Evaluation and Improvement of Performance of Damp Proof Course in Residential Buildings

Engr. Zeeshan Ullah[1], Engr. Shah Jahan[2], Engr. Muhammad Irfan[3], Engr. Faheem Ahmed Soomro[4], Engr. Maryam Sadia[5], Engr. Faizan Ahmed Waris[2]

[1]Department of Construction Engineering & Management, NITSCEE, NUST, Islamabad, Pakistan,
[2]The University of Lahore Gujarat Campus,
[3]Civil Engineering Department KFUEIT Rahim Yar Khan,
[4] Khairpur Medical College, Khairpur, Pakistan
[5]ADF, Islamabad, Pakistan

Abstract: **The quality of construction projects can be enhanced by reducing the defects in the projects during construction and operation stages. Some defects in the construction projects are harmful for the durability and structural stability and some of them are harmful for the indoor air quality and building aesthetic. Dampness is main defect that reduces the life of building as well as the comfort level for the resident of the building. Improper construction of damp-proof course (DPC) creates lots of problems in buildings. An attempt was made to find out the effectiveness of DPC in residential buildings through comprehensive data collection. With help of literature some useful methods of construction and evaluation of DPC were used to check the effectiveness of DPC in the selected sites. Almost, 80% buildings were damaged due to failure of DPC and major reason for that failure was the technical assistant during the construction of DPC. In this research evaluation of concrete mix was carried out by variating the concrete mixture ratios and also by adding one percent of Pudlo powder as an admixture to improve the efficiency of DPC. It has been observed that performance of DPC was improved by using of Pudlo powder in concrete mixture. This study will helpful in finding the best technique of construction of DPC and also in finding out the suitable polymer to improve damp proof ability of DPC of residential building.**

Key Words: **Damp-Proof Course, Residential Building, Pudlo Chemical, Synthetic Polymer and Concrete mixture.**

I. INTRODUCTION

Construction industry is among the largest industries of the world. It contributes a lot in the improvement of grand domestic products of any country. Buildings sector is one of the major sector of construciton industry. It covers residencial buildings, industrial buidligns, educational buildings and commerical buidoigns. Along witht eh befnifits of these types of buidligns, there are many typs of defects in these buildings too ranging from small to medium and medium to large scale deffents.Dampness is also one of the major deffect in building proejcts which damages not only the durability of the buildign but also harmfull for the aesthetic look and health of living beings. This deffect is damaging almost every building structure due to improper construction of damp proof course. Usually, concrete mortar with plastic sheet, a layer of bitumen or mixed with Pudlo powder are used to make the DPC, to make it less permeable. Also other water proofing materials or chemicals are available in markets which are not usually used in the construction of houses due to higher costs. Despite this, DPC fails to perform its function due to technical and others mistakes while laying DPC. Therfore, there is a need to find out the problems associated with the construciton and performance of DPC in buildings. Some admixtures should also be evaluted to improve the performance of buildign by adding them in cocnrete during mixting. Similar type of attempt was made to investigate the performance of DPC in number of buildigns and then anylzed the data to find out the major reason behind the failure of DPC in those buildings. One admixture was also tested by adding that in cocnrete at the time of mixing to evaluate its effect on performance of DPC.

II. LITERATURE RIVIEW

The development of any country highly depends upon the development of construction industry. Construction industry comprises six to nine percent of the gross domestic products of developed countries. Buildings are the most important part of the constructions industry. There are many defects in buildings like structural and temperature cracks, dampness, settlement and failure. These defects produce due to poor quality workmanship. A typical example is water infiltration through some portion of the building structure that is called dampness, which may create an environment for the growth of mold. Most common defect in buildings is the dampness. Dampness is the existence of unsolicited moisture in different members of a buildings, either because of interruption from outside or condensation of water vapors from within the structure. Many techniques are there to control dampness. In this study new waterproofing techniques are introduced using synthetic polymers (Agyekum & Ayarkwa, 2014).

In order to control the dampness bitumen coating is preferred over polymers as some of the polymers are costly and require skilled labor. Conventional techniques of waterproofing are still used in different developing countries. So, there is a need to introduce the new technique to control the dampness that must be equally economical as well as environment friendly. In this study, modern techniques of waterproofing are introduced by using synthetic polymers like crack filler (PP 007), sealer, hyper coating, Concrete mix (PP 500) and PP 50. The polymers are, Acrylic Polymers, Super Absorbent Polymer (SAPs), Epoxy, Dr. Fixit, Kembond K Fix 75, Polypropylene (PP), Polyvinyl Chloride (PVC) and Polystyrene (PS) (Agyekum, Ayarkwa, Koranteng, & Adinyira, 2013).

Structural defects are those which arises in the structural member of the building to cause these defects is due to poor design, use of poor materials and human errors these defects arise separately or may be some time in combination. Structural defects caused in members of building including beams, columns, retaining wall and slab. Defects in brick work, dampness in old structure and defect in the plaster work are some type of non-structural defects (Agyekum et al., 2013). Another study in Malaysia on seven hostel buildings identified some common defects in the buildings. That are the leakages of water, erosion in steel, penetration of rain water and other types of water in the buildings, horizontal cracks in the interior and exterior walls. These all defects need proper maintenance. Buildings need proper waterproofing to stop water from penetration to stop the damages and to protect the health of users of the building from harm (Annila et al., 2017).Crakes are caused in many construction materials because it is nature of construction materials to crake after some time. Contraction and expansion take place due to variation in temperature during winter and summer seasons respectively. This contraction and expansion produce cracks in concrete members which allow the water to enter the structural members through these cracks. As walls cover the major area of buildings that is why thermal cracks are more critical in walls. The cracks in wall are produced due to over loading of wall, use of poor material and poor workmanship. The other reason of wall cracks might be settlement of underneath soil (You, Li, Ye, Hu, & Zheng, 2017).

Different studies exposed that the defects also effect directly users of the building that is some of defects create health and economical problem for users. So, these defects should have identified first and then remedial measure should use. These defects should deal separately. The focus will be on the dampness which is one of the most damaging defects in buildings (Li, Su, Tan, Wang, & Wu, 2019). Roof leakage accident arises many times due to poor and improper waterproofing system. As they are using bituminous membrane which causes a lot of problem for them because the bonding between roof concrete and bitumen was poor due to these cracks appears. The water leakage through those cracks produce dampness which damages the building and effects the health of the users of the building (Agyekum, 2017).

Dampness sources are classified into four major types are, Mounting dampness, Penetrating dampness, Condensation, Pipe leakages. Minor sources or causes are, not proper drainage system at the building site. Poor orientation of building, Flawed slope of the roof (fat slab), Poor construction. Indications of dampness are dull spots on the building, paint detaching, sometime plaster flaking, growth of Fungi (Opoku, Ayarkwa, & Agyekum, 2019).

Buildings should be such that it prevents any kind of water to penetrate through its element. A research was done on six room residential building in which they use three different stages to investigate the dampness. The first one is visual inspection on which they found from the result that interior and exterior walls are damp the symptom they found is dirty spots, sweltering of paint and efflorescence. The second stage is non-destructive test for which they use moisture meter which give the result is that the dampness is very much noticeable (Blay, Agyekum, & Opoku, 2018).

The third and final stage is destructive test in which they found that the dampness in the kitchen and bathroom is due to the pipe leakages and precipitation penetration. From this it is concluded that when there is not proper waterproofing system to each element or where needed this problem will be damage the building and the health of user also. In spatially in residential building if there is not a proper ventilation then the condensation dampness will occur which disturb the health of users (Agyekum, Ayarkwa, & Salgin, 2017). Results from the walls test were carried out like on the double side cladding the free twist limited by 75 % and on the single sided cladding free twist restrained only by 13 %. In order to achieve more rigorous demands from the end users there should be a better interaction between timber producers and contractors of structures and building (Opoku, Ayarkwa, & Agyekum, 2018).
Paint was blistered due to the dampness; plaster was damaged and surface efflorescence could be seen on most of the external and internal wall surfaces. Dampness could be seen on the walls having a height of approximately 1200mm in the walls inside the apartment the dampness could easily be seen on the walls of the bedrooms. Partition walls between the bedrooms and the washrooms were showing serious symptoms of Dampness (Agyekum, Blay, & Opoku, 2018).

The effect of dampness and mold is increasing because the bacteria are becoming stronger than previous many years and there is need to improve lifestyle and stop dampness to cause such types of diseases at the end the researcher suggested that indoor dampness and mold problems constitute an important health hazard. And there is a need to prevent dampness and molds production in workplaces and especially in homes to prevent dangerous diseases of asthma and allergy (Wang, Pindus, et al., 2019).

Indoor dampness and mold problem are universal and major problems for health diseases and structural members which affects the lives of people, their money and resources. The major problem of dampness and mold is health diseases like asthma. These types of issues are very common in countries where temperature remains very low. insufficient maintenance, improper construction work and construction of tight building to conserve energy by ventilation might be the critical factors for the severity of these issues specially in the cold climatic areas and countries. The dampness in residential buildings is significantly dangerous because it increases the chances of asthma specially in the children (Zhang et al., 2018). Polymer Modified Cement Impermeable Coating Material: It is a type of sealing material used in construction and engineering work. When the polymer emulsion and the cement mixed with powder are mixed and took on site and applied to the base, the cement is hydrated to form a seal coat. Polymer modified

cement impervious coatings are commonly used as reliable and safe impervious materials because they have the quality of combining polymer flexibility, hardness and tackiness of cement and they do not require the use of an organic solvent or naked flame (Goldstein, 2010).

A special type of Geo-Polymers has been produced which can be used to increase the strength of structural members and also provide better waterproofing. With the increase in contact angle on Geo-Polymer surface from 210 to 220, the specimen will float in water causing low water adsorption (Agyekum et al., 2018). This is called surface hydrophobic modification of material. These polymers will improve the different properties of materials like short setting time, significantly high flow rate, improvement in compressive strength, high bond strength through interfacial bonding of particles which can be shown through dense microstructure. These polymers can also repair concrete of rigid pavement or it can also provide protective coatings for concrete for marine structures (Wang, Zhao, et al., 2019).. With the application of these polymers on samples, the reduction of water level adsorption can be achieved around 0.5% within 28 days. These polymers repair the materials and improve the properties like short setting time which is only 24 minutes, significant high flow rate which is around 212 m, high early compressive strength of concrete and also high bond strength of concrete (Cai et al., 2019).

III. METHODOLOGY

From the healthy literature view, some failure cuases were identified and then data was collected form the field visit. Number of houses and buidlings from different sectors within Lahore city were visited and evaluated the condition of DPC along with the causes of failure by interviewign the respecitve stakeholders. It was found that mostly buildings have dampness that was started from bottom and moving up in the direction of wall. In some of the buildings the height of dampness patches were different ranging from three feet to seven feet. The dampness was more in much older buildings as compare to newly constructed buildings.

In order to reduce these deffects in DPC in current as well as in future construction, some experimental research was carried out in this research work. In the first step, ordinary concrete mix was prepared and simpe brick masonry layers were constructed along with DPC layers constructed by using traditional practice. In the secodn step same brick masonry was constructed along with the DPC layers that was constructed by following the stadrds codes and guidleines. In the last step concrete was prepared by adding one percent Pudlo pwoder in it and then same brick masonry wall was constructed along with the DPC layer that was constructed by using Pudlo powder.
After the stadrd time duration the rise in moisture contnet was noted and the data was analyzed to find out the effect of using stadrad concrete mix and Pudlo powder concrete on the efficiency of DPC.

IV. RESULTS AND DISCUSSION

During the field visit some major defects in DPC were seen and interview was conducted from stakeholders or construction team about the failure of DPC. The major reasons of failure or low efficient DPC in the buildings were the use of low stadradred construction material for buildign construciton. In majority of the buildings the plythene sheet was not provided at the top of DPC layer and the contractor was told that the polythene layer would cause the laterla slip failure of building during earthquake as polythene sheet is slipery in nature and also it breaks the bound between upper and lower layer of building. This shows that the contractors need technical person at site during construciton of buildings from foundation till finishing level.

Concrete in the DPC layer was prepared by hand without use of mechanical mixture that also was the major reason of DPC failure because hand mix concrete is not as good as mechanically mixed cocnrete. In most of the top walls, the wall capping was not provided that caused the dampness from top to bottom rather from bottom to top through DPC layers. In some of the buildings seapage from the drain or water supply systems were caused the dampness in buildings. Similarly the bricks used in some buildigns were not of high quality and the pores in the body of brickes caused the seapage in the walls.

In order to find out the best suitable method and material to improve the efficiency of DPC layer, two sets of samples were prepared. In the first set of sample brick masonry was constructed along with the DPC layer by adding Pudlo powder in concrete during concrete mix and apply that in different layers of DPC. In the secodn set of sample, cylinders were pored by using same concrete having Pudlo powder in it. These two set of samples were tested by using standard test pratices to find out the rate of increase of moisutre contents in these samples. Following are the details of sample sets. The first sampel set was consisting of the brick masonry along with DPC alyer in between the different layers of brick as per site condition was prepared with cocnrete havind different percentages of Pudlo powder in it. This test was carried out to find hydraulics of moisture rising in the sampel. Aim of this test was to makes the DPC less permeable by adding different percentage of water proofing chemical and concrete ratio. Following are the details of sample mixtures in different layers of brick masonry.

Set 2 consist of concrete cylinders of standard sizes having different percentage of water proofing chemical and concrete ratio. This test was carried out to find the rising of moisture in concrete cylinders of different concrete ratio ranging from 1:1.5:3 to 1:2:4 having different percentages of water proofing chemical that is Pudlo Powder. After the preparation of these two sample sets, rise

in moisture level in these samples were noted after placing the samples into water pond and then moisture content was calculated by using oven dry method.

Table 1: Brick Masonry and Cylinder Samples

Sr. #	Concrete Ratio in DPC Layers and in Cylinders	Pudlo Percentage (%)
1	1:1.5:3	0
2	1:2:4	0
3	1:2:4	1
4	1:2:4	2
5	1:2:4	3
6	1:2:4	6

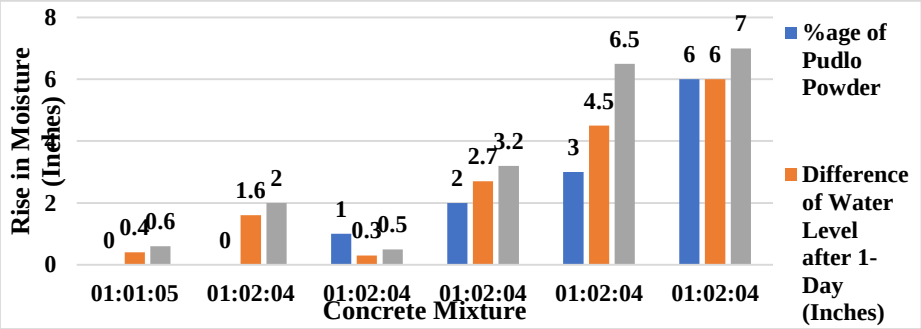

Fig. 1: Rise of Moisture Contents in Different Samples

A. Moisture Content of Brick Masonry Sample

The rise of moisture level below and above the DPC layer in the brick masonry wall sample was noted and then oven dry method was used to find out the moisture content in the brick masonry having DPC in over it. The graph shows that moistur contents of brick layers above DPC and that of cocnrete having mix ration as 1:1.5:3 and that of 1% Pudlo have minimum values as compare to other. The results of oven dry test are shown below.

Table 2: Moisture Contents of Brick Masonry Sample

Sr. #	Sample Type	Wet Weight (kg)	Dry Weight (kg)	Moisture Content % (w-d/w *100)
1	Brick below DPC	4.14	3.27	21.014
2	Brick above DPC	3.84	3.82	0.52
3	DPC Layer (1:1.5:3)	4.16	4.10	1.44
4	DPC Layer (1:2:4)	4.44	4.34	2.25
5	DPC Layer (1% Pudlo)	4.26	4.19	1.64
6	DPC Layer (2% Pudlo)	4.30	4.20	2.33
7	DPC Layer (3% Pudlo)	4.38	4.27	2.51
8	DPC Layer (6% Pudlo)	4.53	4.41	2.65

Ordinary brick masonry has maximum value as compare to other. It is clear that, for the highly efficient DPC layer, either the concrete of mxi design 1:1.5:3 or simple concrete with 1% or Pudlo powder should be added.

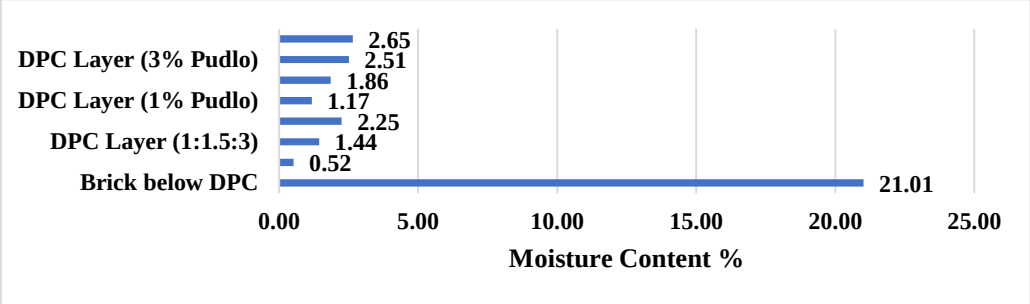

Fig. 2: Comparison of Moisture Content

B. Moisture Content of Cylinder Sample

Similarly, the mositure contnet in six different cylinder samples were calculated by usnig same oven dry method. It is again clear from the table that the moisture contents of cocnrete having mix ratio as 1:1.5:3 and the concrete having 1% of Pudlo powder in it have minimum moisture contents as compare to other samples.

Table 3: Results of Moisture content in Cylinders

Sr #	Sample Type	Wet Weight (kg)	Dry Weight (kg)	Moisture Content % (w-d/w *100)
1	Cylinder-1 (1:1.5:3)	12.77	12.59	1.41
2	Cylinder-2 (1:2:4)	12.49	12.25	1.92
3	Cylinder-3 (1% Pudlo)	12.73	12.6	1.02
4	Cylinder-4 (2% Pudlo)	11.98	11.7	2.34
5	Cylinder-5 (3% Pudlo)	11.98	11.7	2.34
6	Cylinder-6(6% Pudlo)	11.87	11.55	2.70

It is clear from the below figure the by using concrete of mixture ratio 1:1.5:3 or by adding 1% Pudlo powder in concrete have yielded better results. Therefore, 1% Pudlo powder is the optimum limit in concrete to improve the efficiency of DPC.

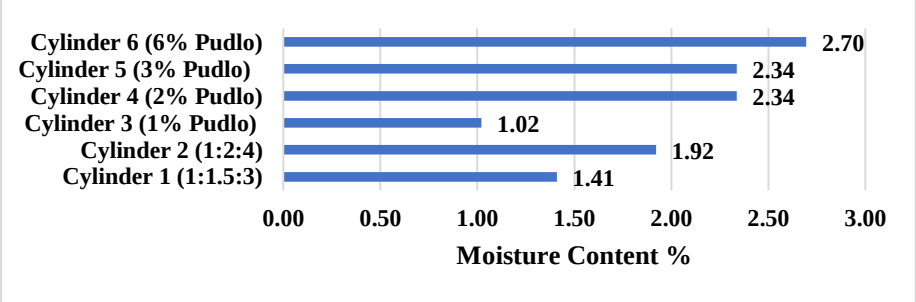

Fig. 3: Moisture Contents in Different Cylinders

V. CONCLUSION

After the collection of data from different location of Lahore from residential as well as from other buildigns, sampling and testign was carried out. Conclusions and recommendations have been extracted from the results of data analysis. Following are the major conclusions of this research work.

- The major reasons of failure or low efficient DPC in the buildings were the use of low stadradred construction material for buildign construciton.
- In majority of the buildings the plythene sheet was not provided at the top of DPC layer and the contractor was told that the polythene layer would cause the laterla slip failure of building during earthquake as polythene sheet is slipery in nature and also it breaks the bound between upper and lower layer of building. This shows that the contractors need technical person at site during construciton of buildings from foundation till finishing level.
- Concrete in the DPC layer was prepared by hand without use of mechanical mixture that also was the major reason of DPC failure because hand mix concrete is not as good as mechanically mixed cocnrete.
- In most of the buildings at top walls, the wall capping was not provided that caused the dampness from top to bottom rather from bottom to top through DPC layers.

- In some of the buildings seapage from the drain or water supply systems were caused the dampness in buildings.
- Bricks used in some buildigns were not of high quality and the pores in the body of brickes caused the seapage in the walls.
- Moisture absorption with different percentage of concrete mixes were also tested. Concrete ratio (1:1.5:3) absorb less water than concrete ratio (1:2:4)
- The addition of 1% Pudlo powder was yeilded better result as compare to all other samples which shows that this is the optimum vlaue of Pudlo powder in cocnrete from inrpovement of efficiency of DPC.
- Moisture absorption with different percentage of concrete mixes in the form of cylinder samples were also tested and similar results were found that is concrete ratio (1:1.5:3) absorb less water than concrete ratio (1:2:4).

VI. RECOMENDATION

- In the builidng areas where chances of dampness are more, the concrete of good mix ratio should be used or pudlo powder should be added in cocnrete to avoind seapage and dampness.
- Specially in healthcare buildigns where asthematic pateints have been admitted, dampness should be controlled by using high cocnrete mxi ratio or by using demapness control chemicals.
- Future research can be carried out to investigate the effect of other chemicals on dampness.
- A research can be carried out to find out the effect of Pudlo powder on the properties of cocncerete.

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