ISSN: 2754-4982

Journal of Civil Engineering Research & Technology

SCIENTIFIC Research and Community

Research Article

Open Access

Comparative Analysis of Concrete Water-Proofing Materials

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ABSTRACT

Concrete is porous when exposed to water, because water passes through its pores defacing the concrete and corroding the reinforcements, this overall effect weakens concrete. Waterproofing of concrete is very essential in building parts which are constantly exposed to moisture from ground water and rain water. This study compared bituminous felt with cementitious crystalline waterproofing materials for concrete. In this study, a particular square area of concrete slab was assumed, and a market survey was conducted to determine the cost of purchase and installation of bituminous felt and cementitious crystalline waterproofing materials for the assumed square area. The bill of quantities for both options was done to aid the comparisons and cost of maintenance of both materials. The results of the study showed that bituminous felt was the most widely used waterproofing material, while cementitious crystalline waterproofing material on the other hand is not a very popular material as most building professionals did not know about its existence. The market survey showed that it was cheaper to install cementitious crystalline waterproofing material than to install bituminous felt and the cost of maintenance of cementitious waterproofing material was also negligible compared to bituminous felt. Though cementitious crystalline waterproofing material is new in Akure market, it has a promising future in the construction industry not only in Akure but in Nigeria's construction industry at large.

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Received: February 09, 2022; **Accepted:** February 14, 2022; **Published:** February 23, 2022

Keywords: Building structure, Concrete, Waterproofing Materials, Bituminous Felt, Cementitious Crystalline

Introduction

Waterproofing is a process designed to prevent water from penetrating a structure. It is typically done in various layers and stages to create multiple barriers and prevent water from penetrating the structure. A combination of such stages is referred to as creating a "Building Envelope". Waterproofing becomes expedient in wet environments or under water to specified depths. Waterproofing protects the structural contents of a building from water infiltration that can cause structural damage to the concrete or corrosion to the imbedded steel. Every element of a building from the walls, roofs, floors and so on should be water resistant or waterproof.

In construction, buildings are waterproofed using so many types of waterproofing membranes, coatings and built-in systems. The different waterproofing materials available today are: asphalt-and-felt built up system, bituminous membranes, polyurethane liquid membrane, acrylic sealers, epoxy sealers, penetrating Sealers, polyaspartic, and cementitious waterproofing, etc. Concrete is porous, and if not waterproofed, can absorb water, waterborne contaminants and chemicals that can cause deterioration. To protect concrete and ensure it has a long serviceable life, waterproofing is essential. Ensuring that water seepage in concrete can be prevented and hydrostatic pressure resisted, as concrete can be waterproofed from the positive (exterior) side, negative (interior) side or from within the concrete itself (integral systems). Bituminous felt has been used as a waterproofing system designed to protect residential and commercial buildings. It is usually black in nature and is often used to protect concrete surfaces from water infiltration. One limitation of its use has been the black and grey colours, as this has limited its use to places that would not be visible to the general public.

Concrete is one of the prominent building materials used in Nigeria today, it has been found to be of good compressive strength and with the use of reinforcement of good tensile strength. Concrete however is susceptible to cracks, shrinkage and when exposed to moisture there is moisture expansion which weakens the concrete and reduces the lifespan. To prolong the lifespan of concrete, it therefore has to be waterproofed. There are various methods of waterproofing concrete, ranging from bituminous felt, Penetrating sealers, epoxy sealer, bentonite, to cementitious crystalline waterproofing material. However, only two were focused on in this research, these are: bituminous felt and cementitious crystalline waterproofing material. These two materials were extensively discussed in terms of what the materials are, the cost implication of installation and maintenance.

This research is an in-depth study of bituminous felt and cementitious crystalline waterproof coating for concrete. The paper presents information on what exactly these materials are in terms of their physical components, their uses and mode of application. It also presents, detailed cost analysis (i.e. cost of obtaining the materials, cost of installing the materials and cost of maintaining the materials after installation), as well as the lifespan of the two materials, which serves as the basis for drawing logical conclusions on the comparative advantages and disadvantages of both materials.

Problem Statement

Concrete waterproofing systems have been known to fail over the years in Nigeria especially those used in concrete roofing. Quite a number of concrete roofs begin to leak a couple of years after construction, some are eventually converted to pitched roofs that are covered with aluminium sheets. Although leakages may be as a result of poor finishing of the waterproofing materials, it could also be as a result of too shallow gradient especially in roofs that don't encourage run off. This paper looks at cementitious crystalline waterproof coating and bituminous felt (which are modern waterproofing materials) as a solution to concrete waterproofing failure in Nigerian buildings.

Aim and Objectives

The aim of this study is to compare bituminous felt and cementitious crystalline waterproofing materials for concrete, which are both concrete waterproofing materials, with a view towards recommending which amongst the two waterproofing materials is more efficient.

The objectives of the study are to:

- Determine what exactly bituminous felt and cementitious crystalline waterproofing materials are in terms of their history, chemical and physical components, their uses and mode of application.
- Carry out a detailed cost analysis of obtaining both materials and installing them
- Evaluate the cost of maintenance after installation.
- Recommend the better option in-terms of cost, usage and maintenance.

Literature Review

Introduction

Concrete is a mixture of cement, aggregates and water in controlled proportions,[1] . The relative amount of each material (i.e. cement, water and aggregates) affects the properties of concrete. Aggregates should be strong and hard, to produce strong concrete outcome. Aggregates should be clean, durable and chemically inactive so that aggregates do not react with the concrete. Aggregates should be stored where they will remain clean, separated from other materials and dry. If the aggregates are wet, less water should be used in the mix [2].

Cement reacts with water in a chemical process called hydration. Many additional ingredients can be added to the basic concrete mix in order to change the properties of the resulting concrete. Some common admixtures are accelerators which speed up the hydration process (often used in colder environments) and retarders which slow down the hydration process (often used in hotter environments). Plasticizers improve the workability of wet concrete while pigments change the colour of concrete for aesthetic reasons [3].

Properties of Concrete

Concrete has three different states: the plastic state, setting state and the hardened state [2]. Concrete has the following properties:

- Workability
  Workability means how easy it is for concrete to be placed, handled, compacted and finished. To improve the workability of concrete some more, cement paste should be added, well graded aggregates should be used, and plasticizers could also be added [2] (Cement Concrete and Aggregates Australia, 2010).
- Cohesiveness
  This is how well concrete holds together when in a plastic state.
- Strength
  Concrete has strong compressive strength and poor tensile strength. This is why concrete is usually reinforced using steel or various fibers. Denser concrete is stronger and more watertight (or less permeable), than less dense concrete.
- Durability
  The stronger the concrete the more durable it is.

Limitations of Concrete

- Concrete has low tensile strength thus the need for reinforcement.
- Concrete has low ductility.
- Concrete is susceptible to cracking due to drying, shrinkage and moisture expansion.
- If soluble salt is present in concrete, it may lead to effervescence when it comes in contact with water, this has adverse effects on reinforcements, that is if the concrete is reinforced.
- Concrete has low permeability when exposed to water; water passes through its pores through capillary action. If concrete is constantly exposed to this kind of condition, it becomes weak and infested with lichen, moss and may disintegrate or break, thus the need for waterproofing.

Concrete is used in several stages and aspect of construction. Concrete is commonly used in the substructures for foundation footing, and flooring. In the super structure, it is used for columns, beams, suspended floors, decking and so on. One of the critical limitations of concrete is that it is porous (i.e. allows water to pass through) and when used as a decking for buildings, this limitation is a very serious issue. It is this limitation that creates the need to waterproof concrete.

Waterproofing of Concrete Roofs

Waterproofing, a process designed to prevent water from penetrating a structure, is typically done in various layers and stages to create multiple barriers and prevent water from seeping into the structure. A combination of such stages is referred to as creating a "Building Envelope". Often times, not enough importance is given to this crucial aspect of construction because there is low awareness on modern waterproofing techniques and little expertise on some of the modern techniques of waterproofing.

Stages of Concrete Roof Waterproofing

There are basically two stages in waterproofing of concrete roofs; there is the construction stage and post construction stage.

Construction Stage

The construction stage involves the use of the right construction techniques and the right waterproofing method. During the construction stage concrete should be mixed to the right water-cement ratio. It should also be properly compacted as water would flow through any pore in the concrete through capillary action. The concrete should be allowed to cure properly; plumbing fittings embedded in the concrete should be properly done to prevent leakages from pipes. It is very important that concrete roofs have the right slope (gradient). There should be no undulation in terms of construction since this allows for free flow of water [4].

The waterproofing method to be used should have been determined and care should be taken to apply waterproofing materials according to the manufacturer's instructions, as this is one of the reasons for failure in waterproofing systems.

Post Construction Stage

Waterproofing should not only be done during construction, but also after construction, as existing building might experience dampness [4]. It appears better to waterproof concrete in roofs especially when the building project is close to the end of construction stage, before handing over is done, to prolong the life of the water-proofing material (WPM) and encourage its lifespan to be as long as the building. This can also be in form of maintenance as some waterproofing materials have different life span or effective life after which they begin to fail.

Methods of Concrete Waterproofing

Concrete roofing is the most crucial segment of a building, and it is exposed to direct climatic variations, extremes of rainfall and structural movements caused within the building. So every effort should be made at the design stage to ensure that a proper protection system has been incorporated. It has often been found that the economic solution is not always the best solution. So, the system, which assures maximum protection, should be selected even though it may cost little more [4]. A building or structure needs waterproofing as concrete is porous and will not be watertight on its own. Flat roofs in modern times are generally constructed of reinforced concrete. This material removes all the problems of flat roofs except that the roof should be made water proof by employing any of the various methods available for waterproofing. The various methods available for waterproofing are: Cementitious Waterproofing, Liquid Waterproofing Membrane, Bituminous Coating Waterproofing, Bituminous Membrane Waterproofing, Polyurethane Liquid Membrane Waterproofing etc. However, only two materials will be considered here for comparison and these are cementitious crystalline waterproofing material and bituminous felt waterproofing material.

Bituminous Felt Waterproofing Materials

Bituminous felt is a waterproofing material which uses tar. Bituminous waterproofing materials are made from bitumen which is a black sticky mixture of hydrocarbons used for waterproofing basements and flat roofs, and for damp-proof courses. It is obtained from natural deposits (asphalt) and from the distillation of petroleum [5]. The physical properties of bitumen make it an attractive option in waterproofing application. Today, there are various bituminous waterproofing products in the markets, some of the bituminous waterproofing products available are: Polyurethane, Cementitious Coating, EPDM Rubber, Rubberized Asphalt, Thermoplastic, Bituminous Membrane, and PVC Waterproofing Membrane amongst others.

Polymer Modified Bitumen Membranes

Polymer modified bitumen membranes are made by mixing thermoplastic polymers with straight-run or oxidized bitumen and a mineral filler, and then coating a fiberglass or polyester mat or other reinforcements with the mixture. The polymer modifier used may be atactic polypropylene (APP) or styrenebutadiene-styrene (SBS) block copolymer, or other polymers with the same chemical families [6].

The main difference between Atactic polypropylene (APP) and styrenebutadiene-styrene (SBS) is that APP is a plastic asphalt i.e. it is modified with plastic, while SBS is an elastic asphalt i.e. it is modified with synthetic rubber [7]. When torching APP it melts like candle in its molten state. SBS on the other hand behaves differently when warm, it is very sticky. When SBS goes through elongation it fully recovers when it is released.

Polymer modified bitumen membranes can be heat (torch) applied, with hot asphalt or with adhesive. The torch application technique requires less man power, and is applied by applying heat evenly to the back side of the membrane using a torch (See plates 1 and 2). In hot application the hot bitumen can be mopped or poured into place, or applied with a mechanical spreader or felt-laying machine [6]. The adhesive application can be done by applying adhesive on the concrete surface before rolling out the membrane on it, it requires more finesse.

Plate 1: Heat (torch) application of polymer modified bitumen membranes.
Source: Construction Update, (2012)

Plate 2: Hot application of polymer modified bitumen membranes.
Source: Davidhazen.com, (2017)

Cementitious Waterproofing

Cementitious waterproofing is the easiest method of waterproofing in construction. The materials for cementitious waterproofing are easily available from suppliers of masonry products, and they are easy to mix and apply. It could be applied using a long handle brush which makes the work easier or it could be mixed with concrete [8]. A picture showing the application process can be seen in plate 3.

There are basically two forms of cementitious water proofing, both of which are non-decorative. The first consists of Portland cement, fine aggregate, and sometimes acrylic or other plastic admix. The second form of cementitious waterproofing is hydraulic cement, which is a compound of cement with rapid setting non-shrinking hydraulic materials. Hydraulic cements are used for many purposes which include sealing holes, cracks, and open joints.

The principal disadvantage is that cementitious products do not contract or expand to any degree worth mentioning, though they will prevent water penetration but will not tolerate joint or crack movement [9]. Therefore, cracks or joints in buildings need to be treated specially.

Cementitious Crystalline Waterproofing Material for Concrete
Cementitious crystalline waterproofing material for concrete was invented decades ago; it makes up for the shortcomings of traditional waterproofing materials. Cementitious capillary crystalline waterproofing coating is a kind of powdery material substrate on cement and quartz sand, incorporated into a variety of active chemical substances [10].

Crystalline technology is the major class of integral waterproofing. They react with calcium hydroxide and other products of cement hydration and form non soluble crystals that plug and fill the pores and micro cracks in the presence of water [11]. It works from both the positive exteriors and negative interiors and even after years. It seals cracks automatically that are not more than 4mm wide. It can form stable crystal by polymerization to prevent water, so it may play a role in remedying a defect automatically [10].

Plate 3: Application of Cementitious Waterproofing Material
Source: Arcon supplies, (2017).

Comparative Study of Conventional and Modern Waterproofing Techniques
Water seepage can cause damage to buildings and thus, the need for waterproofing and selecting the right waterproofing materials [11]. Saurabh and Ghadge, (2016) reported of a study that involved traditional (tarfelt, Brick bat coba) and modern (coatings, integral) approaches to waterproofing, in a comparative study involving both materials. The cost, durability and ease of use of the various waterproofing methods were the criteria used in drawing conclusions in the study.

Findings from the study revealed that traditional waterproofing methods were relatively less expensive to install, easy to use but were not long lasting and as a result not economical in the long run. Modern waterproofing methods on the other hand, are quite expensive compared to traditional methods, and are easier to install. They also had a more lasting effect and, in the case of integral waterproofing, they last the entire life time of the concrete, thus, making modern waterproofing materials more economical in the long run [11].

Research Methodology
Approach and Design
Mixed method approach was used for this study, and this involved the use of quantitative and qualitative approaches. Quantitative approach involves the generation of data in quantitative form which can be subjected to extensive quantitative analysis in a formal and rigid fashion, while qualitative approach on the other hand is concerned with subjective assessment of attitudes, opinions and behaviours [12]. A descriptive survey design was also adopted. Descriptive research includes surveys and fact-finding enquiries of different kinds, the major purpose of descriptive research is the description of the state of affairs as it exists at present [12]. In this study, information was got through personal interviews and questionnaires, which were physically administered by the authors.

The study was carried out within the confines of Akure metropolis, and the Arakale market in Akure was visited for existing and current market prices of waterproofing materials. There, two sample products were selected, comprising bituminous felt and cementitious crystalline waterproof coating for concrete. The cost of the two samples was also determined from the various tradesmen of the products. The costs of installing the materials were also obtained from various artisans on the field and an average of cost implication was arrived at by a quantity surveyor by using bill of quantities (BOQ).

Besides the visit to Arakale market, data collection was also sought out from the information concerning the cost of installation of these materials as obtained from quantity surveyors and contractors.

Data Collection
Both primary and secondary data were used in this research. Primary data were obtained by conducting interviews and administering questionnaires as well as market surveys. The interview method of collecting data involved presentation of oral-verbal stimuli questions and replies in form of oral-verbal responses, while a questionnaire containing a set of questions was arranged in a definite order to elicit information from respondents [12]. However, secondary data were sourced from online brochures, published and unpublished articles written on bituminous felt and cementitious crystalline waterproof materials for concrete.

The interview questions were arranged in such a manner that structured questions were for the quantitative data and unstructured for the qualitative data. The questions were designed to obtain information on the experiences of various building professionals in the use of the materials under study.

Data Analysis
The data obtained were recorded, coded and tabulated. Bills of quantities were prepared for both materials using the current market prices and labour cost of materials. The data were tabulated because it facilitated the process of comparison and provided the basis for the various statistical computations used. A bar chat (figure 1) was also used to show comparisons between the two materials. After data was collected and collated, they were analysed using SPSS version 20.

Results
Calculations for the Cost of Purchasing Cementitious Crystalline Waterproofing
Materials (CCWPM) for Concrete.
The calculations were done for two options for the application of cementitious crystalline waterproofing materials for concrete. The first option was for the application of cementitious crystalline waterproofing material for concrete to be used in the casting of a 150mm thick concrete slab. For the casting option, the concrete mix ratio was assumed to be 1:2:4. While the second option was for the application of cementitious crystalline waterproofing material for cement to be used in the plastering of a 12.5 mm thick

mix. For the last option, it was assumed that the mix ratio for the mortar was 1:4. These two options were arrived at and adopted for this study since concrete slabs thickness is usually 150mm and plaster's thickness is usually 12.5mm. Therefore, 12.5 mm was considered and adopted as the thickness of cement plaster over concrete slabs or horizontal walls that involve the use of CCWPM. The area of the concrete slab that was used throughout the study for the calculations was uniform, although it was arbitrarily chosen as 5.1 x 6.45 m^2.

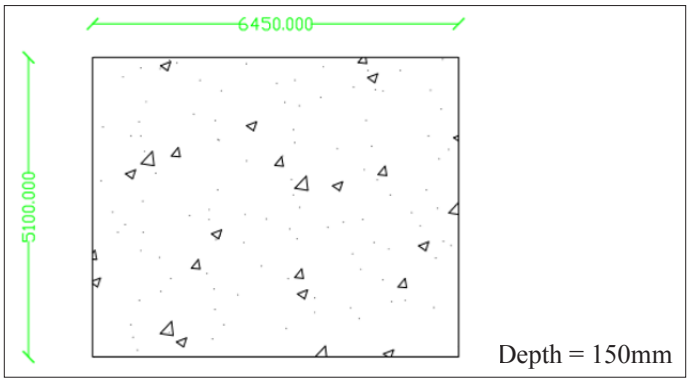

Figure 2: showing dimension of concrete slab in millimetre (mm).
Source: Author's archive, 2019.

Option 1 (For 150 mm Thick Concrete Slab)
Volume of concrete = 5.100m x 6.450m x 0.150m = 4.934m3.
Mix ratio: 1:2:4.
Therefore: 1 + 2 + 4= 7.
Therefore: 1/7 x 4.934m^3= 0.705m^3.
Therefore: 4.934m3 / 0.705m3 = 6.99 cement bags of 50kg, which is approximately 7 no. of 50kg bags of cement.
One bag of 500g of cementitious crystalline waterproofing material =₦750.
Principle of application is 500g of cementitious crystalline waterproofing material to 1 50kg cement bag according to the manufacturer of the product gotten from the market.
Therefore: 7 bags of 500g of cementitious crystalline waterproofing material for 7 cement bags of 50kg = ₦750 x 7 = ₦5,250.
Also cost of 1 bag of cement is ₦ 2,500. Therefore, 7 x ₦ 2,500 = ₦17,500
Cost of 7 bags of CCWPM + 7 bags of cement = ₦5,250 + ₦17,500 = ₦ 22,750
Therefore, cost per m3 = ₦22,750/4.934m^3 = ₦ 4,611.00

Option 2 (For Plastering 150 mm Thick Concrete Slab With a Screed Of 12.5mm Thick)
Volume of mortar needed for the top and bottom sides = 5.1m x 6.45m x 0.125m x 2 = 8.22m^3
Volume of mortar needed for both sides = 5.1m x (0.15+0.125+0.125) m x 0.125m x 2 = 0.228m^3.
Total volume of mortar needed = 8.22m^3 + 0.228m^3= 8.45m^3.
Mix ratio: 1:4.
Therefore: 1 + 4= 5.
Therefore: 1/5 x 8.45m^3= 1.69m^3, which is approximately 2 cement bags of 50kg,
One bag of 500g of cementitious crystalline waterproofing material = ₦750
Principle of application is 500g of cementitious crystalline waterproofing material to 1no of 50kg cement bag according to the manufacturer to the product gotten in from the market.
Therefore: 2no of 500g of cementitious crystalline = ₦750 x 2 = ₦1,500.
And 2 no bags of 50kg cement bags = 2 x ₦ 2,500 = ₦ 5,000
Therefore, total cost for cement bags and cementitious crystalline = ₦ 5,000 + ₦1,500 = ₦7,500
Therefore, cost per m3 = ₦7,500/8.45m3 = ₦888.00

Calculations for the Cost of Purchasing Bituminous Felt
The calculations done were based on the cost of 2mm and 3mm thick bituminous felt respectively.

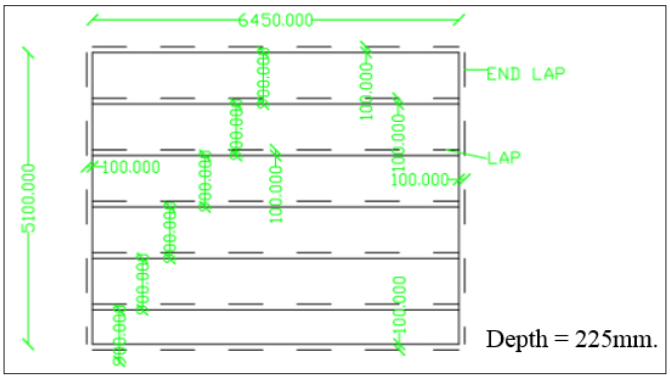

Figure 3: showing application of bituminous felt in millimetre (mm).
Source: Author's archive, 2019.

Minimum side lap = 100mm = 0.1m.
One run = 6.450m + 0.2m lap = 6.650.
Number of runs needed = 6.
1 yard of bituminous felt is 1m by 36 inches.
1inch = 2.54cm = 0.0254m.
Therefore: 6.650m/0.0254m = 261.811inches.
36inches = 1yard.
Therefore: 6.650m = 261.811inches/36inches = 7.272yards.
Number of yards needed for one run = 7.272yards which is approximately 7.3yards needed.
Number of yards needed for 6 runs = 7.3 x 6 = 43.8 ≈ 44 yards.

Option 1 for 2mm Thick Bituminous Felt
Cost of 1yard of 2mm thick bituminous felt = ₦800.
Therefore 44 yards of 2mm thick bituminous felt = ₦800 x 44 = ₦35,200.

Option 2 for 3mm Thick Bituminous Felt
Cost of 1yard of 3mm thick bituminous felt = ₦1,000.
Therefore 44 yards of 3mm thick bituminous felt = ₦1,000 x 44 = ₦44,000.

Bill of Quantities (BOQ) for the Cost of Installing Cementitious Crystalline Waterproofing Materials in Concrete
This section shows BOQ prepared for the two options for the application of cementitious crystalline waterproofing materials for concrete. In the tables below it was observed that the cost of workmanship was nil, and this is due to the fact that the material (which is in powder form) is added to dry cement then properly mixed, before the slab is cast or plastered thus no cost of labour is incurred.

Table 1: BOQ option 1 for cementitious crystalline waterproofing material for concrete

Item	Description	Unit	Qty	Rate (₦)	Cost (₦)
1.	Cost of cementitious crystalline waterproofing material in concrete.	m^3	0.705	32,269	22,749
2.	Cost of workmanship.	_____	____	_____	_____
Total					≈ ₦22,750

Table 2: Showing BOQ option 2 for cementitious crystalline waterproofing material for 12.5mm plaster

Item	Description	Unit	Qty	Rate (₦)	Cost (₦)
1.	Cost of cementitious crystalline waterproofing material in concrete.	m^3	1.644	4,562	7,499
2.	Cost of workmanship.	_____	____	_____	_____
Total					≈ ₦7,500

Source: Author's market survey, 2019.

In comparing tables 1 and 2, it can be deduced that it is more expensive to cast the same floor area of concrete (N22,750) by integrating cementitious crystalline waterproofing material into the mix than to plaster or screed the same floor area using the same material at (N7,500). This is because the quantity needed for CCWPM is more in concrete (7 bags of cement + 7bags of ccwpm) than in plastering the same floor area (2 bags of cement + 2 bags of ccwpm), considering the thickness of both construction elements.

Bill of Quantities Showing the Cost of Installing Bituminous Felt

This section shows BOQs prepared for both 2mm and 3mm thick bituminous felt and their various cost implications by using gas and felt adhesives. In the tables below it has been assumed that 20liters of bituminous felt adhesive will be sufficient for covering the specified floor area of 5.1m2 x 6.45m2. The cost of labour, hot mopped asphalt and the bituminous felt were gotten from interviews with three artisans who install bituminous felt and the average costs were used for these calculations. Tables 3 & 4: Show BOQ options 1 & 2 for 2mm thick bituminous felt using adhesives and gas respectively, while tables 5 & 6 show BOQ options 1 and 2 for 3mm thick bituminous felt using adhesives and gas respectively.

Table 3: BOQ option 1 for 2mm thick bituminous felt.

Item	Description	Unit	Qty	Rate (N)	Cost (N)
1.	Cost of 2mm thick bituminous felt.	Yards	44	800	35,200
2.	Cost of bituminous felt adhesive	Liters	20	400	8,000
3.	Cost of workmanship.	m^2	32.895	650	22,000
Total					N65,200

Source: Author's market survey, 2019.

Table 4: BOQ option 2 for 2mm thick bituminous felt

Item	Description	Unit	Qty	Rate (N)	Cost (N)
1.	Cost of 2mm thick bituminous felt.	Yards	44	800	35,200
2.	Cost of gas	Kg	2	500	1,000
3.	Cost of workmanship and lease of touch.	m^2	32.895	650	22,000
Total					N58,200

Source: Author's market survey, 2019.

In comparing tables 3 & 4, it can be deduced that it is cheaper to use gas than adhesives in installing 2mm thick bituminous felt over a surface area of 5.1 x 6.45m2, while the N7,000 difference may appear small in amount, with larger surface areas, it will definitely become costlier.

Table 5: BOQ option 1 for 3mm thick bituminous felt

Item	Description	Unit	Qty	Rate (N)	Cost (N)
1.	Cost of 3mm thick bituminous felt.	Yards	44	1000	44,000
2.	Cost of bituminous felt adhesive	Liters	20	400	8,000
3.	Cost of workmanship.	m^2	32.895	650	22,000
Total					₦74,000

Source: Author's market survey, 2019.

Table 6: BOQ option 2 for 3mm thick bituminous felt

Item	Description	Unit	Qty	Rate (N)	Cost (N)
1.	Cost of 3mm thick bituminous felt.	Yards	44	1000	44,000
2.	Cost of gas	Kg	2	500	1,000
3.	Cost of workmanship and lease of touch.	m2	32.895	650	22,000
Total					N67,000

Source: Author's market survey, 2019.

In comparing tables 5 and 6, the same scenario plays out like in tables 3 and 4, with a difference of N7,000 in using adhesives or gas. This result shows that a difference of N7,000 is realized between using adhesives or gas. However, since 3mm thick bituminous felt is thicker in width than 2mm, it is advisable to use 3mm than 2mm, but there is a difference of N8,800 between using 3mm and 2mm with adhesives and gas, and this cost (N8,800) will definitely increase as floor area increases.

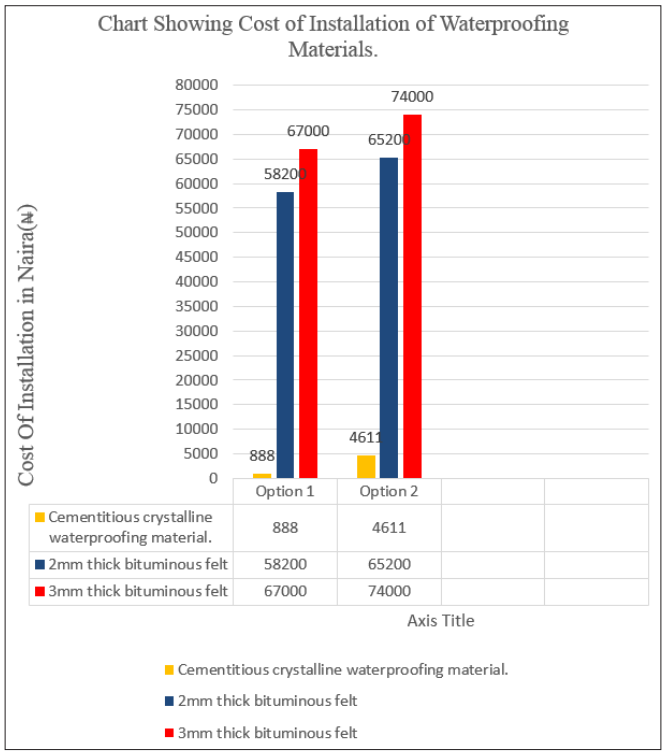

Figure 1: Bar chat comparing cost of installing bituminous felt and cementitious crystalline waterproofing material. Source: Author's market survey, 2019.

The bar chart in Figure 1 clearly shows the difference in cost of using cementitious crystalline waterproofing material, 2mm thick bituminous felt and 3mm thick bituminous felt for the same floor area of $5.1m^2$ x $6.45m^2$ = $32.89m^2$. It can be clearly seen that ccwpm is cheaper to use in concrete and in plaster compared to 2mm thick bituminous felt and 3mm bituminous felt that covers the same surface area.

Summary of Results

From the cost analysis done which showed the cost of purchase and cost of installation of cementitious crystalline waterproofing material and bituminous felt, it was established that:

1. The cost of purchase of bituminous felt is more than the cost of purchase of cementitious crystalline waterproofing material.
2. There is no labor cost for the application of cementitious crystalline waterproofing material as the material is added to the cement during the casting or plastering of the concrete slab.
3. The cost of purchase and installation of 3mm thick bituminous felt is more than the cost of purchase and installation of 2mm thick bituminous felt.
4. The cost of installation of 2mm and 3mm thick bituminous felt is higher than the cost of installation of cementitious crystalline waterproofing material.
5. The cost of maintenance of bituminous felt is high compared to the cost of maintaining cementitious crystalline waterproofing material. This is due to the need to replace damaged portions of the material during maintenance, also because bituminous felt would need to be replaced after expiration of its durability period. Cementitious crystalline waterproofing material on the other hand can last throughout the life span of the concrete even as there is no need for replacement.

Discussions

This study found out through calculations of existing market prices that the cost per m3 of casting 150mm thick of r.c slab using ccwpm is N 4,611 , while the cost of plastering the same cubic meter using ccwpm is N 888. This tends to show that it is more expensive to cast concrete slabs using ccwpm than plastering the same cubic meter using ccwpm. With this knowledge, it will encourage clients and contractors to make early decisions of considering the use of ccwpm in the construction of concrete, concrete slabs or using ccwpm in plastering. However, in buildings where construction was completed without the use of dpm (damp proof membrane) or ccwpm in casting concrete slabs and moisture tends to adversely affect the superstructure of such buildings, it is advisable to use ccwpm in plastering or re-plastering as the case may be, since it was omitted at the initial stage during construction, because it is cheaper to install, with no workmanship cost and no maintenance cost throughout the lifespan of the building.

Findings from this study further reveal that 3mm thickness of bituminous felt costs N44,000, while that of 2mm thickness costs N35,200, (for the same floor area) indicating N9,800 difference between both materials. While this difference may appear small, when large surface areas are covered, the difference in cost may become large. Also, while both materials are good and only different marginally by 1mm thickness, if there are adequate and sufficient funds available, it is advisable to opt for 3mm bituminous felt for water proofing construction because of its thicker gauge. However, where there is paucity of funds for a construction project, the building professionals should opt for 2mm thick bituminous felt material, but should be adequately and well finished using adhesives or touch flame.

In the use of adhesives or touch flame the study found that it is cheaper to use touch flame for sticking bituminous felt than using adhesives for binding. It was discovered that whether 2mm or 3mm is used on site, the difference in cost is N7000 between

both materials. The study found that it will cost N65,200 to use adhesives for 2mm thick bituminous felt, while it will cost N58,200 to use touch flame for 2mm thick bituminous felt on the same surface area. It also found that it will cost N74,000 in using adhesives for 3mm bituminous felt and N67,000 in using touch flame for 3mm on the same surface area. While it appears like using touch flame is cheaper (if it is properly done), than using adhesives (if well done too), using adhesives for bonding bituminous felt may detach in the continuous presence of water seepage and high moisture. Therefore, building professionals should take decisions early on which water proofing materials should be used on construction projects on time, considering all the factors stated above in this study. However, the study advises further that in projects that were completed and plastered without considering water proofing materials, the cost of hacking surfaces or removing parts of previous plaster before re-plastering will increase the cost of re-plastering with the new wpm in mind, and re-plastering such surfaces is cheaper when ccwpm is used compared to using ccwpm in concrete.

Recommendations and Conclusion

Recommendations

After a diligent study on bituminous felt and cementitious crystalline waterproofing materials for concrete the following recommendations were made to guide in the selection of a waterproofing material for concrete:

Extensive research and study of the various waterproofing options should be available before deciding on which waterproofing materials to go for. (During the course of the study it was observed that majority of the professionals who filled the questionnaires did not know about cementitious crystalline waterproofing material. They would therefore not recommend a material for use if they are not aware that the material exists in the market. It would be of great benefit if building professionals continually make adequate research and findings about new construction materials, not only in waterproofing techniques, because as technology advances, newer and better solutions to waterproofing and construction problems will emanate).

Proper study on the waterproofing material and the application method that has been decided to be used must be done on time before construction commences. There are various application techniques, various temperature and environmental conditions in which different waterproofing materials are to be applied. If these conditions are not in place or attention is not paid to proper application techniques, there is the probability of waterproofing failure. So, professionals ought to be aware of the details involved before they decide on which material to use.

1. For future construction works on concrete, cementitious crystalline waterproofing materials should be used instead of bituminous felt as this is more cost effective in the short run and also in the long run. Cementitious crystalline waterproofing material also protects concrete from within and has the ability to fill micro-pores of concrete.
2. For existing concrete works which have not been waterproofed, cementitious crystalline waterproofing material should be used during the plastering, the plastering should however be of sufficient thickness of 12.5mm but not exceeding 15mm.
3. For buildings in which bituminous felt has already been used for waterproofing, in subsequent maintenance or after the expiration of the existing bituminous felt, it should be replaced with better updated versions of modified bituminous felt material that are more durable than the non-modified version. The affected area should be removed and re-plastered with 12.5mm thick of cementitious crystalline that has been thoroughly mixed with mortar for re-plastering.

Conclusion

This study was able to carry out in-depth research by comparing two waterproofing materials for concrete, through market surveys, comparing prices of procuring such materials through BOQs and cost of maintenance of individual items, including interviews with construction professionals. Findings from the study were outstanding from the comparisons carried out on the two materials, as it revealed that cementitious crystalline waterproofing material has not been given widespread recognition, though it is more cost effective compared to bituminous felt. The cost of purchase, installation and maintenance of bituminous felt outweighs that of cementitious crystalline waterproofing material. Cementitious crystalline waterproofing material is not widely known and used by construction professionals around this clime in Nigeria, but in the future, it may become the most widely used waterproofing material if the knowledge and awareness of the material is increased. Public and private buildings, especially private residential buildings that have been inhabited that omitted the use of DPC (damp proof course) or DPM (damp proof membrane) due to moisture seepage through concrete, can opt for cementitious crystalline waterproofing material as a last resort, since it will be extremely difficult to place DPC or DPM when construction is completed and the buildings have been inhabited or put in use. Considering the cost of construction with ccwpm and bituminous felt in a building, it is obviously worth it, because of the inconveniences and defacing aesthetics associated with dampness and water seepage into concretes within buildings [13-15].

This study only observed analyses involving horizontally cast reinforced concretes, horizontally plastered surfaces, and vertically inclined plastered surfaces, but did not consider vertically cast concrete (i.e reinforced columns) in its analyses and calculations. Therefore, authors may consider other concrete castings like the vertically inclined cast concrete etc. For further studies, researchers may compare two or more other waterproofing materials for concrete besides the ones that were studied here, and make comparisons with this study in order to ascertain the most effective, and the most economically viable of all the waterproofing materials, so as to save money for optimum efficiency.

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