*Journal of Contemporary Technology and Applied Engineering (JCTAE), **3**(1), 2024, 54-63*

DOI: 10.21608/JCTAE.2024.291626.1028 Published by: *Faculty of Engineering, Kafrelsheikh University*

THE IMPACT OF CLIMATE CHANGES ON COSTAL ARCHAEOLOGICAL SITE CASE STUDY AL- BURULLUS LIGHTHOUSE

Received: 21-05-2024
Accepted: 20-06-2024

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ABSTRACT. Archaeological sites in coastal regions have suffered from many forms of hazards that have caused damage to materials and historic features. The research in this article concerns one of the oldest metallic structures that still exist in Egypt namely an iconic landmark on the shore of the Mediterranean Sea, the "Al-Burullus-lighthouse". Climate change threatens the state of the lighthouse. The research involves full architecture documentation of the lighthouse, and monitors the natural and climatic changes which are facing the lighthouse through Coastal hazard wheel (CHW) analysis. Where the analysis finding that the high rise of sea level are most effect on the decay and erosion of coastal shores and gradually the lighthouse become more near from sea as research presented ... this phenomena will conduct to the necessity of put an urgent intervention plan for saving the lighthouse. The article describes an urgent technical plan regarding risk management options for restoring the historic image and archaeological value of the lighthouse, which has a significant impact on developing an integrated strategy for managing the process of preserving the lighthouse and the site, and then integrating and including in development plans of the city and surrounding urbanization.

KEYWORDS: Archaeological; Al- Burullus; Climate Change;, Costal line; Lighthouse.

1. INTRODUCTION

The impact of climate change on coastal archaeological buildings is a topic of growing research that highlights the vulnerability of these historical structures to environmental shifts. sea levels, increased storm frequency and intensity, and other related factors associated Rising with climate change pose significant threats to coastal archaeological sites worldwide. Climate change-related threats will increase over the 21st Century and accelerate post-2050 the Analysis refers that <5% of documented coastal sites are definitely affected by coastal erosion but up to 34% could also have experienced past flooding, Rising sea levels, erosion, or storm action and other related factors associated with climate change pose significant threats to coastal archaeological sites worldwide that over 30% to 40% of sites could be impacted by erosion by 2050. (Westley K., 2021)

Egypt is famous as the home of the prototype of all lighthouses, where the Pharos of Alexandria was built in the early third century in the Ptolemaic Kingdom of Ancient Egypt (Clayton, 2013) it was as tall as a modern skyscraper and much taller than any modern lighthouse, but it collapsed after several earthquakes (Darwish, 2018)… after that many trails were made to design and build lighthouses as a Coastal aid to navigation. (Darwish, 2018).

Al- Burullus lighthouse is considered the oldest archaeological iron tower in the world and the only remaining steel lighthouse in Egypt among a group of lighthouses which are located along both the Mediterranean and Red Sea coastlines of Egypt in the north African coastal . The list includes active maritime lighthouses that are named landfall lights (Rowlett, 2016)(Rashid, Damietta, Port Said, Alex, Al-Burullus or Baltim) which were erected by Khedive Ismail in the Ottoman era in 1869 with the completion of the Suez Canal (Russel, 1869). The lighthouse has many historical, architecture and urban values as it is a distinctive land mark in the surrounding urban fabric (Al-Rafi'i, 1951).

The analytical studies presented Al- Burullus lighthouse as a case study through document the Past-Present-Future (PPF) framework, commonly

used in physical geography and archaeological studies (Goudie, 2019; Nesje, Bakke, Dahl, Lie, & Matthews, 2008), in the context of interpretation and conservation (Martini , 2012 and Martini, Zhang, Gu, and Li (2013) whose suggested to apply the PPF framework to improve interpretation and intervention plans.

The research records and determines the characteristics of the north coastline in Egypt and the effect of climate changes on the houselights site to indicate the risks assessment depends on the geological and physical characteristics of the coast by Coastal Hazard Wheels (CHW) application where it measure the risk and erosion hazard levels easier than different methodology and the possibility for saving and managing it in the frame of sustainability.

In the other side the research focused on the role of Climate changes where the climate component are dynamic and change permanently; continuous and played a great and dominancy role in conservation plan and intervention standards (Freie University Berlin, Department of Earth Sciences Website, Kun Li&Max Q.-H. Meng, 2015). The effects of temperature, wind, humidity, and rain vary from location to location on Earth's surface. Coastal areas are particularly complex and dynamic, with a significant impact on archaeological sites and buildings. Continuous monitoring is necessary to track the changes occurring there (Al-Sheikh et al., 2007). the research from Westley k. et al. (2021) highlights the direct impact of sea level rise on coastal archaeological sites, with a focus on the potential submersion of structures and artifacts to assess the risk of inundation and prioritize preservation efforts (Kieran Westley, 2021).other Studies by Garcia et al. (2023) delve into the chemical and physical deterioration of archaeological materials due to saltwater exposure, suggesting conservation measures to counteract these effects (Tanveer A., 2023).

In light of these findings, this research aims to assess the risk of natural hazards at a specific coastal archaeological site and develop holistic strategies to protect the heritage in accordance with international charters.

2. MATERIAL AND METHODS

The research follows an analytical study by Costal hazard wheels and SPSS for determine the impact of climate components on historical steel structure on coastal line and records the agents of deterioration that effect on the statue of the iron lighthouse therfore the research submit an action plan for urgent intervention and treatment the historical site in the frame of international charters and sustainble concept for reingerate the site within surrounding urban.

2.1. CASE STUDY: AL- BURULLUS LIGHTHOUSE:

Egypt has many archaeological sites distributed in the coastal region. More than56 historical buildings, among them five historical military castles, older than 200 years, and 5 remaining historical lighthouses are located along the coastline. As Fig. 1 where the figure appears, the geographical locations of major archaeological sites and socio-economic components and the coastal highway which extends parallel to the shore in the lower coastal plain of Alexandria and the Nile Delta, in which most of them will be excessively inundated and threatened lost, if sea-level will rise by a 1m (Ferehy&Deabes,2010).

The lighthouse was built in 1869 during the time of Khedive Ismail. It was designed by French engineer "Barker" with a planned lifespan of 50 years. However, it has been in operation for 120 years, thanks to annual maintenance and restoration work. The lighthouse stopped functioning in 1970 but resumed operations in 1984 after several maintenance processes. It is currently under the custody of the Antiquities Authority No. 463 since 1998 (Yakout, 2009).

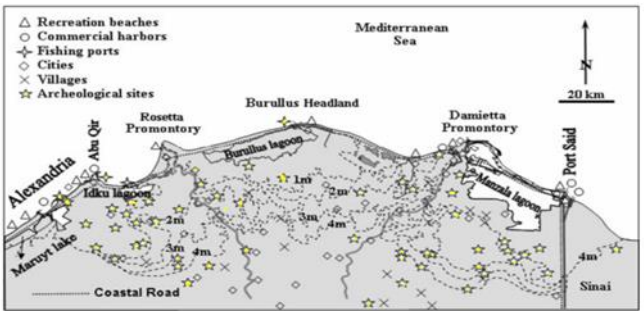


Fig. 1. Archaeological sites on the coastal plain
Source: Archaeological sites are positioned from the web-pages of Egypt Exploration Society Delta Survey.

2.1.1. Location and geographical features

Al- Burullus Lighthouse is located on the middle section of the Mediterranean coast within the borders of the village of "Sheikh Mubarak"followed by Kafr-Elsheik Governorate (Yakout, 2009) in the east of Alexandria where Burullus region represents a peninsula to guide ships to prevent them colliding with the land, where the head of the land is entering a distance between 48 and 35 km into the Mediterranean Sea to shape an arc or a head, the geographic location of the site between 31 °30' 00"N to 31 °40' 00"N latitudes and 31°00′00″E to 31°15′00″E longitudes (Ali. Etal., 2017& Salama etal., 2021). It is considered the oldest surviving offshore lighthouse in the south of the Mediterranean Sea, off the coast of Italy.

2.1.2. Architectural description of lighthouse

The site is approximately a square shape, about 19.25x18.65m and in the middle of site located the body of the lighthouse surrounded by a group of rooms on three sides, as in Fig. 2.

Fig. 2. Shows the plan of the site and its collected elevation ***Researcher 2023.***

2.1.3. The structure of the lighthouse.

The structure of the lighthouse consists of 3 parts (base - body - dome). It is made of solid iron as a hollow cylindrical column with a 3.80 m diameter and a circumference of 5.80 m (Saber, 2015). The column has 19 cast iron belts, the distance between the lighthouse column and the supporting column is about 7.20 m. and the distance between the two supported columns is about 14.4 m. Its weight about 40 tons as Fig. 3.

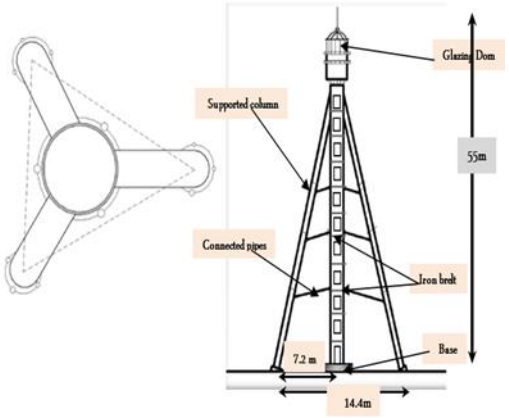


Fig. 3. The Elevation of lighthouse and its components ***Documented by Researcher 2023.***

- There are three pillars (supports) installed on 6 iron springs around the lighthouse to help the flexibility and inclination when the wind is strong, as it tilts in each direction from 8-12cm.

- The door of the lighthouse opens on the northern side as a form of quarter-circle, where leads to the stairs that ascend to the top. There are rectangular openings in the corners of the tower to light the stairs with a frame of wood closed with transparent glass as Fig. 4.

-At the top of the lighthouse there is an iron compass to determine the directions, and a glass part with mirrors inside it has a searchlight to illuminate and guide the ships.

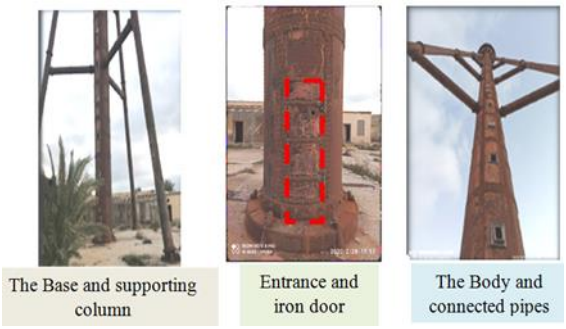


Fig. 4. The main component of Burullus lighthouse. ***Taken by researcher 2023***

The lighting dome is a glass dome. Its heights reach to 7 m. It contains of two floors ... First floor from wood and its diameter about 4 m. The second floor from iron contains a door that leads to an external corridor surrounding the lighting dome with iron balustrades (Saber, 2015). The lighting dome works with kerosene, as this floor contains two cylinders filled with kerosene and compressed with air through a manual air pump. The Encyclopedia Britannica recorded the range of its signal about 118 nautical miles. On the southern side of this room, we found a ladder that goes up to the disc holder for the lenses.

3. RESULTS

The research analysis the various geographical and natural agents that effect on the structure of lighthouse and the susceptibility of coastal areas to inundation and erosion processes

3.1. GEOGRAPHICAL AND TYPOGRAPHICAL CHARACTERS OF COSTAL LINE IN EGYPT

The coastal shore in Egypt extends for more than 1,000 km and is divided into three different geomorphological zones. The Western coastal zone, which constitutes 550 km of the Western Desert (known as the North Coast); The central region represents the coast of the Nile Delta with a length of 250 km. And the eastern costal region extends for a distance of 200 km to North Sinai. (Pirazzoli, 1991). The coastal line has been divided into 5 sections according to their exposure to erosion, where they find the most dangerous sites and the most vulnerable to coastal erosion as Fig. 5. The study focused on Zone 3 in the final parts of the River Nile branch (Rashid, Damietta and along Lake Burullus). Erosion rates in these sites exceeded 2 m/year in especially at the location of the head (Masria A.et al., 2014).

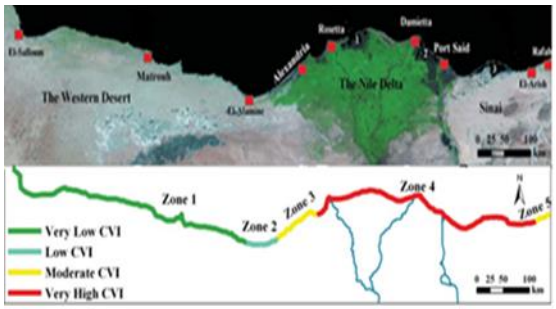


Fig. 5. A satellite image showing the division of the coast line in Egypt into 5 parts and the most exposed places to severe erosion (Masria A.et al., 2014).

The Nile Delta is a part of the mid-coastal region where there are clearly human and natural stresses on it, and they are increasing with time. The coast of the Nile Delta has been designated as a vulnerable zone to a consequence of ongoing coastal processes and accelerated sea-level rise, and natural geographic low-lying deltas, in addition to human influences. And the action of the sand on the coast moves from the Nile as a result of dam construction in the river basin, as Fig. 6 (Stanley, 2005 & Ismail ,2010).

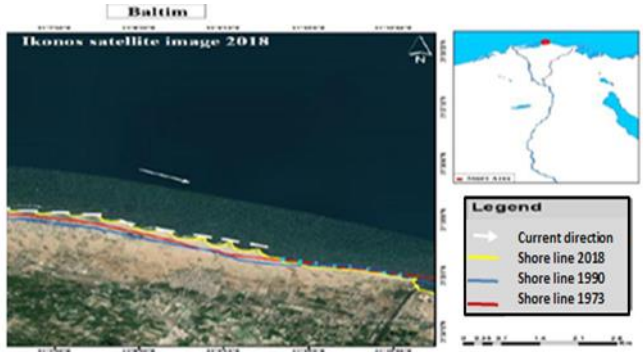


Fig. 6. Image monitored by GIS of the change of the central coast line during last 28 years.
Source: Stanley, 2008

The coastal zone is currently undergoing extensive change (erosion and accretion) due to mutually natural and human impacts. These changes caused damage to the coastal shore which caused demolition and loss of some buildings and agricultural land (Stanley& Warne, 1993) the research record the coastline of Baltim beach between 1973 and 2018 and the dynamics of transformation of the coastline was changed in the rates of regression and forward movement in the period before the construction of waves barriers (17 years ago) from 1973 to 1990 where increased the erosion to 0.59 km2 (erosion normal rate = 0.0348 km/year), however the accumulation decreased to 0.17 km2. at an approximate rate of 0.01 km2 / year after construction from 1990 to 2018 (28 years), and estimated the erosion decreased at 0.12 km2 (erosion rate is about 0.0043 km2 / year) (Salama et al, 2021). On the other hand, the accumulation increased to an estimate of 1.19 km2 (accumulation rate 0.0425 km2/year).... Where the coastline preserves its constant pattern of erosion and accumulation from 1973 to 2018, an overlay of GIS layers was obtained with IKONOS images that were taken in 2018 as shown in (Salama et al, 2021) as Fig. 7 .

Fig. 7. monitoring the changes that occurred on the coastline from 1900 to 2010
Source: Ismail, 2010

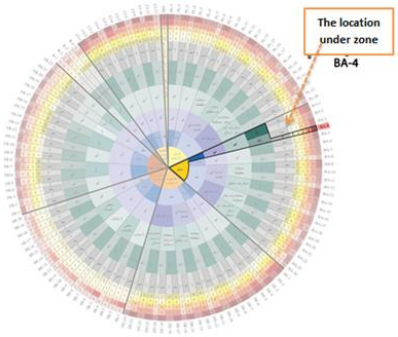
3.2. Risk Assessment in Mediterranean Coastal Line

By recording the characteristics of the Mediterranean coastline using costal hazard wheel app (CHW) where it is consider a simple technical tool that can be used in coastal areas and includes 131 general assessments of different coastal environments and a group of 655 sets assessments of risks, each one comes out to four different levels of risk (Appelquist, 2015) as Fig. 8. CHW facilitated analysis of a number of other inherent hazards including ecosystem disruption, gradual inundation, salt water intrusion, and flooding. CHW characterizes the coastal environment by considering geological layout, wave exposure, tidal range, flora and fauna, sediment balance and storm climate. CHW Application identified coastal erosion to present a high to very high influence on the Mediterranean coastline, with 45.7% of the coast exhibiting a low level of erosion hazard, 12.1% a moderate level, 12.6% a high level and 18.4%, a very high level of erosion hazard.

The risk assessment wheel has shown that more than one third of the coast is highly exposed to sea level rise, especially in the study area, the densely populated Nile Delta coast and highly exposed to sea level rise, which was formed from flat delta sediments with a length of 250 km along the Mediterranean Sea as a result The Nile River has been flooding since ancient times, and the water level data on the tidal range is between 16 and 88 cm and does not exceed 24 cm for monthly readings.... The maps and satellite data also show the main prominent parts located within the delta coast, which are subject to significant erosion. The sediment receives erosion of different degrees, as well as the absence of an engineered structure on the coast to disrupt the waves caused by long-shore sediment erosion in the study area.

The beach will be increasingly exposed to wave action, and significant losses could occur during coastal storms occurring after accelerated sea-level

rise. It would be expected that erosion, caused by the sea-level rise and coastal processes, of the loose sandy barrier.



Coastal classification layers	
Geological layout	Barrier
Wave exposure	Exposed
Tidal range	Micro
Flora/fauna	Intermittent marsh
Sediment balance	Surplus
Storm climate	No
Slope %	1.9

Coastal environment	
Coastal code	BA-4
Ecosystem disruption	Low
Gradual inundation	Low
Salt water intrusion	Moderate
Erosion	Moderate
Flooding	High

Fig. 8. The risk assessment degrees in the delta region - middle section coastal line in Al-burllus.
Analysis by researcher from CHW application. https://www.coastalhazardwheel.org/

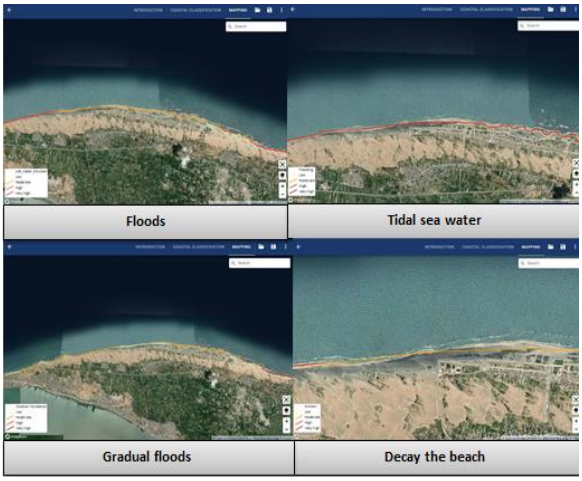
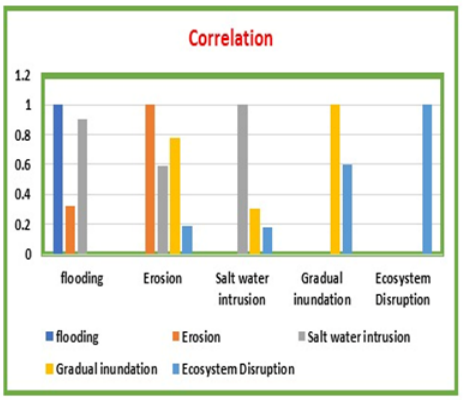


Fig. 9. Satallied Image for natural risk in coastal line From CHW website
Source: https://www.coastalhazardwheel.org

The analysis from Costal Hazard Wheel resulted that:

- The site is exposed to strong wave action.
- The tidal range is acceptable.
- The sediment percentage is relatively high.
- The site is not exposed to tropical cyclones.
- There is a moderate rate of salt water intrusion where Climate-induced changes in sea levels can lead to saline intrusion, affecting on the composition of building materials (Tanveer A., 2023).
- The rate of corrosion on beaches is moderate.
- The site exposure to floods is high.

According to previous analysis , the Delta coastal line and the natural agents of climate that affect strongly on each other (salt water , flooding , erosion, gradual inundation and ecosystem disruption) contribute in direct and indirect links of many phenomena appearing to the coastal shore and change its features. So the research used SPSS statics to analyze the different natural agents and found the co-efferent of correlation between environmental variables, where noticed that all variables moved in a positive direction and the results forward to record a high degree of correlation between salt water intrusion and both flooding and erosion and salt water intrusion and gradual inundation which means a danger agent and sever risk while the analysis clarify a Moderate correlation appeared in the relation between erosion and salt water intrusion and appeared a Low degree of correlation in the relation between flooding and erosion and the relation between salt water intrusion and gradual inundation and Ecosystem disruption as Fig. 10.



Correlation	flooding	Erosion	Salt water intrusion	Gradual inundation	Ecosystem Disruption
flooding	1				
Erosion	0.319838	1			
Salt water intrusion	0.904534	0.592385	1		
Gradual inundation	0	0.77675	0.301511345	1	
Ecosystem Disruption	0	0.183903	0.17978663	0.596284794	1

Fig. 10. The co-efficient of correlation betweewn varouis enviromental variables

4. RESULTS

4.1. THE CHALLENGES WHICH FACING THE LIGHTHOUSE

Al-Burullus lighthouse has faced many natural and human challenges since its establishment, as it was

exposed to many environmental risks which affect the structure and condition of the lighthouse, which change to weather factors and climate changes.

- •The area is considered one of the rainiest regions in Egypt because it is located between 48 and 35 km within the Mediterranean Sea, where rain falls in all winter months, starting from October, and its amount reaches 130 mm - 175 mm.
- Most winds are comes from north and northwest throughout the year, and south winds that increase in intensity in winter reach hurricanes that block the Mediterranean region during these months.
- The distance between the sea and the Burullus lighthouse when it was built was about a mile, and then the distance between it and the sea began to increase, due to the sediments of the floods from the Nile, even after the construction of the High Dam until the beach began to erode until the distance became 100 m, as Fig. 11.
- One of the most important weaknesses, which represent areas of threat to the site by invading the water in the event of a rise in sea level, which is a certain danger facing the area, which is one of the important risks that must be taken into account, as it illustrates the scenarios of sea level rise by 0.1 m to 1.9 m That large areas will be exposed to disappear completely under the sea.
- The lighthouse location on the Mediterranean shore far about 150 meters from the shore where the head of land enters about 35 km into the depth of sea that form a triangle shape which increase the salinity and humidity that affected on the structure of the lighthouse and increase exposure to the rust and corrosion from inside and outside, which threatens to collapse and fall at any time as Fig. 13.
- The site is exposed to risks of gradual disturbance to the ecosystem, flooding, gradual inundation, salt water intrusion, erosion and tidal impact.

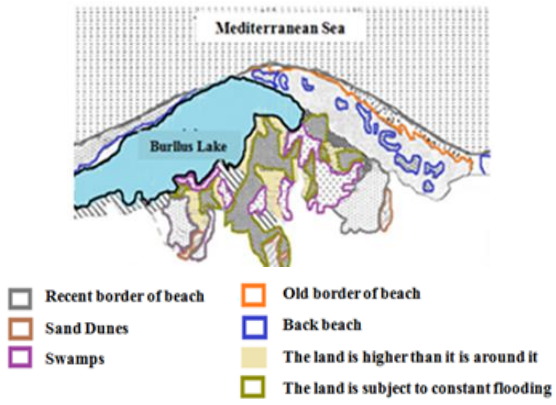


Fig. 11. Natural and morphological studies in the middle Section of the coast of the Mediterranean delta

4.2. RECORD THE TYPES OF DETERIORATION.

Steel buildings face fewer issues with deterioration and corrosion than concrete or wood, and can live more than other structures when properly built and maintained. Most steel buildings last anywhere from 50 to 100 years but it rapidly deteriorated when exposed to various physical and chemical problems as a result of being more affected by weather factors and can maintain a longer life when properly right maintained (USLHS, 2021) .

The lighthouse was subjected to many stages of neglect and deterioration over the course of its lifetime, as it was exposed to corrosion and rust and suffers from clogged pores and filling them with salt water and air immersed in brine that settled in the metal structure over the years. where consider the major cause of corrosion is chloride attack. it has entered the surface via the use of de-icing salts or from a chloride rich coastal environment as shown in Fig. 12, this process is called mineralization of metals (Leveille, 2010).

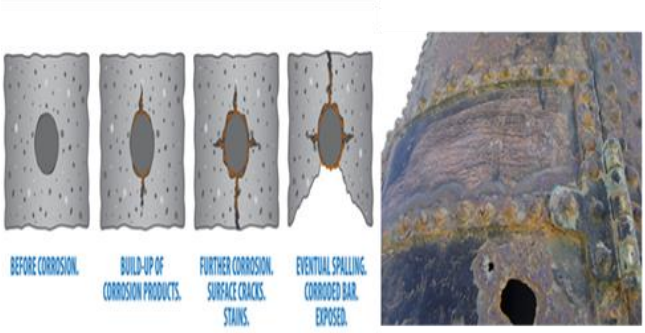


Fig. 12. Rust and corrosion stages in the section iron of lighthouse.
Source: analysis based on (Leveille, 2010)

- Many erosion types appeared in the ceilings and the body of the houselights, where the iron was subjected to erosion between the granular cells that make up the material (uniform erosion), which is called the corrosion between crystals on the boundaries of the metal grains. (Lyon, 2011). Then the erosion is transformed by careful dissociation of impurities and alloying elements at the grain boundaries (irregular erosion). Then the erosion begins to activate the intergranular corrosion driving force, it is the difference between the electrode potentials of the grain boundaries and the grain itself, which forms a galvanic cell (galvanic erosion) in the presence of an electrode, as in Fig. 13.

Fig. 13. Types of corrosion in the structure of the lighthouse: 1- Uniform corrosion, 2- irrugular Corrosion, 3- Galvanic Corrosion, and 4- Stress Corrosion Cracking (SCC).

- Weak bonds between metal and concrete, causing cracks and collapse in areas at risk, which led to tendencies in the body of the lighthouse and the internal staircase being unsafe as shown in Fig. 14-a.

- The high level of groundwater behind the building, which has a bad effect on the surrounding walls and external walls, as shown in Fig. 14-b.

- The dust road leading to the lighthouse is unpaved and difficult to use, as Fig. 14-c.

- The restoration process was carried out with inappropriate materials and due to many cracks appeared in ceils and walls, as shown in Fig. 14-d.

Fig. 14. Many forms of deterioration
Researcher 2023

5. ACTION PLAN: "INTERVENTION STANDARDS FOR PRESERVING THE LIGHTHOUSE".

Conserving historical buildings on the coastal line involves a multifaceted approach that considers the unique challenges posed by the maritime environment. Climate risk is considering the major risks that threaten the lighthouse. The research seeks to assume a strategy for rescue the lighthouse through take a set of measures and procedures to confront the risk of climate change to protect and save the lighthouse , and taking all green measures towards sustainability criteria, and managing the cultural and natural resources …. The intervention process should be done in the framework of international charters to reserve a historical image of the site as well as raise the efficiency of using the place (Maynard, 2019). The intervention plan aims to promote the integration of the various components of the lighthouse or with the surrounding environment as mentioned in "Nara charter" for authority and Venice charter 1964… the strategy explore the intersection of climate change and cultural heritage management, emphasizing the importance of adaptive strategies. This includes the development of conservation plans, community engagement, and the integration of climate considerations into archaeological practice (as following some key elements and strategies for developing conservation plans for such structures:

5.1. CONSERVATION AND ARCHITECTURE LEVEL

The increasing frequency and intensity of storms exacerbate the vulnerability of coastal archaeological sites from previous analysis of the impact of various climate factors that affect both the physical structures and the surrounding landscape, emphasizing the need for adaptive strategies and emergency preparedness to save the site and considering the following [30].

Preserve the original shape of the site and all components (lighthouse and surrounding rooms) for preserving on the visual image of the place [31].

- Restoring the body of the lighthouse, removing the rust, painting the structure with suitable electrostatic materials that face the atmosphere and climate changes, and repairing the holes in the body of the lighthouse.

- Reinforced and strengthened the body of the lighthouse to keep it from the danger of its tendencies and consolidate the cracked beams (Articles 4–5 of the Technical Charter).

- Reconstruction of the demolished rooms and surrounding services; repair of the ceiling where they are slackening; filling the cracks; and treating the wall dampness.

- Making reinforcements that maintain the stability of the lighthouse, removing the demolished parts of the surrounding buildings, and rebuilding it to give it the same old character (Article 11 of the Venice Charter).

- Redesign the urban spaces and landscape around the houselights and paving the destroyed road and the entrance of site and creating a seating area as an extension on the beach, and design a parking zone to serve the visitors of the lighthouse (Article 13 of the Technical Charter).

- Rehabilitation standard is an important intervention to relief the site of proposed activities within the framework of geographical and spatial studies and climatic conditions in a manner that is commensurate with the nature of the place and contemporary urban

needs, through: raising the functional, environmental and social performance of the lighthouse by adopting a function and activities that contribute to a community service.

- Rehabilitation policy combines reuse the site by original function and adaptive use with the surrounding framework by emphasizing the importance of lighthouse as a permanent resource for development and iconic landmark in the surrounding urban from the other side contribute to demand the contemporary needs of visitors of place (Article 13 of the Technical Charter).

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Rehabilitation policy combines reuse of the site by original function and adaptive use with the surrounding framework by emphasizing the importance of lighthouses as a permanent resource for development and iconic landmarks in the surrounding urban ... from the other side, it contributes to the contemporary needs of visitors of place(Article 21,Burra Charter1979 AD), which states that rehabilitation is acceptable when it has the least impact on the value of the cultural site (ICAHM, 1990) and may include the addition of services New, new use, or a change in the protection of the site while ensuring the least change to the fabric surrounding the site by suggesting converting the site into a recreational culture and touristic center , so a place was designed as an art gallery inside the inner courtyard for displaying the historical photos and hosting an event such as holding workshops for technical training, seminars and permanent and temporary exhibitions as well as develop a variety of activities and services area as a restaurant equipped to serve food and soft drinks, in addition to an outlet for selling souvenirs and books (Article 13 of the Venice Charter).

- Equipping an appropriate sound and lighting system commensurate with the history of the place and its archaeological value.

- Providing the lighthouse with security and protection elements through the main gate and the presence of the necessary equipment from the surveillance camera.

5.2. URBAN AND COMMUNITY ENGAGEMENT

The spatial analysis of main buildings and land use surrounding the site are varied between camping , vacant land and services use …the research records the opportunities of the site and suggests many solutions that could improve the site and surrounding urban.

- Presence of vacant lands around the lighthouse that can be used as an open space around the building. This provides opportunities to establish many youth camps. There is a Cairo University camp in front of the lighthouse, as Fig. 15.

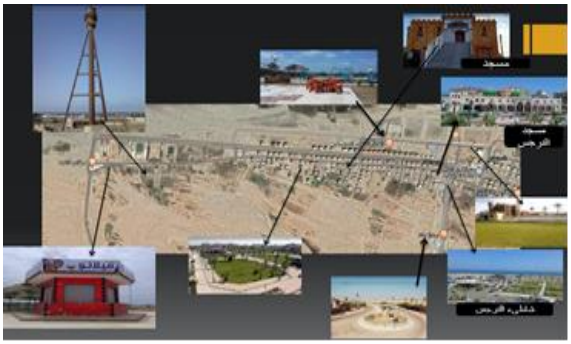

Fig. 15. shows the land use surrounding the house light

- Prompt the role of the lighthouse as an iconic landmark in surrounding areas.

- Make a connection between the site of the lighthouse and the village of "Sheikh Mubarak".

- Create an axis linking the international coastal road to the lighthouse and the heart of the village of "Sheikh Mubarak", which can provide the lighthouse with the necessary services and facilitate the movement of its connection with the village services and the transportation of visitors and trips of school children's, as Fig. 16.

*Fig. 16. Creat a connection link between the site of the lighthouse and the village of "Sheikh Mubarak – **Researcher 2023***

Involve local communities in the conservation process. Educate residents about the importance of preserving cultural heritage, and encourage their participation in monitoring and maintaining the historical lighthouse.

- Collaborate with experts in coastal engineering, architecture, and conservation to ensure a comprehensive and well-informed approach. Interdisciplinary collaboration can bring together

diverse perspectives and expertise.

- Stakeholders can work towards preserving coastal historical buildings in a sustainable and resilient manner, considering the challenges posed by climate change and coastal dynamics.

5.3. Enviromental Level and Emergency Preparedness

Coastal erosion is a major threat to archaeological buildings. As shorelines recede, structures are exposed to the erosive forces of wind and water, leading to the loss of cultural heritage where the proximity of the lighthouse to the sea, as the distance between them does not exceed 150 meters. Therefore, a future extension can be made linking the sea and the lighthouse. Strategies for mitigating erosion, such as protective barriers and site relocation, are explored.

According to SPSS analysis and the risk assessment, which appear the urgent measures we should take to protect the site from the effects of climate change, and the arrangements to stop the decline of the beach line in the coastal zone around the lighthouse that suffered from severe erosion factors, then protecting plans for confronting the decay of beach phenomenon of coastal erosion and beach erosion by placing concrete barriers on the beach and making a series of submersible barriers to protect the Cornice area in front of the lighthouse, especially after the erosion of large part of the sandy area, and the high waves reached to far distances, especially in the season of (Al-Nouha wind) in the winter.

- Develop and communicate emergency preparedness plans to address the immediate threats of severe weather events. This includes evacuation plans for artifacts, emergency stabilization measures, and coordination with local authorities.

- Equipping an appropriate sound and lighting system commensurate with the history of the place and its archaeological value.

- Providing the lighthouse with security and protection elements through the main gate and the presence of the necessary equipment from surveillance camera.

6. Conclusion:

Climate change is considering the main influencing factor in the conservation process, so we should be more cautious when dealing with historical buildings. The research emphasizes the urgent need for proactive measures to safeguard the lighthouse as an example of a coastal archaeological site in the face of climate change. These measures involve a combination of predictive modeling, conservation strategies, and interdisciplinary collaboration to ensure the preservation of valuable cultural heritage for future generations.

- Rising sea level, may increase coastal erosion rates and represent a threat to the many archaeological sites located close to the sea (Friesen 2015) Sea level change, land subsidence, have been affecting on the coastal shore line of the Mediterranean Basin for thousands of years. the analytical studies of these processes are predicting their effects of these interpretation .

Nevertheless, enviromental indicators in archaeological site , including coastal lines, play a crucial role in determining the efect of climate changes parameters as prime indicators of areas that are likely to be further affected by environmental processes in the near future in many archological site

The strategy include an urgent measures to save this region from sea level rise include Create dunes along backshore of beach; includes sand fencing to induce settling of wind-blown sands and erosion of beaches.

Author Contributions

Conceptualization. Methodology, collecting the data, analysis, writing original draft, preparation, writing, review and editing.

Ethics Declaration:

The authors declare that they have no conflicts of interest regarding the publication of the paper.

Funding:

This research received no external funding" and the published included "The APC agreement.

Conflicts of Interest:

I declare that there is no conflict of interest that may be perceived as inappropriately influencing the representation or interpretation of reported research results and the Authors follow the to the Instructions of the journal and make manuscript complies with the Ethical Rules applicable for this journal.

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