THE EFFECT OF EXPOSURE TO COASTAL CLIMATE ON DURABILITY OF LOW-RISE BUILDING ENVELOPES IN NORTHWEST COAST RESORTS

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Abstract

Coastal climate provides very harsh strainings on coastal buildings and their exterior surfaces. Building envelopes are ideally intended to last the life of the whole building and withstand cliamtic conditions. The research focuses on envelope problems in low-rise resorts buildings in NWC (North-West Coast) due to the constant exposure to harsh climatic impacts. The parameters of exposure were recognized and exposure categories were classified according to severity degree. The analytical field study was carried out on a number of resorts in North West Coast of Egypt. The effects of exposure variables were demonstrated by an analytical example on render finished exterior walls and Veneer walls. The problem walls were surveyed. The research indicated areas where there is increased potential for enclosure and durability problems. The results were verified using questionnaires directed to owners and practitioners. Recommendations for enhancing durability were obtained.

Keywords

Durability, building envelope, coastal climate, finishing materials, micro-climate, exterior walls, exterior moisture.

الملخص

يكون لعناصر المناخ الساحلي تأثيرا سلبيا على المنتجعات الساحلية فى الساحل الشمالي –مصر وعلى وجه الخصوص على الغلاف الخارجى للمباني. وقد صمم الغلاف الخارجي للمبانى ليتحمل كافة الظروف والعوامل المناخية. ويركز هذا البحث على مشكلات الغلاف الخارجى في المباني منخفضة الارتفاع بمنتجعات الساحل الشمالي الغربي والتي يسببها التعرض المستمر للظروف والعوامل المناخية من خلال دراسة معايير التأثير وتصنيفه الى فئات وفقا لدرجة شدة وقد أجريت الدراسة الميدانية التحليلية على عدد من المنتجعات في الساحل الشمالي الغربي لمصر. وقد تم توصيف الآثار والمتغيرات الناتجة عن التعرض للعوامل المناخية عن طريق مثال تحليلي لقرية زمرده –الساحل الشمالى وتم دراسة التغيرات على الغلاف الخارجى للمبنى (على تشطيب الحوائط.) وقد تم تحليل تلك التغيرات وعلاقتها بوضع الوحدات السياحية وكذلك توجيهها، وقدمت توصيات للتغلب على أسبابها المحتملة.

كلمات الفهرسة

الغلاف الخارجي للمبانى، المناخ الساحلي، المنتجعات الساحلية، مواد التشطيب ، التأثيرات المناخية على الجدران الخارجية.

1. INTRODUCTION

Tourism is one of the most effective drivers for the development of regional economies and accounts for 9% of the world's Gross Domestic Product [1]. Egypt is the largest single destination in the Middle East Region in terms of international tourists. However Egypt's share of the Middle East tourism market is lower than its share based on population compared to the rest of the region. The NWC of Egypt enjoys a combination of natural and historical underutilized potentials, but unlike many other well established resorts on the Mediterranean basin, it has not positioned its coastal tourism product in the international tourist market [2-5]. High construction expenses and vast real estate investment in coastal Tourism sector, call for giving a great deal of attention for enhancing the efficiency and durability of coastal resorts and prolonging their life span. Tourism development of the NWC has been a subject for extensive research. Many studies were subjected towards sustainable development [6-8], Urban Form [9], and Coastal Management [10-12]. The durability of resort buildings lies at the core of sustainable architecture, and could be considered a measure of Sustainable Tourism Development. The aesthetic and functional performance of resort building, particularly exterior walls are important aspects of the overall touristic product. Almost all stakeholders in the coastal construction industry are aware that the rate of premature coastal building failures in the North west coast of Egypt is substantially higher than inland buildings.

2. METHODOLOGY

Recent experience in the NWC has exposed a range of durability issues relating to the building enclosure. A significant number of low-rise multi-unit residential buildings have been plagued with various durability and performance problems, due to a combination of natural, Urban and technical constraints. The hypothesis in this research is that the principal influence in design decisions for Coastal Climate areas are managing exterior moisture sources and rain penetration control. Once an exposure category has been determined for a wall, or various parts of the building, then the selection of envelope system can proceed. The adopted methodology first identifies the determinants of building envelope durability for low-rise coastal resort buildings in NWC. The basic approach starts with the evaluation of the microclimate conditions, and the degree of exterior walls exposure to climatic strains. The parameters of Exposure were recognized; including design and material parameters. Exposure categories were classified according to severity degree. The analytical field study was carried out on a number of resorts in the oldest segment of North West Coast named "Borg El-Arab". The effects of exposure variables (such as Building Enclosure, Location from the Sea, and Wall Orientation) were demonstrated. A comparative study was made between render finished exterior walls and Veneer walls against different exposure parameters. The objective is to examine the relationship between the building envelope problems and their potential causes in relation to exposure parameters. Data collection methods included: direct observation of inspected resorts buildings, as well as questionnaires directed to the owners, managers, professionals and maintenance personnel at the studied resorts. The problems observed on the surveyed building Envelopes included water penetration, damage to exterior walls, and deterioration of wall finish and components. The analysis of questionnaires was used to interpret the problems observed and reach a number of conclusions and recommendations.

3. DURABILITY AND PERFORMANCE

Durability is the ability of a material, product, or building to maintain its intended function for its intended life expectancy with intended levels of maintenance in intended conditions of use. Performance is the level of service provided by a building material, component or system, in relation to an intended, or expected, threshold or quality [13-14]. Ultimately, what is built must work as expected. Reasonable expectation for durability depends on **cost**, expectations of **end users**, **long term investment value** of the product. Durability also depends on **local climate**, the expected norms when the end user is not intimately involved with or knowledgeable of various **design decisions** and their implications, as well as the **material** itself. For example, a house is expected (at least in theory) to last for 75 years or more with normal maintenance and replacement of various components. However, what one person considers normal maintenance may be perceived differently by another. Durability is, therefore, an exercise in the management of expectations as well as an application of technology [13].

4. BUILDING ENCLOSURE AND MICROCLIMATE

The primary function of the building enclosure is to separate the interior environment from the exterior environment to which it is exposed. The typical building enclosure usually consists of the following components:

- The roof system(s)
- Wall systems including windows (fenestration) and doors ▪ The base floor system(s).

The building enclosure should not be thought of as a combination of numerous one dimensional or even two-dimensional planar components. Each enclosure component is a three-dimensional, multi-layer, multi-material assembly that extends from the inside face of the innermost interior layer (e.g., the paint) to the outside face of the outermost layer (e.g., wall render or roof Tiles). The overall enclosure is made up of all the contiguous enclosure sub-assemblies. Each enclosure component is an assemblage of layers of specified products (such as bricks or render) or materials (such as paint or wood). For instance, a deliberate air space or cavity is also considered to be a layer. [15-18]

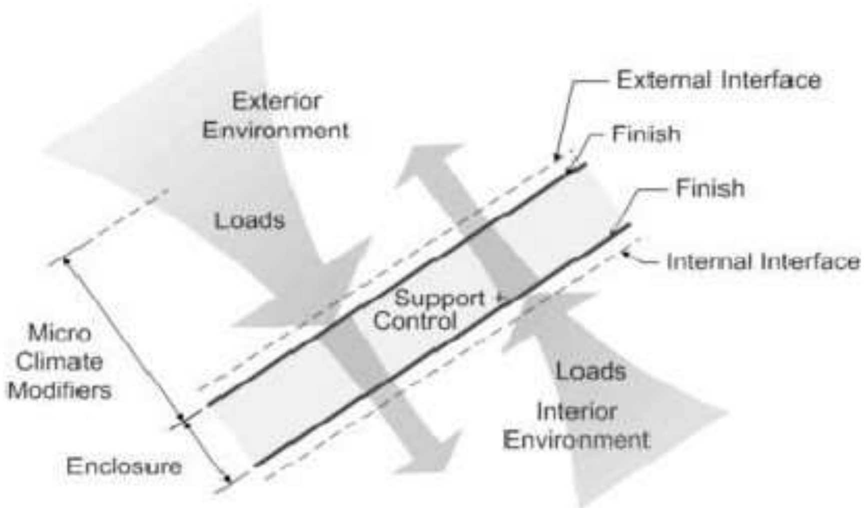
4.1. The Functions of the Enclosure

In practice the building enclosure has to provide the “skin” to the building, i.e., not just separation between the interior and exterior environments but also the visible façade. Unlike the superstructure or the service systems of buildings, the enclosure is seen and is therefore of critical importance to owners, the architect and the public. In general the physical function of separation of the building enclosure may be grouped into four sub-categories, as follows:

1. **Support functions,** i.e., to support, resist, transfer and otherwise accommodate all the structural forms of loading imposed by the interior and exterior environments, by the enclosure, and by the building itself. The enclosure or portions of it can be an integral part of the building superstructure, usually by design but sometimes not.
2. **Control functions**; controlling, regulating and/or moderating all the Strains due to the separation of the interior and exterior environments, mainly the flow of mass (air, moisture, etc.) and energy (heat, sound, etc.).
3. **Finish functions**; finishing the enclosure surfaces the interfaces of the envelope with the interior and exterior environments. Each of the two interfaces must meet the relevant visual, esthetic, wear and tear and other performance requirements.
4. **Distribute functions**, i.e., to distribute services or utilities such as power, communication, water in its various forms, gas, and conditioned air, to, from, and within the enclosure itself. [15-17]

Fig.1 Illustrates a representative portion of a building enclosure, its functions and the nature of the Strains (Damage Factors). The enclosure may also serve other, usually non-physical, purposes such as advertising or as a symbol or image, e.g., as a statement about power or security or wealth, etc., but these are not considered here.

Fig. (1) The enclosure and its functions [16].



4.2. Strains (Impact Factors) from the Enclosure

To properly design buildings and their enclosures it is necessary to have some knowledge and understanding of the relevant environments as well as their interdependence. A considerable body of empirical and experimental data exists on the interaction of climate, site and building [26-28]. The enclosure itself is a source of strain and, as shown in Table 1, Strains arise from the enclosure element under consideration as well as adjacent elements. The enclosure is only one part of the larger system that moderates or controls the environments on both sides of the enclosure at some location on the building. The building itself and the enclosure both influence the exterior microclimate that interfaces with the exterior surface of the building enclosure at a specific location. Consider, for example, the local impact of wind, rain, and solar radiation. In addition, the mass and energy inputs provided by heating, ventilation, air conditioning equipment or other internal gains likewise modify the interior environment [16],[26-28].

Table (1) Strains from the enclosure [16]

Type / Source	Heat related	Moisture related	Air related	Gravity related
Element or component being considered	Volume change, shape change,	RH, built-in moisture, volume change, fungal growth, mold, creep, shrinkage, etc.	air flow, air pressure differentials	Self weight, live loads
Adjacent Elements	Volume and shape change,	Volume change		Dead loads, live loads

4.3 Climate Modifiers

The climate-related Strains (Impact Factors) that a building and its enclosure actually experience are modified versions of the local climate. These microclimates are modified by adjacent buildings, landscaping (*especially trees*), and other parts of the enclosure. Roof overhangs, for instance, are climate modifiers to the walls below as well as integral parts of the roof system (Fig.2).

The influence of climate modifiers, such as trees, overhangs, and the soil on the strains experienced by the enclosure is not always appreciated. Especially in the case of low-rise buildings, the effect on the enclosure from the exterior environment can be intentionally reduced or moderated by the use of microclimate modifiers such as plantings, fountains, building overhangs and windbreaks. For example, a roof overhang (an integral part of the roofing system) will moderate the amount of rain on the wall below and will therefore be a microclimate moderator for the vertical portion of the building enclosure. With taller buildings it is more difficult to modify the external microclimate. (Fig.2)

The exterior environment could be considered to be a three-dimensional space with randomly varying mass and energy properties. The local climate and weather provide the major, but not the only, exterior strains. Local climatic records: for instance, average and extreme values are commonly available but these data are usually based on open-field, weather-station records. The building may be some distance from the weather station, and the terrain (hills, other buildings, etc.), the landscaping (trees, shrubs, etc.) and the building itself (overhangs, protrusions, etc.) can moderate the weather that each enclosure component is actually subjected to (Fig.3.). As a matter of convention, that portion of the exterior environment that is close to, and affected by, the building is called the external microclimate. In fact, different parts of the enclosure are subjected to different exterior microclimates.

Fig. (2) The Effect of using Roof Overhang as a Climate Modifier

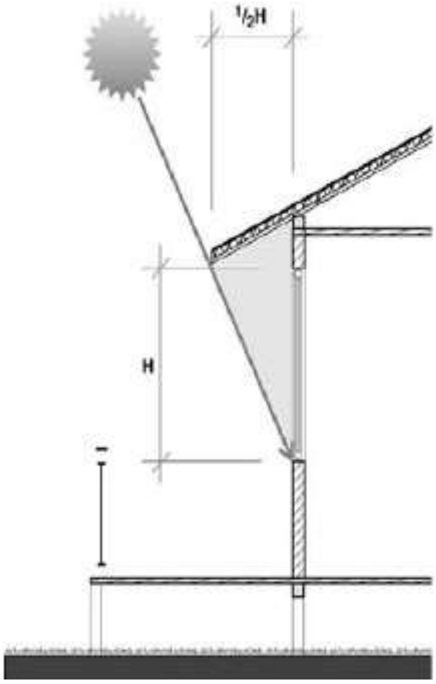


Fig. (3) External reflections: plants in front of openings prevent most of the unwelcome reflections

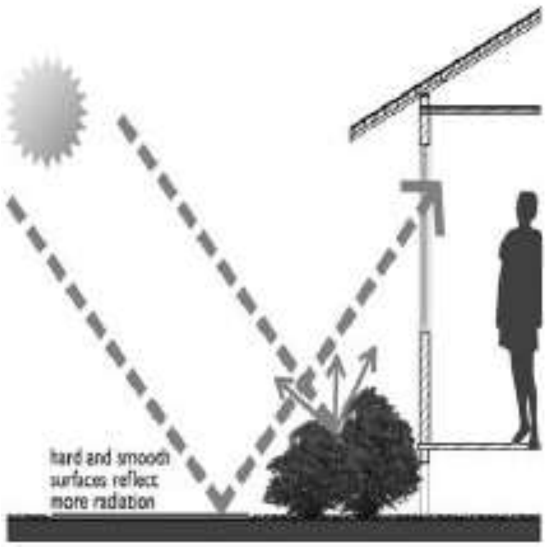
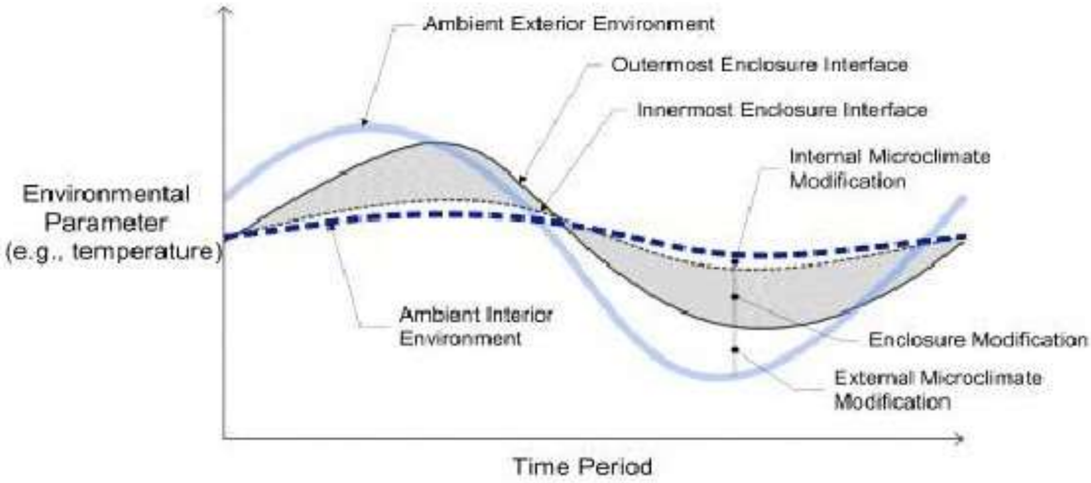


Fig.4 indicates that ; while the building enclosure separates the interior and exterior environments, it really experiences several microclimates. The enclosure interacts with both environments and, in turn, affects both environments. This interaction is usually dependent on the time of day, the day of the week, and the season. There is thus a cyclical (diurnal, workday/non-workday, weekly and seasonal) aspect to the time-dependent response of the enclosure as it separates and, to some degree, modifies the influence of both environments. [16-22]

While the enclosure may be the largest modifier, the difference or the modification between the ambient and interface conditions can also be significant. Note that the scale of Fig.4 will be different for different parameters. Moreover, this simple representation of variation over one cycle of time for one parameter does not accurately or fully represent the complex behavior and interactions that occur. The properties of exterior environments and microclimate environments are separate and major fields of study.[16-22]

Fig.(4) Contributors to environmental modification [16]



5. BUILDING ENVELOPE DURABILITY

Building envelopes are ideally intended to last the life of the whole building. In traditional building forms employing load bearing masonry, this relationship was axiomatic since the structure was also the skin. But as building technology evolved, and the structural and cladding functions became separated, the durability of the skin over the life cycle of the building increasingly challenged the architect. This challenge often focuses on the design of walls, which represent among the highest cost components of the building envelope system, and are also the most visible aspect of the building, its façade. There are also many durability issues related to foundations, roofs and building services. The building envelope comprises the roof covering, exterior wall covering, and exterior doors and windows. The floor is also considered a part of the envelope for buildings elevated on open foundations.

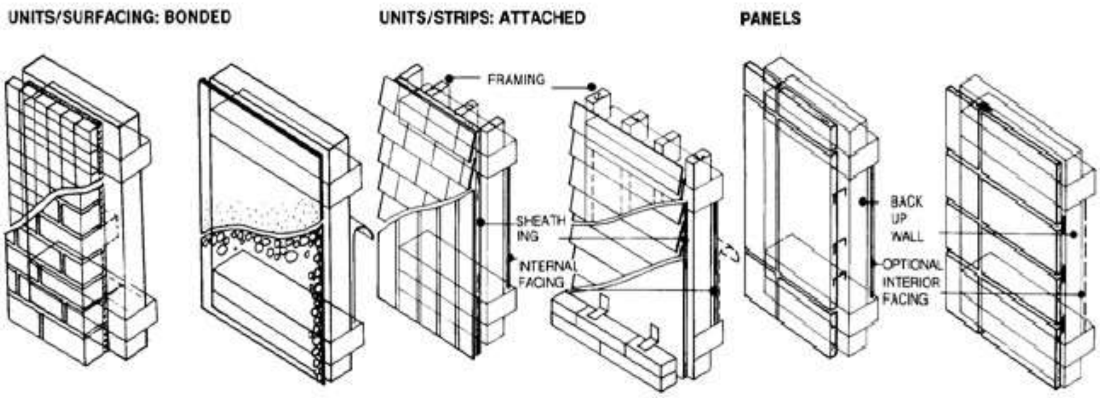
5.1 Exterior Finishing Materials (Wall Covering Systems)

Finishing materials are materials and items used (in construction), to improve the service and decorative qualities of buildings and structures, as well as to protect structural members from atmospheric and other effects. The main finishing materials in modern construction include finishing mortars and concretes; natural and artificial masonry materials; decorative ceramics; materials and items made from wood, paper, glass, plastic, and metals; and paints and varnishes. A subjective classification of finishing materials is as follows:

1- **Proper:** which are used mainly to form decorative and protective coatings (varnishes, paints, polymeric films, and so on), 2- **Structural finishing materials**: which perform the functions of enclosing members and are components of such members (decorative concrete, facing brick, glass blocks, and molded glass).

3-**Facing materials**: are generally distinguished by their good service and architectural qualities .They are produced in the form of sheets, slabs, and tiles (for example, ceramic mosaic slabs and tiles, and decorative laminated-paper plastic) . Under modern industrial construction conditions it is expedient to produce the facing during the manufacture of prefabricated units and to deliver the units to the assembly point with finished surfaces (for example, ceramic mosaic tiles are laid in a form and concreted together with the wall panels or staircase landings). Fig.5. [22-25]

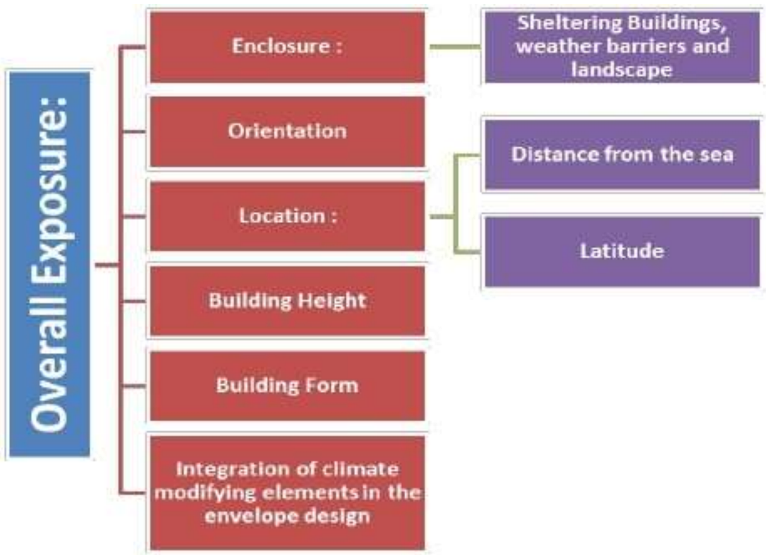
Fig. 5 Exterior wall performance factors



6. THE DESIGN PARAMETERS OF DURABILITY

The significant Design Parameters that affect the durability of the exterior finishing materials are presented and summarized in Fig. (6).

Fig.(6) The Design Parameters that affect the durability of the exterior finishing materials



7 EVALUATION OF EXPOSURE

The determination of exposure is a process that involves the consideration of both *design* variables and *environmental* factors. Design factors range from building orientation, shape, surroundings, and distance from seashore to how the building and its elements deflect wind, water, and solar radiation. Environmental factors include: humidity, duration and intensity of rainfall, and wind velocity and orientation during these rain- storm events. Together these factors will determine how often, and for how long, the building walls will be wet. The process of evaluating exposure can be simplified by considering only the three most influential factors; climate, contact with moisture source, overhang and landscape

Although the coastal climate zone contains various microclimate zones where rainfall intensity and wind directions vary, it is reasonable to establish the entire coastal climate zone as a wetting environment for the determination of exposure categories for all buildings. Locations which are not clearly in one zone or another must use the more conservative determination of exposure. From litrature survey, landscape has a large influence on how much wind driven rain will impact the walls of a building. For the purpose of this research the following four exposure categories were defined:

Very High
Walls usually wet under normal service conditions, or located within the reach of garden sprinklers

High
Walls located facing direct waterfront exposure, or small or few surrounding obstructions, or located on a hill or cliff overlooking adjacent buildings

Moderate
Areas, moderately treed, or buildings mostly fewer than 4 Building height

Low
Adjacent buildings or protective vegetation within 2 buildings heights

The following legend was used to deterime general exposure categories for different microclimate combinations of location,orientation,shading, and terrain. While the range of exposure categories are somewhat arbitrary and require an assessment by the designer, Exposure categories could be summarized as follows:

Very High /Severe
Wall is wet under normal service conditions

High -
Wall is subject to significant exposure to wind and moisture

Average -
Wall is not moist under normal service conditions and average exposure to wind

Low -
Wall is rarely moist under normal service conditions and protected from wind by Vegitation and /or adjescent buildings

An example of a wall in exposure category *Very High* would be a ground floor wall or a plant basin wall directly exposed to wetting by external plant irrigation system.

8. THE STUDY ZONE

In general the NWC is divided into 3 developmental zones. The studied resorts were selected at the First Zone *"Borg El-Arab"*, which stretches between "Agamy" and "Hammam City. It is known to be the oldest segment of the coast; thus most deteriorated due to the long impact of environmental stressors on building materials. The sample resorts were selected to be no less than 15 years old, built between 1994 and 1997, selected within a homogenous sub-climate zone and construction period, but various operation and management styles. A general scan for envelope problems was made over the resorts of the study zone. Survey of Building Envelope Failures in relation to Exposure of the studied coastal resorts Buildings of NWC was performed. Zomoroda village resort was among the studied cases. The analytical study is demonstrated below.

Fig. (7) NWC Location of the study zone

Fig.(8) Zomoroda Tourist Village **:** Aerial View

9. ANALYTICAL CASE STUDY: ZOMORODA VILLAGE RESORT

9.1 Project Identification

- **Location**: From 52,25 Kilometers to 55 Kilometers Alexandria/Matrouh Road
- **Project Area**: 1000 000m2

- **Number** of Phases: 3 phases
- **Number** of units: 3200 housing units.
- **Ownership**: The resort was established by a Co-operative Society for housing and summer resorts.

9.2 Project Planning and features

The illage consists of four main zones, namely: Beach, Three zones of chalet units, 2 zones of apartment building units, and a central public service area. A " 3m wide corniche" road separates chalet buildings from the beach, and another double road separates the chalet units from the services area and apartment units.

9.3 Site Topography, Planning Levels and Patterns

The village extends three kilometers along the sea side, with a gradual linear alignment parallel to the sea. There are four rows of chalets, with each row of chalet buildings raised on a higher contour. The contour slopes down towards the coast, allowing all units to view the sea. The chalets are bound by a central road or spine that runs along the project and divides the chalets zones from the central linear services zone and apartment buildings. The chalet blocks are uniform rectangular two-storey blocks, alligned in 4 row clusters parallel to the beach. Perndicular passages separate each cluster , and connect the corniche road with the central road. All the units are of similar shape and height. The original design of exterior walls contains a combination of white stone and thermal brick cladding combined with render finish parts. some units were modified by the owners, for example; extra wall and roof parapet claddings were added .

9.4 Analysis of the Design Variables in Relation to Exposure

For a fixed buildings protoype and layout, a comparative study was made on the effect of Exposure on durability of exterior walls finishes; namely: Stone/Brick Veneer walls and Rough Render Finish Walls. Table (2) provides an overview of the extent of the problem in the two samples (Render Finish walls and cladded walls). Comparison is between: Stone/Brick cladding and Render Finish walls. Exposure constants and variables are as follows:

- **Exposure Constants**: Building Form,and Heights
- **Exposure Variables**: Location , Enclosure, and Orientaion

Fig.(9) Preview of Zomoroda Tourist Village

Linear alignment of units alongside the coast in rows gradually sloping towards the sea.

Phase one – chalet units

Chalet units are bound by a two way vehicle and pedestrian road that runs along the project forming a major central lateral spine.

Apartment buildings block units

Table (2) Condition and Deterioration features of finishing materials in relation to Building Orientation

Stone /Brick Veneer	Render Finish
First Row: **Exposure:** Average	**Orientation**: South – South West Facades
	
Heat Damage by solar radiation: Cladded parts of the wall were found in a very good condition	Heat Damage by solar radiation: Render finished Southern walls : Cracks at corners due to thermal expansion in non-cladded buildings. Loss of Pigmentation due to UV Radiation.
Exposure: High	**Orientation**: Western Facades
	
Heat Damage by solar radiation: Cladded parts of the wall were found in a very good condition	Heat Damage by solar radiation: Corner cracks in parapet walls due to thermal expansion in non-Cladded buildings. Loss of Pigmentation due to UV Radiation.
Exposure: High	**Orientation**: Eastern Facades
	
Heat Damage by solar radiation: Cladded parts of the wall were found in a very good condition	Heat Damage by solar radiation: Render Finished parts of the wall were found in fair condition

Stone /Brick Veneer	Render Finish
First Row: **Exposure:** Average	**Orientation**: North – Nort East Facades
	
Moisture damage by rain and humidity: Cladded parts of the wall were found in a very good condition	Moisture damage by rain and humidity: High moisture content in corner parapet wall caused partial peeling in wall render finish due to water ingress at the intersection line between the roof slab and the wall. (Moisture carried by high wind velocities, together with probable accumulation of rain water.)
Second Row: **Exposure:** Average	**Orientation**: South Facades
	
	Moisture damage by rain and humidity: High moisture content in corner parapet wall caused partial peeling in wall render finish due to water accumulation on the roof surface and absorption at the intersection line between the roof slab and the wall.
Second Row walkway: **Exposure:** High	**Orientation**: Western Facades
	
Moisture damage by rain and humidity: Cladded parts of the wall were found in a very good condition	Moisture damage by rain and humidity: Efflorescence on parapet wall - and at ground floor walls exposed to garden's moisture and surface water. Step Crack at the corner of stair case side wall

Stone /Brick Veneer	Render Finish
Third Row overlooking walkway: **Exposure:** High	**Orientation**: Eastern Façade Walls
	
Moisture damage by rain and irrigation system: Cladded parts of the wall were found in a very good condition	Moisture damage by rain and irrigation system: Faded color due to high exposure to UV. Slight cracking at the corner of parapet wall-severe damage to render layer (at the staircase side /parapet wall), at the parts where accumulated driving rain water over flow and fall off the wall side, causing complete wetting of the stair case walls
Fourth Row: **Exposure:** Low	**Orientation**: Southern Façade
	
	Moisture damage by rain and UV: High water absorption during driving rainfall months: parapets absorb most water, and dry out unevenly, leaving wet patches , and efflorescence , color bleach of wall render caused by long exposure to UV radiation externally
Fourth Row: **Exposure:** Average	**Orientation**: Eastern Façade Walls
	
Moisture damage by rain: Excellent condition	Moisture damage by rain: Efflorescence and wet marks

Stone /Brick Veneer	Render Finish
Forth Row: **Exposure:** Average	**Orientation**: North Façade
	
Moisture damage by rain: Limestone and brick cladded parts of the façade (including corners) were in a very good condition	Moisture damage by rain: Main damages in rendered parts are : - Corner cracks in parapet wall - Partial fracture in the concrete cover of window sills - Partial Peel off of render finish

10 RESULTS

Table (3) summarizes the observations and provides a descriptive anlysis for wall conditions and damage features, Damge Types and Damage Sources in relation to walls Orientation and Distance from the sea.

Table (3) Material Problems in Study Buildings

	Render Finish Walls	Brick/Lime Stone Cladded walls	Total	Percentage %
No. of buildings surveyed	18	9	27	
No. of walls surveyed	72	36	108	100 %
No. of walls in good condition	25	36	61	56%
No. of “Problem” walls reported	47	0	47	44%

10.1 Analysis of Results

The main differences between problem and control buildings are summarized below:

- The wind exposure of the control buildings was generally lower than that of the problem buildings.
- The materials in the wall sections of control walls were less likely to be the most commonly used materials, namely limestone and brick cladding. It was clear that those walls performed better.
- The quality of the design, construction and building materials indicates that certain details were often poorly designed in the control buildings, as well as in the problem buildings. Problems often arise from the individual trade personnel’s knowledge and experience, the contractor or designer’s diligence in

providing clarification and the sensitivity of the wall element performance to a particular detail.

Main findings from the previous part of the study included:

- There was clear relationship between the absence of protective landscape or building shelter and the degree of deterioration of the exposed wall element.
- Almost all the problems were associated with details such as parapet walls, roofs, corners, eaves, windows, stairs, balconies and cracks and penetrations on walls. With regard to windows, water seemed to penetrate through the window frame joints and through the interface between the windows and adjacent wall connection. With horizontal surfaces, such as roofs and balconies, the problems were related to the installation of waterproof membranes and absence or blockage of sound surface water drainage system (blockage of gutters), and lack of inspection and maintenance due to inaccessibility to balconies and roofs during the rainfall season.
- All wall cladding types experienced better performance. However same types of cladding experienced problems when used in plant basins due to constant exposure to moisture, and properties of bonding and jointing mortars and materials. Yet, the number of problems reported on rendered walls was greater.
- Finally, the study results indicated that in the coastal climate area, face sealed wall assemblies are sensitive to design and construction details, making it difficult to achieve acceptable performance. Cavity walls and cladded wall assemblies are thought to offer the best opportunity to achieve acceptable performance. Also needed is significant improvement in the design and construction of interface details and better communication between designers, contractors and trade personnel.

10.2 Interpretation

The data collected in the study indicate that the defects that allowed water to penetrate walls were widespread and appeared on many wall systems. This suggested that it is the quantity of wetting at these defects, combined with the exposure and drying characteristics of the wall , that determine whether a wall can accommodate the moisture and provide acceptable performance. Moisture problems were not observed in stone/brick veneer of cladded buildings.

10.3 Questionnaires

To establish a practical perspective on the previous issues of Envelope durability in resorts' buildings, and the identified impacts on the commonly applied finishing strategies separate surveys were developed and directed to resort managers, maintenance engineers, personnel, and contractors, and to building owners in different resorts in NWC. The purpose was to verify and further analyze the above findings. The survey was sent to a total of (100) unit owners, consultants, engineers, contractors, property managers and maintenance personnel. A total of (28) responses were received from owners. The majority of responses were from property managers and maintenance personnel (24), and contractors (12). Other respondents included architects, developers, and consultants.

The results of the survey verified the previous interpretations. Problems experienced by respondents mirrored many of the problems and design deficiencies identified in the previous analysis. The questionnaire results also confirmed that the identified design strategies were in fact the same strategies being employed in the design and construction of inland (non-coastal) buildings and projects. The failure to specify and build with materials, and techniques that are appropriate for the degree of exposure to coastal climate stressors was found to be a major cause of premature deterioration.

11. CONCLUSIONS

The following conclusions were obtained from the field study and questionnaires:

- The main services and infrastructure of many NWC resorts are under the threat of complete deterioration within next 5- 10 years.
- Most damages were found to occur due to harsh environmental conditions and lack of adequate maintenances rather than frequency of use.
- Enhancing the Durability of resorts buildings in N.W.C would minimize maintenance costs, encourage investment and ownership, and help in development of NWC. The development approach should not over exploit the natural resources, and respect sustainability principles as the basic element for tourism attraction. Appropriate design and materials selection will influence both the durability and sustainability of a coastal resort building.
- Main urban problems were found to be: underdeveloped hinterland, lack of services, unqualified local caliber and lack of awareness among users, contractors, builders, and owners. Moreover underdeveloped surroundings make site supervision process more difficult and time consuming.
- Seasonal use of resorts, prevent regular maintenance; and delays detection of damages in the right time. The short use period makes owners generally less willing to invest on maintenance.
- Deterioration of building envelope is a normal consequence of weathering and/or poor construction. It is a problem all building owners and executives should keep an eye out for.

- A great deal of attention should be paid to water management principles (associated with control of moisture entry, drying potential and drainage). Local climate conditions need considering when establishing effective water management strategies before and during construction.
- The primary sources of damage to building envelopes in NWC resorts were mostly found be heat, and water (either in form of moisture, liquid or rain) — combined with masonry movement due to thermal expansion.
- Masonry shifts seasonally along a façade and cracks if expansion joints are not present to accommodate the movement. The cracks will grow over time and require intervention.
- Moisture problems were not observed in stone/brick veneer of cladded buildings.
- Moisture leading to performance problems was found to be mostly rain water damage to the parapet wall, usually from the accumulation on roofs, rather than interior sources moisture.
- About 90 % of the problems were thought to be related to interface details between wall components or at penetrations.
- The problems were thought to originate during design and construction activities (due to poor details on drawings) and not as a result of operations and maintenance or defects in the materials.
- The absence of climate modifiers, such as; overhangs or means of shading above walls contributes to heat and moisture damage.

12. RECOMMENDATIONS

Recommendations for enhancing the overall quality of resorts' buildings in NWC:

- Developing a vision that embraces sustainable principles and an integrated design approach.
- Environmental design principles such as conserving resources, should not contradict with specifying durable building materials to minimize energy waste, maintenance and replacement costs, etc.
- Developing a clear statement of the project's vision, goals, design criteria, and priorities.
- Selecting a design and construction team committed to the project's vision.
- Durability and ease of maintenance and replacement should be concerned on selection and specification of building systems, procedures and materials.
- Providing accessible data and material selection guidelines with emphasis on execution procedures and material specifications.
- Moisture sources and control methods should be the basis of a durability standard or risk assessment protocol that addresses the water damage function

and should therefore be considered a “pre-requisite” or “requirement” for any durability standard or risk assessment protocol.

- Developing contract plans and specifications to ensure that the building design is at a suitable level of building performance.
- Developing a project schedule that allows for building and systems testing and commissioning.
- Modifying the selection process to ensure the contractors have appropriate qualifications to identify, select, and implement an integrated system of intended building quality and measures.
- Acquiring qualified Engineering team and professional personnel to deliver the anticipated overall quality.
- Planning (financially and physically) for maintenance during the preliminary stages of project approval.
- Documenting the maintenance processes in a suitable way to provide a database for extraction, analysis; thus avoiding recurrence of many problems.
- Modifying the selection process to ensure qualified management and maintenance caliber are able to implement appropriate maintenance procedures and measures.
- Developing custom-made software to assist or replace management and maintenance procedures for resorts, making maintenance more efficient.

The research extended several recommendations for the housing industry, particularly with reference to design and construction. The recommendations include requirements for the following:

- Greater clarity in design strategies;
- Improvement in details (e.g., larger-scale, project-specific information);
- Development of guidance documents with respect to the details;
- Establishment of an envelope quality management protocol;
- Training of trade personnel with respect to the construction of envelope materials and systems.
- Relying more on factory–controlled quality of building parts and prefabricated components to help minimize human errors.
- Planning to construct prefabricated building components factories nearby (where it doesn’t threaten /pollute natural resources). The resulting reduction of transport energy, employment and training of local calibers, would aid the urban development plans, result in cost reduction. This will thus encourage the use of quality components and enhance the overall quality of buildings and personnel.

The research also suggested further work in areas unrelated to design and construction in NWC, for example:

- Effective remedial strategies to address the envelope performance problems;
- The use of rain-screen systems utilizing claddings and other materials that traditionally have not been used in this way;
- Enhancement of the existing codes and standards to extend performance of finishing/facing materials in high wind prone zones (aerodynamics);
- Guidance for building owners regarding exterior wall system maintenance to reduce premature envelope failure.

References

[1]"Travel & Tourism 2011", Report, The Authority on World Travel & Tourism, World Travel and Tourism Council, London, 2011

[2] WTO, Guide for Local Authorities on Sustainable Tourism Development, 2002

[3] GOPP, Regional Planning of The North West Coast of Egypt, 1998 [4] World

Tourism Organization (WTO) –World Bank Atlas,1997.

[5] Coastal Area Management Program (CAMP) Fuka-Matrouh – Egypt Carrying Capacity Assessment for Tourism Development, UNEP Mediterranean Action Plan, International Conference of Development and Tourism in Coastal Areas, Sharm el-Sheikh, Egypt, March 2005.

[6] Helmy E. M.," Tourism development in the Egyptian Northwest Coast: a sustainable development approach" , International Conference Development and Tourism in Coastal Areas, Sharm el-Sheikh, Egypt, March 2005.

[7] El Khorazaty M.T. and El Mohamady E.M.," Sustainable Development On the Strategic Level : An approach to the Formulation of Development constraints for Urban Touristic Projects in Marsa-Matruh", International Conference of Development and Tourism in Coastal Areas, Sharm el-Sheikh, Egypt, March 2005.

[8] Metwally M.and Abdalla,S.," An Approach to Sustainable Tourism Development in Coastal Area-Egypt", International Conference of Development and Tourism in Coastal Areas, Sharm el-Sheikh, Egypt, March 2005.

[9] Ahmed K. G. and EL-Gizawi L. , "Sustaining The Urban Form of Coastal Tourist Resorts in Egypt: An Approach for Sustainable Tourism", International Conference of Development and Tourism in Coastal Areas, Sharm el-Sheikh, Egypt, March 2005.

[10] Shemais, R.A, Mahrous, M , "GIS for Monitoring and Protection of Coastal Zones" , International Conference of Development and Tourism in Coastal Areas, INTA, Sharm el-Sheikh, Egypt, March 2005.

[11] El-Raey M, K.R. Dewidar and M. El-Hatab, "Adaptation to the Impact of Sea Level Rise in Egypt: Mitigation and Adaptation Strategies for Global Change", Institute of Graduate Studies and research, Alex. Egypt, Volume 4, Numbers 3-4 (1999)

[12] W. Kamel and A. Soliman "An Approach to Environmental Management for Egyptian Northwestern Coast", First International Conference on Environmental Change of Lakes, Lagoons and Wetlands of the Southern Mediterranean Region, 3-7 January 06, Cairo, Egypt. ECOLLAW, 2006.

[13] “Durability by design: A guideline for residential builders and designers”, U.S Dept. of Housing and Urban Development, Washington, DC, 2009.

[14] Durability Precedent: Cedar Shake Clad Building, Fruitvale ,2005

[15] A.J. Elder (Ed.), *A Handbook of Building Enclosure*, The Architectural Press, London, 1974.

[16] Straube J. , Burnett E. *Building science for building enclosures*, Building Science Press, 2005. pp 25,30- 32, 36-38 ,49-50

[17] Allen, E., *How Buildings Work*. Oxford University Press, Oxford and New York, 1980.

[18] Brown, G.Z. and DeKay, M., Sun, Wind and Light. *Architectural Design Strategies*, Second Edition, Wiley, 2001.

[19] Givoni, B., Man, Climate, and Architecture. Van Nostrand Rheinhold, New York, 1981.

[20] Hutcheon, N.B., Requirements for Exterior Walls. *Canadian Building Digest* 48. Division of Building Research, National Research Council, Ottawa, 1963.

[21] Markus, T.A. and Morris, E.N., *Buildings, Climate, and Energy*. Pitman Publishing, London, 1980.

[22] Moore, F., *Environmental Control Systems*. McGraw-Hill, New York, 1993.

[23] ASHI NEWS Press Release, American Society of Home Inspectors, Des Plaines, IL, 2000

[24] Makotinskii, M. P. *Novye otdelochnye materialy.* Moscow, 1972.

[25] Vorob’ev, V. A., and A. G. Komar. *Stroitel’nye materialy.* Moscow, 1971.

[26] Brown, G.Z. and DeKay, M., *Sun, Wind and Light. Architectural Design Strategies*, Second Edition, Wiley, 2001.

[27] Olgyay,V., *Design with Climate*. Princeton University Press, Princeton, New Jersey, 1963.

[28] Watson, D., and Labs, K., *Climatic Building Design*. McGraw-Hill Inc., New York, 1983.