Influence of coatings on energy conservation in construction industry: A case study in the new Egyptian administrative capital

Nancy Abdel Moneim Sakr

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INFLUENCE OF COATINGS ON ENERGY CONSERVATION IN CONSTRUCTION INDUSTRY:

A Case Study in the New Egyptian Administrative Capital

A Thesis Submitted to
The Department of Construction Engineering

In partial fulfillment of the requirements for the degree of
Masters of Science in Construction Engineering

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December 2017
ACKNOWLEDGEMENT

I thank God for reaching to this step in my life. Having faith is the key to success. I am grateful to my family and my husband for standing beside me in such difficult times. I could not do anything without their continuous support. Professor Mohamed Nagib Abou-Zeid who is my advisor is one of the most considerate and understanding doctors in AUC. I thank him very much for believing in me and being considerate to many situations during writing this paper. I also enjoyed working with him; he pushed my limits to the maximum. Support, appreciation and persistence are powerful factors in anyone's life.

Moreover, my colleague who helped me a lot during my writing and data collection is Amr Fathy; I owe him a lot; I could not reach to some of my data without him; he was such a good friend and guide for me.

Last but not least, Engineer Amr Abdel Samei who is one of the top managers in the new Egyptian Administrative Capital; he was helping me as if I am his daughter although it was my first time to have the honor to know him.

Also, behind the scenes my manager in work was such a supportive manager; engineer Mohamed Abdel Latif, and my loyal friend, Ahmed Salah. I was fortunate to have all those people supporting me all the time. This reflects the importance of help and support from others throughout your life journey. It cannot be full of such experiences without the cross talking between people.
ABSTRACT

World energy consumption has increased rapidly in the past few years. Due to population growth, total energy consumption is increasing; a large amount of energy is wasted on the cooling and heating processes in buildings. However, using thermal heating management can minimize costs, heat consumption and create a management system for the heat insulation for buildings. This concept is being implemented through different approaches. Based on analysis and research, there is an evidence in the energy consumption before and after testing and applying construction approaches for thermal heating management in building units.

This investigation addresses an evaluation of the influence of external coatings on energy consumption. Coatings are considered one of the smart effective available approaches for energy efficiency. Unfortunately, this approach is not widely applied in the construction industry. It needs more data to prove effectiveness and credibility between people to use it as a smart thermal insulation approach. Two precedents have been analyzed in order to monitor buildings’ heat exposure, and how the buildings will be affected by thermal insulation materials. Data sheets from chemical companies which produce similar coatings are compared with the usual products and the protective thermal products.

The New Egyptian Administrative Capital is considered the new heart of Egypt, where energy saving concept is taken into consideration from the beginning. This shows that Egypt is also moving towards achieving the concept of energy conservation. The site visits reveal a potential for energy conservation up to 70% using protective coatings; which can be implemented in Egypt. Furthermore, based on interviews with site engineers and the head of operational projects inside the capital, they are open for studying more effective approaches for energy savings, as it is highly needed; especially, in the ministries’ zone.

Keywords: (Energy Consumption, Building Envelope, Thermal Insulation, Protective Coatings)
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CHAPTER 1: INTRODUCTION

1.1 ENERGY CONSERVATION IN CONSTRUCTION

Thermal energy conservation is considered one of the important approaches to energy consumption all over the World. Most of the buildings need a heating and a cooling system from the inside, as the outside is not acting efficiently due to the surroundings and inefficient use of external building materials. This consumption has caused global warming on a large scale. Each building is seeking to control the heat gained inside the building without paying attention to the consequences, or even thinking of sustainable alternatives that can serve the environment and save energy at the same time. This lack of awareness has led to overheat consumption from many different energy sources. In fig.1, the total energy consumption worldwide in the different categories is shown; the renewable energy consumption is 19%, including all the subcategories of it; fossil fuel consumes 78.4% from the total energy consumption in 2013. [1]

Figure 1: Total World Energy Consumption; Fossil Fuel consumes 78.4% which is Being Used in Generation of Electricity. [1]
Smart alternatives for energy consumption can start in an early phase of the construction process. These alternatives can be taken into consideration during the construction and the architecture process; they minimize the energy used in the building and serve the sustainable environment. The world needs more saving of its energy, especially non-renewable energy. This energy conservation can be conducted within a big community through the buildings’ use of energy, and on a smaller scale, within each home. If each single house manages the amount of energy used and applies the concept of sustainability, there will be a great amount saved. This illustrates the importance of thermal heating management. It has a wide scale influence on the environment and a small-scale influence on the houses' heating and cooling system in relation to the cost and the lifetime of thermal heating management. In order to apply this system, building envelopes can be used as one of the approaches. [22]

The building envelope is considered a general term which can be categorized on many levels. What it is focused on from the concept of the building envelope is the materials (Coatings) used on the exterior surface of any building, including the roof. Coatings are considered a successful approach that are categorized as a building envelope; they are a smart method for energy efficiency. These materials should be well selected in order to minimize the heat gain from inside the building. The concept behind it is to achieve an ecological envelope for homes. This envelope provides the building with a ventilation system and a suitable temperature. This will minimize electricity consumption inside the building which can save money for its inhabitants. Residential buildings are categorized as one of the most energy consuming buildings; that’s why energy conservation is important to be better implemented in residential buildings. [14]
According to the United Nations Environment Program, “In most countries, residential buildings are responsible for a major part of the energy consumption in the building sector (UNEP, 2007). Studies indicate that buildings in Brazil (commercial, residential and public services) account for 44.7% of the energy use (electricity): the non-residential sector accounts for 22.7% and the residential sector for 22% of the total (BEN, 2007)”.[14]

1.2 GREEN CERTIFICATES AND INSULATION MATERIALS

This section is to introduce how different Green certificates address insulation materials and the building envelope in their criteria for energy conservation. Nowadays, the Green concept is spreading all over the world. Many countries started to seek Green in their lives in order to minimize energy consumption, costs and to save the planet. There are many buildings in different countries which have applied the concept of Green during the construction and the design process. Material choices are considered a very important factor in applying Green. In order to reach this concept, there are many certifications to prove which category of Green the building is, as shown in table 1. One of these International certifications is LEED certification. LEED has four levels of applying the Green building concept. There are buildings all over the world which are certified, as illustrated their requirements in table 2. In Egypt, certain commercial buildings have received LEED certification.[4]
Table 1: International Ecological Building Rating Systems. [4]

<table>
<thead>
<tr>
<th>International System</th>
<th>Country</th>
<th>Introduced Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>BREEM</td>
<td>UK</td>
<td>1990</td>
</tr>
<tr>
<td>LEED</td>
<td>USA</td>
<td>1998</td>
</tr>
<tr>
<td>CASBEE</td>
<td>Japan</td>
<td>2001</td>
</tr>
<tr>
<td>GREEN STAR</td>
<td>Australia</td>
<td>2003</td>
</tr>
</tbody>
</table>

Table 2: LEED Requirements for Existing Buildings 2009. [4]

<table>
<thead>
<tr>
<th>LEED 2009 Minimum Program</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Floor Area</td>
<td>93 m²</td>
</tr>
<tr>
<td>Minimum Occupancy Rate</td>
<td>12 continuous months</td>
</tr>
<tr>
<td>Building Energy and Water Usage Data</td>
<td>A period of at least 5 years</td>
</tr>
<tr>
<td>Minimum Building Area to Site Area Ratio</td>
<td>No less than 2% of the gross land area</td>
</tr>
</tbody>
</table>

Table 3: Comparison between LEED Home and Code-home Cost. [4]

<table>
<thead>
<tr>
<th>Comparison Criteria</th>
<th>Code Home ($)</th>
<th>LEED Home ($)</th>
<th>Difference ($ Month)</th>
<th>Savings ($ Day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sticker Price</td>
<td>300,000</td>
<td>308.500</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mortgage Payment</td>
<td>1,890</td>
<td>1,945</td>
<td>+ $ 55</td>
<td>+1.80</td>
</tr>
<tr>
<td>Energy Bill</td>
<td>150</td>
<td>105</td>
<td>-$ 45</td>
<td>- 1.50</td>
</tr>
<tr>
<td>Water Bill</td>
<td>30</td>
<td>20</td>
<td>-$ 10</td>
<td>- 0.30</td>
</tr>
<tr>
<td>Net Cost of Ownership</td>
<td>2.070</td>
<td>2.070</td>
<td>$ 0</td>
<td>0</td>
</tr>
</tbody>
</table>
The first step towards Green buildings and minimizing energy consumption is a cost comparison between LEED home and code home, as reflected energy savings shown in table 3. This is the code home of the United States compared to the LEED home costs. It shows that the initial cost of LEED home is higher than the code home, yet the energy consumption is higher in the code home than the LEED home standards. Taking a step forward, Egypt has initiated its national certification towards Green and energy saving. The Green Pyramid is the Egyptian certification towards going Green, as shown in table 4 and table 5. [4]

Table 4: LEED Certificated All Over the World. [4]

<table>
<thead>
<tr>
<th>National System</th>
<th>Country</th>
<th>National System</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>GREEN GLOBES</td>
<td>Canada</td>
<td>Hkbeem</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>GBAS</td>
<td>China</td>
<td>IGBC Tools</td>
<td>India</td>
</tr>
<tr>
<td>GREEN PYRAMAID</td>
<td>Egypt</td>
<td>Protocolloitaca</td>
<td>Italy</td>
</tr>
<tr>
<td>PRMISE</td>
<td>Finland</td>
<td>Lider A</td>
<td>Portugal</td>
</tr>
<tr>
<td>HQE</td>
<td>France</td>
<td>Green Mark</td>
<td>Singapore</td>
</tr>
<tr>
<td>DGNB</td>
<td>Germany</td>
<td>Verde</td>
<td>Spain</td>
</tr>
</tbody>
</table>

Table 5: Green Certificates All Over the World. [4]

<table>
<thead>
<tr>
<th>Scheme</th>
<th>BREEMAMUM</th>
<th>LEED US</th>
<th>CASBEE</th>
<th>NABERS</th>
<th>GPRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>United Kingdom</td>
<td>United States</td>
<td>Japan</td>
<td>Australia</td>
<td>Egypt</td>
</tr>
<tr>
<td></td>
<td>of America</td>
<td>of America</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definition</td>
<td>The Building</td>
<td>Leadership in</td>
<td>Comprehensive</td>
<td>The National</td>
<td>Green</td>
</tr>
<tr>
<td></td>
<td>Research</td>
<td>Energy and</td>
<td>Assessment</td>
<td>Australian</td>
<td>Pyramid</td>
</tr>
<tr>
<td></td>
<td>Establishment</td>
<td>Environmental</td>
<td>System for</td>
<td>Built</td>
<td>Rating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design</td>
<td>Building</td>
<td>Environment</td>
<td>System</td>
</tr>
<tr>
<td>Introduced Date</td>
<td>Assessment Method</td>
<td>Environmental Efficiency</td>
<td>Rating System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------</td>
<td>---------------------------</td>
<td>---------------</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Updated</td>
<td>2008</td>
<td>2009</td>
<td>2007</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Developed By</td>
<td>Building Research Establishment, UK (BRE)</td>
<td>US. Green Building Council (USGBC)</td>
<td>Japan Green Building Council (JAGBC)</td>
<td>Green Building Council of Australia (GBCA)</td>
<td>Egyptian Green Building Council (EGBC)</td>
</tr>
</tbody>
</table>
HSBC Bank is one of the leading projects in Egypt which has received the LEED certification, as shown in fig.2. There are many other projects which have received LEED certification, such as Dar Al Handsa in fig.4, and also, Siemens Company building received LEED certification, as shown in fig.5. One mega project, a complete commercial complex for Smart Village is based on Green factors receiving LEED certified buildings and having achieved successful merits in the Green industry. The Smart Village is a complex based on Green, as shown in fig. 3. The common merits between fig.2, fig.3, fig.4, fig.5 and fig.6 are that all these buildings received the LEED certification according to their building classification, floor areas and occupancy rate, as illustrated before in table 2. [2]
Figure 3: Dar Al Handasa Building-Smart Village; LEED certified. [2]

Figure 4: Smart Village; Consistency, Green Concept and Sustainability. [2]

Figure 5: Siemens Certified LEED Building. [2]
The Millennium Waterway Ave is considered one of the projects which has received LEED silver certification; it is the first certified residential project in The Woodlands in Texas, as shown in fig. 6. There are energy and Green benefits in such projects; a better life quality and less utility consumption. Having such residential projects winning LEED certification is a strong approach towards the Green concept in this specific sector as it presents energy conservation through different factors, which protective coatings are one of them. [12]

As explained from the project description of The Millennium Waterway, “Designed as a luxury sustainable apartment community, The Millennium Waterway Ave is a joint venture between The Dinerstein Cos. and The Woodlands Development Co. In 2011 the four-story, 393-unit project became the area’s first LEED(R) Silver certified apartments, and is one of the greenest apartments in Texas”. [12]
1.3 OBJECTIVE SCOPE

The objective of this study is to evaluate the influence of specialized protective coatings on energy consumption on the external walls of residential buildings. In order to meet this objective, literature review, analysis, precedents, methodology, field trips, technical sheets and lifecycle cost analysis are being conducted and analyzed to be able to come up with a developed approach to minimize energy consumption in residential buildings.

1.4 VARIOUS MATERIALS AND TECHNIQUES USED FOR ENERGY CONSERVATION

1.4.1 GREEN HOUSE STRUCTURE AND ENERGY EFFICIENCY

The Green concept has its own variables and criteria for energy efficiency. Green starts from the outside to the inside. The outside part includes materials used (Coatings and paintings), green areas and its response to external buildings’ walls [6]. The inside includes paintings, coatings, air ventilation and heat exposure inside the apartment. All these elements have two different approaches; it is either a Green approach or the usual non-environmental approach which consumes more energy. [1]

1.4.2 ECO BUILDING MATERIALS FOR INDOOR AND OUTDOOR COATINGS: [22]

1.4.2.1) Reflective Indoor Coatings
1.4.2.2) Phase change materials
1.4.2.3) New insulation foams
   1.4.2.3.1) Insulation in wall cavities
   1.4.2.3.2) External Insulation
1.4.2.1 REFLECTIVE INDOOR COATINGS

Indoor coatings are being used as a part of the indoor paintings for interior spaces. It has various functions and uses. Different colors of paintings can have an effect on the way gets inside the space. Also, these coatings maximize the feeling of space and lighting. As a result, the use of artificial lighting will be decreased up to 20% because of the maximum use of natural light. [24]

"In recent tests, reflective indoor coatings have shown a life expectancy of 5-10 years without losing any performance” [1]. These coatings are long run efficient as it decreases the electricity consumption and HVAC consumption, as well. This makes these coatings a bit higher in cost than the normal good quality paints, “The effect of using these coatings is the highest in climate zones which suffer from limited daylight intensity and duration (North and middle Europe)” [24]

1.4.2.2 PHASE CHANGE MATERIALS (PCM):

Phase Change Materials “PCM” are considered semi-finished materials which are available in the market. Its ingredients are plaster, cement, plasterboard and multifunctional wall and roof modules. PCM is being used in interior walls and ceilings as well as it permits the absorption and storing of excessive heat during the day. PCM increases the thermal inertia of the wall and ceilings as it makes them behave like the old-fashioned thick stone walls; this is to dissolve that excessive heat during the night when air temperatures have gone down. PCM is also containing walls and ceilings to reduce fluctuations of the inside temperature (especially reducing the number of hours that the inside temperature exceeds 26˚C which is normally the threshold to initiate active cooling) and thus, saves energy. [24]
“In recent tests, PCM has demonstrated to have a life expectancy of 30 years without losing any performance. In concrete cases, it has been shown that up to 10% of cooling energy can be saved. In addition, the PCM allows downsizing of the air conditioning (AC) system which reduces the investment required for this AC system” [1]. As shown in fig.7, it illustrates the conventional system of internal temperature compared to PCM system internal temperature; it shows the difference in the internal temperature throughout the hours of the day, and how the temperature in PCM decreases in different timings throughout the whole day. [24]

![Figure 7: The Difference between Conventional System and PCM of Internal Temperature. [1]](image)

### 1.4.2.3 NEW INSULATION FOAM

Advanced insulation foams with high insulation performances allow significant energy savings and can be adapted to different building’s configurations. It’s estimated that these high-performance foams can reduce the energy costs of heating by 30%-80%. [24]
1.4.2.3.1 INSULATION IN WALL CAVITIES

Cavities are what is between wall layers; its wall insulation fills this space between the two layers of the external wall of a building. Wall cavity can be injected with foam; this is a part of an energy efficiency refurbishment. Yet, the cavity is filled up using rigid pre-foamed panels attached to the wall if it is a new construction building. Each ‘stack’ is varied based on the characteristics of the wall, climate and orientation of the building. There are other materials’ choices, which are based on fire resistance, mechanical strength, stability, water absorption, permeability and cost. “For most applications, the lifetime expectancy of these insulation facade systems is up to 20 years”. [1]. As elaborated in fig. 8 and fig 9, an example of how the wall is being injected by showing a cross section of each layer and material in the wall layers. [24]

Figure 8: Wall Thermal Insulation Layers and Wall Injection throughout the Cavities. [1]
1.4.2.3.2 EXTERNAL INSULATION

This method is done through adding efficient energy saving materials as part of the outside wall layer. This works as an external coating to minimize heat gained inside the building, which leads to a lesser need for more electricity (energy) consumption. This is considered another approach of coatings used when there are no wall cavities, as it maintains the thermal storage capacity. Fig. 9 shows the layers and composites of the external wall insulation. [23]

Figure 9: External Wall Insulation Cross Section. [1]
CHAPTER 2: PRECEDENTS

There are some international and national projects which have applied similar approaches for energy conservation concept. Coatings are considered an advanced approach which is not widely known in the construction industry. Unfortunately, not many people know about it due to lack of awareness and its cost. On the architectural level, using architectural solutions for the buildings, such as specific cladding materials, green materials, and smart ventilation systems can save huge amounts of energy. These small key words represent “Coatings” which is using a sustainable envelope. This concludes the scope of this study which is to introduce the concept of energy saving through external protective coatings and to state where Egypt stands from this advancement. [2]

A study in sustainable energy potential in the Egyptian residential sector has been conducted in 2011/2014 in Egypt. It showed how the energy consumption varies from sector to another, and how it varies among the different sectors. The residential sector is the most energy consuming sector among the rest of commercial, governmental, agriculture, public utilities and industrial sectors. This means that if this energy can be minimized and saved, the potential of energy saving in Egypt will be more feasible and can be implemented. The subsidies of the residential sectors are like lighting, fridges' electricity, air conditioning, etc. However, there are three main subsidies that also control the energy consumption of residential buildings in Egypt. These three subsidies are Lighting systems, kitchen appliances and air conditioners. People seek instantaneous non-environmental solutions to these subsidies for a better lighting system all day, better air ventilation and a more comfortable life style without paying attention to the consequences that can lead to a real damage in the energy consumption rate all over Egypt. [2]
As it is shown in fig. 10 and fig. 11, a study which has been conducted in 2011/2014 shows that the residential sector is the most energy consuming sector which takes 42.3%. Also, each of the residential units consists of energy consumption factors, such as home appliances, lighting, air conditioners, kitchen appliances, and others. [2]

Figure 10: Electricity Consumption 2011-2014 (Left)-2014 (Right). [2, 21]

Figure 11: Energy Consumption 2011-2014 (Left)-2014 (Right). [2, 21]
2.1 National PRECEDENT- Al Wardan Institute-Renovation (Alexandria- Egypt)

Initial approaches have been applied in Egypt. Al Wardan Institute is an actual case study which was redesigned for minimizing heat exposure inside the buildings of the complex, as shown in fig. 12. This automatically has led to a decrease in energy consumption inside the whole complex. Moreover, an international study has applied a thermal insulating concept. Although, both of the national and international precedents are seeking energy saving, there is no focus on introducing protective coatings’ approach. And all these are considered various approaches to introduce protective coatings to the Green market and the sustainable environment as part of the energy saving process. Especially, data sheets from different chemical companies and studies from the International Institute for Applied systems and the Building Performance Europe Institute prove that these protective coatings save up to 50% of energy consumption inside the buildings; this is will be discussed more in the paper. [4]

Al Wardan Training Institute is located on Cairo/Alexandria desert road, 6th of October, Egypt. It is a staff housing where the sun heat is penetrating the buildings. This obliged them to use air conditioning systems for a better ventilation from the inside. The methodology of enhancing energy consumption efficiency was to calculate the energy consumption and the costs of different electricity supporters. This hostel was having problems in how the heat is gained inside the space, and how the exterior is engaged in such a real problem for its users. That’s why; renovation took place in this hostel; fig .12 shows the location in Egypt, and fig. 13 reflects the proposed layout for the staff housing. [4]
Figure 12: Wardan Institute after Renovation. [4]

Figure 13: Wardan Institute Master Plan. [4]
Fig. 13 is a master plan of the whole complex; it shows the sectors in each unit and its areas. The project has various activities. It is not only residential buildings, but also it has a school of engineering, a social club, a medical Centre, villas, a theatre, an administration building, a mosque, and other facilities. Fig. 13 shows the master plan after the renovation, and how Green concept can achieve this transformation. This project has implemented various Green approaches, such as thermal insulation materials, solar panels, walls' redesign and achieving smart air ventilation systems for the whole complex. [4]

Fig. 14 and fig. 15 shows the scale of the project, and the existing status before renovation. The materials of the existing building units (the villas) are shown in table 6. Also, the zoning of the functions inside the complex serves the same concept, as shown in the following tables of Al Wardan zoning. [4]

<table>
<thead>
<tr>
<th>Al Wardan Zones</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Educational Zone</strong></td>
<td>- Workshops building (24 workshops)</td>
</tr>
<tr>
<td></td>
<td>- Laboratories (14 labs)</td>
</tr>
<tr>
<td></td>
<td>- Classrooms (47 classrooms, 3 drawings, conference hall and staff offices)</td>
</tr>
<tr>
<td></td>
<td>- Main Library</td>
</tr>
<tr>
<td></td>
<td>- Administrative building</td>
</tr>
<tr>
<td></td>
<td>- Students Housing (288 double rooms)</td>
</tr>
</tbody>
</table>
Residential Zone and Sports’ Zone

- Visitors Housing (15 double rooms)
- Experts Housing (36 double rooms)
- Staff Housing (18 blocks with 280 flats)
- Executive villas (8 villas with 360 m², 3 villas with 600 m²)

Sports’ Zone:
- Olympic swimming pool
- Sports and social club
- Sport courts (football, basketball, volleyball, tennis and track)

Services Zone

- Main restaurant & Main Kitchen
- Laundry
- Bakery
- Electrical Station
- Water Station
- Boilers Station - Schools
- Super Market
- Clinic - Registration building
- Inside Train Station
These previous pictures in fig. 14 show the scale of the project, and how it has various functions and spaces which energy efficiency is an issue to be argued and find alternatives for better energy conservation.
### Staff Housing Area
- 18 housing units with 4 floors
- 8 villa with 2 floors (total area 360 m²)
- 8 villa with 2 floors (total area 600 m²)
- 3 schools
- Super Market

### Executive Villa (a), 2009
- Villa (a) northwest perspective
- Villa (a) southwest perspective

### Executive Villa (b), 2009
- Villa (b) northwest perspective
- Villa (b) south elevation

---

**Figure 15:** Sectors and Spaces of the Institute. [4]
Table 6: Buildings’ Materials in Al Wardan Project.

<table>
<thead>
<tr>
<th>Items</th>
<th>Flooring</th>
<th>Walls</th>
<th>Windows</th>
<th>Doors</th>
<th>Piping</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrance and living &amp; Dining area</td>
<td>Mosaic tiles</td>
<td>Cement plastering</td>
<td>Soft wood shutters and glass</td>
<td>Painted soft wood</td>
<td>-</td>
<td>Electricity</td>
</tr>
<tr>
<td>Office</td>
<td>Soft wood</td>
<td>Cement plastering</td>
<td>Soft wood shutters and glass</td>
<td>Painted soft wood</td>
<td>-</td>
<td>Electricity</td>
</tr>
<tr>
<td>Kitchen</td>
<td>Ceramic tiles</td>
<td>Ceramic tiles</td>
<td>Soft wood and glass</td>
<td>Painted soft wood</td>
<td>Lead, asbestos and steel</td>
<td>Electricity</td>
</tr>
<tr>
<td>Bedroom</td>
<td>Soft wood</td>
<td>Cement plastering</td>
<td>Soft wood shutters and glass</td>
<td>Painted soft wood</td>
<td>-</td>
<td>Electricity</td>
</tr>
<tr>
<td>Bathroom</td>
<td>Ceramic tiles</td>
<td>Ceramic tiles</td>
<td>Soft wood and glass</td>
<td>Painted soft wood</td>
<td>Lead, asbestos and steel</td>
<td>Electricity</td>
</tr>
<tr>
<td>Terrace</td>
<td>Mosaic tiles</td>
<td>Cement plastering</td>
<td>Soft wood shutters and glass</td>
<td>Soft wood shutters and glass</td>
<td>-</td>
<td>Electricity</td>
</tr>
<tr>
<td>Roof</td>
<td>Ceramic tiles</td>
<td>Cement plastering</td>
<td>-</td>
<td>-</td>
<td>Cast iron</td>
<td>-</td>
</tr>
<tr>
<td>Elevations</td>
<td>-</td>
<td>Mud brick with cement plastering and limestone</td>
<td>Soft wood shutters and glass</td>
<td>Painted soft wood</td>
<td>Cast iron</td>
<td>-</td>
</tr>
</tbody>
</table>
After the observations, modifications have been implemented on the apartments’ divisions and external facades’ design. The life cycle costs of local electricity, PV panels and Diesel Generators have been calculated and compared between the results. In addition, the amount of heat gained inside the housing has been calculated. The Wardan staff housing results of the heat gain and loss degrees have been reported. A comparison between the old and the proposed has been made. This comparison demonstrated that energy consumption of buildings can be treated through construction and architecture solutions in the design itself. [4]

The used insulation materials and modified wall angels minimized the energy consumption inside the housing units. The apartment units had less heat exposure and more air ventilation through having wider openings (windows and balconies). These openings enhance air circulation inside the apartment. Fig. 15 shows the modified drawing of the designed plan. It gives more openings for air circulation and moderate sun heat inside the buildings. Fig. 16 shows self-shading devices from the building form itself which maintain less direct sun exposure in sunny facades; and this is how it got implemented on elevation as it is shown in fig. 17. [4]
Figure 16: Proposed Air Ventilation in Plans. [4]

Figure 17: Proposed Air Ventilation Systems Inside Buildings (Section). [4]
This shows that the concept of energy saving is knocking the doors in Egypt which is a good indication for expansion. This will give people an incentive to apply sustainable coatings for less energy consumption because this will lead to less electricity consumption and more space efficiency. [4]

Al Wardan (Alexandria) staff housing shows the different items for providing energy and their costs in table 7. This project has introduced different factors of energy efficiency, and how it can be minimized through other alternatives. One of these alternatives was through using insulation materials as a tool to minimize heat gained inside the building and achieving the concept of the building envelope. So, experimentations and trails have been introduced, as shown the following table.
Table 8 introduced sun heat exposure throughout the whole day directed on the buildings' facade. This is a primary step in order to be able to apply an efficient building envelope on the buildings; table 8 illustrates the results of energy observation inside the building before changes. Fig.19 illustrated the proposed ecological system to be implemented on each unit, while table 9a and 9b show the final budget is cheaper than the typical and proposed renovation. [4]

Table 8: Temperature Readings. [4]

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>North Room</th>
<th>East Room</th>
<th>South Room</th>
<th>West Room</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Out</td>
<td>In</td>
<td>Out</td>
<td>In</td>
</tr>
<tr>
<td>1/7/2010</td>
<td>8:00</td>
<td>26</td>
<td>28</td>
<td>28</td>
<td>29</td>
</tr>
<tr>
<td>15/7/2010</td>
<td>8:00</td>
<td>26</td>
<td>29</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>1/8/2010</td>
<td>8:00</td>
<td>29</td>
<td>30</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>15/8/2010</td>
<td>9:00</td>
<td>30</td>
<td>28</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>31/8/2010</td>
<td>9:00</td>
<td>30</td>
<td>29</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>1/7/2010</td>
<td>5:00</td>
<td>34</td>
<td>30</td>
<td>30</td>
<td>29</td>
</tr>
<tr>
<td>15/7/2010</td>
<td>11:00</td>
<td>34</td>
<td>31</td>
<td>30</td>
<td>29</td>
</tr>
<tr>
<td>1/8/2010</td>
<td>5:00</td>
<td>35</td>
<td>32</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>115/8/2010</td>
<td>7:00</td>
<td>36</td>
<td>33</td>
<td>32</td>
<td>30</td>
</tr>
<tr>
<td>31/8/2010</td>
<td>7:00</td>
<td>36</td>
<td>33</td>
<td>33</td>
<td>31</td>
</tr>
</tbody>
</table>

Figure 19: Proposed Villa and Its Ecological System. [4]
Table 9a: Comparison Between the Typical and the Proposed Renovation. [4]

<table>
<thead>
<tr>
<th>Items Work</th>
<th>Typical Renovation</th>
<th>Typical Budget</th>
<th>Proposed Renovation</th>
<th>Proposed Budget</th>
<th>Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demolition Works</td>
<td>Removing all the materials accept the wooden floors.</td>
<td>5,000 EGP</td>
<td>Removing all the toxic and damaged materials</td>
<td>10,000 EGP</td>
<td>+5,000 EGP</td>
</tr>
<tr>
<td>Maintenance Works</td>
<td>Wooden floors and cupboards</td>
<td>5,000 EGP</td>
<td>Doors, windows, wooden floors and cupboards</td>
<td>15,000 EGP</td>
<td>+10,000 EGP</td>
</tr>
<tr>
<td>Water Insulation</td>
<td>Polyester 5 mm layer</td>
<td>5,000 EGP</td>
<td>Polyester 5 mm layer</td>
<td>5,000 EGP</td>
<td>0.0</td>
</tr>
<tr>
<td>Thermal Insulation</td>
<td>—</td>
<td>—</td>
<td>Roof and walls insulation with 5 cm reinforced foam panels</td>
<td>8,000 EGP</td>
<td>+8,000 EGP</td>
</tr>
<tr>
<td>Reinforced Concrete</td>
<td>—</td>
<td>—</td>
<td>Air catchers, photovoltaic slab and stair clear story.</td>
<td>5,000 EGP</td>
<td>+5,000 EGP</td>
</tr>
<tr>
<td>Plain Concrete</td>
<td>Insulation protection layer</td>
<td>5,000 EGP</td>
<td>Insulation protection layer</td>
<td>5,000 EGP</td>
<td>0.0</td>
</tr>
<tr>
<td>Brick Works</td>
<td>Mud brick</td>
<td>5,000 EGP</td>
<td>Air catchers, walls with clay bricks which contains rice straw.</td>
<td>7,000 EGP</td>
<td>+2,000 EGP</td>
</tr>
<tr>
<td>Plaster Works</td>
<td>Cement plastering</td>
<td>10,000 EGP</td>
<td>Rammed earth plastering</td>
<td>5,000 EGP</td>
<td>-5,000 EGP</td>
</tr>
<tr>
<td>Int. painting Works</td>
<td>Eco-paintings</td>
<td>15,000 EGP</td>
<td>Eco-paintings</td>
<td>15,000 EGP</td>
<td>0.0</td>
</tr>
<tr>
<td>Ext. painting</td>
<td>Cement dry mix</td>
<td>20,000 EGP</td>
<td>Rammed Earth</td>
<td>10,000 EGP</td>
<td>-10,000 EGP</td>
</tr>
</tbody>
</table>

Table 9b: Comparison Between the Typical and the Proposed Renovation. [4]

<table>
<thead>
<tr>
<th>Works</th>
<th>plastering</th>
<th>EGP</th>
<th>plastering</th>
<th>EGP</th>
<th>EGP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>Aluminum windows</td>
<td>30,000 EGP</td>
<td>The existing wooden windows are renovated</td>
<td>—</td>
<td>-30,000 EGP</td>
</tr>
<tr>
<td>Doors</td>
<td>Soft wood with HPL finishing layer</td>
<td>25,000 EGP</td>
<td>The existing wooden doors are renovated</td>
<td>—</td>
<td>-25,000 EGP</td>
</tr>
<tr>
<td>Electrical Works</td>
<td>Transformers, cables, generators, main and distribution panels</td>
<td>86,400 EGP</td>
<td>Distribution panels and electrical features</td>
<td>10,000 EGP</td>
<td>-76,400 EGP</td>
</tr>
<tr>
<td>Photovoltaic System</td>
<td>—</td>
<td>—</td>
<td>Photovoltaic panels, inverters and batteries</td>
<td>89,916 EGP</td>
<td>-89,916 EGP</td>
</tr>
<tr>
<td>Plumbing Works</td>
<td>Wells, tanks, piping and plumbing features</td>
<td>40,000 EGP</td>
<td>Piping and plumbing features</td>
<td>20,000 EGP</td>
<td>-20,000 EGP</td>
</tr>
<tr>
<td>Underground Water</td>
<td>—</td>
<td>—</td>
<td>Submersible pump in the well and water tank</td>
<td>10,000 EGP</td>
<td>+10,000 EGP</td>
</tr>
<tr>
<td>Greer water System</td>
<td>—</td>
<td>—</td>
<td>Greer water filter, pump and underground tank</td>
<td>5,000 EGP</td>
<td>+5,000 EGP</td>
</tr>
<tr>
<td>Air Conditioning Works</td>
<td>Air conditioning units, compressors and connections</td>
<td>80,000 EGP</td>
<td>—</td>
<td>—</td>
<td>-80,000 EGP</td>
</tr>
<tr>
<td>Air Fresh Works</td>
<td>—</td>
<td>—</td>
<td>Ceiling and wall fans</td>
<td>3,000 EGP</td>
<td>+3,000 EGP</td>
</tr>
<tr>
<td>Total in EGP</td>
<td>386,400 EGP</td>
<td>257,916 EGP</td>
<td>98,484 EGP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.2 INTERNATIONAL PRECEDENT-CEPT UNIVERSITY
Centre for Environmental Planning and Technology- Net Zero Energy Building

There was a study in India conducted by the Indian Forum which has reflected the building energy consumption. Their vision was "To enhance awareness of using thermal insulation in building envelope and cold chain industry for energy conservation through coordination with Government bodies & nodal agencies" [19]. It showed the different energy consumption of each building unit. Statistics have been taken to measure the amount of consumption throughout the years; this will be illustrated more in the methodology chapter. [5]

The Indian Forum conducted a study about energy consumption and the factors which increase its consumption in the buildings, as shown in fig.20. There are various examples of projects which have applied energy saving approaches in the buildings, such as thermal insulation and protective coatings. CEPT University in India is the international example of energy conservation concept. [5]

![Energy Consumption in India](image)

Figure 20: Residential Units’ Energy Consumption in India. [4]
The methodology was to calculate building energy consumption and the total primary energy supply and use. These statistics have been calculated from 1992 until 2000. There are smart materials, which support the circulation of heat and air ventilation in the buildings, especially if the building classification is an office building where many air conditioning systems are being used. Rigid insulation materials and mineral insulation materials, such as rock wool, slag wool, and glass wool achieved success in thermal insulation.

The rigid materials are Extruded Polystyrene Foam, Polyurethane Foam, Polyisocyanurate Foam and Expanded Polystyrene Foam. According to Energy Statistics in 2012, “The building sector represents 34% of the country’s final electricity consumption”; fig. 21 shows the increase in the final electricity consumption per sector in India. [5]

![Energy Consumption in India](image)

**Figure 21: Building sectors’ Energy Consumption in India. [5]**
In this case, an insulation envelope was a suitable solution for enhancing the temperature of the building unit. An insulation envelope is presented in using insulation materials which minimize the heat loss gained inside the building and keep an efficient heating/cooling cycle, as shown in fig. 22a and fig. 22b. [5]

![Figure 22a: Wall Insulation envelope effect; the Insulated buildings absorb less heat inside 31 degrees’ throughput morning and afternoon hours. [5]](image1)

![Figure 22b: Difference between Roof Insulation heat exposure between the normal RC slab and the insulation cladding. [5]](image2)
Fig. 23 reflects the impact of insulation on the building units. This has been applied on roofs and walls; after applying insulation materials. Reduction in heat inflow through roof was achieved by 90% and through walls by 70%. [5]

<table>
<thead>
<tr>
<th>Building Specs.</th>
<th>Project Design Team</th>
<th>Scope of Insulation</th>
<th>Project Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of stories: 4</td>
<td>Architect: VaniShar Consultant: Green Consultant: CARBSE</td>
<td>Roof: Over deck PUF Spray 45 mm thick Wall: Insulation with XPS – 50 mm First floor: Under deck - Insulation with XPS – 50 mm Ground Floor: Over deck - Insulation with XPS – 50 mm</td>
<td>Civil work completed</td>
</tr>
</tbody>
</table>

Figure 23: Reduction in Heat in Buildings after Applying Insulation Materials. [5]
2.3 ENERGY SAVING IN BUILDINGS USING REFLECTIVE COATINGS

The building envelope is considered the interface between the interior and the exterior of the building, and this includes the walls, roofs and the foundation of the building itself. This envelope controls the thermal heating and the amount of energy coming inside the building. There are various types of coatings based on the building classification and the surrounding environments; this will be elaborated later in the paper. There were analyses about coatings on the roof tops and the walls. “The results of these analyses indicate that significant energy savings from high reflectance surface coatings are achievable not only with cool roofing products but also on vertical surfaces, such as wall panels and window frames. These coatings also provide reductions in cooling loads and design airflows, potentially allowing equipment downsizing and first cost reductions.” [2]

2.4 CASE STUDY: THE NEW EGYPTIAN ADMINISTRATIVE CAPITAL AND ENERGY CONSERVATION.

The new Egyptian administrative capital is considered the current mega project in 2017 in Egypt. It has initial approaches towards minimizing energy consumption through thermal insulation materials as one of the approaches. However, the conventional materials are being used. An actual case study is being conducted on one of its residential buildings comparing the amount of energy saved for both of the conventional coatings and the protective coating, especially thermos shield material. A cost lifecycle analysis is implemented and calculated the differences in the energy consumption and cost analysis. This will be illustrated more in the coming chapters in the paper.
CHAPTER 3: EXTERNAL COATINGS FOR ENERGY CONSERVATION

This chapter provides findings and analysis of previous discussed protective coatings and their impacts on energy saving. Fig. 24 illustrates how the world production of paints and coatings in 2016; the Middle East produces an obvious percentage comparing to other countries. [18]

![Figure 24: World Production of Paints and Coatings. [18]](image)

Unfortunately, little work has been done to identify the influence of coatings on energy consumption. These types of coatings are based on the site merits and functions of the buildings. For example, Carbon nano Coatings is one of the successful energy saving coatings, yet it is being used in big scale projects, such as commercial buildings and mega projects. There are different types of coatings in the construction industry that are categorized as a building envelope. However, they differ according to the building classification and the building envelop type. There are various types, such as
that are categorized as a building envelope. However, they differ according to the building classification and the building envelop type. There are various types, such as wood coatings, plastic coatings, metal coatings, paper and film coatings, and packaging coatings. [18]

The whole idea is about protecting a surface of an object whether it is a wall, a metal sheet or a wood sheet. The following coatings are the selected ones according to the scope of the study: [18]

- Solar control coatings
- Carbon nano coatings
- Cool Roof coatings
- Protective coatings

3.1 SOLAR CONTROL COATINGS (SCC)

Solar Coatings consist of small deposits of appropriate materials, which interact with electromagnetic radiation. This comes through absorbing or reflecting these solar panels of these particles. This interface with electromagnetic light takes 50% of energy gained from sunlight; as shown in fig. 25. The sun heat gained inside the building can be controlled and minimized by these solar control coatings. There are certain

Figure 25: Solar Panels on Facades. [1]
properties which solar control coatings should be contained. These are the following properties: [1]

- Solar Control Coatings must have high transmittance in the visible region in order to let light pass through the window.
- The optical properties in the infrared region, however, might be different, depending on the application, such as in what kind of climate the coatings will be used.
- The ideal SCC for climates should maximize the solar radiation entering the building while minimizing the heat escaping from it, and this is achieved by using Low-E glasses. These glasses have coatings that are transparent to short-wave infrared radiation, allowing most energy from the sun to pass through.
- SSCs should reflect long-wave infrared radiation, which means that most of the energy coming from heating the building, with a longer wavelength, will not pass through the window and escape.
- SCCs for warm climates should minimize solar radiation entering a building; so, the materials should be highly reflective in the infrared region. These kinds of coatings are normally referred to as heat mirrors.
3.2 CARBON NANO COATINGS

Nano particles have a large surface area to volume ratio, which makes them highly interactive. This makes few numbers of particles enough to produce large effects. “Researchers of the Fraunhofer Institute for Chemical Technology ICT in Pfinztal are using these characteristics to create novel coatings. They are incorporating active nano materials into polymer systems. “These coatings can be applied easily like paint or varnish” [3]. The integration of nano particles in the plastic system provides extra safety. In addition, the binding forces prevent the uncontrolled release of individual nano particles. The process is adaptable to process varied nano materials. [1]

Additional advantages: [1]

- Small numbers of substances can be bound in a friendly environment, water-based systems of plastics that release hardly any volatile organic compounds.

- These coatings can be applied directly without first requiring a primer coat; experts refer to this property as "direct-to-metal". In addition, the layers prevent oxygen from reaching the metal and thereby protect the structure from corrosion.
“Researchers at Fraunhofer ICT worked together with partners in industry under a project funded by the German Federal Ministry of Education and Research (BMBF) on novel Nano-coatings for metallic wire and strip. Experts have developed thermo chromic coatings; these kinds of coatings have been introduced the color change based on their temperature” [1].

A coating mechanism aims to absorb heat or become transparent and permit its reflection. Metal strips preserve certain properties when coated in this way. “If temperatures are below 30 °Celsius (about 86 °F), the black coating absorbs heat”; and when it is getting warmer, the color changes. The paint which has now become transparent, allows the infrared radiation to be reflected,” Schmid explains. They can be interwoven and used as an exterior self-regulating thermal cladding for walls and façades to help cool buildings passively and thereby reduce operating costs. [1]

The researchers are working on additional nano-systems, such as coatings with luminescent properties. “The coatings can also help clearly differentiate branded products from pirated copies, since pirates do not have these kinds of luminescent nano-coatings at their disposal”. [1]
This type of roof coating is reflective to heat for roofs. Life time of this roof coating lasts for 6 to 7 years, as shown in fig. 26. It is considered a flexible coating which is ready for use anytime. This kind of coating is seeking the principle of continuous rejection of UV (Ultra-Violent) and IR (Infrared Resistant) Rays, which prevents the roof from getting heated up. “Ultraviolet and Infrared Resistant – Continuous rejection of solar heat resulting in drastic reduction of roof heat. Increase in temperature due to heat radiation from the roof is stopped, keeping the coated area comfortable even in peak summer afternoons”. This is because it reflects the heat from getting inside, and it does not affect the roof materials from being heated up in all seasons. This prevents the roof air from getting hot temperature keeping the rooms well ventilated and cool. It keeps the building surviving for a longer period. There are many advantages to this type of roof coating: [2]
• Being cool even under intense sunlight conditions.
• Maintaining a higher level of productivity from the staff.
• Lowering costs up to 40% of humidification and air conditioning
• Having an efficient reduction of roof heat up to 20°C.
• Completing Green solutions (High SRI value, no hazardous/toxic substance, Low VOC, saving energy) helps reducing carbon footprints.
• Blocking 90% of solar infrared rays and 85% of ultraviolet rays by “EXCEL Cool Coat” keeps the roof cool, even in peak summer.
• Reflecting UV and IR rays back to the atmosphere.
• Minimizing the need for false ceiling.
• Having more of the sunlight reradiates more of energy
• Having the flexibility of coating any roofing material or sidewalls.
• Helping in reducing the emission of greenhouse gasses.
• Resisting to water, fungus and mold.
• Improving the efficiency of roof ventilators.

These coatings reflect sunlight radiation both in the visible and infrared parts of the spectrum. When applied to roofs and walls, the reflection of the sun’s energy reduces roof and wall temperature. Therefore, it reduces the heating of spaces underneath the roof and inside the walls, as illustrated in fig. 27. High reflectance and durable outdoor coatings applicable on building roofs and walls in hotter climate regions can save up to 15% of air conditioning energy consumption while also allowing for down scaling the size of the air conditioning system. Life expectancy of this technology is 12-15 years depending on the climate. [2]
Costs of applying these coatings are affordable; they also offer reasonable payback times. In case a roof needs re-painting for maintenance reasons, then choosing a high quality, low LCA solar reflecting paint is an obvious smart choice especially in sunny, Southern European cities. [2]

3.4 PROTECTIVE COATINGS (Exterior Wall Coatings)

There are various types of protective thermal coating for external walls. These coatings enhance walls’ efficiency and energy saving for the building. It serves long-term efficiency for the walls. The important part in these coatings is that it is being used in different residential buildings not only abroad, but also in Egypt. These materials have the same chemical ingredients, yet chemical factories classify them according to their companies. This means that there are various chemical factories manufacture the same product with different brand names, but it carries the same chemical interaction. In this paper, two types of protective coatings will be elaborated according to their efficiency and environmental influence. [13]
- Thermo-Shield
- Nu-Guard NRG Energy Efficient Coating Systems

"THERMOSHIELD is considered heat insulated mortar with high quality. This insulated mortar is designed for interior and exterior solutions. Table 10 shows the technical data sheet of Thermo-shield material. This material has its own insulating properties which make it unique in the market of high quality mortar. Its classification is "ASTM C195 (USA) American Society for Testing and Materials" [14]. It has the following advantages: [9]

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density</td>
<td>0.370 kg/L</td>
</tr>
<tr>
<td>Mortar density after addition of water</td>
<td>800-900 kg/m³</td>
</tr>
<tr>
<td>Compressive strength after 28 days</td>
<td>3.3 N/m³</td>
</tr>
<tr>
<td>Weight of set mortar</td>
<td>400-450 kg/m³</td>
</tr>
<tr>
<td>Thermal conductivity (K)</td>
<td>0.1028 W/m°C</td>
</tr>
<tr>
<td>Over all heat transfer coefficient (U)</td>
<td>0.36 W/°C</td>
</tr>
<tr>
<td>Resistance value (R)</td>
<td>2.78 °C/W</td>
</tr>
<tr>
<td>Grade</td>
<td>0/2/mm</td>
</tr>
<tr>
<td>Coverage (2.5 cm application thickness)</td>
<td>2 m²/23kg bag</td>
</tr>
<tr>
<td>Wall application thickness</td>
<td>2.5 cm</td>
</tr>
<tr>
<td>Double wall application thickness</td>
<td>5 cm -10cm</td>
</tr>
<tr>
<td>Roof deck application thickness</td>
<td>2.5 cm -5 cm</td>
</tr>
<tr>
<td>Pot life</td>
<td>3 hours</td>
</tr>
<tr>
<td>Curing time</td>
<td>14 days</td>
</tr>
<tr>
<td>Mixing ratio</td>
<td>16L Water: 23 kg</td>
</tr>
</tbody>
</table>

- Reducing heat absorption
- Reducing of heat transfer by 40%; so, it maintains cooler temperature for the units.
• Working as sound and heat insulation, yet this is not valid in the regular type of mortar.

• Working for double wall design, roof and single walls. This encouraged its spread in the market, as it is flexible in its use and application; in the following fig. 28, it shows how it is coated in both of the double and single walls, and its application in the roof deck as well. [9]

• Conserving Energy

• Reducing Noise

• Retarding fire

• Having light weight

• Having direct application

• Being safe for the environment

• Being eco-friendly
Figure 28: Cross Section Details for Thermo-Shield Application in the Walls and the Roof Deck. [15]
3.4.1 HYDRON PROTECTIVE COATINGS- Nu-Guard NRG Energy

Efficient Coating Systems

Nu-Guard systems are being used for the exterior and interior walls as a protective coating. They are being tested based on their usage both inside and outside. Also, they are mainly designed to reduce electricity consumption. This system is applied on the residential, commercial and industrial buildings. The overall reduction of electricity consumption is a result of applying “Hydrons range of Nu-Guard NRG coatings”. [13]

Advantages of Nu-Guard systems: [13]

- Losing heat;" Wet walls transfer heat twice as quickly as dry walls"
- Saving money by reduction of electricity consumption.
- Protecting the buildings from water ingress considering that water ingress results 80% of masonry damages.

There are two types of Nu-Guard “NRG” systems, which are the clear and the color system. This provides the client with more varieties to choose from. It adds an artistic sense to their selection which encourages people to choose them for an environmental approach and an artistic approach. [11]

Therefore, they serve two functions through using "the most technological hybrid chemistry available that can effectively deal with the elements and the disruptive influences of even the harshest climates, creating endless value to those who benefit from the technology"[13]. Both systems are considered "hydrophobic coatings" which maintain self-cleaning mechanism keeping the building clean. This is because it can
take the dirt particles away by water droplets which come from the rain. It has other advantages, such as the following: [11]

- Enhancing thermal properties for 15 years and above-fully function properties
- Reflecting and Insulating heat
- Affecting moisture penetration
- Reducing thermal conductivity of building materials
- Protecting against adverse common defects caused by weathering influences
- Achieving hydrophobic water repellency (self-cleaning properties)
- Maintaining complete breathability of building materials- Water vapor permeability
- Being permanent-UV stability
- Resisting to dirt, pollution and stain
- Reducing efflorescence
- Reducing Sound properties
- Producing chemical and abrasion resistant
- Advancing fire resistance
- Preventing of moss, algae forming upon surface.
- Applying to any mineral based substrate and pre-existing coated surface
- Having flexibility-Available in various colors
3.5 PROTECTIVE COATINGS’ MARKET

There are positive approaches from the market towards better energy saving. For example, there are some material-producing companies that use the same material in their paints. The best outcome is that there are clients going in the direction of energy saving. Though, they are not many, they make the product purchased from its market; so, it can be found when different companies are selling the same coating material, yet with a different brand name. Thermo-Shield is one of these coating materials, which are being used in various companies, such as Jotun and Sika, while they are the same effective material. [10]

Jotun is considered one of the leading companies in building materials in Egypt and abroad, as well. It has various materials and coatings which vary according to the building function and the location. It has a strong online database which can be a good reference for any material a client is searching for. Also, safety data sheets give the reader enough background about the product and its chemical ingredients, especially the projects which have used Jotun products. Other information included is and what are the most suitable materials for your building based on its function and location, as it is mentioned before. Protective coatings take a separate section in the Jotun database for building materials. It is a vast key word, yet the part which is included in this study is protective coatings in the construction industry for exterior walls. The main use of it is to minimize heat temperature from getting inside the building, in order to make the inside stay air ventilated for as long as possible. As a result, electricity consumption will be decreased and electricity consumption will be cheaper, as well. [10]
Jota-shield Thermo is identified in Jotun as a protective coating which is being used specifically in residential buildings/exterior walls to minimize heat gain inside the building. Also, this protective coating has its own primer which is called Jota-shield Thermo Primer. This primer works as a protective layer underneath the Thermo shield paint. It is a good binder between cement and Jota-shield Thermo (final paint layer). The advantage of this primer is to extend the lifetime of Jota-shield Thermo and prevent the paint from cracking throughout the years. The included sheets in the appendix chapter are technical data from Jotun about this Thermo shield protecting coating. [10]

Sika is considered another big company in the Middle East, and it has many branches in Egypt. Many projects are using Sika as a supplier for their building materials. New Capital project is one of these big projects that are dealing with Sika in their building materials. More details will be presented in the new capital chapter in the paper. [16]

FOSROC is another approach, yet wider than Jotun as this company is a foreign company. Middle Eastern projects are using its materials, such as Al Haram Al Makky in Saudi Arabia. It has protective coatings, as well with its technical data sheets for residential buildings. [16]

Dekguard S is a protective coating product for any structure type and it is used for new buildings. In fig. 29, It shows the product which is categorized in FORSOC under protective coatings. It has advantages as protective coatings from different materials: [16]

- Excellent barrier to carbon dioxide, chloride ions, sulphates, oxygen and water.
- Allowance of water vapor to escape from the structure.
• Highly UV-resistant aliphatic acrylic gives exceptional resistance to the effects of long-term weathering.
• Highly durable in all climatic conditions.
• Wide range of decorative colors and excellent resistance to dirt pick-up.

Another marketing tool for protective coatings is a construction management services companies. They offer the most appropriate protective coatings according to the building classification. Greenman Pedersen Inc is a construction management services company which has a specialized technical department for protective coatings. This company plays a role of a consultant in the project management chain, as they are providing the parties with the most suitable protective coatings with a reasonable budget. [8]

3.5.1 GUARANTEE AND STORAGE

As Thermo-Shield is widely spread because of its flexibility. This makes its quality a guarantee for the clients. “Our guarantee and liability are restricted to the quality of our products at the time of acceptance of the customer of such products. In no case shall our liability extend beyond replacement of defective products, if any, found at the time of acceptance. For all deliveries and services, our General Sales Condition including warranties stipulated for each case is valid". Thermo-Shield should be stored in a cool and dry place. Its mortar will be remained utilizable for 9 months from the date of manufacturing. [13]
Fosroc Dekguard S

High performance coating for concrete and masonry

Uses
Dekguard S is designed to provide protection for atmospherically exposed structures against attack due to high moisture levels, acidic gases, sulphates and chloride ions. Typical uses include:
- Bridge abutments
- Concrete cladding and precast units
- Boundary walls
- Plinths and pipe support racks
- Concrete storage tanks
- High rise buildings and villas

Advantages
- High performance - comprehensive barrier against carbon dioxide, water, sulphates and chloride ions.
- Breathable - also allows moisture vapour to escape from the structure.
- Extremely durable - highly resistant to the effects of long term UV weathering.
- Protection in depth - dual action system protects both the surface and the substrate.
- Highly decorative - wide range of colours available, with low dirt pick-up to minimise maintenance costs.

Standards compliance
Fire tested to BS 476, Pt 7. Spread of flame - Class 1.
Fire tested to BS 476, Pt 6. Propagation index I - 1.5. Sub index i - 1.3. Building Regulations rating - Class 0.

Description
Dekguard S is a pure aliphatic acrylic, solvent based protective coating. It is available in a wide range of colours.

The complete system also includes a primer (Dekguard Primer or Dekguard Primer DG) which is supplied as a clear liquid, based on a silane-siloxane dissolved in a penetrating organic carrier. The primer is reactive and capable of producing a chemically-bound hydrophobic barrier, thus inhibiting the passage of water and water-borne contaminants.

The Dekguard S system thus comprises a single component, penetrating silane-siloxane primer and a single component pigmented coating, both ready for immediate site use.

Design criteria
The coating should be applied in two coats to achieve a total dry film thickness of not less than 150 microns. To achieve the desired protective properties, the Dekguard S system must be applied to the substrate at the correct coverage rates.

Figure 29: Dekguard S Protective Coating and its Data Sheet. [16]
NEW EGYPTIAN ADMINISTRATIVE CAPITAL

Although protective coatings are not well known in Egypt, new projects have been started to employ protective coatings for energy savings in their specification. This gives a positive indication for the coming years in Egypt. Especially, Egypt like other countries, has started to suffer from high rates of energy consumption and high living prices. This initiative is likely to be popular at this time in specific, because people will start to look for other alternatives to reduce energy consumption and costs. There are finished projects which have used such coatings, such as Smart Village. They are a complete complex for commercial and educational buildings; it has received the LEED certification for applying Green concept. The second coming complex/district which applies coatings for energy saving is the New Egypt Administrative Capital; this project is located in Fifth Settlement in Cairo. "This new capital city will be a Smart City, and it will embrace an ethos of sustainability born from Egypt’s tradition. The new capital will take advantage of the sustainable technologies of today as well as be adaptable to future technologies, further enhancing its resource-efficiency." [17]

It is an under-construction project which has the merits of sustainability and energy saving concept included in its design concept and project specifications. Fig. 30 shows the location of the project and how it is accessible to the surroundings area. [8]
Functions/spaces inside the complex: [8]

- Residential neighborhoods areas
- The Green River
- Regional investment areas
- Special projects
- Mixed-use areas
- Aero City and International Airport
- Green and open areas
- The city's main roads
New Egypt Administrative Capital will be the future for Egypt; fig. 31 shows its master plan. It is considered a self-sufficient city where all investments, ministries, services and social life are incorporated. Fig. 32 is a 3D simulation of the proposed final product. For the purpose of this research, the scope of the study focuses on the residential part, as shown in fig. 33. The space is designed for luxury social life. It is divided into districts and villas. The first constructed districts in the New Capital are the residential districts. Each district has its own subcontractor taking the responsibility of constructing and finishing the apartments (By Investigator-Site Visit).
Protective coatings are taken into consideration through two approaches. The first one is applying protective coatings in basements and underground structure. The second approach is applying protective coatings on walls and roofs, which is the main scope of this study. Sika is the building materials’ importer to the new capital project. Tests and Data sheets are included in each material which is being used or even taken into consideration. (By investigator, site visit).

Figure 33: Residential Zones in the Capital Cairo. (By Investigator from Site)

Table 11: Contracting Companies for the Residential Sector in the Capital Cairo. (From Site)
Figure 34: Apartments of the Residential Area. (From Site)

Figure 35: On Site when all Blocks are still under Construction. (By Investigator)
Figure 36: Residential Units on Site. (By Investigator)
Fig. 35 and fig. 37 show the group of residential buildings. In this phase of the process, construction is complete, and the finishing phase is in progress. This is illustrated in fig. 36, the finishing materials work, as a sample for the final output. While walking in the site, it is noticeable that the contractors are following the vision of the whole project, which is sustainable environment. For example, hollow blocks concrete is used during the construction process as it reduces the amount of concrete used in the project, as shown in fig. 35. In addition, underground protective coatings are implemented in underground piles and water pipes as illustrated in fig. 38.

Figure 37: Semi-Finished Materials on One of the Residential Units. (By Investigator)
Figure 38: Insulated Pipes in the Site; well coated infrastructure. (By Investigator)

Figure 39: Concrete Hollow Blocks. (By Investigator)
Second Visit (2 months later)

Figure 40.: A Complete Desert in Some Locations in the Site. (By Investigator)

Figure 41: Construction Process has been started and some areas are done. (By Investigator)

Figure 42: Clear Transformation to the Desert in 2 months. (By Investigator)

In the second visit, more units were painted, and by the end of 2017, 2000 units will be finished. As it is illustrated in fig. 40 and fig. 41, it is still a desert area, yet main elements of infrastructure are in its way to be done. This takes the project into a more developed phase, which is clear in fig. 42, how the desert is transforming into an inhabitant. The outside form of the buildings responds to the outside surrounding environment; Shading devices and private units in each block are implemented. Also, the project creates a green court between the units for better air ventilation, as shown in fig. 43 and fig. 44.
Figure 43: Desert Transformation in the Site. (By Investigator)

Figure 44: In between Courts and Green Areas. (By Investigator)
4.1 ECONOMIC ASPECT

The costs of applying these coatings are considered affordable. The advantage of these coatings is to offer reasonable cost recovery period; as durability of the product makes it last more. For the roof coatings, "re-painting for maintenance reasons, then choosing a high quality, low LCA solar reflecting paint is an obvious smart choice especially in sunny, Southern European cities". Also, “Given the overall building stock energy consumption average of some 200 kWh/m2 across Europe (residential and non-residential) and possible heating/cooling cost savings of 40%”. Table 12 illustrates the energy efficiency programs in Egypt as one of the selected countries. [20]

Table 12: Industrial Energy Efficiency Programs in Selected Countries. [20]
Another important point to be taken into consideration is that the financial benefit is not the only actual benefit people get, it is also the increased value of the apartments, durability of the apartment and health of occupants. "The cost / benefit equation of an energy efficiency building refurbishment depends very much on local conditions, which can impact both on the investment required (depending on labor costs, taxes, permits, cost of capital) as well as the incomes / benefits generated (energy savings in terms of KWh per m2/ year, cost of kWh in Euros, energy mix applied (gas, electricity, nuclear, oil or renewable)". All these factors should be counted as advantages for using coating for saving energy. As shown in fig.30a, the economic, social and environmental aspects are a continuous loop which affects each other; the environmental is through minimizing the use of non-renewable energy (fossil fuels) used in the electricity systems. The economics aspect is through minimizing electricity consumption and maintenance. The social is through protecting the community from this pollution, and get used to act Green. [1]

![Figure 45: Three main aspects for Energy Saving Concept. (By Investigator)](image_url)
The material cost is divided into five factors, as shown in fig. 30b. Skilled labor is highly needed in order to do the work right. Moreover, this point is solved because the companies are training the contractor labor on how to implement protective coatings on the building. Logistics is considered the same as any other work. Labor has certain pricing in the market as it is shown in the appendix chapter; some cost analysis for residential blocks in the new Egyptian administrative capital. This is applied also on the time factor; there are certain square meters that should be finished per day. So, the material cost and the cost recovery are the two factors which complete each other. The material cost is more expensive than the usual coatings, yet it is a reasonable price related to the long-term advantages of the material.

- Less Maintenance and more life time
- Less electricity consumption
- Less consumption of fossil fuel (nonrenewable energy)
- Less maintenance cost
The difference between the usual coatings and the protective coatings for each square meter: As referred to in table 11 for a finished seven floors/residential building in the New Egyptian Capital.

4.1.1 LIFECYCLE COST ANALYSIS APPLICATION

This section will introduce the lifecycle cost analysis procedure. The aim behind this analysis is to analyze and calculate the differences in the cost between the conventional paint and “thermo-shield” as a thermal insulation material under the category of protective coatings. This cost analysis is implemented on one of the residential buildings in the New Egyptian Administrative Capital as it is the actual case study of the investigation. The total area of the exterior walls of one floor in a seven-floor building is calculated to get the costs of labor, maintenance, walls per square meters, the initial cost, the running cost and the total lifecycle cost of each of the conventional and thermal material. The value of money is calculated as a consistent factor to the present value of money. In addition, HAP simulation is used in order to get the differences in the energy conservation on the exterior walls based on certain parameters which will be stated later in this section. [24]
Table 13: The Main Factors Affecting Cost Recovery of Protective Coatings and the Conventional Coating for Residential Buildings in 2017 (By Investigator).

<table>
<thead>
<tr>
<th>Main Factors</th>
<th>Conventional Coating</th>
<th>Protective Coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of money</td>
<td>Constant Factor</td>
<td>Constant Factor</td>
</tr>
<tr>
<td>Labor</td>
<td>Fixed Factor</td>
<td>Fixed Factor</td>
</tr>
<tr>
<td>Finishing Time</td>
<td>Fixed Factor</td>
<td>Fixed Factor</td>
</tr>
<tr>
<td>Initial Cost</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>Running Cost</td>
<td>Higher 30%</td>
<td>Less 30%-40%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Each 7-10 year</td>
<td>Each 15-20 year</td>
</tr>
<tr>
<td>Quality</td>
<td>Maintenance each 7-10 year</td>
<td>Maintenance 15-20years</td>
</tr>
<tr>
<td>Price per m²</td>
<td>70-100 LE/ m²</td>
<td>200 LE/ m²</td>
</tr>
<tr>
<td>Energy Conservation</td>
<td>20-30%</td>
<td>Up to 80%</td>
</tr>
</tbody>
</table>

Table 13 illustrates the constant factors and the variables which will be applied in the following lifecycle cost analysis for both of the conventional coating protective coating (thermos-shield). As it is shown in table 15, the total costs of both of the materials are almost similar. The obvious cost difference is the initial cost which makes people avoid using such an approach for energy conservation. This was the same situation of the national precedent, Al wardan when applying the ecological system, and it was implemented through applying energy conservation approaches as elaborated earlier in the paper. Table 14 reflects the guidelines of the ecological system and its wide approaches. This gives a potential for such energy conservation approaches to be implemented more widely in Egypt.
**Lifecycle Analysis Consistent Factors:**

- Software program for 3D model simulation: HAP Inputs
  - Exporting 3D building model with different orientations.
  - Plotting wall cross sections.
  - Using Cairo weather as an input data.
  - Plotting August as the time of the year.
  - Plotting thermal resistance value 0.1016 m²k/W (Referred to in the thermos shield material data sheet).
  - Thermal conductivity value a 0.1055W/ (Referred to in the material data sheet).
  - Plotting human thermal comfort in summer= 78 °F= 25.5 °C, winter= 68 °F=20 °C.
  - U value= 0.4 watt/m2 is recommended for East and West walls.
  - Having fixed ratios between the relation of window to wall.
  - HVAC operating hours through the year = 4000 hours.

**Standard Equations:**

- 1 TON= 12000 BTU/hr. (for block works and hollow block)
  - BTU= British Insulation Unit, the amount of energy required to heat or cool.
  - Total external energy consumption= 25% of the total heat gain of the building.

- $T(^oC) = (T(^oF) - 32) / 1.8$
• U (overall heat transfer) = 1/R total (thermal resistance) W/ m².K
  - R (Insulation)= 2.29 (K. m²/W)
  - R (Concrete)= 0.35 (K. m²/W)
  - R (Outdoor air film) = 0.04 (K. m²/W)

• Thermal Conductivity (k) = Q/T times 1/A times x/T

• Q = U × A × (tb - ti)
  - U = overall heat transfer coefficient of the surface.
  - A = Area of Surface.
  - T = Temperature differences of the surfaces.

• Monthly Electricity Consumption: KW/hr.=0.65 LE.

• Total Cooling Load= total space load components for exterior walls= total space sensible load + total space latent load.

• Total Cost= (total cooling load/number of tons/12000 BTU) × 9000 LE.

Table 14: Design Guidelines for ecological systems. [4]

<table>
<thead>
<tr>
<th>Ecological Items</th>
<th>Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Environmental Quality</td>
<td>Indoor materials</td>
</tr>
<tr>
<td></td>
<td>• Avoid using asbestos, lead, growth of legionella or moulds, and radon</td>
</tr>
<tr>
<td></td>
<td>• Put a plant at home</td>
</tr>
<tr>
<td></td>
<td>• Use sand, lime and mud plaster (mixed with rammed earth)</td>
</tr>
<tr>
<td></td>
<td>• Using water-based eco-paints and varnishes</td>
</tr>
<tr>
<td></td>
<td>• Avoid using wood preservatives</td>
</tr>
<tr>
<td>Thermal comfort</td>
<td>• Temperature (dry bulb): 19-23 degree C</td>
</tr>
<tr>
<td></td>
<td>• Relative Humidity: 40 – 70%</td>
</tr>
<tr>
<td></td>
<td>• Air Speed: 0.1 – 0.3 m/sec</td>
</tr>
<tr>
<td></td>
<td>• Sound: Max. 46 DBA</td>
</tr>
<tr>
<td></td>
<td>• Lighting: Max. 500 lux</td>
</tr>
<tr>
<td>Renewable resources</td>
<td>Solar energy</td>
</tr>
<tr>
<td></td>
<td>Photovoltaic Panels, solar hot water system</td>
</tr>
<tr>
<td>Shelter design</td>
<td>Orientation: East and West walls should decrease North and South walls should increase. Integrated cooling systems: Wind catchers (the Malign). Use white paints on sun exposed surfaces</td>
</tr>
<tr>
<td>Building envelope</td>
<td>• A maximum &quot;U&quot; value of 0.9 watt/m² deg C is recommended for roofs. (HBRC, 2006)</td>
</tr>
<tr>
<td></td>
<td>• A maximum &quot;U&quot; value of 0.4 watt/m² deg C is recommended for East and West walls. (HBRC 2006)</td>
</tr>
<tr>
<td>Home office</td>
<td>• Provide space and services room to be used as a home office</td>
</tr>
<tr>
<td></td>
<td>• A telephone line as well as a connection to the internet for data transfer</td>
</tr>
</tbody>
</table>
Table 15: A Cost Analysis Study of a Seven Floor Residential Building in the New Egyptian Capital.

<table>
<thead>
<tr>
<th>Input</th>
<th>Conventional Paint</th>
<th>Protective Coating</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Cost</td>
<td>100.00 LE/m²</td>
<td>200.00 LE/m²</td>
<td></td>
</tr>
<tr>
<td><strong>Labor</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor</td>
<td>6,000.00 LE/Month</td>
<td>6,000.00 LE/Month</td>
<td>Fixed factor</td>
</tr>
<tr>
<td>1 Labor per day</td>
<td>200.00 LE / day</td>
<td>200.00 LE / day</td>
<td>6,000 LE/m² Monthly salary</td>
</tr>
<tr>
<td>Number of labor</td>
<td>5.00 workers</td>
<td>5.00 workers</td>
<td></td>
</tr>
<tr>
<td>Total labor per day</td>
<td>1,000.00 LE / day</td>
<td>1,000.00 LE / day</td>
<td></td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td>100.00 m²/day</td>
<td>100.00 m²/day</td>
<td>100-120 Range</td>
</tr>
<tr>
<td><strong>Labor per m²</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Bucket of coating</td>
<td>5,000.00 LE / Bucket</td>
<td>10,000.00 LE / Bucket</td>
<td></td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total material per m²</td>
<td>50.00 LE/m²</td>
<td>50.00 m²</td>
<td></td>
</tr>
<tr>
<td>Total cost per m²</td>
<td>100.00 LE/m³</td>
<td>100.00 LE/m³</td>
<td>Labor + Material cost</td>
</tr>
<tr>
<td>External finishing per floor</td>
<td>110.00 LE/m³</td>
<td>210.00 LE/m³</td>
<td></td>
</tr>
<tr>
<td>Number of floors</td>
<td>675.00 m²</td>
<td>675.00 m²</td>
<td></td>
</tr>
<tr>
<td><strong>Total External Finishing</strong></td>
<td>4,725.00 LE / m²</td>
<td>4,725.00 m²</td>
<td>Total Finishing for the whole residential building</td>
</tr>
<tr>
<td><strong>Total Initial Cost/ per floor</strong></td>
<td>74,250.00 LE/m²</td>
<td>141,750.00 LE/m²</td>
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<tr>
<td><strong>Total Initial Cost</strong></td>
<td>519,750.00 LE/m²</td>
<td>992,250.00 LE/m²</td>
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</tr>
<tr>
<td><strong>Maintenance Cost</strong></td>
<td>3,742,200.00 LE/50 year</td>
<td>4,762,800.00 LE/50 year</td>
<td></td>
</tr>
<tr>
<td>Cost of maintenance</td>
<td>623,700.00 LE</td>
<td>1,190,700.00 LE</td>
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<tr>
<td>Maintenance cycles</td>
<td>7 years</td>
<td>15 years</td>
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</tr>
<tr>
<td>Lifetime under study</td>
<td>50 years</td>
<td>50 years</td>
<td></td>
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<tr>
<td>Number of maintenance times</td>
<td>7.14287143 times</td>
<td>3.333333333 times</td>
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</tr>
<tr>
<td><strong>Total maintenance cost/floor</strong></td>
<td>636,428.57 LE</td>
<td>567,000.00 LE</td>
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</tr>
<tr>
<td><strong>Total maintenance cost</strong></td>
<td>4,455,000.00 LE</td>
<td>3,969,000.00 LE</td>
<td></td>
</tr>
</tbody>
</table>

**Operational Cost**

| Total Cooling Load (Q)               | 432,000.00 BTU/hr  | 378,000.00 BTU/hr  | 1) Total area of the exterior walls for one floor= 675 m²= 36 tons/4 units per floor= 9 tons per one single unit. |
| Total Cost /floor                    | (324,000.00) LE    | 283,500.00 LE     | 2) 25% of 36 tons= exterior walls energy consumption= 9 tons= 4.5 ton (50% saving) |
| U factor                             | 0.204              | 0.0408            | 3) 1 ton= 9000 LE= 12000 BTU (block work-hollow block) |
| External Energy Saved                | 0 BTU/floor        | 54000 BTU/floor   | 4) Q = U × A × (tb - ti) |
| **Total Running Cost**               | 131,040.00 LE      | 114,660.00 LE     | 5) KW/hr= 0.65 LE |
| **Total Life Cycle Cost/per floor**  | 1,273,718.57 LE    | 1,201,410.00 LE   |                              |
| **Total Life Cycle Cost (7 floors)** | 8,916,030.00 LE    | 8,409,870.00 LE   |                              |

**Note:**
- This residential building is taken from an actual exterior walls' floor area in the New Egyptian Administrative Capital.
- Total external energy consumption= 25% of the total heat gain of the building.
- The External Energy Saved = 54000 BTU/floor= 4.5 ton----> 50% saving
Figure 47: Money Value Affecting the cost feasibility of Normal Paints and Protective Coatings. (By Investigator)

Figure 48: Running Cost Vs Initial cost for each of Normal Paints and Protective Coatings. (By Investigator)
In the previous figures and tables, there is a clear difference in the costs between normal paints and protective coatings. The two main obvious factors are the running costs and the initial costs as shown in fig. 48. The initial cost of the normal paint is less than the protective coatings by 50%, as shown in the life cycle analysis in table 15. However, the running cost which is more demanding than the initial cost, is much cheaper in protective coatings, as shown in table 16. This is because the maintenance life cycle of protective coatings ranges from 10-12 years; while normal paints is between 4-5 years. This concludes that quality and monetary value of protective coatings achieve the concept of energy conservation in the construction industry; as shown in fig. 47 and 49. Table 16 and table 17 are an actual residential building cost analysis in the New Egyptian Administrative Capital.
Table 16: Total Finishing Costs in A Residential Building Located in The New Egyptian Capital According to the Total Area Per Meter Square.

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<td>٥٤٤٣,٢٠٠</td>
<td>جمالي أعمال الفرشاة العليا والسلكمة</td>
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<tr>
<td>٣</td>
<td>٢٢٧,٠٠٠</td>
<td>جمالي أعمال الديكأت الفعلية</td>
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<tr>
<td>٤</td>
<td>١,٢٤٩,٥٠٠</td>
<td>جمالي أعمال المباني</td>
</tr>
<tr>
<td>٥</td>
<td>١,١١٤,٣٠٠</td>
<td>جمالي أعمال الرياض</td>
</tr>
<tr>
<td>٦</td>
<td>٨٤٩,٣٠٠</td>
<td>جمالي أعمال الأضواء والدرج</td>
</tr>
<tr>
<td>٧</td>
<td>٩٩٩,٨٠٠</td>
<td>جمالي أعمال الأشراف</td>
</tr>
<tr>
<td>٨</td>
<td>٨٨٥,٠٠٠</td>
<td>جمالي أعمال الدهليز</td>
</tr>
<tr>
<td>٩</td>
<td>٥٥١,٠٠٠</td>
<td>جمالي أعمال الأدوبيوم والرجال</td>
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<tr>
<td>١٠</td>
<td>٣٢٧,٢٠٠</td>
<td>جمالي أعمال التجارة</td>
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<td>٢٨٤,٧٠٠</td>
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<td>٢١٤,٤٨٠</td>
<td>جمالي أعمال المكتبة</td>
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<td>١٠٦٢,٣٠٠</td>
<td>جمالي أعمال الأثاث</td>
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<tr>
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<td>٩٩٩,٥٠٠</td>
<td>جمالي أعمال الملمع</td>
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<tr>
<td>١٥</td>
<td>١٥٢,٤٣٠</td>
<td>جمالي أعمال الديكأت</td>
</tr>
<tr>
<td>١٦</td>
<td>١٢,٥٨٢,٤٣٤</td>
<td>جمالي أعمال الديكأت</td>
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</tbody>
</table>

مساحة المبنى (٢٥٠م٢) = ٨٢٥,٠٠٠ جنية (٢٥٠م  ارضي - خمسة ادوار علوية)

قيمة المتر المسطح = ٧٧٤.٣ جنية / م  
قيمة المتر المسطح محصل عليه البتروم = ٣٧٢.٠ جنية / م
Table 17: Insulation Finishing Materials Along the Residential Unit.

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<tr>
<th>الوحدة</th>
<th>الكلمة</th>
<th>B6 الإجمالي</th>
<th>اللقاح السطحي A</th>
<th>الإصلاحات الإضافية</th>
<th>B6 الإجمالي</th>
<th>اللقاح السطحي A</th>
<th>الإصلاحات الإضافية</th>
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<tr>
<td>3</td>
<td>أعمال الطبقات العازلة</td>
<td>34.000</td>
<td>34.000</td>
<td>34.000</td>
<td>34.000</td>
<td>34.000</td>
<td>34.000</td>
</tr>
<tr>
<td>2.3</td>
<td>إلزامي السطحي</td>
<td>2.300</td>
<td>2.300</td>
<td>2.300</td>
<td>2.300</td>
<td>2.300</td>
<td>2.300</td>
</tr>
<tr>
<td>2.4</td>
<td>باركة المزيد</td>
<td>2.400</td>
<td>2.400</td>
<td>2.400</td>
<td>2.400</td>
<td>2.400</td>
<td>2.400</td>
</tr>
<tr>
<td>5</td>
<td>الدوافق المصلحة السطحية</td>
<td>5.000</td>
<td>5.000</td>
<td>5.000</td>
<td>5.000</td>
<td>5.000</td>
<td>5.000</td>
</tr>
</tbody>
</table>
CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Based on the literature review, site visits, and analysis, this chapter provides a summary of key findings of the study with key conclusions addressed as well as recommendations for future work and considerations by the construction industry.

1- Energy consumption rates are increasing due to misuse of energy resources, which has led to a depletion of nonrenewable energy; fossil fuel consumed 78.4% of the total world energy consumption in 2013.

2- According to the Indian Forum study in 2012, Air conditioning systems counted for 57% of the overall consumption of energy in buildings, and the residential building sector represented 34% of the final electricity consumption.

3- The residential and commercial sectors are responsible for more than 50% of the final energy consumption in Egypt as it faces an electricity shortage because of the high-energy consumption.

4- Green house structure is one of the techniques that address insulation materials as a category of the building envelope in energy efficiency, which has its own specifications for energy conservation in buildings.

5- Effective protective coatings should be considered as the buildings’ external wall paint acting as a building envelope; it is one of the smart methodologies for energy conservation. Many people are not well aware of its advantages and long-term merits.
6- These protective coatings can last up to 20 years and have various colors, which gives the product flexibility in its usage.

7- According to CEPT university in India, after applying insulation materials, reduction in heat through roof was achieved by 90% and through walls by 70%.

8- Thermo-Shield and Nu-Guard NRG Energy are categorized as efficient Protective Coating Systems. There are two types of Nu-Guard “NRG” systems, which are the clear and the color system. This concept provides the client with more varieties to choose from. It adds an artistic sense to their selection which encourages people to choose them for an environmental approach and an artistic approach.

9- Nu-Guard systems are being used for the exterior and interior walls as a protective coating. They are being tested based on their usage both inside and outside. Also, they are mainly designed to reduce electricity consumption. This system is applied on the residential, commercial and industrial buildings.

10- “Thermo-shield” is considered heat insulated mortar with high quality; it is designed for interior and exterior solutions, reducing heat transfer up to 80%, so, it maintains cooler temperature for the units. Thermo- shield has its own thermo-shield binder which enhances the energy conservation efficiency outside the building.

11- Protective coatings data sheets show how these coatings can save up to 80% of energy consumption. (these data sheets are referred to in the Appendix chapter in this paper).
12- Product initial cost is a crucial factor for clients; however, its cost recovery can act as an incentive for the sake of durability, flexibility, less electricity consumption and less maintenance. Thermo-shield is considered a new product which is available on a limited scale in the market; that’s why it is expensive as any new product in the beginning, and the price will go down by time. This was similar to Al Wardan Institute precedent in Egypt which the initial cost acted as a limitation, yet the approach of energy conservation got implemented in the institute, and the amount of energy saved was more than 40% of the conventional approach.

13- The simplified lifecycle cost analysis which was conducted in this paper elaborates the feasibility of using thermo-shield as a thermal insulation material and its value-added money.

14- Based on site visits, the New Egyptian Administrative Capital is the second mega project in Egypt after the Smart Village, with energy conservation as a vision from its beginning.

15- The New Egyptian Administrative Capital mega project is targeting energy conservation concept through construction and architecture approaches. Thermal insulation materials are one of the initial approaches which are implemented in their projects.

16- More than 2000 residential buildings are completed in the New Egyptian Administrative Capital using conventional materials on the exterior walls. A case study of a residential building in the new capital is being conducted in the paper.

17- Based on the cost analysis and the suppliers’ bidding of the materials in the residential zones, the New Egyptian Administrative Capital is effectively
seeking efficient materials according to their building classifications with a consideration of the proposed specifications and costs. (costs and data sheets provided in the appendix chapter).

18- These initiatives pave a potential for implementing protective coatings, such as thermo-shield in the New Egyptian Administrative Capital. There are some limitations which make the new capital not seeking more efficient approaches towards energy conservation. Lack of awareness and high initial cost are the two main reasons which limit implementing more effective approaches. This can be done through the following:

- A coordination between the construction industry, the chemistry industry and the government should be achieved.
- Lifecycle cost analyses for protective coatings and their cost recovery vs electricity consumption should be conducted.
- Thermo-Shield is considered one of the most appropriate protective coatings to be implemented in the New Egyptian Administrative Capital, as they fit with the buildings classification of the residential and commercial functions inside the complex.
- Technical data sheets from the chemistry industry should be conducted for efficiency and documentations.
- Project monitoring is needed to ensure that the project achieves the expected environmental benefits and monitor the project progress throughout its phases.
- This will make the New Egyptian Administrative Capital is the pioneer in applying protective coatings in Egypt seeking energy conservation and raising the awareness towards energy conservation.
• Having a new construction service in the construction industry which are specialized in implementing protective coatings can increase the demands to apply energy conservation and enhance its market in Egypt.

5.2 RECOMMENDATIONS FOR FUTURE WORK

1- More available data sheets about the chemical ingredients of different types of protective coatings should be widely available for a public access in order to have a wider market for these coatings.

2- Additional testing on protective coatings’ materials in real buildings and calculating the amount of energy conservation should be encouraged in Egypt.

3- Durability tests of protective coatings are needed for clients to have more trust towards the product.

4- Although protective coatings are efficiently successful within the materials’ market and the construction industry, there is no publicity or talk about it like the other insulation materials, such as fibers and thermal panels.

5- There should be a detailed cost analysis in order to reflect the efficiency level of such products according to its costs.

6- Most of the provided national precedents are tackling the concept of sustainability and thermal insulation materials; however, protective coatings are still unpopular in the construction and architecture industry.

5.3 RECOMMENDATIONS FOR THE CONSTRUCTION INDUSTRY

1- Raising the awareness about energy conservation through seeking Green approaches and highlighting their impacts.

2- Keeping updated with the approaches of Green concept and sustainability, not just following the usual known materials is needed in Egypt.
3- Sitting a minimum rate of energy conservation for buildings in the construction industry based on a Green concept, especially as non-renewable energy sources are depleting.

4- Promoting options for customers seeking these contributions between the government and the construction industry in Egypt.

5- Using cost recovery as an attractive marketing tool for energy conservation users, such as less electricity consumption and less maintenance.

6- Pursuing fossil fuels usage minimization; Construction industry is a high rate energy consumption sector. Protective coatings are a smart alternative rather than high nonrenewable energy consumption.

What will make people have the motive for energy saving approaches?

- Less Electricity consumption
- Product Durability
- Less maintenance
- Government Regulations

7- Having companies that can offer consultant services in protective coatings in Egypt can encourage the industry to choose the most appropriate protective coatings based on the building classification and the project scale; Greenman-Pedersen Inc (GPI) is an example of a construction company located in New York.
8- While the savings between the conventional and thermos shield coating in the lifecycle cost analysis are not initially very high, yet it is very promising depending on two main factors:

- Initial costs of new products expected to go
- Fossil fuel prices is expected to be high because of its high demand in the market and being a non-renewable energy source.

9- It will be a positive initiative if people are willing to use these kinds of coatings. We are dealing with two main sectors. The first initiative comes from the government by sitting regulations for both of the contractors and the residents to use certain coatings for saving energy. For the contractor, this will have a strong impact if the contractors are abiding by regulations to select appropriate coatings in their projects' specifications. For the owner (residents), lowering electricity consumption will be a strong incentive encourage them applying such a smart technology.
WORKS CITED


Information can be found in: http://www.ecbcs.org/docs/Annex_39_Report_Subtask-B.pdf
APPENDIX

APPENDIX A

These documents are related to the specifications and the cost analysis of the new Egyptian administrative capital. Also, these have documents related to the data sheets and safety sheets of the protective coatings from subcontractors, and how it saves a reasonable amount of energy. These papers are all being referred to in the paper.

In section A, these documents are the cost analysis of one of the finished residential buildings (one block). It illustrates the pricing of coatings’ work by meter per day. It gives an estimate price for the following:

- Paintings’ work
- Flooring
- Coatings
- Concrete blocks
- Labor
- Insulation
- Contractors for each sector (steel, paint, flooring, etc.)
- Each single construction work in the residential block.
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<td></td>
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**بيان الأعمال**

- المتر المسطح - توريود وصل دهان أكريليك مست داخلي للأسطح والمواد البلاستيكية. وهو جارح عن عروض تحديدي ووجوه محملة. من سطر إنتاج الشركة المدولة للدهانات والملعقات. يتوافق أوجه والملعقات. يتوافق أوجه والملعقات. يتوافق أوجه والملعقات.
- بالمشحذة المسطح - توريود وصل دهان أكريليك مست داخلي للأسطح والمواد البلاستيكية. وهو جارح عن عروض تحديدي ووجوه محملة. من سطر إنتاج الشركة المدولة للدهانات والملعقات. يتوافق أوجه والملعقات. يتوافق أوجه والملعقات. يتوافق أوجه والملعقات.

**الいただきました**

- المتر المسطح - توريود وصل دهان أكريليك مست داخلي للأسطح والمواد البلاستيكية. وهو جارح عن عروض تحديدي ووجوه محملة. من سطر إنتاج الشركة المدولة للدهانات والملعقات. يتوافق أوجه والملعقات. يتوافق أوجه والملعقات. يتوافق أوجه والملعقات.

*لا يوجد معلومات إضافية.*
APPENDIX B: PROTECTIVE COATINGS DATA SHEETS

Technical Data
JOTASHIELD THERMO

Product description
Jotashield Thermo is a medium texture flexible thermal insulation coating based on a high quality 100% pure acrylic water based binder and special glass spheres.

Recommended use
Specially recommended for exterior use on all types of cement plaster and concrete surfaces. The product has excellent weather and water resistance. Jotashield Thermo provides an attractive texture that will hide and cover minor imperfections in the surface when applied with a sponge roller or Trowel. The product has been independently tested at the Dubai Municipality central lab, the Thermal resistance value obtained is 0.1016 m2k/W and the Thermal conductivity value a 0.1055W/mk. Jotashield Thermo is classified as a suitable concrete protection system with Thermal insulation properties.

Film thickness and spreading rate

<table>
<thead>
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<th>Minimum</th>
<th>Maximum</th>
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<tr>
<td>150</td>
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<tr>
<td>330</td>
<td>2400</td>
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Theoretical spreading rate (m²/l)

<table>
<thead>
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<tr>
<td>3.3</td>
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</tbody>
</table>

Comments:
Film thickness will vary and are calculated as an average. Spreading rates depend on type of texture, surface porosity, imperfection

Physical properties
Colour
White and a selection of colours as shown in the Jotashield Thermo Brochure

Solids (vol %)*
50 ± 2

Gloss
Semi-gloss

Water Resistance
Very good

Flexibility
Very good

Surface preparation
The Substrate must be sound, clean and dry, free from dust, oil, grease, laitance etc. all traces of release agents must be removed. On chalky and dusty surface, all loose material must be removed by stiff bristle brushing.

Condition during application
Apply at a temperature between 10°C and 35°C. The temperature of the substrate should be min. 3°C above the dew point of the air, temperature and relative humidity measured in the vicinity of the substrate.

Application methods

<table>
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<td>Airless or conventional spray</td>
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<tr>
<td>Brush</td>
<td>Recommended</td>
</tr>
<tr>
<td>Roller</td>
<td>Recommended</td>
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<tr>
<td>Other</td>
<td>Trowel, see application procedure</td>
</tr>
</tbody>
</table>

JOTASHIELD THERMO
Page 1
Application data

Mixing ratio (volume)  Single pack.
Thinner/Cleaner       Water
Guiding data airless spray  20 mpa (200 kg/cm² 2800 psi)
Pressure at nozzle   (0.021" - 0.031") (0.53mm - 0.79mm)
Nozzle tip           45° - 80°
Filter              Check to ensure that filters are clean.

Drying time

Drying times are generally related to air circulation, temperature, film thickness and number of coats, and will be affected correspondingly. The figures given in the table are typical with:
- Good ventilation (Outdoor exposure or free circulation of air)
- Typical film thickness
- One coat on top of inert substrate
- Relative humidity 70%

<table>
<thead>
<tr>
<th>Substrate temperature</th>
<th>10°C</th>
<th>23°C</th>
<th>40°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface dry</td>
<td>120 min</td>
<td>60 min</td>
<td>45 min</td>
</tr>
<tr>
<td>Through dry</td>
<td>48 h</td>
<td>24 h</td>
<td>12 h</td>
</tr>
<tr>
<td>Dry to recoat, minimum</td>
<td>10 h</td>
<td>5 h</td>
<td>3 h</td>
</tr>
</tbody>
</table>

1. Recommended data given for recoating with the same generic type of paint.
2. In case of multi-coat application, drying times will be influenced by the number and sequence and by the total thickness of previous coats applied – reference is made to the corresponding system data sheet.
3. The surface should be dry and free from any contamination prior to application of the subsequent coat.

The given data must be considered as guidelines only. The actual drying times/before recoating may be shorter or longer, depending on film thickness, ventilation, humidity, underlying paint system, requirement for early handling and mechanical strength etc. A complete system can be described on a system sheet, where all parameters and special conditions could be included.

Typical paint system

On porous and chalky surfaces:
- Penetrating Sealer
- Jotashield Thermo Primer
- Jotashield Thermo

1 Coat
2 Coats.

On new surfaces and old, sound paint surfaces:
- Jotashield Thermo Primer
- Jotashield Thermo

2 Coats
2 Coats

On new concrete, as a concrete protection system:
- Jotashield Thermo Primer
- Jotashield Thermo

1 Coat
2 Coats
(undiluted)

If any imperfections exist on the substrate, use Jotashield filler to level the surface.

Other systems may be specified, depending on the area of use.

Storage

The product must be stored in accordance with national regulations. The product must be kept in a cool and well-ventilated place, protected from heat and direct sunlight. Containers must be kept tightly closed.

JOTASHIELD THERMO
Page 2
Test Certificates

Determination of Crack Bridging Ability: Performed by Taywood Engineering UK. (Under Test)

Determination of Carbon Dioxide Diffusion Resistance: Performed by Taywood Engineering UK. (Under Test)

Determination of Moisture Vapour Transmission Rate: Performed by Taywood Engineering UK. (Under Test)

Determination of Liquid Water transmission rate: Performed by Taywood Engineering UK. (Under Test)

Determination of Chloride Ion Diffusion Resistance: Performed by Taywood Engineering UK. (Under Test)

Handling
Handle with care. Stir well before use.

Packing size
1 US gal and 5 US gal.
Packing may vary from country to country according to local requirements.

Health and safety
Please observe the precautionary notices displayed on the container. Use under well ventilated conditions. Do not breathe or inhale mist. Avoid skin contact. Spillage on the skin should immediately be removed with suitable cleanser, soap and water. Eyes should be well flushed with water and medical attention sought immediately.

For detailed information on the health and safety hazards and precautions for use of this product, we refer to the Material Safety Data Sheet.

DISCLAIMER

The information in this data sheet is given to the best of our knowledge based on laboratory testing and practical experience. However, as the product is often used under conditions beyond our control, we cannot guarantee anything but the quality of the product itself. We reserve the right to change the given data without notice.

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ISSUED MARCH 2005 BY JOTUN SAUDIA CO. LTD.
THIS DATA SHEET SUPERSEDES THOSE PREVIOUSLY ISSUED

JOTASHIELD THERMO
Page 3
## SECTION 1: Identification of the substance/mixture and of the company/undertaking

### 1.1 Product identifier
- **Product name**: Jotashield Thermo
- **Product code**: 4263
- **Product description**: This product is a superior quality, flexible, exterior, water based textured paint based on pure acrylic emulsion with special glass spheres.
- **Product type**: Liquid.
- **Other means of identification**: Not available.

### 1.2 Relevant identified uses of the substance or mixture and uses advised against

<table>
<thead>
<tr>
<th>Identified use</th>
<th>Use in Coatings - Consumer use</th>
<th>Apply this product only as specified on the label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use in Coatings - Industrial use</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 1.3 Details of the supplier of the safety data sheet
- **Jotun UAE Ltd. L.L.C.**
  - P.O.Box 3671, Dubai, U.A.E.
  - Tel: 009714 3302600
  - Fax: 009714 3308888
- **Jotun Abu Dhabi L.L.C.**
  - P.O.Box 3714
  - Abu Dhabi, U.A.E.
  - Tel: 00971 2 5510000
  - Fax: 00971 2 510232
- **SDS.Jotun@jotun.com**

### 1.4 Emergency telephone number
- **SHE Dept., Jotun AS, Norway**
  - +47 32 45 70 00

## SECTION 2: Hazards identification

### 2.1 Classification of the substance or mixture
- **Product definition**: Mixture
- **Classification according to Regulation (EC) No. 1272/2008 [CLP/GHS]**
  - Skin Sens. 1, H317
- **Classification according to Directive 1999/45/EC [DPC]**
  - The product is classified as dangerous according to Directive 1000/45/EC and its amendments.
- **Classification**: R43
- **Human health hazards**: May cause sensitization by skin contact
  - See Section 16 for the full text of the R-phrases or H-statements declared above.
  - See Section 11 for more detailed information on health effects and symptoms.

### 2.2 Label elements
- **Date of issue**: 09.05.2014
  - 1/12
Technical Data
Jotashield Thermo Primer

Product description
Jotashield Thermo Primer is a solvent based acrylic copolymer primer with excellent penetrating properties and water repellency effect. It forms a film with superior alkaline resistance.

Recommended use
As a primer or a sealer on exterior surfaces such as cement plasters, concrete, GRC and brickwork etc. specifically for use in combination with the Jotashield product range, ideally with Jotashield Thermo.

Film thickness and spreading rate

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film thickness, dry (μm)</td>
<td>30</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>Film thickness, wet (μm)</td>
<td>00</td>
<td>120</td>
<td>155</td>
</tr>
<tr>
<td>Theoretical spreading rate (m²/l)</td>
<td>11.3</td>
<td>8.6</td>
<td>9.71</td>
</tr>
</tbody>
</table>

Physical properties

- Colour: White
- Solids (vol.%): 34 ± 2
- Flash point: 40° ± 2 (Setaflash)

*Measured according to ISO 3233:1998 (E)

Surface preparation
The substrate must be sound, clean, dry, free from dust, oil, grease and laitance etc. All traces of release agents must be removed. On chalky and dusty surfaces, all loose material must be removed by stiff bristle brushing.

Other surfaces
The coating may be used on other substrates. Please contact your local Jotun office for more information.

Condition during application
Apply at a temperature between 10°C and 35°C. The temperature of the substrate should be minimum 3°C above the dew point of the air. The temperature and the relative humidity should be measured in the vicinity of the substrate.

Application methods

- Spray: Use airless spray or conventional spray
- Brush: Recommended
- Roller: Recommended
ROHMHAAS

PRIMAL™ AC-261P
100% Acrylic emulsion polymer for interior / exterior quality paints

Description

Rohm and Haas PRIMAL™ AC-261P acrylic emulsion is manufactured without added formaldehyde or formaldehyde generators. It is based on Rohm and Haas Company’s widely successful full-acrylic platform PRIMAL™ AC-261. Like its predecessor, PRIMAL™ AC-261P acrylic emulsion is noted for its good abrasion resistance, excellent resistance to ultraviolet radiation, excellent adhesion to masonry, wood, metal and old paint surfaces, very good alkaline resistance and great versatility in formulating.

PRIMAL™ AC-261P acrylic emulsion is low foaming and quickly develops hardness and adhesion properties.

PRIMAL™ AC-261P can be formulated into paints into different gloss/sheen levels: it is especially suitable for sheen and flat offering a good balance of DPV and durability. With its lower pH, paint manufacturers can also formulate it into paints with lower ammonia odor.

In addition, excellent coatings for floors, cement roof tiles, and tennis courts can be formulated with this product. Because of its versatility, it is possible for paint manufacturers to consolidate their inventory by utilizing PRIMAL™ AC-261P acrylic emulsion as their general purpose binder.

<table>
<thead>
<tr>
<th>Key Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% acrylic composition.</td>
<td>Excellent long term durability, excellent water resistance, excellent resistance to hydrolysis on masonry.</td>
</tr>
<tr>
<td>Excellent scrub resistance.</td>
<td>Paint films can withstand wear and tear and cleaning very well.</td>
</tr>
<tr>
<td>Excellent wet and dry adhesion to aged alkyl paints, masonry, wood and metal substrates. Compatible with a wide variety of pigments and extenders.</td>
<td>Excellent performance over a range of surfaces.</td>
</tr>
<tr>
<td>Small particle size.</td>
<td>Excellent paint formulation cost/property balance.</td>
</tr>
<tr>
<td>APEO free and no added formaldehyde or formaldehyde generators.</td>
<td>Excellent response to rheology modifiers.</td>
</tr>
<tr>
<td>Low ammonia level</td>
<td>Ability to formulate environmentally friendly paints</td>
</tr>
</tbody>
</table>

Typical Properties

These properties are typical but do not constitute specifications.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Milky white emulsion</td>
</tr>
<tr>
<td>Solids, by weight, %</td>
<td>50.0</td>
</tr>
<tr>
<td>Density (g/ml), wet</td>
<td>1.04</td>
</tr>
<tr>
<td>pH</td>
<td>0.8</td>
</tr>
<tr>
<td>Minimum film formation temperature, (°C)</td>
<td>18</td>
</tr>
<tr>
<td>Glass transition temperature, Tg (°C)</td>
<td>24</td>
</tr>
<tr>
<td>Viscosity (Brookfield LV #2, 60rpm), cps</td>
<td>≤ 300</td>
</tr>
<tr>
<td>Stabilization</td>
<td>Anionic</td>
</tr>
<tr>
<td>Storage precautions</td>
<td>Protect from freezing</td>
</tr>
</tbody>
</table>

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March, 2009
APPENDIX C: OTHERS

This is insulation and proofing work in the New Egyptian Capital. It is like a tender between two agencies for buying an efficient proofing material with a reasonable price. It reflects the concept of the New Egyptian Capital, which is about energy conservation and smart cities.
Technical Data

**Density**
Comp. (A+B) = 2.0 kg/l

**Chemical base**
Cement, selected graded aggregates and polymer dispersion

**Substrate Temperature**
+5°C minimum / +40°C maximum

**Compressive Strength**
After 28 days, 30-65 N/mm²
- Note: compressive strength based on mortar consistency 1:4.5 by weight.

**Flexural Strength**
After 28 days, 8-10 N/mm²
- All results based on mortar test, lab condition to 16°C.

**Bond Strength**
After 28 days, 7-8 N/mm²
- (ASTM-C-1042-89)

**Application Details**

**Mixing Ratio**
- Skim (Comp. (A) : Comp. (B) = 1 : 4 by weight.
- Mortar (Comp. (A) : Comp. (B) = 1 : 4.5 by weight.

**Coverage**
Approx. 2 to 2.5 litres² for two coats application depending on the surface and consistency required.

**Surface Preparation**
Concrete surfaces must be mechanically cleaned, free from all grease and loosely adhering particles. On "new" or smooth faced concrete, surfaces should be sand treated to provide an "Owen Pont Surface" to enhance the effectiveness of the crystallization process.
Non-sand blasted surfaces will affect the performance of the crystallization process and the bond of the cementitious skim.
All surfaces must be as true and flat as possible. Saturation absorbent concrete surfaces thoroughly with water to achieve a surface saturated dry (SSD) condition.

**Application**
Mixing
- Place three quarters (3/4) of component (A) (liquid) in a suitable mixing container.
- Add component (B) (powder) to the liquid while mixing.
- Mechanical mixer must be used to ensure proper dispersion of component (B).
After the entire component (B) has been added mix for an additional three minutes.
- The remaining one quarter (1/4) of component (A) is added during the addition of the component (B) to achieve the desired consistency.

Application
- While the substrate is still in a SSD condition, apply the first coat and leave to harden (4-6 hours).
- Apply the second coat as soon as possible, after hardening of the first coat, to ensure proper adhesion between layers.
- For skim consistency apply with a hard-bristled brush or broom. For the troubleable mortar use a notched trowel.
- After application of the second coat, clean Silica Sate®-105 by rubbing down with a soft dry sponge.
- In case of a third coat, scratch the surface of the second coat with the edge of the trowel to provide a mechanical key.
- In case of needed plaster layer over Silica Sate®-105, broadcasting is recommended to apply a bonding agent.

**Cleaning**
Clean all tools and equipment with clean water immediately after use.
Hardened material can only be removed mechanically.

**Waiting Time / Over-coating**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Waiting Time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+10°C</td>
<td>12</td>
</tr>
<tr>
<td>+20°C</td>
<td>8</td>
</tr>
<tr>
<td>+30°C</td>
<td>6</td>
</tr>
</tbody>
</table>

If waiting time exceed 24 hours, lightly brush down the surface.
Silica Sate®-105 can be over-coated using solvent based primers or coatings.
Silica Sate®-105 must cure for a minimum of 7 days before over-coating.
Sika Seal®-105
Multi-Purpose Water Proofing Slurry

Product
Description
A cement base, polymer modified, 2 component, multi-purpose water proofing slurry. Sika Seal®-105 resembles the crystallization action (pure block) and the water proofing capability of polymer.
It consists of special fillers, cement and properly graded aggregate.

Base
Sika Seal®-105 is used as an economical and easy to apply water proofing slurry, for both external and internal applications in generally wet areas.
Sika Seal®-105 is suitable for the following applications:
- Water management works, sewage treatment plants (such as tanks, digesters, clarifiers, etc...).
- Basement/lift pits.
- Retaining wall/foundation structures.
- Sew wall/irrigation channels.
- Swimming pools.
- Basements, kitchens and bathrooms.

Advantages
Sika Seal®-105 is part of a complete Sika® system for the economical waterproofing of water containment structures.
Sika Seal®-105 offers the following advantages:
- Two-component (no water needed).
- Multi-purpose water proofing, crystallization and polymer modified cementitious slurry.
- Impermeable
- Brush or trowel applied.
- Good adhesion to soiled surfaces.
- Produced under the exacting standards of Sika®

Approvals / Tests
For direct contact with drinking and sewage waters, issued by the Egyptian National Organization for Water and Sewage.
Sika Seal®-105 has been tested as per SCAQMO Rule 1188.
Result: VOC Content < 5 g/L.

Product Data
Form
Comp. (A): Liquid
Comp. (B): Powder

Colour
Comp. A: White & Comp. B: Grey
Colour of mix is light blue
White colour available upon request.

Packaging
25 kg units (A+B).

Storage Conditions
Store in dry conditions, protected from moisture and frost.

Shelf Life
12 months from date of production if stored properly in undamaged and unopened original sealed packaging.
Legal notes

The information, and in particular, the recommendations relating to the application and end-use of Sika products, are given in good faith based on Sika’s current knowledge and experience of the products when properly stored, handled and applied under normal conditions in accordance with Sika’s recommendations. In practice, the differences in materials, substrates and actual site conditions are such that no warranty is expressed of workability or of fitness for a particular purpose, nor any liability arising out of any legal relationship whatsoever, can be inferred either from this literature, or from any written recommendations, or from any other advice offered. The user of the product must test the products suitability for the intended application and purpose. Sika reserves the right to change the properties of its products. The proprietary rights of third parties must be observed. All prices are accepted subject to our current terms of sale and delivery. Users must refer to the most recent basis of the local Product Data Sheet for the product concerned, copies of which will be supplied on request.

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