USE OF NANOPARTICLE TITANIUM DIOXIDE (TIO_2) IN SEEPAGE CONTROL

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NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

RISALPUR CAMPUS

SESSION 2017-2020

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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 and teachers.
For their endless love, support, and encouragement

APPROVAL SHEET

This is to certify that the contents and format of this research titled ‘‘USE OF NANOPARTICLE TITANIUM DIOXIDE (TIO$_2$) IN SEEPAGE CONTROL” submitted by FYP Group #34 in partial fulfillment of the requirements for the award of degree of BS have been approved.

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ABSTRACT

Seepage has been one of the major and foremost nuisance in construction industry since its inception. It has disastrous effects on structures stability, durability, and aesthetics. In Recent times hazardous effects of seepage on human health have also been discovered ranging from sinusitis to dyspnea. Hence seepage has emerged as a critical technological issue in construction industry. Major causes of pre-dominant seepage are presence of high-water table, poor construction practices, lack of expertise and many other reasons. The current global practices to eradicate this menace are use of chemical agents and damp-proof courses apart from use of good construction practices. This study is therefore an effort to control this menace by use of nanoparticle Titanium di oxide TiO_2 known for its hydrophobic qualities and its comparison with already available chemical agent PUDLO. The physical system associated with this real time problem is selection and application of three strips of plaster on a seepage affected site with different concentrations of the said nanoparticle in all strips. The nanoparticle TiO_2 has been used in cement paste and applied as plaster while keeping one control strip where PUDLO has been added as a seepage control agent for comparison in terms of economy and effects. Moreover, it is pertinent to mention that we have selected a site which is highly effected by seepage and exposed to atmospheric agencies. The suggested procedure and its results will serve as guideline for cost effective control of seepage flow and further research work for optimizing the procedure.

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CHAPTER 1

INTRODUCTION

1.1 Background

Shelter has always been a necessity to mankind because it is one of the basic human needs. Seepage weakens the bonds within structures and even bonding of concrete with steel. The seepage which occurs drop by drop might destroy the building which was built brick by brick. Seepage can cut short the integrity of the building and slowly make it rot. Constructing buildings have always relied on technological innovations. New developments have continuously been taking place in the world which has led us to construct the high rise and huge skyscrapers. Over the course of time our needs have undergone a serious transformation in the way the construction industry has also witness a profound transformation. To reduce or overcome the problem of seepage, it is better to take precautions and dexterous 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 utilization of utilities. "Ounce of prevention is worth a pound of cure" cannot be truer than in case of seepage.

Seepage in construction means the escape of liquid or gas through porous materials or small holes. Seepage in any building not only makes the building appear unpleasing and dull but also worsen the basic structure reducing its life and causing insalubrious environment which might lead to health issues. If a building can be averted from seepage almost 80% of building defects can be eradicated. Construction of building involves attention to many aspects such as structural safety, functionality etc. As building are to be used greatly by us, they must be utilitarian and are supposed to be user friendly. In order to make the building functional, services of the building have the key role to play. It is, yet unfortunate that the attention, which is required to be paid to planning, designing and execution of services has not always been available. Since bricks is being used as a basic construction material for constructing small encampments to multistory buildings. Unfortunately, the brick is a porous material, any brick that is exposed will be subject to penetration of liquids and gases when subjected to wetting and drying. Most of the problems of brick resilience occur because of water penetration. Vulnerability to attack is related to poor quality control on site. Water is the predominant agent for the destruction of many natural materials. In our country we use many different materials for water proofing, but most of them fail due to various reasons. A successful waterproofing relies upon quality control and durability of the water proofing materials and the quality and design of the structure itself. Nanotechnology has a remarkable application in almost every flied. The unique properties, such as high surface to volume proportions, the use of Nanoparticles therefore have increased in almost every filed but most importantly in civil engineering they are being ventured up gradually to make wonders for sustainability. One of the chemical compounds which can be for tested for water proofing is Titanium di oxide. Titanium dioxide has been used for almost a century in a wide range of industrial and consumer products which includes paints, coatings, adhesives also floor covering, roof materials, catalyst and many more. Titanium dioxide exists in nature as the notable mineral rutile, anatase and brookite. It is used as a fractional trade of bond in concrete for enhancing its quality also compressive flexural and rigidity.

1.2 Problem statement

Controlling seepage, movement of water into porous materials by applying waterproof plaster with nanoparticle titanium dioxide (TIO_2) as a constituent which will be made by mixing cement, sand, water and titanium dioxide. Seepage can be caused by various reasons such as leakage in drainage or water supply pipes, deteriorated water proofing of slabs. The most common and recurrent cause in Risalpur and other cities of Pakistan is seepage of wastewater or rainwater through roof or external wall. Water seepage can cause serious damage to structural stability and interior as well as exterior aesthetic, not only that it can affect the health of the inhabitants. People pay a handsome amount of money to treat seepage as well as to restore the beauty of the existing structure.

1.3 Objective of the study

The objectives of this project are kept simple, pragmatic and attainable keeping in view the available time span.

The focus of our research is enlisted below:

a. To check the effectiveness of nanoparticle (titanium dioxide) in seepage control.

b. Analyze the cost effect of nanoparticle (titanium dioxide) based compound Vis-à-vis available chemical compounds (PUDLO) in controlling water seepage.

1.4 Justification of the study

a. Seepage issues is a major issue in almost every military accommodation.

b. Immense importance to highlight the use of nanoparticles which may lead to new indigenous techniques in seepage control.

c. Exceeding cost of repair vis-a-visa service life of structure increases.

d. Making use of established qualities of hydrophobic nanoparticle (titanium dioxide) in increasing structure qualities.

1.5 Significance

a. To prevent ingress of dampness and moisture inside building
b. Reduce the maintenance cost
c. Improve aesthetics
d. Long-lasting/safe construction

1.6 Aim of study

To study and analyze Indigenous method of seepage control through use of Nanoparticle Titanium dioxide TIO_2 in cement mortar mix through application on structural building.

1.7 Research Question

The study focused on answering the following questions:

a. What causes seepage?
b. How can seepage control benefit the structural building?
c. Can Titanium dioxide (nanoparticle) be used to control seepage?
d. What is the cost effect of using Titanium dioxide (nanoparticle) for seepage control?
e. Comparison with other chemical compound available in market.

1.8 Limitations

The sample structure chosen for the research has very small covered area by making 3 boxes of 3’x2’ and each box is further divided into 4 strips of 2’x 9” by making different composition of titanium dioxide (TiO_2) and Pudlo samples which does not confirm the effectiveness and efficacy of the nanoparticle (titanium dioxide) in controlling seepage. Research does not cover any soil investigation reports and structure stability studies. Moreover, the nanoparticle (titanium dioxide) is not abundantly available commercially. The research was conducted under natural conditions hence the weather conditions could not be controlled.

1.9 Organization of the study

The thesis comprises of five chapters. Detail of each chapter is appended below:

Chapter I: In this chapter a brief introduction to the measure of seepage control has been given. It also explains the background along with the problem statement.

Chapter II: This chapter highlights the literature review based on researches done on global level. The issue of dampness and seepage has also been discussed.

Chapter III: The following chapter covers the structural selection for testing, concentration of nanoparticle applied, and method of application.

Chapter IV: The chapter includes results, discussion, data analysis and presentation. Brief explanations have been given for the understanding of the reader.

Chapter V: This chapter covers findings, conclusions and suggested recommendations basing on the research. References have been annexed at the end.

1.10 Summary

In this chapter a prelim to the study of seepage control measure was discussed, along with the background to the study and the problem statement. It also included the aim of the study, the objectives and research question. The significance and delimitations of the study were discussed at the end of the chapter.

CHAPTER II

LITERATURE REVIEW

2.1 Operational Definitions

Seepage – The slow escape of a liquid or gas through porous material or small holes. (Lexico Dictionaries, 2020)

Nanoparticle – also known as ultrafine particle of matter that is between 1 and 100 nanometers (nm) in diameter) (Wikipedia, 2020)

Titanium dioxide – a white unreactive solid which occurs naturally as the mineral rutile and is used extensively as a white pigment. (Lexico Dictionaries, 2020)

Permeability - is defined as the property of a porous material which permits the passage or seepage of water through its interconnecting voids, (Punmia & Jain, 2006)

Capillary Rise – Capillary action is the ability of a liquid to flow in narrow spaces without the assistance of, or even in opposition to, external forces like gravity. (Wikipedia, 2020)

2.2 Causes of Seepage

The major causes of seepage are:

a. Defective or deteriorated waterproofing

b. Use of low-quality material

c. Faulty internal pluming

d. Rainwater accumulation

e. Clogging, cracking or improper installation or pipes

f. Penetration of water through cracks or joints in external wall

g. Leakage in drainage pipes

2.3 Effects of Seepage on structure

a. Causes pockmark and gouges on the floors or walls.

b. Causes corrosion of metallic installations.

c. Crumbling and softening of plaster

d. Disintegrates the structure

e. Efflorescence causes the paint surface to blister and peel off

f. The unsightly patches created due to seepage affects the anesthetic of the building

g. Causes deterioration in timber fittings

h. Promotes breeding and growth of termites and other bacteria hence creating unhealthy conditions for living.

i. Causes growth of mold and mildew on the walls insulting in musty smell.

Figure 1: Seepage visible on EOD sidewall

2.4 Sources of Dampness

2.4.1 Rain penetration: the porous brick may cause the penetration of rainwater. Water seeps through the pores and penetrates the masonry.

2.4.2 Level of site: the water already present in the ground may rise above the ground level through the walls.

2.4.3 Condensation: When moist air meets a surface that is cold like a wall or a window it causes the condensation. Since the air cannot hold the moisture, the small drops of water appear**.**

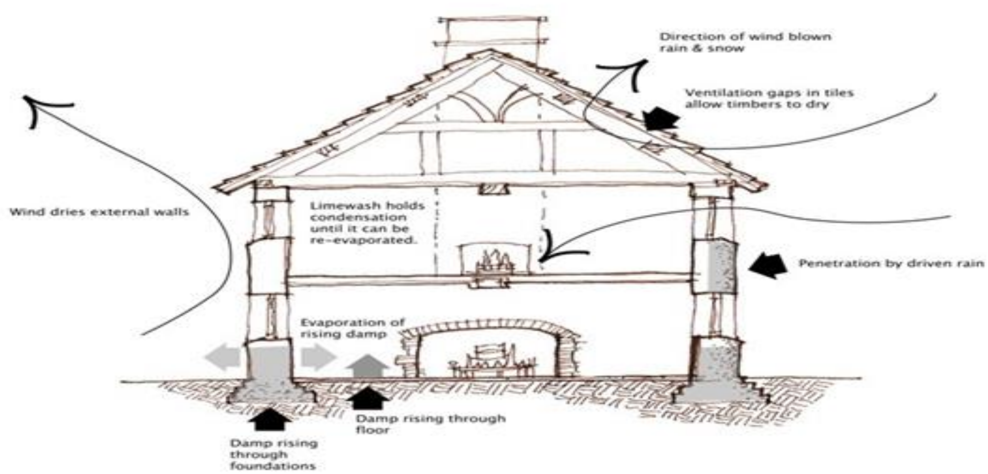


Figure 2: Sources of Dampness

2.5. Techniques used for damp proofing:

2.5.1 Membrane damp proofing. A major source of damp in buildings is the earth surface under the concrete structure of a building through capillary action. Damp Proof Course or DPC is therefore placed between the origin of moisture and the part of building to be protected.

A DPC could also be a Damp Proof Membrane which can be an impermeable polyethene sheet laid under the concrete slab so that it stops the transmission of moisture through it.

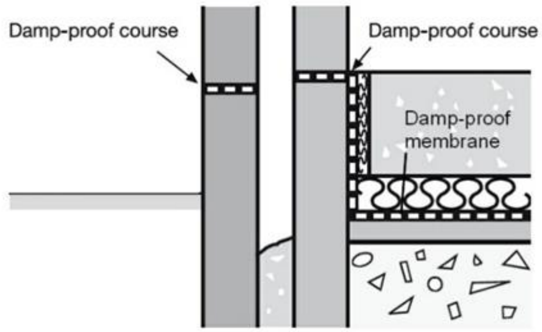


Figure 3: Membrane Damp Proofing

2.5.2 Integral damp proofing: In Integral damp proofing certain water proofing compounds are added into concrete mix which makes it impermeable or water repellant. The integral damp proofing consists of incorporating commercially available compounds in water before concrete is mixed. These water proofing compounds may exist in three forms:

a. Compounds made from chalk, fullers earth which may fill the voids of concrete.

b. Compounds like alkaline silicate, aluminum sulphate, calcium chloride etc, which react chemically with cement to better fill the voids and make it waterproof.

c. Compounds that work on water repulsion principle, like soap, petroleum, oils, fatty acids like ammonia etc. when they are mixed with concrete, it becomes water repellant.

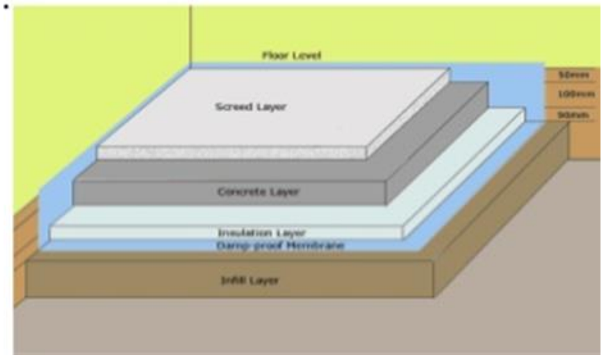


Figure 4: Integral Damp Proofing

2.5.3 Surface treatment: The application of layer of water repellant substances or compounds on surfaces which are permeable or through which water enters is called surface treatment. In some instances, moisture may enter through pores and penetrate the material. To fill these pores up, products are available that can be applied by pressure or non-pressure means to the material and the chemical penetrates 2 to 4 mm inside the surface, to block cracks and pores that could have been the source of moisture.

Figure 5: Surface treatment

2.5.4 Cavity wall construction: In cavity wall construction the main wall of the building is bulwarked by an outer skin wall leaving a cavity in between the two, this is called the cavity wall construction. The cavity is built to prevent the entering and travelling of moisture from the outer to the inner wall. It is an expensive method which can help hide the eccentricity of the wall such as rain screen construction.

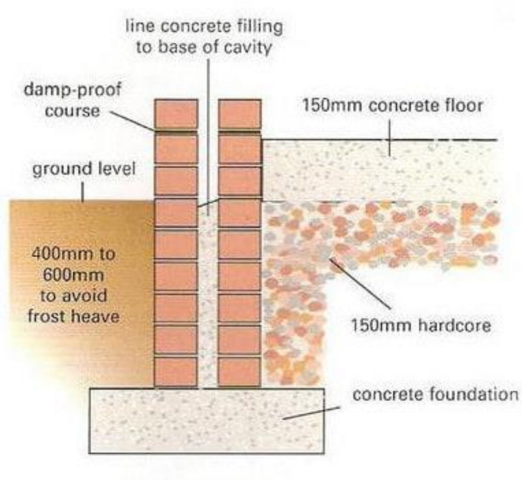


Figure 6: Cavity wall construction

2.5.5 Guniting: The coating or covering of the exposed damp surface with an impervious layer made of rich cement mortar in order to make it waterproof is called Guniting. To guarantee dense compaction and better adhesion of the rich cement, the mixture is applied under pressure using a guniting gun which makes the treated surface impermeable or waterproof.

Figure 7: Guniting

2.5.6 Pressure grouting: is the process of filling the cracks or joints in the masonry material to create an impermeable layer between the walls.

2.6 Nano Based Materials

2.6.1 Use of Nanoparticles for water proofing:

Nanoparticles are ultrafine particles sized between 1 and 100 nanometers. Creating nano water proofing by using nanoparticles is one of the newest damp proofing solution available today. This method uses the nano-sized particles to penetrate the tiniest crack or spaces bonding them with particles to create a superior long-lasting durable coating. Nanoparticles not only fill the cracks but also, it can stop any further input that might be coming from the external environment by securing them all completely. While most of the other solution tend to become weaker by the time, nano waterproofing remains long-lasting, durable and effective over the time. Nanoparticles are highly UV and weather resistance which makes them durable even under stresses of extreme temperature fluctuations (Ohama, 2011). The traditional waterproofing membranes tend to lose potency or effectiveness on exposure to heat and break down while the nanoparticles stay strongly bonded to the substrate and prevent them from breaking down under various extreme conditions. Since the nanoparticles are physically very tiny, the waterproof coating is completely invisible. Therefore, the nano waterproof coating do not change the aesthetics of the structure.

2.6.2 Common Application

As discussed earlier the nanoparticles can bond strongly to any substrate due to its high material bonding strength also it can withstand extreme weather, it can also be applied to any surface. Nano waterproofing is usually applied by spraying porous substrates like cement and masonry. The unique properties of nanoparticle make this solution highly flexible solution that offers industrial grade performance. Using water based nano tech, wood surfaces can also be coated with nano coatings, doing so will stop the surface from absorbing water, making it water resistance. The water-based nanotech can also be used for marble surfaces.

2.7 Effectiveness of nanoparticles for water proofing

The issue of seepage has been a problem since forever. The rapid advancements in science and technology has allowed us to use nanoparticles to produce eco-friendly products to control seepage by waterproofing all kinds of building material. The inherent porosity and micro cracks are main reason behind causing water seepage and water leakage in building materials. Waterproofing is a treatment, which is expected to make the material impervious and impermeable to water. For the last 50 years, there has been a lot of development in technology and product development in various waterproofing solutions ranging from membranes to chemicals and nanotech.

Another important area in construction is coating paints and isolation materials coatings; coating that are widely used on doors, walls and windows. To give a surface requisite protection or a special function, a layer has to be bound to the base to provide a coating. Application of Nanotechnology to paints can give insulating properties to it and are these paints are manufactured by incorporating nano-sized cells to the pores and hence limiting the paths for thermal conduction. These methods are now widely used. These coatings are also hydrophobic and have water repelling qualities and can impart anti-corrosion properties to surfaces and materials. Better adherence and transparency is proved by nanoparticle based systems. For insulating properties, the use of silica gel particles with nano sized pores combining it with reinforcing fibers paints and coating are also on being developed and used. (S, A, & SharmaD, 2013). The extraordinary properties of TiO_2 nanoparticles are now being tested along with addition of self-cleaning coatings to it in order to give construction an environment friendly approach. (Mann S. , 2006).

2.8 Use of Nanoparticles in construction

Nanomaterials, with their inherent change in molecular structure, have paved way for construction materials to be applicable more effectively and beneficially in the industry of construction. Benefits like added strength, economical use of natural construction materials, lower density of nanoparticles can be sought along with decrease in energy usage. It is envisioned that using nanoparticles will lead to safer means, faster, low costing and more productive employment of construction materials. Making use of technology and research, nanoparticles offer a productive and balanced approach by obtaining the most out of construction processes and materials by giving them more durability, cutting costs, and providing the user with various enhanced properties in materials that were previously hard to achieve or even unheard of. The inculcation of special features and technical qualities like water-resistance and fog resistance among many others, in materials through altering nanostructure of a molecule seem particularly promising, not only in construction but other industries as well. By harnessing special chemical and physical properties of nanomaterials, special design systems with high surface areas, special surface effects, catalytic effects and high strain resistance of materials has been made possible.

As use of nanoparticles increases in chemical, biological and mechanical industries, the construction industry has also started adopting it with newer and innovative products with improved qualities being researched constantly. Some of the qualities that nanoparticles provide which are associated with construction are development of stronger and lighter structures of steel, improvement and enhancing properties of cement materials, increasing compressive strength of concrete, improving joints in pipes, providing effective insulation against heat and sound. Properties of glass can be enhanced and thereby making it more reflective or opaque, making it water repellant, anti-fouling, protection against UV light and improving efficiency (S, A, & SharmaD, 2013).

According to a research nanomaterial were estimated at $14,741.6 million and are expected to reach $55,016 million by 2022. Nanotechnology decreases the environmental hazard posed globally by "clinker" production alone which is a massive 8%. Moreover, photo catalytic reactions can result in cleaning the environment through application or coating of nanoparticles on the surfaces of buildings. (BBC News, 2018). These days it is common to use hardeners such as fibers supplemented by nano-silica particles to enhance strength of existing concrete members/structures. It is termed "Fiber-Wrapping" and it operates by the nanomaterial closing small cracks on the concrete and the fiber bonding itself strongly to the surface. It is an efficient way to obtain stronger concrete and because it is non-destructive in application, it decreases the environmental pollution posed by use of cement products. (Saurav, 2012). (Ganesh, 2012).

The table below shows the application of some of the nanoparticles in construction. The following Nano materials can be used in constructions with possible advantages: (Daniyal, Azam, & Akhtar, 2018)

Table 1. 1: Use of Nanoparticles in Construction (Daniyal, Azam, & Akhtar, 2018).

NANOMATERIAL	BASE MATERIAL	POSSIBLE BENEFITS	References
Carbon Nanotube CNT	Cement and concrete	Enhancing strength by reinforcing the molecular structure.	(M.A. Ahmed, 2015) (Iijima, 2002) (Małgorzata, 2014)
	Ceramics	Improved strength and thermal properties.	(Becher, 1991)
	Nano electrical mechanical system	Increased mechanical strength	(saafi & Romine, 2005)
Silicon Di oxide SiO_2	Cement and concrete	Enhancement and durability of mechanical strength	(Bahadori & Hosseini, 2012)
	Glass	Alters reflective properties and better insulation	(Rana, Rana, & A. Kumari, 2009)
Titanium Dioxide TiO2	Solar cell	IPP (independent/nonutility power generation)	(Serpone & E. Pelizzetti, 1989)
	Glass	Anti-fogging, hydrophobic, self-cleaning properties.	(Guerrini, 2012)
	Cement, sand & concrete	Rapid hydration, increased strength and decreased water absorbing properties	(Nazari, Shadi, Sharin, Shamekhi, & Khademno, 2010)
Ferric Oxide (Fe2O3)	Cement and concrete	Improvement in strength	(Nazari, Shadi, Shari, Shamekhi, & Khademno, 90-93)
Copper oxide (CuO)	Cement and concrete/steel	Improvement in strength and durability, enhanced weld ability and corrosion resistance	(Nazari, Rafieipour, & Shadi, 2011)
Aluminum oxide (Al_2O_3)	Cement and concrete	Improvement in strength of concrete and cement products.	(Zhenhua, Huafeng, Shan, Yang, & Miao, 2006)
Zirconium oxide (ZrO_2)	Cement and concrete	Improvement in strength of concrete and cement products.	(Nazari, R, Riahi, Shamekhi, & Khademno, 2010)
Zinc dioxide (ZnO_2)	Cement and concrete	Improvement in strength of concrete and cement products.	(NAZARI & RIAHI, 2011)

Calcium carbonate ($CaCO_2$)	Cement and concrete	Enhancement in mechanical strength	(Sato & Diallo, 2010)
Chromium oxide (Cr_2O_3)	Cement and concrete	Improvement in mechanical strength and durability	(NAZARI & RIAHI, 2011)
Silver (Ag)	Paints	Antimicrobial properties	(Kumar, Vemula, Ajayan, & John, 2008)

2.9 Nanoparticle Titanium dioxide

The major properties of TIO_2 nano particle are as follows:

a. Corrosion immunity

b. High strength

c. Reflective surface texture

d. Low thermal expansion

e. Self-cleaning(photocatalytic)

f. Reduce setting time

g. Increase hydration process

h. Reduce volume of pores

The element Titanium was found in 1791 by William Gregor, in England. It is obtained by extraction from its ores and subsequently alloys and compounds to be made from pure titanium. Titanium dioxide is used in cement and concrete and affects the structure at molecular level to improve its properties like flexural strength, compressive strength, and rigidity. Moreover, the durability can also be increased by inhibiting quality degrading factors and preventing micro cracking. (Guo, Sen & Wu, Zhongbiao & Zhao, Weirong, 2009). Titanium dioxide has gained popularity in construction industry due to its self-cleaning properties and ability to remove air pollutants by reacting with unpleasant matter in the air and converting into harmless products instead. The titanium dioxide nanoparticles when added to concrete improves it properties. This compound can also be used as an excellent reflective coating on for Solar cells. Through powerful photo catalytic reactions, titanium dioxide can break down organic pollutants, thereby reducing air pollutants when it is applied to outdoor surfaces of buildings. Anatase TiO_2 gives high oxidizing power when exposed to UV light, and is very useful owing to its low cost, high chemical stability, and low toxicity. It promotes decomposition of organic pollutants.

The hydrophilic property of Titanium dioxide provides self-cleaning properties to the surface on which it is being applied. As rainwater accumulates over surfaces and forms layer which can attract pollutants and dirt, TiO_2 nanoparticles can make these surfaces water-repellent hence improving the aesthetic and cleanliness of a surface (Saurav, 2012). Titanium Dioxide has a wide range of use and application in coating and also the paint industry. TiO_2 can be added to paints and pigments to be applied to surfaces and it exhibits improvement in optical properties. Due to a significant reduction in photo-catalytic activity the surface retains color over a longer time and is less prone to deterioration. (Gleń, Marta & Grzmil, Barbara. 2013).

In order to prevent sticking of pollutants nano TiO_2 can be applied to the exterior of the building which will reduce the maintenance cost. (Zhu W, 2004,).

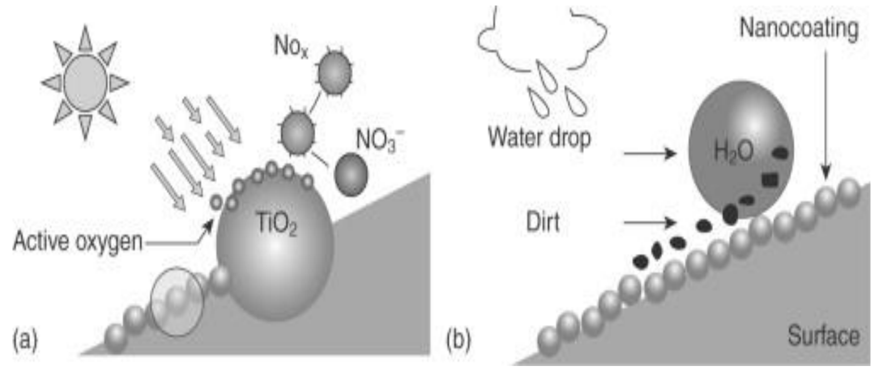


Figure 8: Use of TiO2 in removal of pollutant

According to research which showed that Adding 1% of TiO_2 nanoparticles into concrete resulted in improving the compressive strength and durability performance of high-performance concrete. Therefore, Titanium dioxide TiO_2 can improve the compressive strength and durability performance of high performance concrete hence, TiO_2 nanoparticles can prove to be very useful to construction industry (Daniyal, Azam, & Akhtar, 2018).

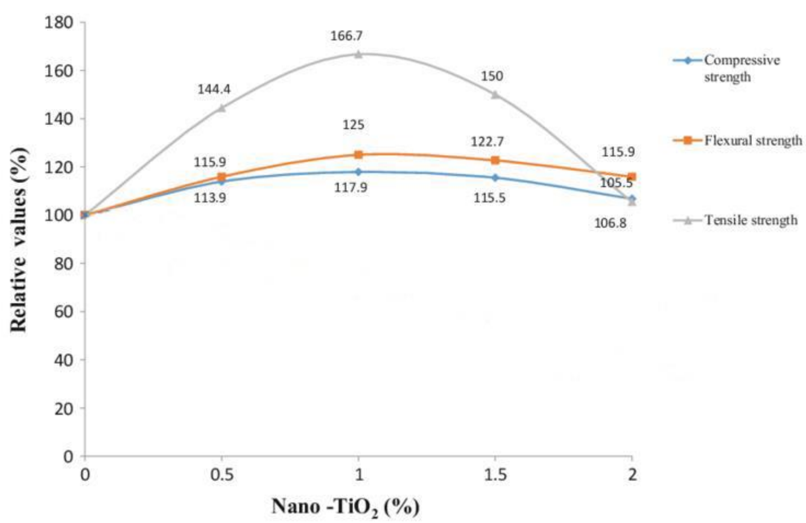


Figure 9: Use of TiO_2 to improve performance of concrete. (Daniyal, Azam, & Akhtar, 2018)

Another research work on “The effects of curing medium on flexural strength and water permeability of concrete incorporating TiO_2 nanoparticles” investigated the effect of nanoparticle Titanium Dioxide nanoparticle when mixed with concrete. Alteration was made by compensation of cement by 0.5, 1, 1.5 and 2 percent. The results showed that up to a maximum of 2 percent of addition of titanium dioxide, flexural strength concrete cured in saturated limewater increases compared to concrete cured in normal water. High pozzolanic action of nanoparticles acts at a molecular level to give a better bond by better filling the voids. (Nazari A. , 2011).The use of Titanium Dioxide includes the role of “chalking” of the paint, which enhances the corrosion resistant performance, and also influence the cure characteristics and self-cleansing property. According to a study, Titanium Dioxide nanoparticle resulted in decreasing the curing time. (Hasnan & Ahmad, 2015).

2.10 Waterproofing Admixtures

The process of making a structure or an object water resistant is called as waterproofing, which is achieved using waterproofing chemicals. The foundation, roofs and other areas of the structure must be waterproof. Various waterproofing compounds are hence used to make cement concrete or plaster water resistant. The table below shows a comparison of effectiveness and price of various waterproofing compounds available and widely used:

Table 2. 1: Comparison of effectiveness and price of various waterproofing compounds

PRODUCT DESCRPTION	EFFECTIVNESS	PRICE
CICO TAPECRETE	Increases the water tightness without impeding the breathing of the walls, thus reducing the risk of condensation and damage due to frost and efflorescence	**Rs 179/kilogram**
PERMA CHEMICAL WATERPROOFING POWDER	Provides waterproof, based on special surfactants and synthetic resin thus provides cohesiveness	**Rs215 /kilogram**
MISTER CARE WATERPROOFING POWDER	Reducing the ingress of water Can seal hairline cracks up to 0.4 mm Resists hydrostatic pressure.	**Rs 189/kilogram**
PUDLO CEMENT WATER PROOFING POWDER	A dual purpose, multi component powdered admixture consisting of a powerful single dosage pack which provides outstanding durability and waterproofing properties to all concrete mixes. Also includes plasticizing and corrosion-inhibiting benefits.	**Rs 150/kilogram**
DR FIXIT	Reduces permeability of water in concrete, increases durability by improving waterproofing of concrete.	**Rs 414 rupees/kilogram**

Figure 10: Pudlo waterproofing cement

2.11 Summary

The review of literature discussed in this chapter is based on researches done on global level. In this chapter the issue of seepage and uses of nanoparticles in construction has been discussed**.**

CHAPTER III

METHODOLOGY ADOPTED TO CHECK EFFICACY OF TiO_2 AND PUDLO POWDER

To check the efficacy of Nanoparticles we decided to look for its hydrophobic nature. Pudlo powder already being used in DPC, we decided to check its impact on plaster to stop the spalling of plaster due to water ingress.

3.1 Selection of Site

We visited different parts of Risalpur Cantonment to look for appropriate site where there is water ingress in any part of wall. The aim was to choose a site where we can apply the plaster on an existing building wall where spalling of plaster has affected the appearance of wall. Buildings in Risalpur have plaster spalling issues usually in the vicinity of washrooms where water leakage is abundant. An extensive survey of Risalpur cantonment was carried out to find out an ideal location with maximum possible chances of seepage and severely hit by seepage. After carrying out detailed visit of Risalpur cantonment we found a wall in EOD unit adjacent to OD block which we thought to be appropriate for application of plaster. It had three inherent advantages for application of nanoparticle mixed plaster. Spalling of plaster was there throughout the height of the wall. It was an appropriate site so that we can check efficacy of the nanoparticles at three different locations i.e percolation of water from the top, vertical capillary rise of water through bottom and effect of wind carrying rain and water on centre portion.

a. The application of plaster at the top patch below slab would allow us to check the effect against rainwater.

b. The application of plaster on the mid of wall was appropriate because once the existing plaster was removed, there was a sanitary pipe which would assist in checking the hydrophobic nature of Nanoparticles against water emerging from the pipes inside wall.

c. The application of plaster on the bottom of the wall was appropriate to check the strength of nanoparticles against water rising the wall from outside ground via capillary rise.

Figure 11: 499 EOD Group Office Wall

Figure 12: Residential wall opposite Farhad Sports Complex

The selected site for the conduct of experiment was 499 EOD GP. The reasons for its selection are as follows

a. Site is exposed to environment/weather. As it is a single-story building, the effect of rain and weather is more pronounced on the face of the wall. The wall is exposed to weather from all sides and hence is an ideal location for seepage and moisture dampness. Moreover, in humid weather air drops and wind carrying moisture can affect the site from all sides.

b. Shows vegetation growth at base. The presence of vegetation at the base of wall depicts that moisture will travel up through capillary rise as well as rainwater has reach to the base of the wall and hence greenery is present. This factor makes the site more attractive for application of testing.

c. Continuous signs of seepage (Top/Bottom). The wall has seepage all along its height with Centre portion most effected due to the sanitary pipe running through the Centre and leakage of water through the pipe. The sewerage pipe makes seepage more distinct in the wall.

d. Roof thickness is relatively less I.e. 6inches. It aids in seepage of rainwater through the roof into the wall more easily, hence aiding seepage. Rainwater would travel faster, and signs of seepage would appear sooner and will be more enhanced.

e. Easy of monitoring and access. Since the site was available in cantonment within travelling distance so it was easier to observe the results and apply plaster though removal of already existing plaster.

f. Wall is made from brick masonry. Since it is made from bricks, hence results will be more distinct and visible as compared to block masonry.

3.2 Materials Specification

The specifications of different materials used in plaster are as follows: -

a. Ordinary Portland Cement

b. Fine to Medium Sand - 0.15mm - 0.3mm (ASTM)

c. Pudlo Powder

d. Titanium dioxide - 24g

3.3 Distribution of plaster on Wall

The plaster was applied at three different locations on the wall. One rectangular patch at the top, one in middle and one at the bottom. The size of one larger rectangular portion is 3-feet x 2-feet. Each strip was further divided into 4 equal strips of 9-inch width x 2-feet height. Three of these smaller strips had varying concentrations of Titanium dioxide nanoparticles (TIO_2) and on the (right most) strip the Pudlo mixed with cement mortar paste was applied as plaster to act as a control. The results of Titanium dioxide nano particle applied strips would be compared to that of the strip containing PUDLO mixture and their efficiency determined. The plaster applied was of ½" thickness. Pictorial view of the distribution of strips on wall is as follows: -

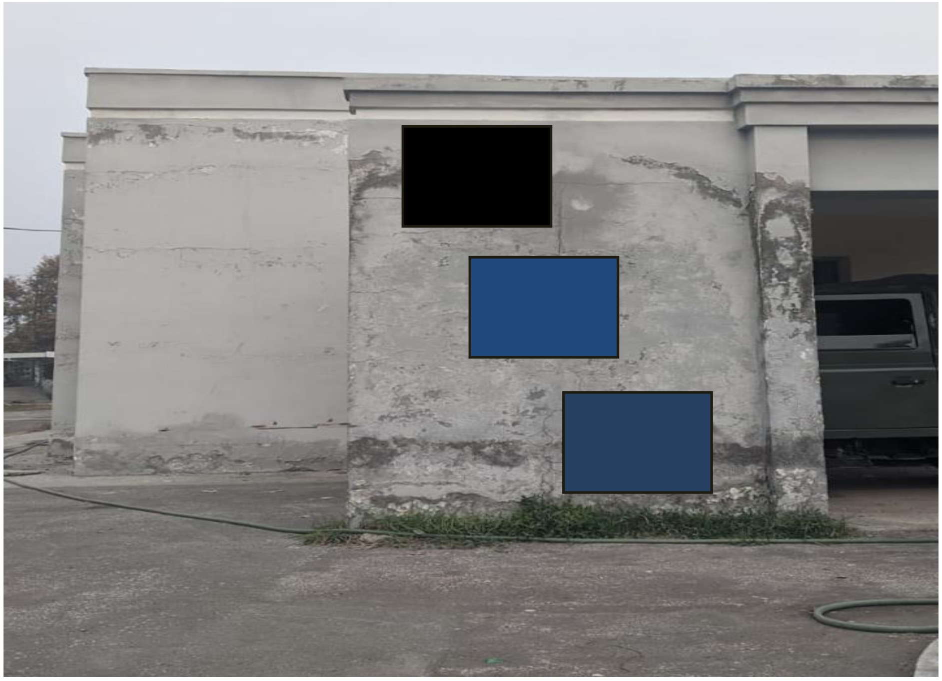


Figure 13: Distribution Of Patches

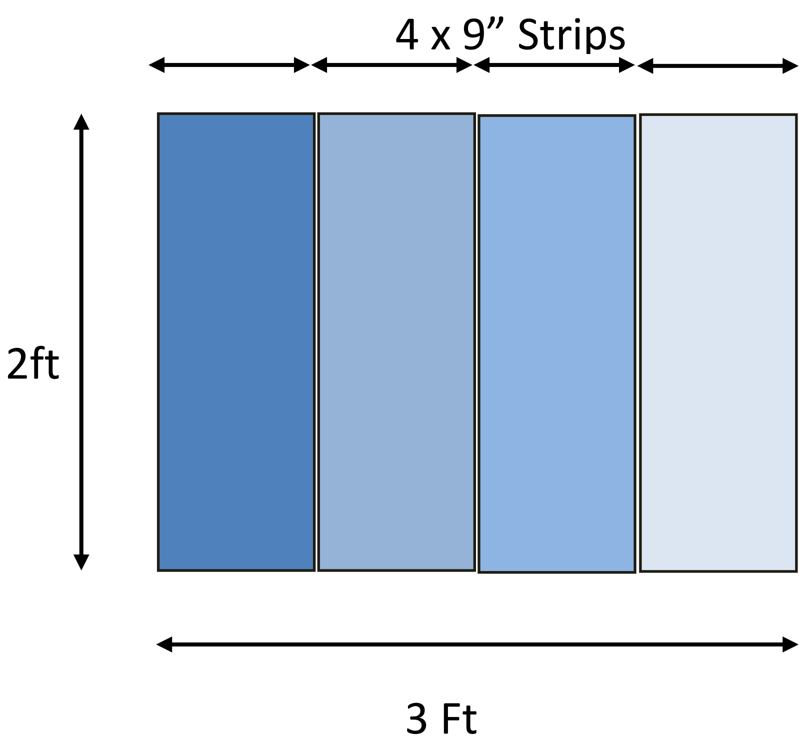


Figure 14: Distribution of Strips

3.4 Sample Preparation

The mixing of Titanium dioxide (TIO_2) with cement was required to be done with care. In order to obtain good results, a very small quantity of dry cement was mixed with nanoparticles. A blender was used for the said purpose of mixing. The percentage of nanoparticles for each patch was calculated against weight of dry cement. The varying concentrations of Nanoparticles (TIO_2) and the Pudlo concentration by weight will be discussed in succeeding paragraphs. Dry mixing of cement with nanoparticles was carried out. Titanium di oxide was mixed with 200g of cement in a normal grinder at one time. The mixing in such a small amount helped to mix the titanium Nanoparticles thoroughly and homogeneously. Instead of making separate mortar for each small strip the amount of cement required was calculated for three of the small strips at three different locations having same concentration of nanoparticles. Doing so saved us from wasting nanoparticles which were already in less quantity. After dry mixing, 4 different samples were prepared: three having varying titanium nanoparticles concentration and one having the pudlo powder. To avoid early setting of the cement we did not prepare the mortar of all concentrations at once. Initially the mortar of highest concentration of nanoparticles was prepared and applied at three small strips from top to bottom. Similarly mortars of other concentrations were prepared and applied subsequently. The water cement ratio was kept 0.5.

3.5 Concentrations of Ti02 and Pudlo Powder

The total amount of titanium dioxide available was 24g. The strips which we selected for plastering was 3-feet x2-feet each with the thickness of ½-inch. The varying concentrations of Titanium dioxide (TIO_2) were 12g, 7.5g and 4.5g as per the available quantity of Nanoparticles. The concentration of TiO_2 at small strips was calculated to be 4g, 2.5g and 1.5 g respectively. Pudlo was applied 5% by weight of cement to all the small strips as per its instruction manual. The weight of pudlo for each strip was calculated to be 26g. The percentages are computed in relation to weight of Titanium dioxide with respect to weight of cement in each small strip. The percentage concentration in each small strip is as follows: -

Table 3. 1: Percentage of Ti02 and Pudlo Powder

TiO_2(Heavy Conc)	TiO_2 (Med Conc)	TiO_2(Low Conc)	Pudlo
0.75%	0.47%	0.28%	5%

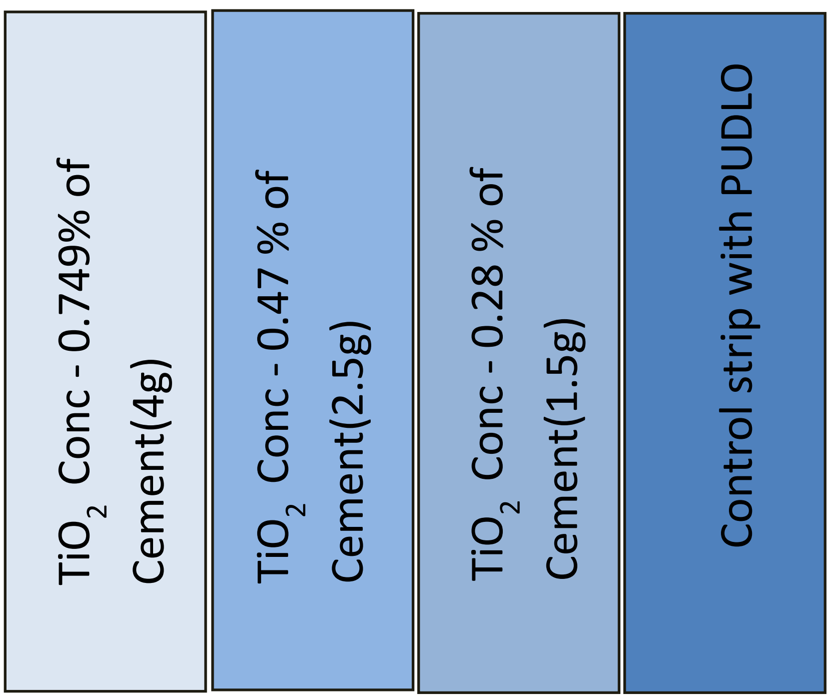


Figure 15: Percentage of Titanium dioxide in strips

One Patch of Pudlo will be used as a control for comparison of results with Titanium di oxide containing mortar mix due to its proven properties in the field which are:

a. It is a powdered, non-toxic, odorless admixture
b. It makes concrete completely waterproof
c. It increases concrete's strength
d. It provides resistance to corrosion
e. It significantly improves workability
f. It reduces wetting expansion

3.6 Calculations

One strip

a. Total area to be plaster (1 strip)	=2x3	= 6ft ^{2}
b. Total volume of mortar required	= 6x.5/12	=.25ft^3
c. Cement Sand Ratio	= 1:4	
d. Volume of Cement required	=.05 ft^3	
e. Volume of Sand required	=.2 ft^3	
f. Weight of cement required	=2.13kg	
g. Weight of Sand required	=9.24kg	
h. W:C	=0.6	
i. Water Req(ltr)	= 0.6x0.05	= 0.86L

Total Requirement (3xstrips)

Weight of cement required =6.39kg

Weight of Sand required =27.72kg

3.7 Construction of Ponding Area

A barrier of 4 bricks height i.e. 12 inches and 1 ft wide was created astride the wall with plaster in order to keep it wet and aid in seepage through penetration of moisture from the barrier filled with soil. It was done to enhance the effects of seepage as it would increase capillary rise and get quicker results due to shortage of time. The soil around the wall was kept constantly wet by watering every day.

Figure 16: Construction of Platform

3.8 Summary

This chapter represented the way in which varying concentrations of nanoparticle titanium dioxide were added in the mortar and applied at various locations.

3.9 Pictorial Section

Figure 17: Mixing in grinder

Figure 18: Mixing in cement and prep of mortar

Figure 19: Chalking out Strips

Figure 20: Prepared Strips

Figure 21: Titanium di Oxide Nano Particle Powder

Figure 22: Ponding Area

CHAPTER IV

OBSERVATIONS / RESULTS

In this chapter we will compute the results by observation of plaster strips on wall and measurement of moisture content. The results would be compared to those produced by control strip where PUDLO was applied to resist seepage. Due to shortage of time period available for testing, the results may not be too prominent. Different strips consisting of different concentration of nanoparticle will also be compared to each other to check effective nanoparticle concentration required for seepage control. The aim is not only to check effectiveness but also to check effective concentration and cost optimization of the concerned titanium dioxide plaster. This is the first research of its kind on the subject; hence it carries obvious ambiguity regarding materialization of results. The results are determined on regular time intervals i.e. every week during curing period and fortnightly after curing.

4.1 Moisture Meter

Figure 23: Moisture meter

Table 4.0: Specifications ((http://www.mastech-group.com/products.php?cate=114&PNo=106)

Specifications	Range	Resolution	Accuracy
Material Moisture	0.0~60.0%	0.1%	±2.0%
Ambient Temp	-10℃~50℃/14℉~122℉	0.1℃ / 0.1℉	±2℃ / ±3.6℉
Relative Humidity	10~90%	0.1% RH	±5.0% RH

4.2 Curing Results

TABLE 4. 1

Days	**Moisture content**	**Comments/Remarks**
7	4%	• Curing being carried out to set plaster • Weather conditions are generally moist • Wall exposed to rain

TABLE 4. 2

Days	Moisture content	Comments/Remarks
14	3.8%	• Curing being carried out to set plaster by manually applying water daily • Plaster gaining strength

TABLE 4. 3

Days	Moisture content	Comments/Remarks
21	3.6%	• Curing continued • Plaster gained sufficient strength and hardened

TABLE 4. 4

Days	Moisture content	Comments/Remarks
28	3.5%	• Curing completed • Plaster fully hardened • Observation for any visible signs of seepage shall be done • The site will be regularly kept wet

TABLE 4. 5

Days	Moisture content	Comments/Remarks
56	• **Top Strip** **1.3**, 1.4, 1.5% PUDLO- 1.2 % • **Middle Strip** **1.6**, 1.7, 1.9% PUDLO-1.7 % • **Bottom Strip** **1.8**, 1.8, 2% PUDLO-1.8% • **Wall** 2.2 top, 4% bottom	• Regular rainfall • No visible signs of seepage yet possibly because the plaster is still fresh and durable • The first strip with highest concentration of TIO_2 is giving a bright appearance • The bottom strip has the highest moisture content due to capillary rise and availability of ponding at the bottom

TABLE 4. 6

Days	Moisture content	Comments/Remarks
75	• **Top Strip** **1.4**, 1.4, 1.5% PUDLO- 1.2 % • **Middle Strip** **1.6**, 1.7, 1.7% PUDLO-1.6 % • **Bottom Strip** **1.7**, 1.7, 1.8% PUDLO-1.6% • **Wall** 1.9 top, 3.8% bottom	• Regular rainfall is occurring • No visible signs of seepage yet on the strips possibly as the plaster his still fresh and has sufficient strength • Seepage is seen on the bricks around strip • Top strip has the lowest water content possibly due to shade provided which is reducing surface area exposed to rain • There's very slight difference in moisture content of PUDLO strip and TIO_2 strips which is a positive sign

TABLE 4. 7

<u>**Days**</u>	<u>**Moisture content**</u>	<u>**Comments/Remarks**</u>
90	• <u>**Top Strip**</u> **1.1**, 1.1, 1.2% PUDLO- 0.8 % • <u>**Middle Strip**</u> **1.3**, 1.3, 1.4% PUDLO-1.4 % • <u>**Bottom Strip**</u> **1.6**, 1.6, 1.8% PUDLO-1.5% • <u>**Wall**</u> 2top,15.2% bottom	• Regular rainfall • Construction of ponding area to retain water around the base to keep the wall constantly wet and provide water for capillary rise to aid seepage • No visible signs of seepage yet on strips hence, to speed up the process barrier is made • Wall has increased water content at the bottom because of construction of ponding which holds water and keeps it moist

TABLE 4. 8

Days	Moistur Content	Comments/Remarks
97	• **Top Strip** **1**, 1.1, 1.1% PUDLO- 0.9 % • **Middle Strip** **1.2**, 1.3, 1.3% PUDLO-1.2 % • **Bottom Strip** **1.7**, 1.8, 2% PUDLO-1.6% • **Wall** 1.9 top, 15.3% bottom	• Dry period of extreme hot temperature • No rainfall during the week • Still the signs are not so prominent possibly due to high temperatures not favoring seepage or due to efficiency of titanium dioxide • More time required for investigation • Wall around the plaster portion has effects of seepage which is a positive outcome favoring the effectiveness of titanium dioxide layer

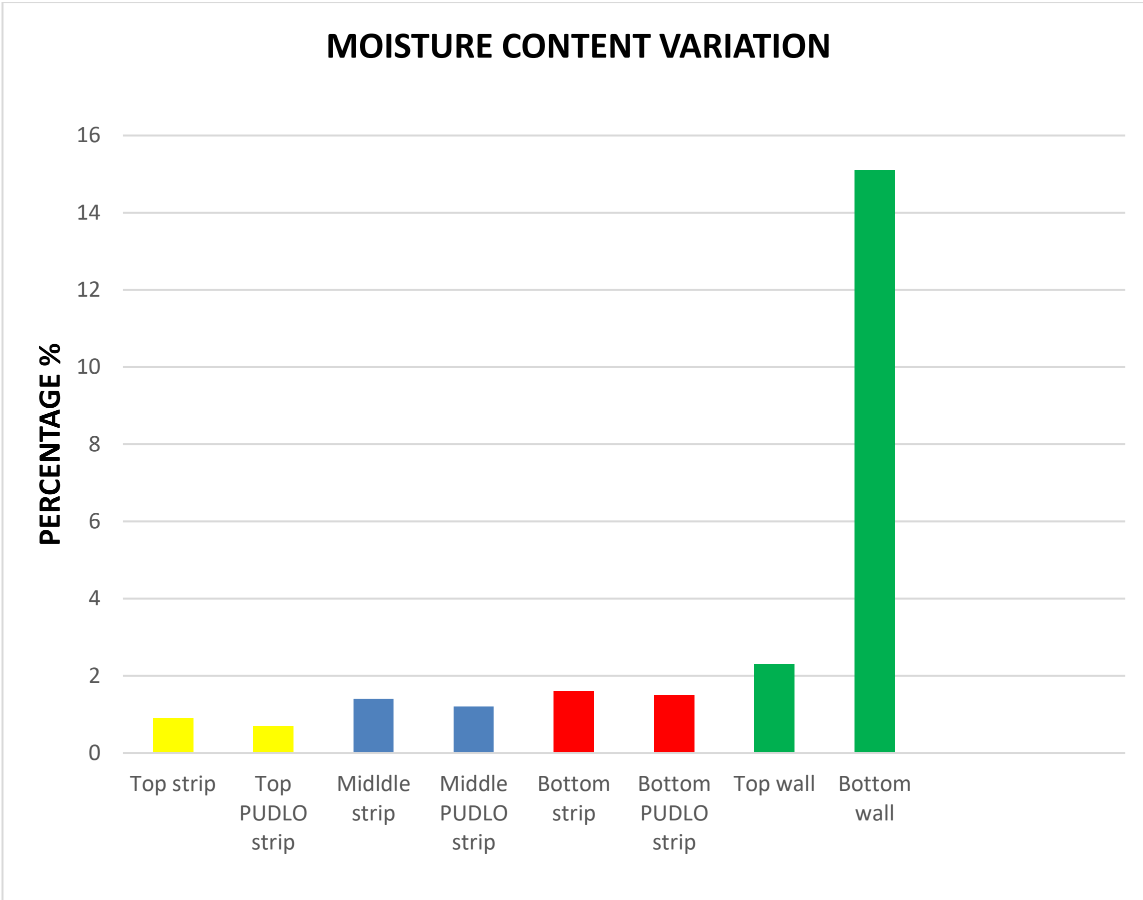
TABLE 4. 9

Days	Moisture content	Comments/Remarks
102	• **Top Strip** **1.1**, 1.1, 1.3% PUDLO- 1 % • **Middle Strip** **1.5**, 1.6, 1.6% PUDLO-1.6 % • **Bottom Strip** **1.7**, 1.8, 1.8% PUDLO-1.7% • **Wall** 2.1 top, 15% bottom	• Signs of seepage on wall around Nano particle-based plaster • No signs of seepage on strips yet • Strips are effectively controlling seepage so far • The top strip has considerably reduced moisture content due to lack of rainfall as no water percolates down from roof. Hence it has the least chances of getting affected


TABLE 4. 10

Days	Moisture content	Comments/Remarks
109	• **Top Strip** **0.9**, 0.9, 1% PUDLO- 0.7 % • **Middle Strip** **1.4**, 1.4, 1.4% PUDLO-1.2 % • **Bottom Strip** **1.6**, 1.7, 2% PUDLO-1.5% • **Wall** 2.3 top, 15.1% bottom	• Signs of seepage on wall are getting pronounced as compared to strips with titanium dioxide • White efflorescence patches also visible on wall • Strips have been able to stop seepage yet as visible from their shiny appearance so far • Pudlo strip is also giving the same results of seepage control and the moisture content is generally the same as TIO_2 layer • More time required to study the effects

Table 4.11


MOISTURE CONTENT VARIATION
PERCENTAGE %
16
14
12
10
8
6
4
2
0
Top strip
Top PUDLO strip
Midldle strip
Middle PUDLO strip
Bottom strip
Bottom PUDLO strip
Top wall
Bottom wall

CHAPTER V

FINDINGS, RECOMMENDATIONS AND CONCLUSION

5.1 FINDINGS

a. Since it is the first time that Titanium dioxide nano particle are being investigated for seepage control hence it carries certain uncertainties with regards to appearance of results and timeline related to appearance of results. An ideal location was selected keeping in view highest effects of seepage in surrounding areas with the expectation that results would materialize in 2-3 months.

b. The results spanned over the duration of 28 Feb to 16 June.

c. The environmental condition throughout the experiment were that of winter rainy season in initial half and extreme sunny conditions towards the latter half.

d. The moisture content of the wall remained at an average of 0.9-1.6% for nanoparticle-based strips and 0.7-1.5% for PUDLO layer. Whereas rest of the wall had a moisture content averaging 2% at top and 15% at bottom.

e. It was estimated that due to existing condition of the wall, the seepage effects would appear in shorter time duration, but it was revealed that the time allocated was lesser and results could not appear as significant and clearly.

f. After initial visit and evaluation of the project site, ponding area was provided to enhance the process of seepage in the walls.

g. The main indicator of results was presence or absence of appearance of seepage effects on the of strips.

h. No major signs of seepage have appeared yet on any of the strips. Though surrounding walls have slight appearance of seepage as is clear from the figures of the complete project time span.

i. The strip with higher concentration of titanium dioxide gives a better appearance than rest of the strips.

j. The control strip (PUDLO) in all the patches with established qualities of controlling seepage is giving the same results as the other strips as far as appearance is concerned.

k. The results possibly indicate three outcomes:

   1) The strips of titanium dioxide were equally effective in controlling seepage along with control strip since both show similar results in terms of appearance with Pudlo having proven qualities of controlling seepage.

   2) More pronounced effects of seepage could not appear because of lack of time and dry summer heat. In addition, capillary rise and downward percolation was not so effective during the period as indicated by moisture content of the wall which remained close to 2-3%. Hence more time could have been availed to analyze the results. Possibly monsoon conditions would be ideal to determine accurate results.

   3) Plaster was still fresh and young to have any visible seepage hence its strength and quality did not allow seepage to occur. It might take some time with the quality of concrete applied for seepage to occur. Although a barrier was constructed to retain water but possibly it was not sufficient to increase the moisture content to sufficient levels.

l. To ensure accuracy of results further testing is necessary with varying concentrations of titanium di oxide at multiple locations and more time available for testing.

5.2 RECOMMENDATIONS

a. The experiment to be repeated in a controlled environment with controlled conditions such as temperature, humidity, wind flow and exposure to rain.

b. There are uncertainties related to the study like as it was being undertaken for first time and titanium dioxide has never been used for seepage control before. Hence the results could not manifest in estimated time and further testing to be carried out during monsoon season on existing project.

c. The time allocated for testing should be longer. At least 6-8 months testing (including monsoon season) to be carried out at 2-3 different locations. The coming monsoon season should be utilized for further testing at the same location due to its inherent high moisture content conditions which aid seepage and accurate results would appear.

d. Different sites should be chosen to check the effectiveness since they will have different moisture contents and hence show range of results in determining accurate analysis. Testing should be carried out simultaneously at all locations.

e. The concentrations of titanium dioxide to be kept variable at all locations to study effect of varying concentrations to determine optimal concentration.

f. The test results show a positive trend in use of titanium dioxide for further testing of its hydrophobic nature in terms of dampness and seepage control because one of the possible outcomes as determined by comparison with control (Pudlo) layer is appearance of no seepage. If that is the case, then it is worth studying further for detailed analysis. The effectiveness should be further probed as it may entail a possible solution to the menace of seepage control.

g. A possible drawback could be the cost of nano based seepage control chemical as it might be slightly higher than already available products like Pudlo which are available for an economical price of around 150 Rs per bag.
h. The increased price could be offset by the fact that titanium dioxide can be used for countering effects of weathering agencies when used on exterior surface. It has photo catalytic effect. It has self-cleansing property and is commercially used as outer coating.
i. Another possible advantage to offset increased price is use of titanium dioxide inside the building to counter indoor pollution health hazards related to seepage. In addition, it provides extra strength to the structure

5.3 CONCLUSION

Seepage and dampness are a great menace to the construction industry and account for millions of dollars being expanded on maintenance purposes especially in humid areas like Risalpur. Proper workmanship from the start will pay rich dividend in overcoming this menace but use of chemical products cannot be denied in ensuring long term effectiveness. Titanium dioxide nanoparticles also holds good prospects in overcoming this hazard when used in cement mortar owing to its hydrophobic nature. As this is a new study being undertaken the first time hence it carries certain ambiguities of correct evaluation and effectiveness of results and optimum concentrations which can be further probed with testing under controlled conditions. It may revolutionize the construction industry. It will offset the increased expenditure drawback vis-a-vis already available cheap commercial products like PUDLO by providing additional strength to the structure and its self-cleansing effect in structures. Although further and elaborate testing is still required under controlled conditions for ensuring effectiveness of results.

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