by first applying a coat of primer. Although the introduction of primer makes it easier to apply coating layers, the effects of introduction of primer on the adhesion and water transmission properties of the masonry need to be investigated.

The purpose of this study is to verify the effects of moisture on the adhesive properties of the retrofitted masonry and the change in evaporation rate from masonry wall due to the introduction of retrofitting coating. In order to check the effects of water retention on the peeling off property of the brick surface, the first section consists of a series of pull out tests on saturated and unsaturated masonry specimens. The effects of introduction of primer between the masonry and fiber reinforced coating, on the adhesive strength are studied. The next part of the paper the water transmissivity properties of the masonry and retrofitted masonry is compared. In this study, the specimens are prepared following the testing method in modified version of the ASTM E96 [11] standard and the method the past study shows [12][13], which can be used for practical purposes.

2. Effect of moisture on adhesion

2.1 Experimental setup

A series of pull out tests are performed in order to study the effect of moisture on adhesion. The experimental setup is shown in Fig. 1. Single bricks which are half painted are fixed at one end and the paint is pulled vertically upwards as shown in Fig. 1 in order to create a paint peel-off action. The mechanism of the experiments essentially involves the peeling off of the paint surface and the tensile extension of the paint between the testing machine and brick surface. In order to prioritize the peeling off phenomenon a thick coating of paint is applied; thickness of fiber reinforced coating used for the experiment is 2 mm before the dried condition. Testing is performed on two cases of saturated brick and one case of unsaturated brick specimen.

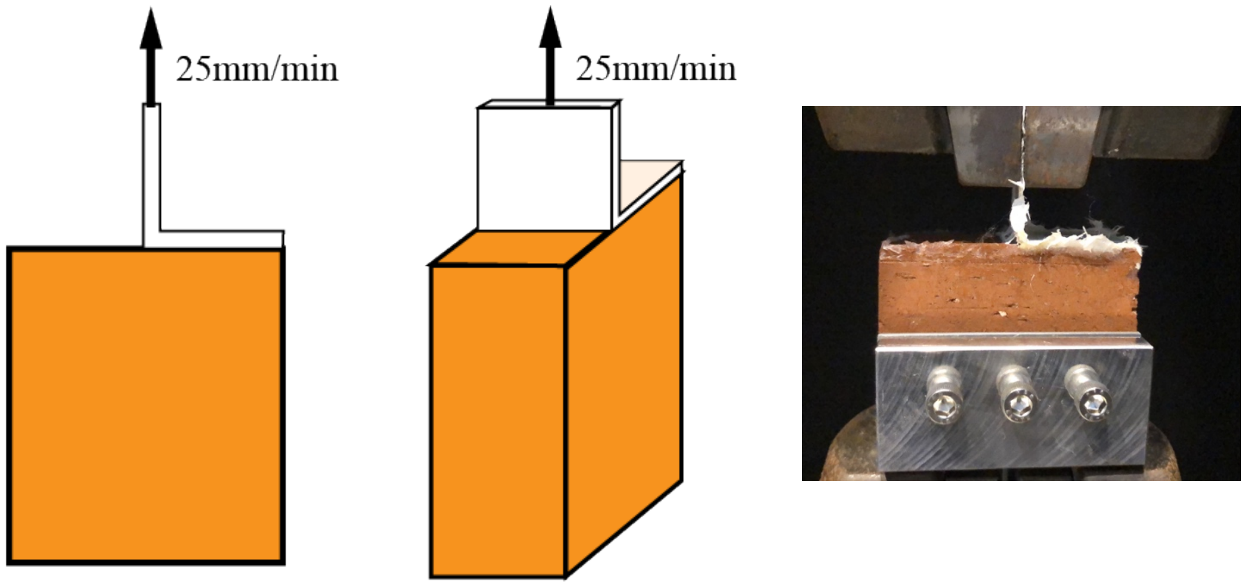


Fig. 1 – Experimental setup for pull-out test

2.2 Effects of moisture on adhesion between brick and fiber reinforced paint

The force displacement relationship obtained from the testing of the bare brick specimen can be seen in Fig. 2. From Fig. 2 it is evident that the behavior is completely different depending on whether the brick is saturated or not. In the case of the unsaturated specimen, there is good adhesive strength between the brick and the fiber reinforced paint. Therefore, there is no peeling off of the paint, but rather the paint undergoes tensile failure. The behavior can be represented by three phases (i) the elastic phase (ii) the initiation of tensile failure (iii) complete tensile failure of the specimen. The three phases can be clearly seen in Fig. 3.

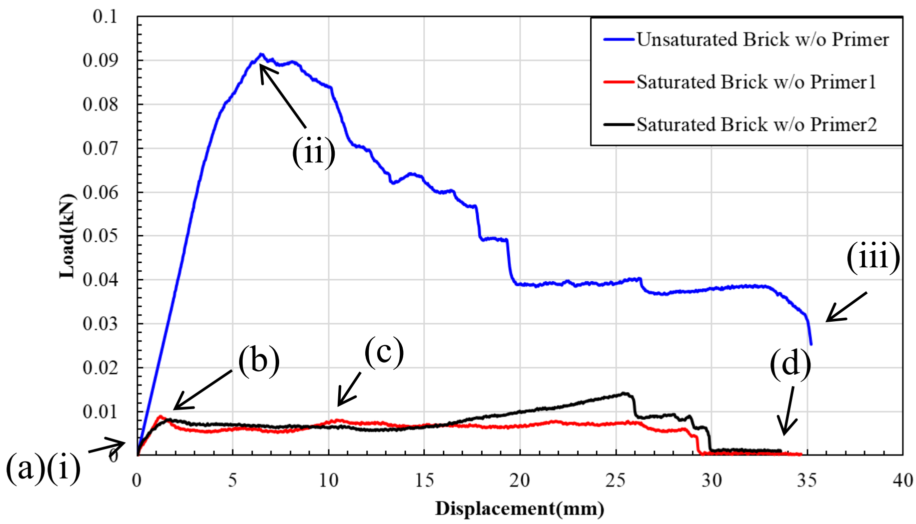
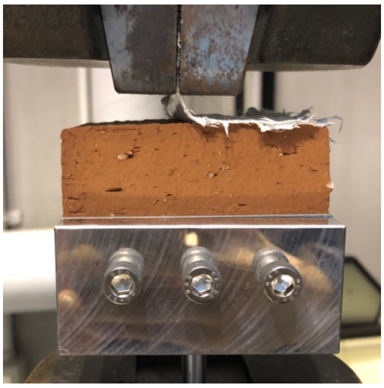
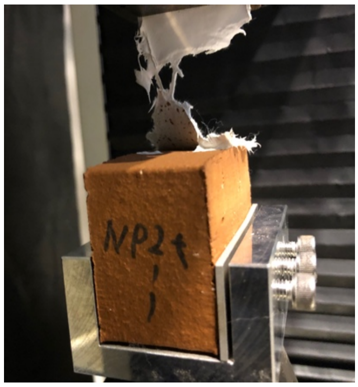


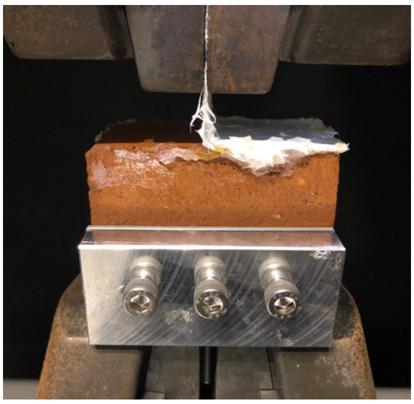
Fig. 2 – Force-Displacement response obtained from brick coated without primer pull-out testing





(i) Initial setup (ii) Initiation of tensile failure (iii) Final specimen failure

Fig. 3 – Pull out testing of unsaturated bare brick coated without primer specimen


(a) Initial Setup


(b) Initiation of peel-off


(c) Peeling-off process


(d) Final specimen failure

Fig. 4 – Pull out testing of saturated brick coated without primer specimen

With the introduction of primer coating between the brick surface and the fiber reinforced paint, the adhesion generally tends to increase. This can be observed from the maximum load capacity obtained from the force-displacement relation shown in Fig. 5 as compared to Fig. 2. As similar to the previous section, when the brick is saturated the adhesive strength reduces, however the difference in response between saturated and unsaturated is more significant when primer is not provided. The failure pattern is also similar, with the unsaturated brick undergoing tensile failure of paint and saturated specimen undergoing paint peel-off failure. Experimental images of the failure can be seen in Figs. 6 and 7.

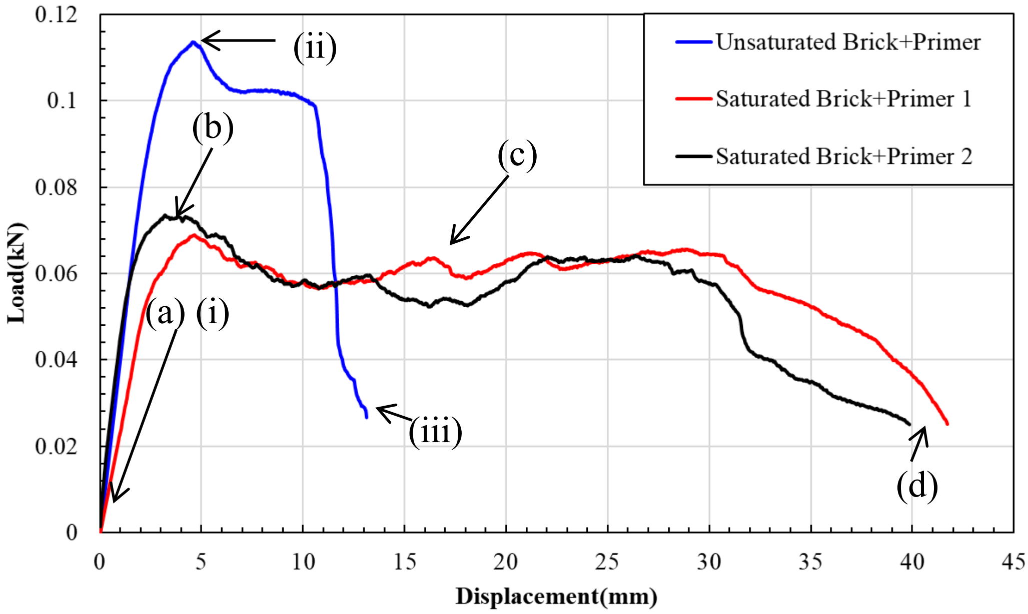
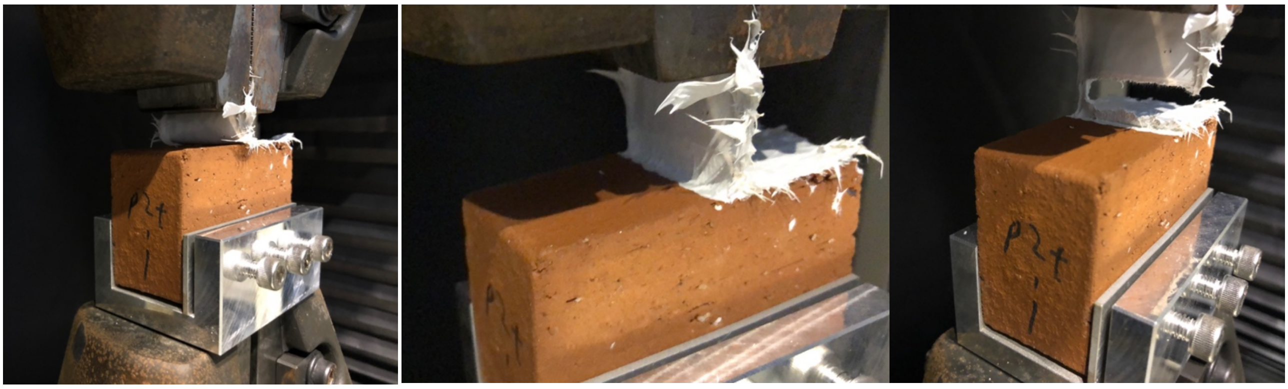


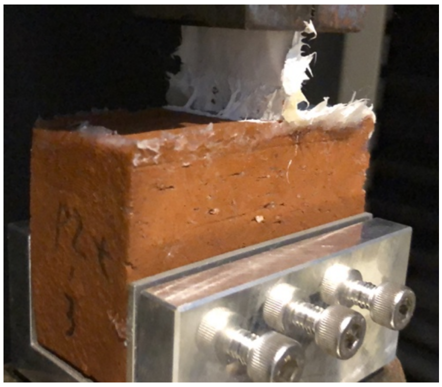
Fig. 5 – Force-Displacement response obtained from brick primer pull-out testing



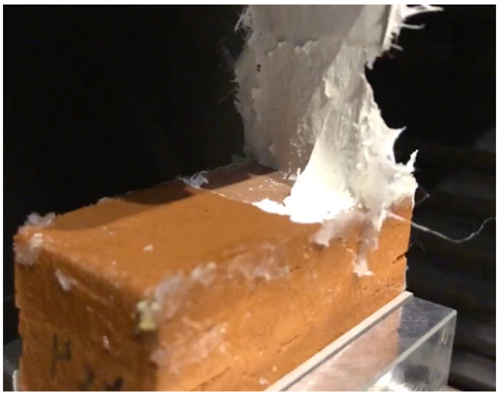
(i) Initial Setup (ii) Initiation of tensile failure (iii) Final specimen failure

Fig. 6 – Pull out testing of unsaturated brick with primer specimen

(a) Initial Setup



(b) Initiation of peel-off



(c) Peeling-off process

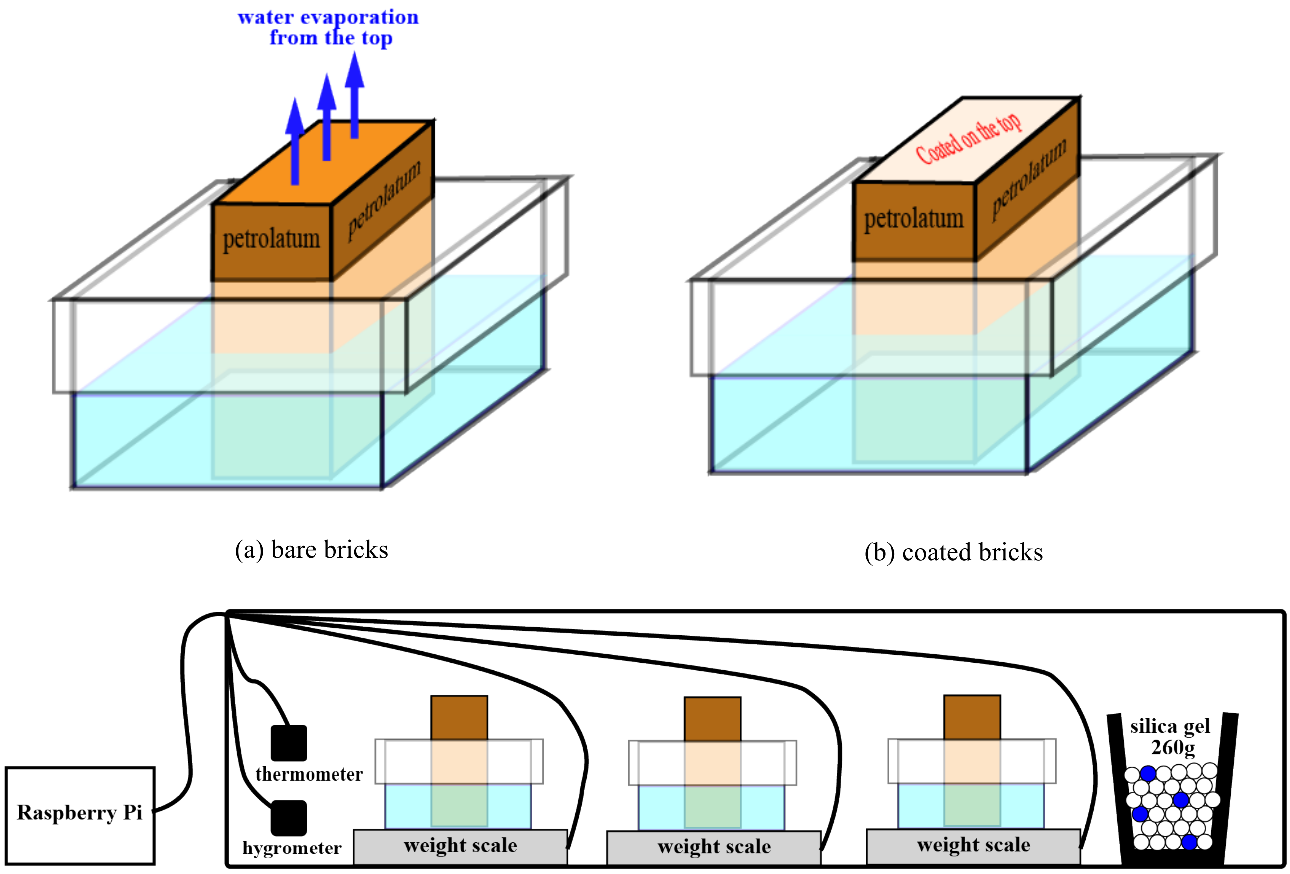
(d) Final specimen failure

Fig. 7 – Pull out testing of saturated brick with primer specimen

3. Effect of coating layer on masonry wall water transmissivity

3.1 Experimental setup

In order to check the water vapor transmission rate of the masonry surface, a modified testing procedure as shown in Fig 8, which is based on ASTM E 96-80 is used. The experimental setup consists of a single brick placed in a container passing through a hole cut through in the center of the lid of the container and soaked in water. This enables the water inside the container to evaporate only through the top surface of the brick. Petrolatum has been coated on the sides, as well as the small gaps between the lid and the brick in order to ensure that water can evaporate only through the top surface of the brick (Fig. 8). The water amount is 100g, and the dimension of the brick is 75mm x 36mm x 50mm and the top surface is 36mm x 50mm. In order to clarify the place the water evaporates, 10g salt is added. As the brick is soaked in the water, water initially rises thought the specimen through capillary action up to the top surface and after that evaporation from the surface starts. The groups of test specimens are placed in a large air tight box with silica gel. This creates a negative pressure inside the box and speeds up the capillary action. The weight of the specimen is contributed by the brick, coating, water, container and petrolatum. The temperature and moisture variation in the box is constantly monitored.



(c) measuring environment

Fig. 8 – Experimental setup to check water vapor transmission

Four kinds of specimens were prepared according to the finishing of the top surface of the brick where water evaporates. The properties of the specimens are shown in Table 1. For the current study 2 samples cases were considered for each surface case.

Table 1 – Properties of specimens in test i)

Name	Top finishing	Number of specimen
BB	Bare brick	2
P0.5	Coating with primer	2
NP0.5	Coating w/o primer	2
VB	Full coated with Petrolatum	1

3.1 Experimental results

The introduction of coating layers generally tends to inhibit the free flow of water in the masonry. This trend can be observed in the experimental results given in Table 3. Table 3 gives the values of weight reduction of specimens. Since the evaporation surface area is constant and one batch of specimen testing is performed in the same temperature and humidity condition, these values directly correspond to the water evaporation rate of masonry. The experimental results given in Table 3 are for an experimental period of 30 and 50 days. The introduction of the fiber reinforcement paint reduced the water evaporation rate and with the addition of primer the evaporation rate further reduces.

Table 3 – Amount of water transmitted through various specimens

	Weight Reduction in Test Sample (g)				
	Bare Brick	Coating w/o primer	Coating with primer	Full coated with Petrolatum	
Case 1	28		4	0	30 days
Case 2	70	26	15		50 days
Case 3	70	22.5	20		

Although, the evaporation rate is lowered due to the introduction of coating layers, there is still substantial water movement through the layers.

4. Conclusions

The current study aims at establishing methods to test surface application based retrofitting technologies. Such methods like the fiber reinforced paint used in the current study, essentially work like thin layered ductile membranes that blanket the masonry wall to prevent masonry spalling and eventually collapse. The tensile strength and adhesion of such coating layers play an important role in the seismic performance of such technologies.

Moisture plays an important role in the adhesive property of the masonry surface. Through the pull out testing method mentioned in the current study, the adhesive behavior of the coating can be studied. The fiber reinforced paint requires only a thin layer of paint to be applied for good seismic performance. However, when only fiber reinforced paint is applied, there is significant difference between saturated and unsaturated brick adhesive strength. When the fiber reinforced paint in applied on uneven surfaces, water ingress in the gaps between the paint and masonry reduces the adhesive strength. When a layer of primer is applied in between, the surface smoothens out increasing the adhesive strength. Therefore, in buildings susceptible to moisture ingress it is recommended to have a layer of primer between the masonry and reinforced paint.

Masonry buildings are known for their ability to let water flow through them and surface evaporation. The introduction of fiber reinforced paint and primer on the evaporation ability of the brick surface is investigated. Although, there is a reduction in the evaporation rate when compared to bare bricks, the brick surface still manages to let water flow thorough it, after coating it with fiber reinforced paint and primer. When compared to other commonly used retrofitting technologies which involve application of cement mortar on the surface which is averse to evaporation, the fiber reinforced paint effects on the evaporation rate of the brick is lower.

The current study only considers two samples in maximum for each testing case. The adhesion strength depends on the brick surface property and will vary depending on the location, method of preparation and construction quality control. Further sampling is required to truly understand the material property distribution. In actual construction practices a layer of plaster is applied on the brick surface. The introductions of this plaster on the masonry moisture properties and adhesion of the fiber reinforced paint needs to be investigated. Also the study on masonry wallets (brick and mortar) rather than only brick will be performed in future studies.

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