INDIGENOUS METHODS OF SEEPAGE CONTROL

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OD 84, Sec A

MILITARY COLLEGE OF ENGINEERING

NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

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SESSION 2016-2019

INDIGENOUS METHODS OF SEEPAGE CONTROL

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Submitted in partial fulfillment of the requirements for the degree of

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This research is dedicated to our parents.
For their endless love, support and encouragement

APPROVAL SHEET

This is to certify that the contents and format of this research titled ‘‘Indigenous Methods of Seepage Control” submitted by FYP Group #19 in partial fulfillment of the requirements for the award of degree of BS have been approved.

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ABSTRACT

Since inception of construction industry, presence of seepage is affecting structural aesthetics, durability of structure and is becoming paramount concern for everybody. Seepage flow through soils has great influence on stabilities and performances of civil structures, Hence seepage control is critical and technical issue in engineering practices. Major problem of pre-dominant seepage is presence of high water table, poor construction practices, lack of expertise and many other reasons. Globally much research work has been carried out on seepage which consists use of various high resilient chemicals, improved coating/treatment techniques, transparency in execution of workmanship and labor skills. Buildings and infrastructure in Risalpur Cantonment have also been subjected to aggravated seepage problem since long. This study is therefore an effort to ascertain issues related to seepage focusing on existing construction practices. In order to evaluate the real time problem, we have constructed ten different samples in situ by using different DPC materials and configurations to study the impact of seepage due to poor construction practices and workman ship. Moreover, it is pertinent to mention that we have selected a high water table construction site and by ensuring adequate workmanship under technical supervision. Our results have revealed that if the construction practices and good workmanship are practiced in true letter and spirit, the seepage problem in Risalpur Cantonment can be avoided.

Acknowledgements

First of all we are thankful to Almighty Allah who granted us with the chance to study BS Engineering (Civil) at Military College of Engineering Risalpur cantonment and empowered us to successfully complete our research. With the bounty of Almighty Allah, We would like to express our special appreciation and thanks to our advisor Maj Dr. Naeem Shahzad, who has been tremendous mentor for us. We would like to thank him for encouraging us. We would also like to thank our Chief Instructor Col Khurram Sattar for allowing us to conduct research on ‘‘Indigenous Methods of Seepage control’’. We would also like to show our gratitude to our parents who supported us and has been a source of encouragement and inspiration for us throughout our life. We want to thank all the authors who made their works available for use without which we would have no literature to back up the research.

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CHAPTER I

INTRODUCTION

1.1 Background

What is built brick by brick may get destroyed drop by drop by seepage of water in buildings. We have come a long way since Stone Age of building construction to High rise and sky scrapers in construction industry. Shelter has been and continues to be one of the three basic needs of mankind. With passage of time our needs have undergone a profound transformation and so as the building construction. Prevention is better than cure cannot be truer than in case of seepages. To minimise the problems of seepage, best course is to take precautions and proficient workmanship in all stages of the project which include steps required at the Planning Stage, Steps required to be taken during the Execution Stage and care during utilisation of utilities.

Seepage of water is one of the major causes of construction building defects. If the building can be prevented from seepage or leakage, almost 80% building defects can be eliminated. Construction of buildings involves attention to various aspects such as structural safety, functionality etc. As buildings are to be used extensively by us, they have necessarily to be serviceable and are required to be user friendly. For making the building functional, services of the buildings have an important role to play. It is, however, unfortunate that the emphasis which is required to be paid to planning, designing and execution of services has not been always available. It is truer in the case of planning, detailing and installation of water supply, sanitary fittings/fixtures and drainage. Whereas lot of literature is available on different aspects of building designing and construction; lack of literature on making buildings leakage. Therefore it is no surprise that the brick is being used as a construction material from small hutments to multi-story buildings. Unfortunately brick is a porous product, any brick that is exposed will be subject to penetration by liquids and gases when subjected to wetting and drying. The take up of water and resultant expansion being a factor vary according to quality control on site. This wetting is always more pronounced on the most exposed areas. Many of the problems of brick durability occur because of this water penetration. Susceptibility to attack is usually related to poor quality control on site. Impermeability of brick masonry, apart from its direct bearing on water tightness, is also important for its influence on durability. Water is the primary agent for the destruction of many natural materials. It happens to be dominant to most durability problems in brick masonry. With water tightness the structure above DPC can be made to resist to water penetration etc. There are various methods and materials in use, for waterproofing in our country. But most of them fail due to one or another reason. A successful waterproofing depends upon quality control and durability of the waterproofing materials, and the quality and design of the structure itself. Seepage depends on several factors, including permeability of the soil and the pressure gradient, essentially the combination of forces acting on water through gravity and other factors. Permeability can vary over a wide range, depending on soil structure and composition.

Unloading and water head difference between the inside and outside of a foundation pit would induce seepage in high water table ground, which had significant influence on excavation engineering.

1.2 Problem Statement

Seepage, movement of water in to porous materials due to capillary rise, is often a critical problem in building foundations. The most common cause of moisture is in the lower levels type homes. In basements, or in below-grade rooms and bedrooms where seepage from the outside which passes through cracks in the foundation walls and runs onto the floor.

Seepage in high water table area/water log area due to capillary rise is a recurrent problem specifically in Risalpur and Sialkot Cantonment and other cities of Pakistan. Seepage and dampness effects structural stability and interior as well as exterior aesthetics. People are spending handsome amount of money on seepage treatment to get rid from infectious diseases and to restore the beauty of existing structure. Moreover, due to prevailing effects of seepage in surroundings, Research has to be done to reduce the seepage control in upright manner and economical way.

1.3 Objectives of the Study

Objective of this project is kept simple, realistic and achievable during the available time span. The focus of our research is as under:

a. Analyse the Capillary Rise in different foundation samples after ensuring the proper execution of workmanship.
b. Use of different materials to check there efficiency as DPC to resist capillary rise.

1.4 Justification of the Study

a. Seepage problem is very common and pertinently observed in overall the military accommodation.
b. Immense importance to highlight the lacking of workmanship expertise and to fetch new indigenous techniques in seepage control.
c. Cost of repairs is exceeding as the service life of structure increases.
d. Variance in cost effect by performing engineering/ MES practice.

e. The role of site engineer is to be improved for the transparency of workmanship at the site.

1.5 Significance

a. Prevention from penetration of moisture inside building

b. Low maintenance cost

c. Better Aesthetics

d. Durable/ strengthened construction

e. No health related issues

1.6 Aim of the Study

To study and analyze Indigenous Methods of Seepage Control and seepage behavior through various foundation types to limit seepage in structural building.

1.7 Research Questions

The study focused on the following questions:

1. What are the causes of Seepage?
2. What is the advantage of seepage control to the structural building?
3. What kind of foundation can reduce capillary rise?
4. What Cheapest material can be used in DPC to stop capillary rise of water through foundation?
5. What is the cost effect of different material use in foundation?

1.8 Limitations

This research has limited scope only to check the permeability of the DPC by preparing 3x3x0.75 cubic feet samples on ground. Various types of materials are used and characterized to check the capillary rise of moisture from the ground through moisture meter. It does not cover any soil investigation reports and structure stability studies.

1.9 Organization of the Study

The present thesis has been organized in to five chapters. A brief introduction of each chapter is given below.

Chapter I: This chapter was an introduction to the study of the Seepage control measures. It gave a brief background to the study and the statement of the problem.

Chapter II: The review of literature given in this chapter is based on research conducted on global level. This chapter briefly describes the issue of dampness and seepage.

Chapter III: The chapter involves the research methodology. That covers the material selection for DPC, there characterization and practical field work done.

Chapter IV: The chapter of results and discussions deals with data analysis and presentation. Brief explanation have been given for the understanding of the readers.

Chapter V: This chapter includes research findings, the conclusions of the study and recommendations identified from the results. At the end, specimen copy references have been annexed.

1.10 Summary

This chapter was an introduction to the study of the Seepage control measures. It gave a brief background to the study and the statement of the problem. The aim of the study, the objectives and research questions have also been discussed. The chapter looked at the significance of the study and the delimitations of the study.

CHAPTER II

LITERATURE REVIEW

2.1 Operational Definitions

DPC – It is a barrier through the structure designed to prevent moisture rising by capillary action such as through a phenomenon known as rising damp, (*Wikipedia*).

Seepage – he slow escape of a liquid or gas through porous material or small holes, (*Oxforddictionaries.com*, 2019).

Permeability - is defined as the property of a porous material which permits the passage or seepage of water through its interconnecting voids, (*fao.org*, 2019)

2.2 Causes of Seepage

a. Poor workmanship.

b. Capillary rise in high water table area.

c. Poor quality of material in foundation.

d. Lack of waterproofing measures.

e. Water penetration through joints and cracks of external walls.

f. Seepage inside the walls due to leakage pipes caused by poor installation.

g. Seepage occur due to moisture in walls.

2.3 Effects of dampness on building

a. Decaying of wood.

b. It causes the erosion of metallic fixtures.

c. Deteriorate electric installations inside the walls.

d. Deteriorate carpet and furniture inside the building.

e. It can causes blemish spots on the floors and walls of the building.
f. It cause stroking off and removal of plaster.
g. It can cause blistering of paint on the wall.
h. It can cause efflorescence in bricks and tiles.
i. It is very dangerous for the health of residents inside.
j. It may shrinks the life of structures.
k. Seepage attracts the growth of termites.

2.4 Sources of Dampness

Dampness may result due to the reasons as follow:

2.4.1 Rising damp: Rising damp is the upward movement of water through any permeable material. In buildings, the groundwater may be drawn up into walls through capillary action, in non-uniform or uniform manner.

2.4.2 Wind-driven rain: Wind-driven rain is rain falling with a horizontal velocity onto the exterior surfaces of a building. Rain water penetrates through joints, cracks and pores thus emerging moisture inside the walls. Moreover upward pressures produced by wind boost moisture already collected in the weak areas thus permits further penetration into the walls through capillary action.

2.4.3 Condensation: When warm air contacts with the cooler surface, the water vapor present in the air precipitates into a liquid against the cooler surface. The amount of saturation in the air is often referred to as relative humidity; and the temperature at which fully saturated water vapor precipitates is called the dew point. The term “condensation” describes this phenomenon of precipitation, which often occurs within cavity walls where the airspace forms a barrier between the cooler outside atmosphere and a warmer, more humid indoor atmosphere.

2.4.4 Leaks: Deficiencies in roof cover, improper flashing, lack of drainage due to blocked gutters, and open mortar joints are examples of poor construction and maintenance methods that can result in leaks. Moisture, acted upon by the force of gravity, will continue to move in a downward pattern, wetting materials beneath the point of origin.

Once moisture comes into contact with, and is absorbed by, building materials, it moves from wetter to drier areas through capillary action. Capillary action, or the ability of liquid to flow through the narrow tube-like spaces of a material, is the result of inter-molecular attractive forces and surface tension within the walls of the tube. It is stronger within narrower spaces, and may occur in opposition to gravity.

2.5 Techniques of Damp Proofing Worldwide

Some of different techniques that are practices worldwide are:

2.5.1 **A damp-proof course (DPC)** is a barrier through the structure designed to prevent moisture rising by capillary action such as through a phenomenon known as rising damp. Rising damp is the effect of water rising from the ground into property. The damp proof course may be horizontal or vertical. A DPC layer is usually laid below all masonry walls, regardless if the wall is a load bearing wall or a partition wall.

2.5.2 **A damp-proof membrane** (DPM) is a membrane material for example water resistant tape or a polyethylene sheet that is applied to prevent moisture transmission. A common example is polyethylene sheeting laid under a concrete slab to prevent the concrete from gaining moisture through capillary action. A damp proof membrane can be effectively used as DPC.

2.5.3 **Integral damp proofing** means adding of any hydrophobic material to the concrete mix that can be used as DPC.

2.5.4 **Surface coating** it refers to the coating of any surface with thin water proof material which acts as a resistance to the moisture. Coating can be done for both pressurized and non-pressurized moisture. For example spraying of cement as a shotcrete for resistance to the pressurized moisture.

2.5.5 **Cavity wall construction** is an expensive technique used to hide the anomalies of the wall such as rain screen construction. In this technique Interior walls are constructed as such they are separated from the exterior walls by a cavity.

2.5.6 **Pressure grouting** it refers to fill the cracks and joints in masonry materials in order to achieve impermeable layer between the walls.

2.6 Materials that can be used for Damp Proofing

a. Flexible materials like hot bitumen (asphalt), rubber, plastic sheets, bituminous felts, copper, led sheets etc.

b. Coarse sand layers under floors.

c. Rigid materials, like, cement mortar, or cement concrete painted with bitumen, impervious brick etc.

d. Semi-rigid materials like mastic asphalt.
e. Slate and Stones.
f. Plastic sheets under floor.
g. Mortar with waterproofing compounds.

2.7 General principles to be observed while laying damp proof course are:

a. DPC should be laid on level surface. Rough base is likely to cause damage to DPC.
b. DPC should be laid in such a way that it covers the whole width.
c. Each DPC should be placed correct in relation to other DPC laid, this is to ensure a continuous barrier for the water from floors, walls or roof.

2.8 Worldwide reported cases of dampness in Buildings

In Ghana, dampness in the walls of buildings has existed for some time and efforts are being made by building occupants to address such problems (Agyekum et al., 2013 effects to the health of occupants (Oxley, 2003). It is one of the most serious structural effects and can occur in the walls of both old and modern types of construction (Hetreed, 2008; Burkinshaw & Parrett, 2004). Dampness in walls spoils paints and interior decorations, encourages mould and rots growth, hampers aesthetics, poses threats to the health of occupants through providing breeding conditions for mosquitoes, bacterial and fungal growths. It undermines structural integrity of wall elements, reduces thermal insulation property of building materials as well as affects the comfort of the occupants (Trotman et al., 2004; Mbachu, 1999). In Ghana, dampness in the walls of buildings has existed for some time and efforts are being made by building occupants to address such problems (Agyekum et al., 2013). In Pakistan dampness issue is very critical at

Sialkot cantonment. Around 400 to 500 houses are the victims of damp. Similarly in Risalpur cantonment 100s of building's walls are deteriorated due to dampness.

2.9 Effectiveness of some damp remediation measures practiced worldwide

Dampness/moisture damage of buildings does not have a homogenous appearance, henceforth each building should be analyzed discretely. Despite the fact that there are unvarying marvels found in the microbial pollution of the indoor condition and wellbeing impacts of the inhabitants, the unusual reasons for dampness issues and the potential outcomes of disposing them vary (Haverinen-Shaughnessy, 2007; Bornehag et al., 2001). Interference ponders on some posh buildings have appeared some beneficial outcomes after remediation or end of exposure on tenants' wellbeing (Meklin et al., 2005; Shoemaker & House, 2005). As indicated by to Haverinen-Shaughnessy (2007), cautious remediation technique comprises of comprehending the cause the cause(s) of the damage, taking out filthy materials, good quality reconstruction and follow-up procedures. For over 2000 years now, dampness in buildings has received serious attention and lots of remediation measures have been proposed to address the problem. Remediation measures started in the days of the Israelites where the earliest written instructions were given for evaluating microbial contamination in housing environments (Leviticus 14, verses 35-38). These four aspects of dampness remediation measures were given: inspection (Lev 14:36); remediation (Lev 14:40–42); evaluation criteria for failure (Lev 14:43–45); and evaluation criteria for successful remediation (Lev 14:48). Among the measures proposed for the treatment of the dampness problem in scripture was removal of stones on walls in affected areas and thoroughly scraping off mould from the contaminated ones. Also proposal was made for the replacement of affected stones followed by replastering of affected areas (Lev 14:40-41). It is seen from the scripture that replastering was one of the highly used damp remediation measures in the days of old. Scripture, however, does not give accounts of the effectiveness of these measures. Only two instructions were given on the success or failure of the method, thus, if it was found that the dampness was still present and kept on spreading, the house was to be torn down (Lev 14: verse 45). If after the inspection it was found that the dampness had not reappeared upon replastering, then the house was pronounced clean and occupants could use the building (Lev 14: verse 48).

2.9.1 The Comer method

Tamas & Tons (2008) provided remedy to reduce capillary rise from masonry walls. It can be applied in two methods i.e Processing hole and silt method. In former method holes were drilled in series and silicon mortar was inserted inside the holes to reduce moisture in seepage area, after this new series of holes were drilled and treated in same way. This process was carried until total isolation of moisture between lower and upper side of walls. In the second method which can be used for both interior and exterior walls of masonry. A certain portion of mortar affected was removed by scrapping. A horizontal cut was made in length and special foil which act as membrane was placed in those horizontal cuts. This was more efficient and durable method.

2.9.2The Dry Zone Technology

Tomas and Tons (2010) removed moisture from walls of building, they treated the problem which appear due to lack of horizontal insulation membrane. A special damp proof cream was introduced that is injected in pre drilled holes. This was fast, clean and simple method due to water resistant cream and nontoxic nature. It can be inserted faster than ordinary liquid fluids.

2.9.3 Chemical injection methods/Chemical damp proof courses

Since 1950s, damp proof courses are in use with multiple variations in their composition and effectiveness. With minimum installation cost can be offered by the most effective chemical damp proof systems with comparable protection to physical damp proof courses.

Silicates in solvent, wax, latex. Silicones, stearates and aqueous carriers are main ingredients of chemical damp proof courses which are injected in the liquid form in holes drilled with a specific inter-gap in a horizontal plane along masonry. The effectiveness and life expectancy will depend on formulation of product.

2.9.4 Wall base ventilation system

Torres & de Freitas (2007) performed many experiments to validate a new technology for treating the rising dampness in the walls. They felt that many methods used as remedial measures are not very effective specially while considering rise of dampness in thick walls and heterogeneous materials. They performed an experiment at the Building Physics Laboratory (LCF) of the Faculty of Engineering of Porto University using a wall base ventilation system. This method involved installing of ventilated peripheral channels in addition to diminishing water contact with porous walls. This increased the evaporation of moisture which took place below the ground level. Installing a hydro-regulated mechanical ventilation device could increase the system's effectiveness. This experiment showed that implementing this treatment technology (wall base ventilation system) reduced the rising dampness but did not fully eliminate the problem.

2.9.5 Brandt Method

In a study in Denmark Brandt et al. (2012) explored numerous methods taken to improve basements, i.e. getting the basement dry by ventilation and explored new methods to stop capillary rise in the basements walls. These measures included diversion of surface water away from buildings by constructing adequate drainage, use of capillary braking layer beneath floors to avoid capillary rise in the floors, sloping of ground at least 1:40 away from the building etc. But in this study all of his methods proved to be failed. These methods were very expensive and were not suitable for the commercial use.

2.9.6 Solutions to home moisture problems

Brook (2008) sketched some solutions to home dampness issues and they included:

a. Repair and redesign of rain water downpipes.
b. Checking and replacing of all leaking pipes inside and outside the walls.
c. Construction of adequate drainage around the house.
d. Ceasing all moisture generation activities inside the buildings like drying of wet clothing indoors, cooking without lids, etc.

Most of these actions displayed a success for dampness problems like water penetration and condensation. However other methods were needed to cater for dampness problems occurred by capillary rise.

2.9.7 Traditional methods

Guiderails et al. (2013), in Portugal, says that rising damp inside the walls can be treated with any of following traditional methods :

a. Proper execution of a DPC.

b. Installing ventilation pipes.

c. Installing atmospheric drainage.

d. Applying coating with controlled porosity.

e. Creation of a potential against the capillary action.

f. By hiding the anomalies by any method.

Table 1 Comparison

Author	Damp Remediation Method (Main)	Appearance	Effectiveness	Limitation
Guimeraes *et al.* (2013)	Execution of a damp proof course • Reducing absorbent section • Water tight barriers • Hydrofuge products	Bad	Bad, Mean	Not used for aesthetics and structural reasons
		Mean	Good	Causes vibrations that can lead to stability problems
		Good	Very good	Has little effect on thick and heterogeneous walls
	Creation of a potential against the capillary potential	Good	Bad	Considered ineffective
	Installing atmospheric drainage or ventilation pipes	Mean	Bad	Considered ineffective
	Applying coating with controlled porosity and porometry	Good	Mean, Good	Cannot be used on non-plastered walls
	Hiding anomalies	Good	Mean	Reduces space and hides the original wall from view
Tamas & Tuns (2008)	The Comer Method	Good	Good	Its application is limited to only masonry walls of bricks, capstone, etc.
Tamas & Tuns (2010)	The Dry Zone Technology	Good	Good	
Rirsch & Zhang (2010)	Chemical injection methods/chemical damp proof courses		the most effective chemical damp proof systems can offer comparable protection to physical damp proof courses at a lower cost of installation	The degree of effectiveness and life expectancy will depend on the exact product formulation
Torres &de Feitas (2007)	Wall base ventilation system		The method only reduced the level of rising dampness	Method did not eliminate the problem of rising dampness
Brandt *et al.* (2012)	Explored several measures to stop rising dampness in the basements of structures.		All the tested methods proved usable	Not all of them were considered suitable for commercial use either because of their safety implications or because they were very expensive in use

2.10 Summary

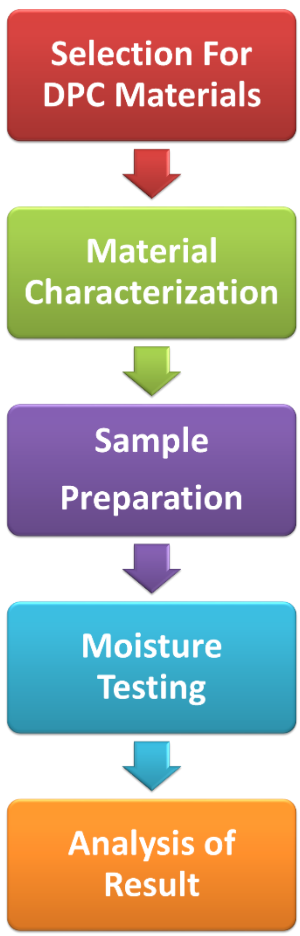
The review of literature given in this chapter is based on research conducted on global level. This chapter briefly described the issue of dampness and seepage and there prevention practices worldwide.

CHAPTER III

RESEARCH METHODOLOGY

Various kind of foundation having difference in design of DPC were prepared on ground and checked for seepage through Moisture Meter (MS 6900) after a month of construction..

3.1 Research Methodology



3.2 Selection for DPC Material

DPC material was selected by our team members after considering different constraints in our perspective. Various aspects were kept in consideration to provide safety of structure, economy in construction and provision of least permeable DPC layer to stop the capillary rise.

3.3 Material Characterization

The specification of different materials used in DPC are as follows: -

a. Terrazzo 13mm
b. Crush 0.5-1 in
c. Marble 1in
d. Chemical Treatment
e. Tile bond
f. Bricks (Best Quality)
g. Titanium 4 gm
h. Lime
i. Stone less than 3mm

3.4 Sample Preparation

First of all best suited location for the preparation of samples was required. MCE training ground is the place where we easily found a location with high water table. All the construction material was delivered to the construction site and handed over to the contractor for the preparation of samples. It took around two weeks to prepare ten samples. Proper curing of samples was ensured and samples were let to dry.

3.5 Moisture Testing

Moisture testing was carried out after a month. The sample had been tested through MS-6900.Two reading were simultaneously taken on each sample, first below the DPC level and second above the said level to get clear and fair readings and idea of how much the DPC is preventing seepage.

3.6 Analysis of Result

Analysis of results are discussed in Chapter V in detail.

3.7 Practical Field Work

3.7.1 Foundation Description

a. Digging of trench 3' x 3'.

b. Leveling of ground surface.

c. PCC/Lean was laid of 3' x 1.5' x 0.5' (1:4:8) to provide smooth surface as well as to enhance the bearing capacity.

d. First step was provided above the PCC of 13.5" x 6"(1:6)

e. Second step was provided above first step of 9" x 12" up till ground level

3.7.2 Foundation with single DPC (plaster cut at DPC level)

a. Use of sand, cement and aggregate in DPC (1:1.5:3) at 1' above ground level.

b. Concrete mixing was ensured as per the best practices.

c. DPC is 2" in height and it's our standard sample for comparison.

d. Plaster cut is provided on DPC level to stop the capillary rise action.

e. Nominal cost effect.

f. Plaster cut is provided on DPC level to stop the capillary rise action.

3.7.3 Foundation with Double DPC

a. Use of sand, Cement and aggregate in DPC (1:1.5:3) at 1’ and 1.5’

b. DPC is 2” in height at both level

c. Purpose of 2X DPC’s provision is to curb the moisture movement in a better way

d. It is also a standard practice use by MES

e. Twice the cost of single DPC

3.7.4 Foundation with Single Chemical treated DPC

a. 3 coats of chemical layer is provided after 90 minutes of each coats to subjugate the seepage in efficient way.

b. Further construction above DPC was executed after complete drying.

c. Purpose is to provide chemical membrane and stops capillary rise.

d. Adds extra cost over DPC which is expensive.

3.7.5 Use of Marble Stone instead of DPC

a. Used marble layer as a DPC instead of PCC

b. Marble is very impermeable and provides good retention against water

c. Use of marble instead of PCC showed better results in seepage control measures

d. It is easily available in market at different rates and is not much costly.

3.7.6 Single DPC with Limestone Piling

a. 4” diameter holes are drilled on 4 corners of the sample

b. Each hole is filled with 4 kg of Limestone

c. The property of limestone include the suction of moisture form the soil.

d. Limestone is cheap material and can easily be acquired from the market

e. Lime piling is practiced in Quetta by MES

3.7.7 DPC of 13mm Terrazzo Chips layer

a. 13mm terrazzo has been used in DPC.

b. Terrazzo in DPC make stronger bond with cement and sand (1:6) as compare to crush.

c. Mortar with terrazzo prevent structure from seepage more efficiently.

d. 13mm Terrazzo is successfully being practiced in Quetta by MES.

3.7.8 Double DPC Horizontal and Vertical

a. This sample has double DPC.

b. In this case Horizontal DPC is connected with Vertical DPC from all sides.

c. The purpose of this kind of DPC is to stop not only the capillary rise moisture but to also stop moisture from lateral direction.

d. It is two times expensive from double DPC as additional cost is involved in making horizontal one.

3.7.9 Use of Tile Bond as binder

a. We have used tile bond instead of cement as a binder up to DPC level.

b. Tile bond provides better mechanical grip onto the bricks and have good water retentively characteristic.

c. Tile bonds can be easily acquired from the market but is expensive substitute to cement Mortar.

3.7.10 Stone Backfilled Foundation

a. Stone Backfilling is done instead of ordinary sand filling.

b. Stone used for backfilling is less than 3mm.

c. Purpose is to stop the capillary rise as well as horizontal inflow of water.

d. It is expensive practice.

3.7.10 Use of Nano Particle Titanium in DPC

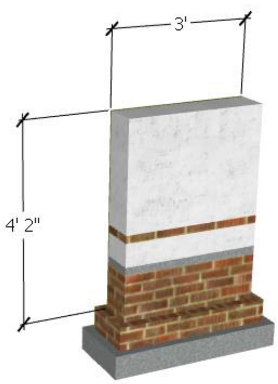
a. 4gm of titanium powder is rapidly mixed with cement with the help of grinder in fixed proportion.

b. Purpose of use of Titanium was its hydrophobic nature.

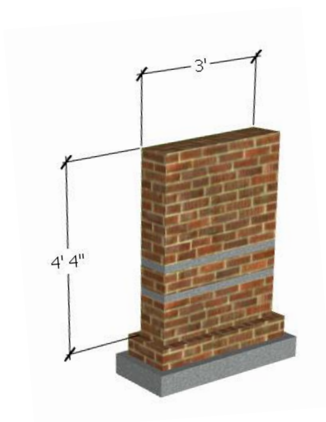
c. Moisture content penetrate above DPC is due to side plaster and voids.

d. Nominal cost.

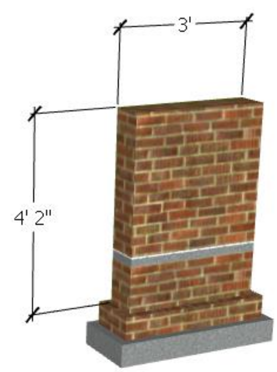
3.8 3D Models



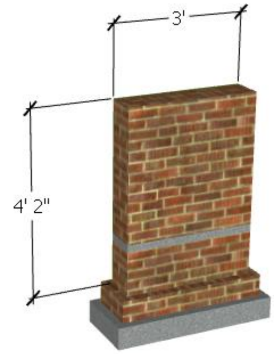
1.1 Plaster Cut Above DPC

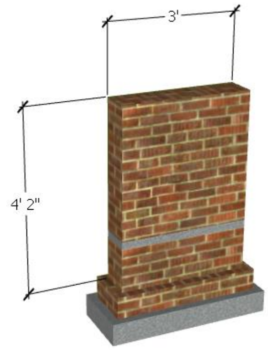


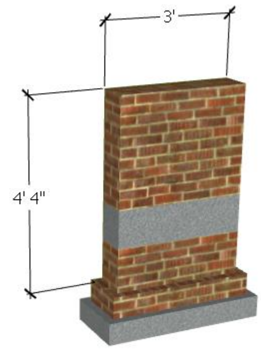
1.2 Double DPC 1



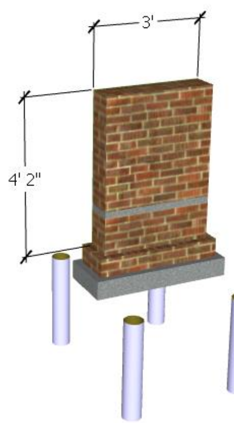
1.3 Chemical Treated DPC 1

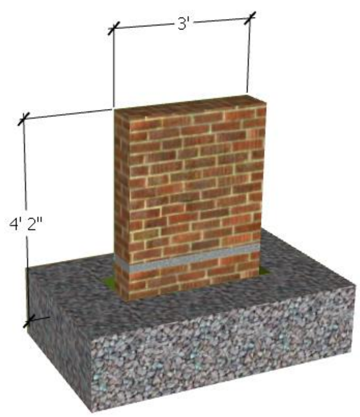


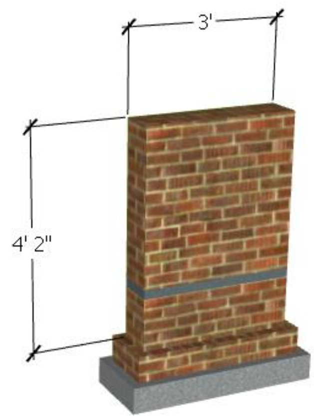




1.4 Marble Stone *1.5 Tile Bond Single DPC* *1.6 Horizontal and Vertical DPC*







1.7 Lime Piling *1.8 Stone Backfilling* *1.9 Chips layered DPC*

3.9 Pictorial Section

3.1 Earthwork 1 *3.2 Excavation 1*

3.3 Preparation of ground

3.4 Lean Prepared

3.5 Foundation

3.6 Curing

3.7 Single DPC

3.8 Marble Stone

3.9 Mixing of Nano Particle (Titanium)

3.10 Chemical Treatment

3.11 Prepared Sample 1

3.11 Lime Piling

3.12 Plastering 1

3.13 Plaster Cut 1

3.14 View of DPCs

3.14 View of Prepared Samples

3.10 Summary

This chapter presented the methodology and methods that were used in the study. It described the material we selected for DPC, there characterization, and the field work done to prepare the samples.

CHAPTER IV

MOISTURE READINGS

In this Chapter we will compare the moisture content present in the sample individually through tables and charts as well as comparison of all the samples with each other. It will give a fair idea of which material is more resistant to the dampness inside the wall. With the help of which we can choose the best suitable type of DPC for analysis purpose. 1st reading of moisture testing was carried out after a month. Two reading were simultaneously taken on each sample, first below the DPC level and second above the said level to get clear and fair readings and idea of how much the DPC is preventing seepage. All the samples were tested twice after the preparation.

All the samples had been tested through MS-6900. MS6900 is a material moisture, temperature, humidity all-in-one multi functions Meter. The Meter is ideal for measuring moisture of wood and concrete buildings. Following materials can be tested through this meter

1: Beech, Spruce, Larch, Birch, Cherry, Walnut

2: Oak, Cedar, Maple, Ash Tree, Citigroup, Tamarisk

3: Smoothing Cement, Concrete

4: Anhydrite Screed

5: Cement Mortar

6: Lime Mortar, Plaster

7: Brick

Table 4.1 Foundation with Single DPC plaster cut at DPC Level (Standard Sample)

Location	**1st Reading**	**Pictographic**
Below DPC	0.6 %	
Above DPC	0.5 %	
	2nd Reading	
Below DPC	3 %	
Above DPC	0.6 %	

Remarks:

Plaster cut of 1.5" was provided just above the DPC to check the discontinuity of capillary rise in our sample. We have observed an increase in moisture content from (0.6-1.3%) below DPC in 15 days interval. Second reading of our sample shows the difference in moisture content below DPC and above DPC is reduced to **2.4%** above DPC in 15 days from the first sample.

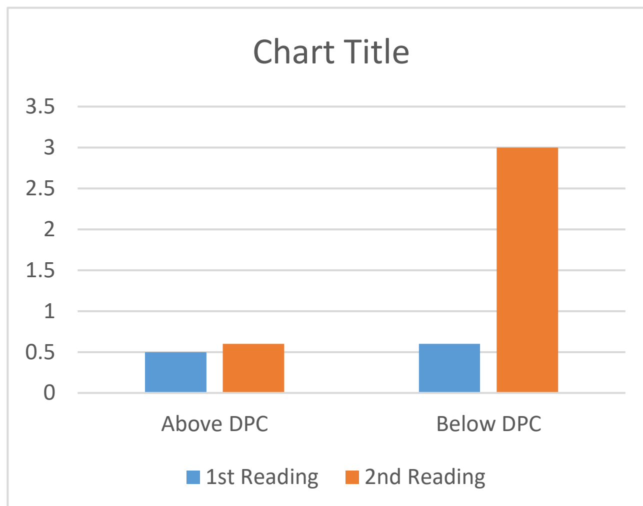
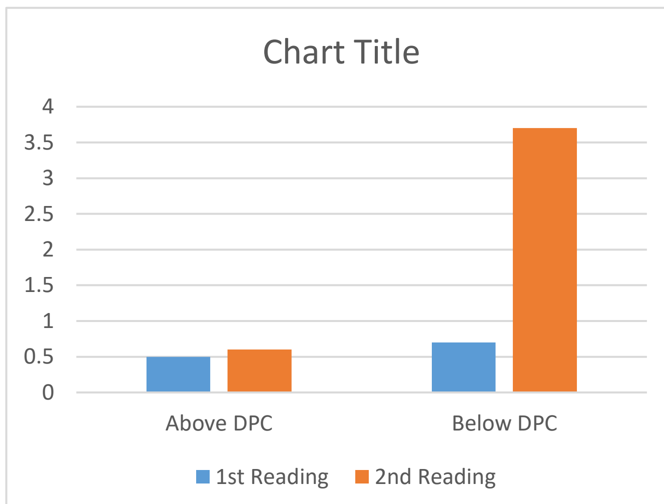


Table 4.2 Foundation with Double DPC

Location	**1st Reading**	**Pictographic**
Below DPC	0.7 %	
Above DPC	0.5 %	
	2nd Reading	
Below DPC	3.7 %	
Above DPC	0.6 %	

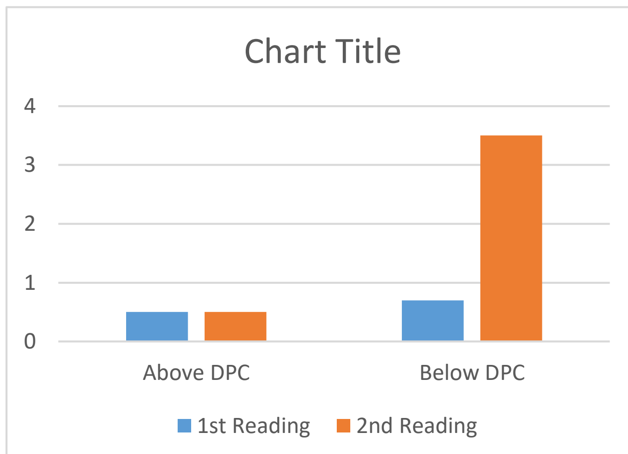
Remarks:



Providing Double DPC is a new trending technique in construction industry as a seepage control measure, it provides a double impermeable layer to give a twice interruption in up rise of seepage, In second reading of our sample we observed significant reduction in moisture content i.e. **3.1%** above DPC in 15 days from the first sample.

Table 4.3 Foundation with Single Chemical treated DPC

Location	1st Reading	Pictographic
Below DPC	0.7 %	
Above DPC	0.5 %	
	2nd Reading	
Below DPC	3.5 %	
Above DPC	0.5 %	



Remarks:

Chemical treatment is a resilient obstruction for capillary rise, as in the construction industry it's the best replacement technique used for bituminous coat's. Second reading of our sample shows substantial reduction in moisture content of **3%** above DPC in time span of 15 days from the first sample

Table 4.4 Single DPC with Limestone Piling

Location	**1st Reading**	**Pictographic**
Below DPC	0.8 %	
Above DPC	0.6 %	
	2nd Reading	
Below DPC	3.1 %	
Above DPC	0.7 %	

Remarks:

It has been remained as a seepage control construction measure in Quetta Cantonment, Second reading of our sample gives a reduction of **2.4%** moisture above DPC in time span of 15 days from the first sample.

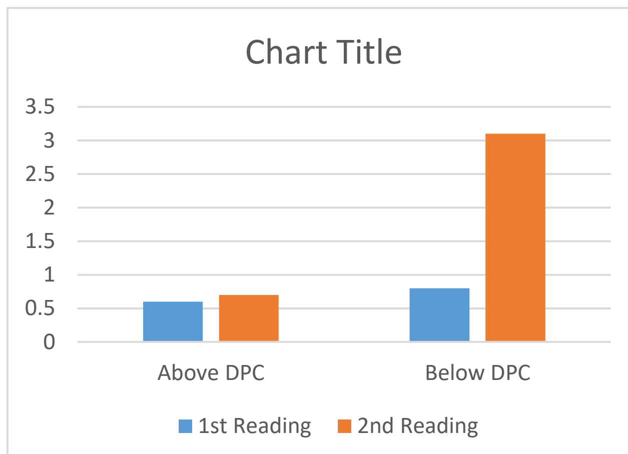


Table 4.5 DPC of 13mm Terrazzo Chips layer

Location	**1st Reading**	**Pictographic**
Below DPC	0.7 %	
Above DPC	0.6 %	
	2nd Reading	
Below DPC	3.2 %	
Above DPC	0.7 %	

Remarks:

It has been once practiced in Mangla Cantonment, Second reading of our sample shows reduction of moisture content i.e. 2.5% above DPC in time span 15 days from the first sample.

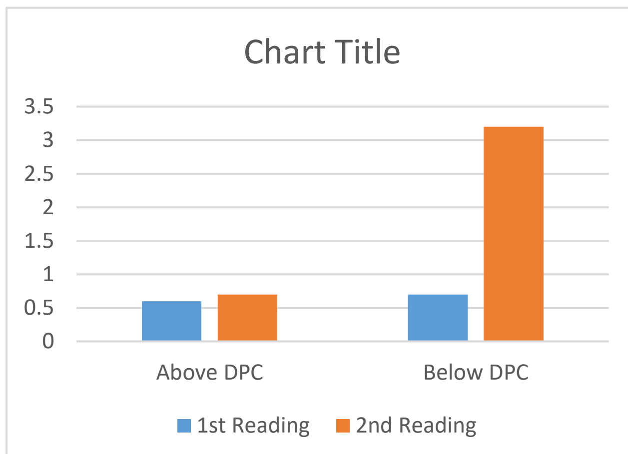


Table 4.6 Nano particle Titanium in DPC

Location	1st Reading	Pictographic
Below DPC	0.7 %	
Above DPC	0.5 %	
	2nd Reading	
Below DPC	3 %	
Above DPC	0.7 %	

Remarks:

As titanium is hydrophobic in nature, we have mixed 4gm of titanium powder in fixed proportion with cement, our sample shows reduction of moisture content is **2.3**% above DPC in time span 15 days from the first sample.

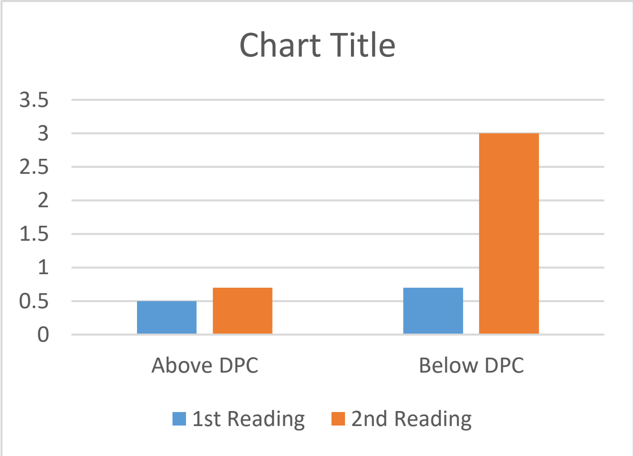


Table 4.7 Stone Filling in Foundation with Single DPC

Location	1st Reading	Pictographic
Below DPC	0.7 %	
Above DPC	0.6 %	
	2nd Reading	
Below DPC	1.2 %	
Above DPC	0.7 %	

Remarks:

It has been practiced in MES due to its better result in seepage control measure, it can be seen through the results that all sample carries moisture content in range of 3% whereas the said sample carries 1.2% moisture content below DPC which is due to presence of stone (less than 3mm).

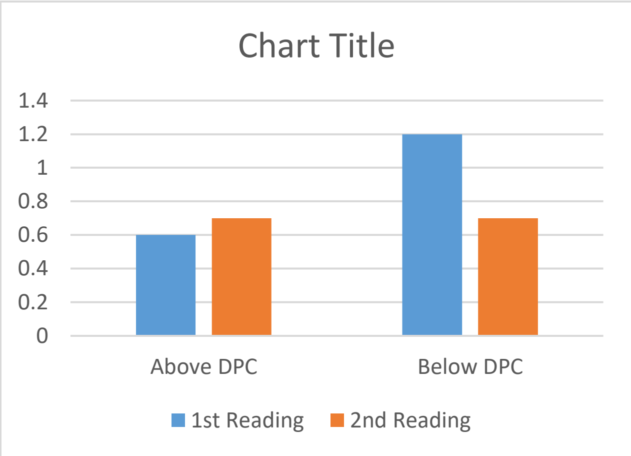


Table 4.8 Use of Marble Stone instead of DPC

Location	**1st Reading**	**Pictographic**
Below DPC	0.6 %	
Above DPC	0.5 %	
	2nd Reading	
Below DPC	2.9 %	
Above DPC	0.4 %	

Remarks:

Use of marble layer instead of DPC gives blockage to capillary rise of water. Marble is 1” thick and it provide significant reduction of moisture content which is 2.5% above DPC in time span of 15 days from the first sample.

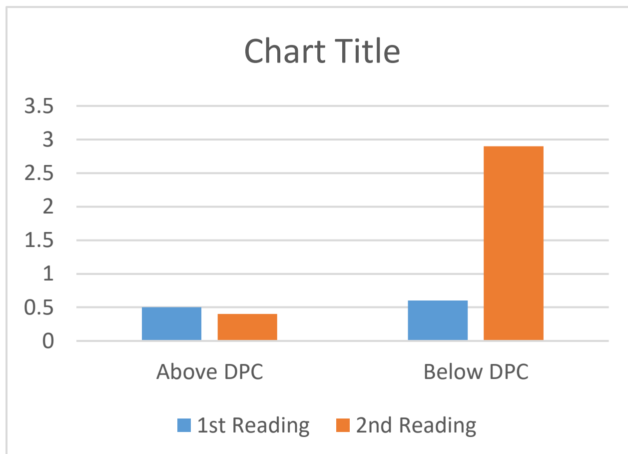


Table 4.9 Double DPC Horizontal & Vertical

Location	**1st Reading**	**Pictographic**
Below DPC	0.8 %	
Above DPC	0.6 %	
	2nd Reading	
Below DPC	2.8%	
Above DPC	0.6 %	

Remarks:

Double DPC horizontal and vertical covers all side of sample as this sample blocks the capillary rise from all sides and provides significant reduction in moisture content i.e. 2.2% above DPC in time span of 15 days from the first sample.

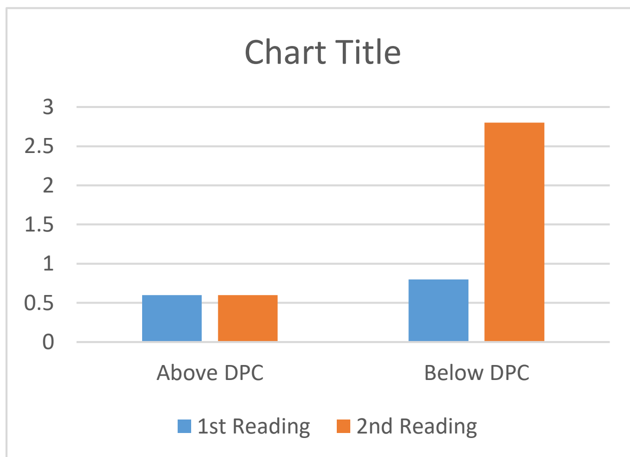


Table 4.10 Tile Bond Foundation

Location	1st Reading	Pictographic
Below DPC	0.7 %	
Above DPC	0.6 %	
	2nd Reading	
Below DPC	1.3 %	
Above DPC	0.6 %	

Remarks:

It can be seen through the results that all sample carries moisture content in range of 3% whereas the said sample carries 1.3% moisture content below DPC which is due to presence of tile bond in joints between bricks. Provides significant reduction of moisture content which is 0.7% above DPC in time span of 15 days from the first sample.

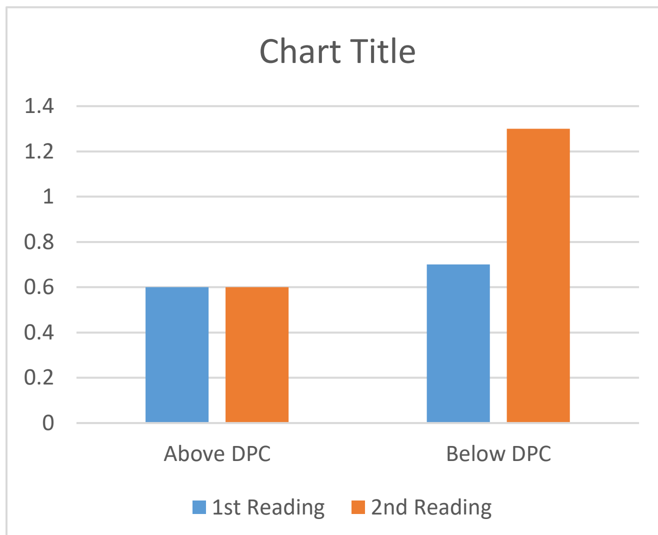


Table 4.11 Comparison of Reading of ten samples

1st Reading				
Sr. No	**Samples**	**Moisture Below DPC**	**Moisture Above DPC**	**Dry Sample Above DPC**
1	**Single DPC with Plaster Cut**	0.6	0.5	99.5
2	**Double DPC**	0.7	0.5	99.5
3	**Single Chemical treated DPC**	0.7	0.5	99.5
4	**Single DPC with Limestone Piling**	0.8	0.6	99.4
5	**DPC of 13mm Terrazzo Chips layer**	0.7	0.6	99.4
6	**Nano particle Titanium in DPC**	0.7	0.5	99.5
7	**Stone Filling in Foundation**	0.7	0.6	99.4
8	**Use of Marble Stone instead of DPC**	0.6	0.5	99.5
9	**Double DPC Horizontal & Vertical**	0.8	0.6	99.4
10	**Tile Bond Foundation**	0.7	0.6	99.4

Chart 4.1

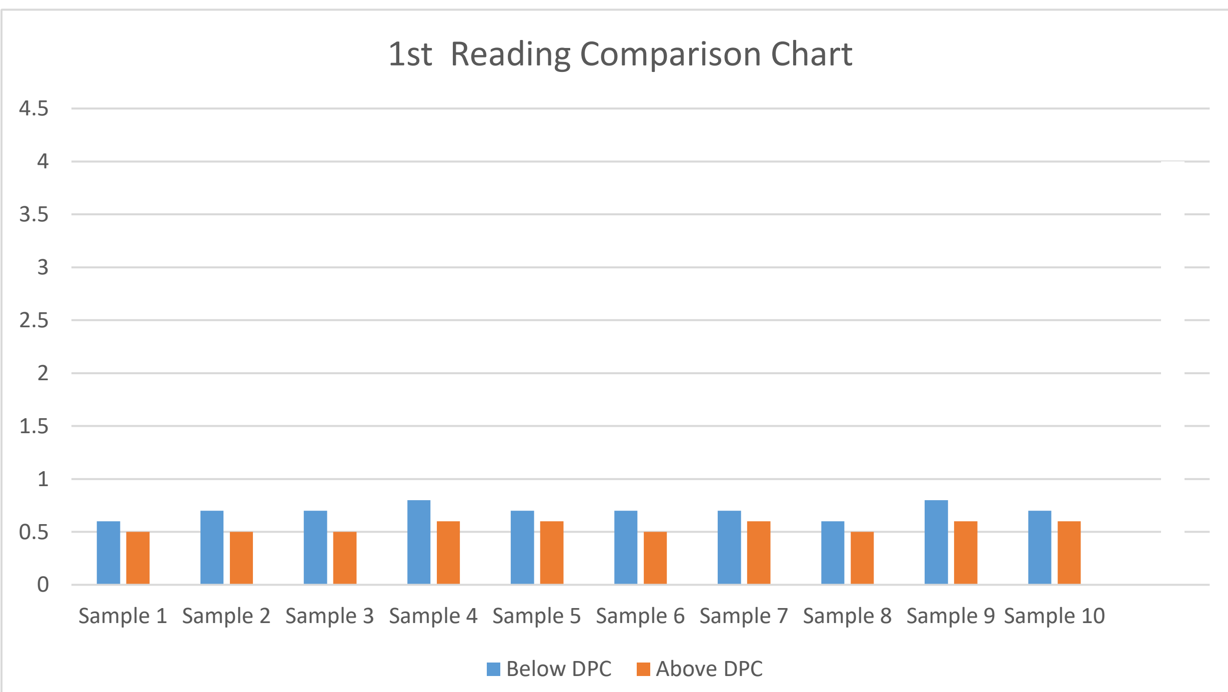
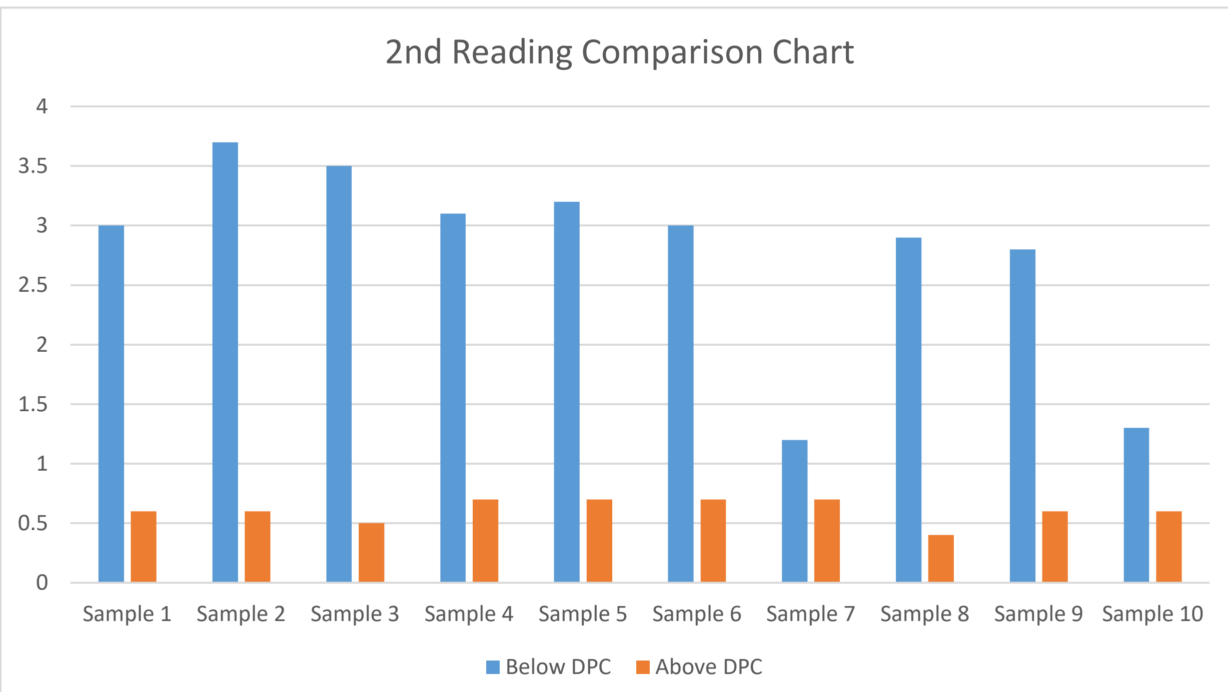


Table 4.12 Comparison of Reading of ten samples

2nd Reading				
Sr. No	**Samples**	**Moisture Below DPC**	**Moisture Above DPC**	**Dry Sample Above DPC**
1	**Single DPC with Plaster Cut**	3	0.6	99.4
2	**Double DPC**	3.7	0.6	99.4
3	**Single Chemical treated DPC**	3.5	0.5	99.5
4	**Single DPC with Limestone Piling**	3.1	0.7	99.3
5	**DPC of 13mm Terrazzo Chips layer**	3.2	0.7	99.3
6	**Nano particle Titanium in DPC**	3	0.7	99.3
7	**Stone Filling in Foundation**	1.2	0.7	99.3
8	**Use of Marble Stone instead of DPC**	2.9	0.4	99.4
9	**Double DPC Horizontal & Vertical**	2.8	0.6	99.4
10	**Tile Bond Foundation**	1.3	0.6	99.4

Chart 4.2



CHAPTER V

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Current study was carried out to determine seepage control due to capillary rise in different foundation samples.

5.1 Findings

5.1.1 Foundation with Single DPC plaster cut at DPC Level (Standard Sample)

Plaster cut of 1.5” was provided just above the DPC to check the discontinuity of capillary rise in our sample. We have observed an increase in moisture content from (0.6-1.3%) below DPC in 15 days interval. Second reading of our sample shows the difference in moisture content below DPC and above DPC is reduced to **2.4%** above DPC in 15 days from the first sample. Second reading of our sample shows the sample is 99.4% dry above DPC.

5.1.2 Foundation with Double DPC

Providing Double DPC is a new trending technique in construction industry as a seepage control measure, it provides a double impermeable layer to give a twice interruption in up rise of seepage. Second reading of our sample shows the sample is **99.4% dry** above DPC.

5.1.3 Foundation with Single Chemical treated DPC

Chemical treatment is a resilient obstruction for capillary rise, as in the construction industry it’s the best replacement technique used for bituminous coats. Second reading of our sample shows the sample is 99.5% dry above DPC.

5.1.4 Single DPC with Limestone Piling

It has been remained as a seepage control construction measure in Quetta Cantonment. Second reading of our sample shows the sample is 99.3% dry above DPC.

5.1.5 DPC of 13mm Terrazzo Chips layer

It has been once practiced in Mangla Cantonment, Second reading of our sample shows the sample is 99.3% dry above DPC.

5.1.6 Nano particle Titanium in DPC

As titanium is hydrophobic in nature, we have mixed 4gm of titanium powder in fixed proportion with cement, second reading of our sample shows the sample is 99.3% dry above DPC.

5.1.7 Stone Filling in Foundation with Single DPC

It has been practiced in MES due to its better result in seepage control measure, it can be seen through the results that all sample carries moisture content in range of 3% whereas the said sample carries 1.2% moisture content below DPC which is due to presence of stone (less than 3mm). Second reading of our sample shows the sample is 99.3 % dry above DPC.

5.1.8 Use of Marble Stone instead of DPC

Use of marble layer instead of DPC gives blockage to capillary rise of water. Marble is 1” thick and it provide significant reduction of moisture content. Second reading of our sample shows the sample is 99.4% dry above DPC.

5.1.9 Double DPC Horizontal & Vertical

Double DPC horizontal and vertical covers all side of sample as this sample blocks the capillary rise from all sides. Second reading of our sample shows the sample is 99.4% dry above DPC.

5.1.10 Tile Bond Foundation

It can be seen through the results that all sample carries moisture content in range of 3% whereas the said sample carries 1.3% moisture content below DPC which is due to presence of tile bond in joints between bricks. Second reading of our sample shows the sample is 99.4% dry above DPC

5.2 Recommendations

Based on the result deduced from the different foundation samples. Keeping the different constraints in consideration the order of priority will be as follows.

a. Proper workmanship should be ensured during execution of different phases of construction activities which gives significant reduction in capillary rise.

b. Three Coats of resilient chemical treatment above DPC has reduced the moisture content in a significant manner hence it can be used as a waterproofing agent on DPC surface.

c. Use of 1” Marble instead of DPC has sufficiently reduced the moisture content above DPC but structural integrity of use of marble may be further investigated specifically in earthquake zone.

d. Stone filling in foundation (less than 3 mm) used as backfill has stopped the capillary rise penetration from all sides and reduced moisture content below and above DPC. This can be the substitute to the backfill of soil where easily available.

e. Tile bond usage in joints instead of cement mortar provides reduced moisture content below and above DPC. It is an expensive binding mortar hence where construction budget is not an issue, there it should be uses as a substitute to the common mortar.

f. As titanium is hydrophobic in nature, so it can also have sufficient reduction in moisture content above DPC.

5.3 Conclusions

In construction industry seepage presence is evident due to multipurpose problems. Stone backfilling and use of tile bond are better options to reduce moisture in walls but very expensive. Construction site was a high water table area but despite this the result shown that moisture did not travel above DPC in all samples of project. Due to the presence of salt the capillary rise is very common in this area but despite all this issues due to good workmanship and practice the seepage remained under control. If the structural stability is not compromised, the use of 1” marble instead of DPC is the most suitable optional because of nominal cost and availability in the market. Use of Titanium is suggested as it is economical but not easily accessible.

5.4 Summary

This chapter includes research findings, the conclusions of the study and recommendations identified from the results .At the end, specimen copy references have been annexed.

ANNEXURE

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