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Assessment of Embodied Energy/ U-Value in Historic Buildings of Karachi-Pakistan

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Abstract

The benefits of reusing historic and existing buildings versus those of constructing new buildings are frequently discussed considering economic, cultural, and design values. If those discussions are expanded to include environmental impact, one must address the topic of embodied energy. Due to the recent focus on sustainable construction practices; conservationists have explored the benefits of building conservation in relation to embodied energy calculations. Such studies are popular in international market and became important ground for expanding restoration practices. In our local context it is comparatively a newer domain.

Different methodologies have been devised by Advisory Council for Historic Preservation (ACHP), in year 1979, for assessing the embodied energy calculations in historic structures. For performing the respective study, inventory model of assessment has adopted. The focus of this study is "to provide practical guidance on how to calculate embodied energy/ u-value in historic structures of Karachi and promote the concept of adaptive reuse from the environmental perspective".

"If more widely and comprehensively used, embodied-energy assessment can be a benefit to preservation and sustainability advocates alike."

Mike Jackson

Keywords

Embodied Energy; Historic buildings; Preservation; Adaptive Reuse.

1. Introduction

The benefits of reusing historic and existing buildings versus those of constructing new buildings are frequently discussed considering economic, cultural, and design aspects. If those discussions have expanded to include environmental impact, one must discuss the topic of embodied energy. Embodied energy is the sum of all the energy required to extract, process, deliver, and install the materials needed, to construct a building. Such studies are getting popular in international market and became important ground for expanding renovation and restoration practices. It is acknowledged that embodied energy is a complex and relatively new area of research.

This study is an attempt to combine domains of preservation and embodied energy; so that a stronger argument for environmental benefits of building reuse can be made. In doing so different areas have to be dealt parallel apart from just devising guidelines. One is the making of comprehensive database of building materials' embodied energy, for the local context. Due to time constraints, embodied energy of only sample building materials has incorporated in this research paper.

2. Background

Historic preservation in the United States evolved from a local movement and desire to preserve sites associated with national identity. With the 1966 National Historic Preservation Act, cooperation between local and federal governments was established (U.S. ICOMOS, 2009). "Shortly after, in the 1970s, the country faced two energy crises—each prompted by oil embargoes in oil-producing states. As a result, energy prices increased, the United States experienced shortages of gasoline and fuel oil, and became acutely aware of the country's dependency on foreign oil. These factors produced a push for energy conservation nationwide with the formation of the Department of Energy in 1977 and citizen participation through reductions in air travel, reduced highway speed limits, and to turn down thermostats six degrees - as just a few measures. The preservation field responded to these threats with a number of initiatives including, in 1978, *Preservation Briefs 3*— "Conserving Energy in Historic Buildings" by the National Park Service." (National Park Service, 1978). This initiative laid the groundwork for the embodied energy argument of retention of existing buildings rather than replacement with new buildings. Embodied energy became the focal point for the preservation field as an argument, focusing on all the energy that has existed within structures.

This study explores energy's role in the preservation field, specifically, how energy value has determined in historical structures and provide strong justification for the reuse of historic buildings. It has provided a rationale that historic buildings would be used as an asset rather than liability.

3. Embodied Energy: Definition and Interpretation

"Buildings are constructed with a variety of building materials, each of which consumes energy throughout its stages of manufacture, use, deconstruction and disposal. Similarly, each building consumes energy during its life cycle in stages, such as raw material extraction, transport, manufacture, assembly, installation as well as its disassembly, demolition and disposal. Post construction phases, such as renovation and refurbishment, and final demolition and disposal also consume energy. The energy consumed in these life cycle stages of a building is collectively interpreted as **embodied energy**. The process (or a boundary) which -to- includes the extraction of raw materials until the end of the products' lifetime known as 'Cradle Grave'. **Embodied energy** is commonly specified as 'Cradle-to-Gate'; an energy which includes all primary form of energy until the product leaves the factory gate. The final process is 'Cradle–to-Site'; this includes all energy consumed until the product (material) has reached the building or site."(Dixit et al.,2012)

3.1. Significance of Embodied Energy

Until recently, the emphasis of energy conservation research was on the operational energy of a building, while embodied energy had assumed to be relatively insignificant. However, current research has invalidated this assumption and found that embodied energy accounts for a significant proportion of total life cycle energy. Operational energy conservation may be accomplished with readily available energy efficient appliances, advanced insulating materials and the equipment of building performance optimization. For example, an increase in the number of Energy Star labeled home appliances in the United States could reduce operational energy gradually. Embodied energy, however, can only be reduced if low energy intensive materials are selected at the initial stages of building design.

3.2. Embodied Energy in Historic Structures

Historic buildings are a valuable, existing resource. Many older buildings had designed to take advantage of natural daylight, ventilation and solar orientation and utilize durable materials. They had designed before an era that relied on mechanical heating, cooling and shading devices, and utilized simple design solutions that kept human occupancy and comfort levels high. In addition, historic structures often were constructed with traditional, durable materials such as stone, timber, and glass. When properly maintained, these materials can have a much longer lifespan. However, these are resources that our culture tends to disregard as a valuable commodity. Demolition and rebuilding takes vast amounts of energy and resources depletion. Preservation and reuse of historic buildings reduces resource and material consumption, puts less waste in landfills and consumes less energy than demolishing buildings and constructing new ones. Over the past decade, advancement in high performance or "green" buildings has tremendously increased, but mostly they have focused on new construction. Preservation and reuse of historic buildings has not always remained prime consideration of the 'green' movement agenda. However, this is changing.

A number of researchers have suggested that embodied energy should be taken into account in valuing historic buildings. For example:

"It has been argued that historic buildings are highly beneficial within the built environment by providing an enhanced quality of life and a deeper 'sense of place' for residents" (Pettit, 2009). In another research, author has reviewed the development of embodied energy assessment in buildings and concluded that "it should be another factor to be considered in sustainable design especially for historic preservation. He appealed for better green-building rating systems which were suitable for historic buildings and which promoted the principle of re-use of buildings and materials" (Jackson, 2005). Another working organization has suggested that "life cycle analyses of the building fabric need to be considered as part of the conservation process to attain optimum energy performance outcomes." (The Heritage Council of Victoria, 2009a).

Internationally the importance of embodied energy has evaluated with in different domains of construction industry including conservation. Unfortunately its benefits have never been explored in local restoration exercises. Policies or guidelines have never formalized in the field of conservation or construction industry itself in the native context.

4. Historic Core of Karachi

Historic core of Karachi city comprised of structures that had built during the British Annexation. According to available records, there existed about 19 historic quarters, in which more than 1000 historic buildings have identified and enlisted as protected heritage under Sindh Cultural Heritage Preservation Act 1994. The Sindh Cultural Heritage Preservation Act is applicable to the entire province of Sindh. However, for Karachi and its historic quarters an additional security has provided through the Sindh Building Control Authority Regulations - 2002 (formerly known as Karachi Building and Town Planning Regulations – 2002) in which a separate chapter has included, which deals with the "historic areas" of the city. Both the authorizing institutes are equally responsible for the upkeep of historic structures, existed in the city of Karachi. However, at present, both of them seem incapable in fulfilling their responsibilities. Present regulations briefly include some definitions, right for designating a building historical or heritage status, emphasis on informing the owner, and methods for getting approval for de-listing or demolitions. Regarding the concept of embodied energy evaluation, adaptive reuse strategies or methodologies for historic structures preservation, nothing has added in the present legislation. Studies related to building materials' embodied energy, have never performed. It is so because this aspect has never considered in earlier time; reason being, lack of awareness and information. Embodied energy is totally a new domain for native context and contains immense potential to get explored.

Regarding the status of the existing historic structures, most of such buildings have built of limestone as their prime construction material; following the technique of **"wall bonded with mortar".** Roofing of most of these structures are either timber pitched style or flat roof. Exposed limestone is evident in most of the historic buildings while internal finishes are usually of limestone plaster. Structural technique of historic buildings of Karachi is load bearing; erecting thick walls with usually low-rise construction. (i.e., maximum Ground + 3).

5. Sustainability and Preservation – A connection

"Detailed review of where modern sustainability grew from reveals that a credible model to account for the overall energy benefits with retention of historic buildings have been needed since preservation became policy in 1966, internationally. The initial need to measure energy capital in buildings arose from the two energy crisis in the 1970s, with a second need to address the sustainability goals of the 1990s/2000s. Both responses measure overall energy efficiency of historic buildings by attempting to account for the "energy capital."(Menzies, 2011)

The Advisory Council on Historic Preservation introduced the measurement model in 1979, for introducing the benefits of preservation of historic structures over new constructions.

5.1. Context of Karachi

In our local context, progress in the field of preservation is very slow. Different administrative bodies that are responsible for the upkeep of historic buildings of the city have not performed their duties accordingly. The aspect of embodied energy in old and new structures has never considered. Regulations have not addressed this issue and hence not prepared any legal framework accordingly. Lack of technical expertise, lack of awareness and limited information are key factors in declining the overall progress. Administrative agencies are also not capable enough to cope up with the challenge due to lack of expertise and up to date information.

Looking at the in-depth evolution of both sustainability and preservation in international market and comparing this growth with local context; it is crystal clear that we are far more behind. (Refer Table 1) It is high time to adopt and ascertain internationally recognized practices at local level. Need is to take immediate measures in this direction and formulated the methodologies of embodied energy calculation, considering the local context. Following comparative table, give a brief overview on the legislative modules formulated and practiced over time.

Table 1. ComparativeTimeline (courtesy by the Author)

Sustainability Evolution	Historic Preservation Evolution	Local scenario
1962: Silent Spring, by Rachel Carson	1966: National Historic Preservation Act	
1970: First Earth Day Environmental Protection Agency Formed	1971: Executive Order for the Protection and Enhancement of the Cultural Environment	
1972: The Limits to Growth, Club of Rome Report	1978: Preservation Briefs 3 – Conserving Energy in Historic Buildings	Late 1973: Islamic summit conference, Give Rise to Oil crises in international world
1973: OPEC oil embargo	1979: Advisory Council on Historic Preservation report released	1975: Antiquities Act (covering archaeological sites only)
1974: Federal Energy Administration Act signed	1981: New Energy from Old Buildings: Book Published	1979: Sindh Waqf Properties Ordinance (covering shrines, tombs and mausoleum only)
1977: The Department of Energy Organization Act signed	1994: Guiding Principles for Sustainable Design, The National Park Service	1994 Sindh Cultural Heritage Preservation Act

Continued on next page

Table 1 continued

Sustainability Evolution	Historic Preservation Evolution	Local scenario
1979: Second oil crisis begins, Iranian Revolution	1998: Sustainable Design and Historic Preservation, Sharon C. Park	2002: Karachi Building & Town Planning Regulations
1987: Our Common Future, Brundtland Commission report	2004: Association of Preservation Technology formed Technical Committee on Sustainable Preservation	2012: Pakistan Green building Council (An independent body formed)
1993: U.S. Green Building Council established	2009: Preservation Green Lab formed, The National Trust for Historic Preservation	2017: Pakistan Green building Council organized two conferences. In which a committee has formed for devising practical guidelines by 2018.
1997: The Kyoto Protocol 2002: UN World Summit on Sustainable Development 2007: Intergovernmental Panel on Climate Change Fourth Assessment Report 2013: President Obama commits U.S. to 17% reduction below 2005 greenhouse gas emissions levels by 2020	2012: Further Research began	

6. Embodied Energy and the Advisory Council on Historic Preservation (ACHP) Model

The response of the two oil crises leads towards the formation of National Historic Preservation Act and an Advisory Council on Historic Preservation in the late 1970s. This council has determined a credible calculus for the overall energy benefits of existing buildings. “The identification of embodied energy as a quantitative measurement to account for the energy capital stored in historic buildings was a conservation associated response, aligning with conservation synergies that were evident across the nation. Embodied energy exploits the value of commitment to resources that already exist.” (Booz, Allen & Hamilton, Inc. 1979) This result, a comprehensive published research named “Assessing the Energy Conservation Benefits of Historic Preservation: Methods and Examples”, to equate embodied energy in historic buildings, provided a tool and argument for the preservation field.

7. Advisory Council on Historic Preservation Model

In 1979, the Advisory Council on Historic Preservation published *Assessing the Energy Conservation of Historic Preservation: Methods and Examples*, instituting the term and concept of embodied energy for the preservation field. The concept that historical buildings have energy embodied in them from initial construction was the driving force of development for this report. This report introduced a standard into the industry that is still put into practice successfully. Mathematical equations were developed to compute how much energy is embodied within existing structures by computing embodied energy in an equivalent structure. The report states, “This study provides the Council with a tool for determining the total worth of threatened properties, and, in particular cases, whether retention and continued use are in the public interest.” (Booz, Allen, & Hamilton, Inc., 1979). The report has defined a push towards energy valuation and energy conservation crisis. This pursued to fill that call by strongly stating, “Energy conservation is an important concern, and one that needs careful consideration in decisions affecting the built environment.” (Booz, Allen, & Hamilton, Inc., 1979).

The methodology of the report looks at embodied energy of materials and construction for existing, rehabilitated and new construction.

The first model is the building concept model. This model is the simplest and least detail-oriented and considered least accurate. The report states that “results are generally correct but not precise.”(Booz, Allen, & Hamilton, Inc., 1979). This model states that embodied energy is measured by assessing the building type and gross square footage. A single calculation is conducted to provide a result. The concept model formula is expressed as:

$$Embodied\ Energy\ Investment = Gross\ floor\ area\ of\ historic\ building\ x\ invested\ energy\ per\ square\ foot\ specific\ to\ the\ building\ type\ from\ Exhibit\ 1 \tag{1}$$

The second model is the building survey model. This method is an intermediate model compared to the concept model and is deemed to “be the most useful.” (Booz, Allen, & Hamilton, Inc., 1979). This model can provide refined results with some additional data over and above that needed for the building concept model. Embodied energy is determined using a rough survey of primary material quantities and applying their respective energy values. The survey model formula is expressed as:

$$Embodied\ Energy\ Investment = \{Energy\ used\ in\ construction + Energy\ invested\ in\ seven\ primary\ materials'\ category\ i.e.,\ Exhibit\ 4\}\ (for\ Exhibit\ 4\ please\ refer\ table\ 2\ below) \tag{2}$$

Table 2. *Exhibit 4: Embodied Energy of Primary Materials (Courtesy of ACHP Energy Conservation and Historic Preservation Report 1979)*

S.No	Material Category	Embodied Energy per Material Unit
1	Wood products	9000Btu
2	Paint products	1000Btu/sq.ft (450sq.ft/gal)
3	Asphalt Products	2000Btu/sq.ft
4	Glass products	15000Btu/sq.ft – windows
		40000Btu/sq.ft – plate
5	Stone & Clay products	96000 Btu/cu.ft - concrete
		40000Btu/cu.ft. - brick
6	Primary Iron & Steel products	25000 Btu/lb.
7	Primary Non-ferrous products	95000 Btu/lb.

The third and final model is the building inventory model. This model is quiet complex and provides the most precise results. Embodied energy is determined by conducting a detailed inventory of material quantities, and an analysis of energy embodied in each material type. The inventory model formula is expressed as:

$$Embodied\ Energy\ Investment = \{Energy\ used\ in\ construction + Energy\ Invested\ in\ Materials\ (include\ all\ materials)\} \tag{3}$$

This report also includes three case studies whose embodied energy had been calculated following the three different models as mentioned above.

8. Sample Case-Study

To strengthen the respective research, a church building has taken as sample case study for performing detailed embodied energy calculations. Excel sheets have developed to perform relevant computation following the inventory model formulae of ACHP Model. The respective example is a listed historic property of Karachi under the Sindh Historic Building Preservation Act 1994.

9. Case Study: Rose United Pentecostal Church, 1940

(Plot No: 245; Jamshed Quarters at M.A. Jinnah Road Karachi-Pakistan)

9.1. Building Introduction

The Rose Church is located on main M.A. Jinnah road, near Numaish roundabout Karachi. It is a rectangular plot covering an area of 9880 square feet. Over the years several minor alterations (mostly as per need) have taken place within the historic structure; though its function remains the same. Church structure is surrounded by high boundary walls and limited people have known about this church. The building followed the hybrid style of construction which was common, during the British annexation. It is made up of limestone blocks with lime-plaster finishes. The church consists of meeting area, office area and bedroom area apart from the worship hall and services spaces. Metallic spiral staircase also added to access the roof area. The church building incorporated both types of roofing i.e., straight roof and pitched roof. The overall condition of the building is quite good. Plan and Elevations of the building have drawn on-site initially and later digitized (Refer Fig 1, 2, 3)

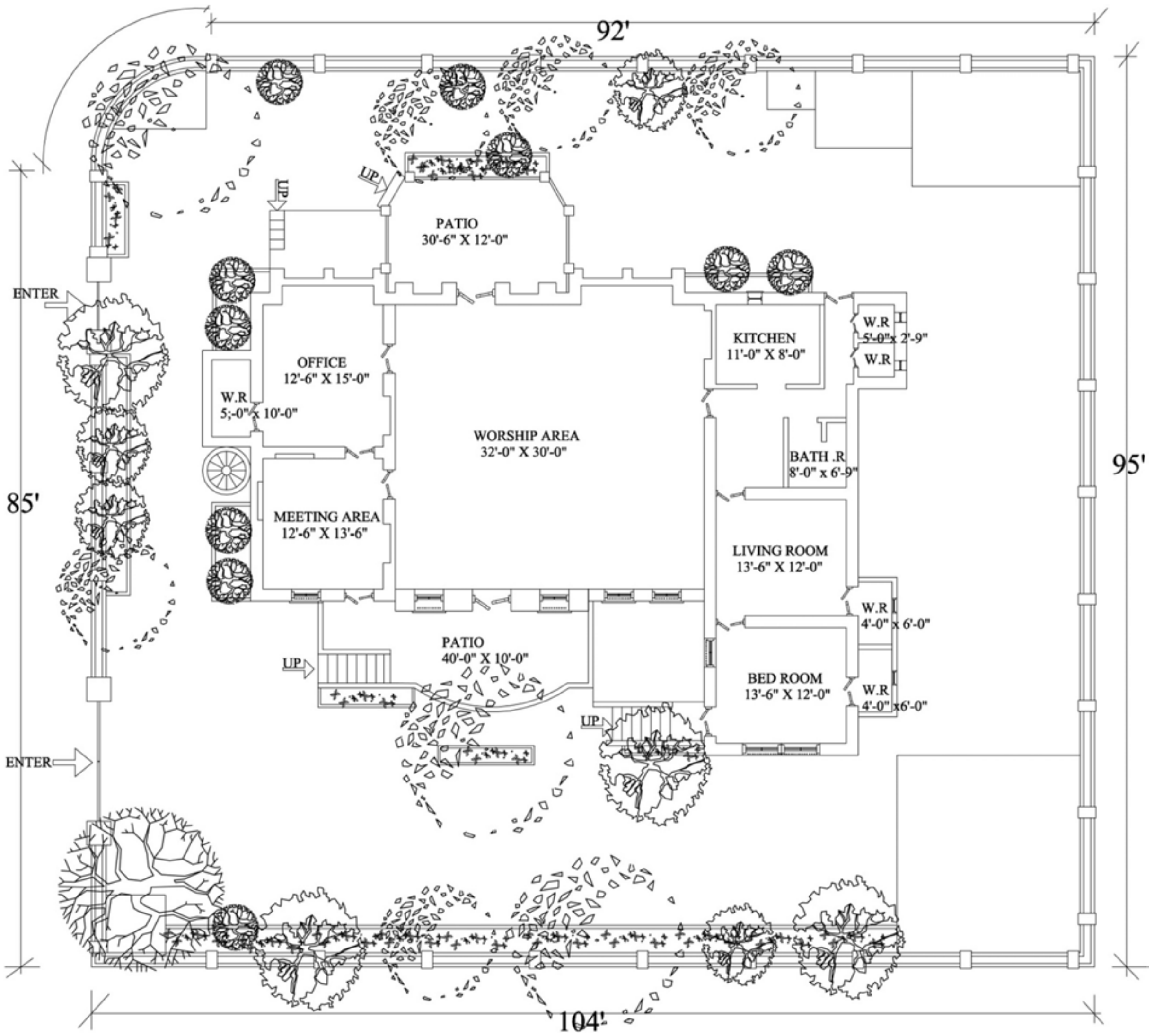

Figure 1. Church Plan (Courtesy by the Author)

Figure 2. East Elevation (Courtesy by the Author)

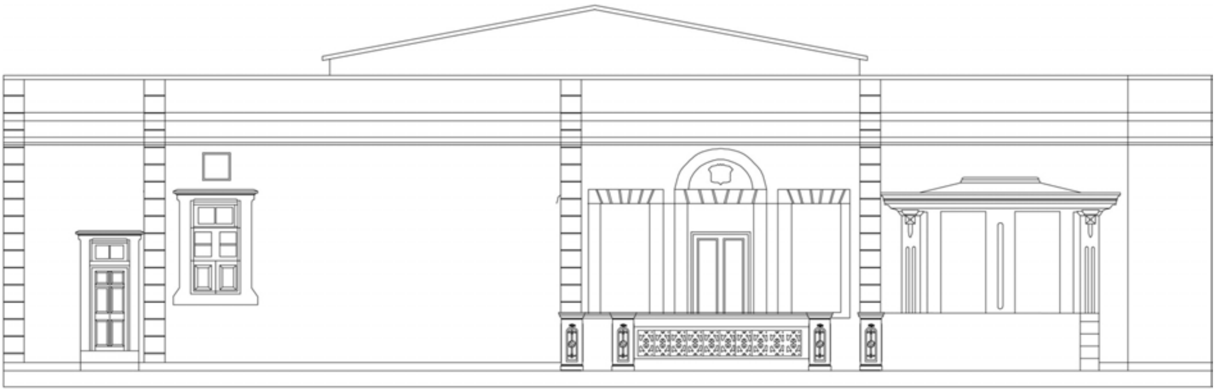

Figure 3. West Elevation (Courtesy by theAuthor)

9.2. Building Material:

Major building material used in construction of Rose United Pentecostal Church building is Limestone. Construction technique utilized for erecting this building is “using binding material”. Lime is the prime binding material; it is also used as internal and external finishing material. The technique of construction is **load bearing,** hence wall thickness of this building is about 1.25 feet. Regarding roofing style this structure has combination of straight and pitched roofs. Worship area has pitched roofing while other parts of building have straight roof. Doors, windows are of timber. Spiral staircase added in this building for accessing the roof. A complete list of building materials constituted in this structure has mentioned below. (Refer Table 3). The energy used in this study has provided by Geology Department of University of Karachi, who is currently involved in making comprehensive database of different building materials’ energy.

Table 3. Embodied energyand Density of relevant building materials (Courtesy by Department of Geology,University of Karachi)

Material	Database Embodied Energy MJ/kg	Density (kg/m3)
Limestone	0.85	2180
Lime/ Gypsum Plaster	1.80	1120
Terrazzo tiles	1.40	1750
Clay tiles	6.50	1900
Plywood planks	15.00	540 - 700 (taking 600)
Bitumen (membrane)	51	no density
Timber (general - excludes sequestration)	10.00	480-720 (taking 550)
Timber frame	230 - 490	480-720 (taking 550)
Glass	15	2500
Iron rods	25	7850
Water-borne paint	59.0	no density
Concrete (1:1.5:3 ; in-situ floor, slab, structure)	1.11	2400

9.3. Research Procedure:

The data has gathered from a site visit performed during the last semester of master studies; included a basic site visit to collect building dimensions, identification of observable materials and making preliminary on-site sketches. Later these drawings have redrawn on AutoCAD software for finer look. These drawings have rechecked on site, during the present session of study after special permission. At present, building used as **church**. The inventory method has used for the calculation of embodied energy. Regarding system boundary consideration “cradle to cradle” approach has considered which is considered to be the most appropriate boundary for historic structure.

9.4. Worksheets:

Worksheets include list of area calculations that are relevant to the embodied energy computation. These include area calculations of church building plot, church buildings’ wall, doors, windows and ventilators in square meters. Those areas were than transformed into cubic meter volumes. These cubic meter volumes have further multiplied with density and mass of the respective materials. Further they have multiplied with respective materials’ energy in order to get the embodied energy of the whole building envelope. Similarly, U-values of church building’s walls, doors, windows, ventilators, pitched roof area and straight roof areas have calculated. U- value of all four sides elevations have calculated. All these calculations have performed on excel worksheets. (Refer Figure 4, 5 and 6)

Embodied Energy Calculation For Church Project

S.No	Components of Church with Material Specification	Area in m2	Volume in m3	Density (kg/m3)	Mass in kg	Mass in kilotons	Energy in MJ/Kg(megajoules energy needed to make a	Total Embodied Energy(MJ/kg	Total Embodied Energy (MJ/ktons)
1	Limestone block wall (1.25 ft thick)	1014.53	1268.16	2180.00	2764580.63	2.76	0.85	7642906.03	2.350
2	Plaster over Limestone block wall, applied both sides of 0.25 ft thickness each	2029.05	126.82	1120.00	142033.50	0.14	1.80	255660.30	0.256
3	Paint on walls both sides (water borne)	2029.05	no thickness of paint	–	–		59.00	119713.95	0.000
4	Flooring is of Pigmented Cement tiles; similar to that of terrazzo tiles; (2 inches or 0.1667 ft thick)	247.25	41.22	1750.00	72129.74	0.07	1.40	100981.63	0.101
5	Doors made up of timber (2 inches or 0.1667 ft thick)	36.72	6.12	550.00	3366.67	0.00	10.00	33666.73	0.034
6	Doors frame (2 x 7 inches) or (0.1667 X0.58 ft) are made up of timber (total 17 doors)	0.15	1.18	550.00	650.89	0.00	10.00	6508.90	0.007
7	Windows made up of double glazed 4 MM thick glass (total 2 inches or 0.1667 ft thick)	12.96	2.16	2500.00	5401.08	0.01	15.00	81016.20	0.081
8	Windows frame around glass is of timber having size (2 x2 inches or 0.1667x0.1667 ft thick) (total 8 windows)	0.02	0.08	550.00	44.02	0.00	10.00	440.18	0.000
9	Window fixed frame (3 x 7 inches) or (0.25 x0.58 ft) are made of timber (total 8 windows)	0.10	0.42	550.00	229.68	0.00	10.00	2296.80	0.002
10	Ventilators composed of 4 MM thick glass	1.62	0.01	2500.00	16.20	0.00	15.00	243.00	0.000
11	Ventilators frame around glass is made up of timber (2 x 2 inches or 0.1667x 0.1667 ft thick) (total 6 ventilators)	0.02	0.02	550.00	12.38	0.00	10.00	123.80	0.000
12	Ventilator fixed timber frame (2x4 inches) or (0.1667x 3 ft)made of timber (total 6 ventilators)	0.27	0.41	550.00	222.79	0.00	10.00	2227.95	0.002
13	Pitched roof is found on worship area. It composed of clay tiles (khapril), bitumen and plywood plancks					0.00			0.000
a	Clay tiles/ Khapril (8 MM thick)	86.40	0.69	1900.00	35873.28	0.04	6.50	233176.32	0.233
b	Bitumen coating/ Geo membrane	86.40	no thickness of bitumen			0.00	51.00	4406.40	0.000
c	Plywood Plancks (5 MM thick)	86.40	0.43	600.00	259.20	0.00	15.00	3888.00	0.004
14	Straight roof of concrete (6 inch thick)	95.30	47.65	2400.00	114358.50	0.11	1.11	126937.94	0.127
a	Steel reinforcement 3/8" dia bars running all over the straight roof inside concrete forming 4 inch thick layering of steel (taking stainless steel MJ energy)	35.74	107.21	7850.00	841607.09	0.84	56.70	47719121.77	47.719
b	Plaster on straight roof with cement mortar (1:3) and on 3 feet high parapet	95.30	285.90	–	–	0.00	1.33	380.24	0.000
c	Parapet wall of lime stone block 3 feet height	95.30	285.90	2180.00	623253.83	0.62	0.85	529765.75	0.530
15	Spiral staircase leading to midloft , made up of Mild steel.they are 2 in numbers. Size = (3 x 0.041) ft and height = 15.25ft	0.02	0.34	7800.00	736.04	0.00	25.30	18621.92	0.019
15	Foundations are of limestone block (1 feet thick) also and its about 7 feet deep	247.23	1730.61	2180.00	3772729.80	3.77	0.85	3206820.33	3.207
16	Boundary Wall made of limestone blocks of 1 feet thick and its about 10 feet high	889.20	8892.00	2180.00	19384560.00	19.38	0.85	16476876.00	16.477
17	0.25 ft thick Gypsum plaster is applied on both sides of the boundary wall	358.20	22.39	1120.00	25074.00	0.03	1.80	45133.20	0.045
18	Paint on boundary walls both sides (water borne)	358.20	no thickness of paint				59.00	21133.80	0.000
19	Transportation of limestone blocks is from the former "quarries quarter" that is present day PECHS society area; located approximately 1 kilometers from the specific site of church								0.000
	Total Embodied Energy							**76632047.14**	**71.193**

Figure 4. Tabular detail of building materials used in construction of the church building along with Embodied Energy calculations (courtesy by the Author)

U-VALUE OF CHURCH WALL			
MATERIAL	**THERMAL CONDUCTIVITY(k)**	**THICKNESS(l)**	**THERMAL RESISTANCE (W/m2-K)**
OUTSIDE AIR			0.03
LIMESTONE WALL	1.5	1	0.666666667
LIME PLASTER	0.87	0.5	0.574712644
INSIDE AIR			0.12
TOTAL RESISTANCE			**1.39137931**
U-VALUE			**0.719**

U-VALUE OF CHURCH WOODEN DOOR			
MATERIAL	**THERMAL CONDUCTIVITY(k)**	**THICKNESS(l)**	**THERMAL RESISTANCE(W/m2-K)**
OUTSIDE AIR			0.03
WOODEN DOOR(TEAK)	0.14	0.1667	1.190714286
INSIDE AIR			0.12
TOTAL RESISTANCE			**1.340714286**
U-VALUE			**0.746**

U-VALUE OF CHURCH WINDOW			
MATERIAL	**THERMAL CONDUCTIVITY(k)**	**THICKNESS(l)**	**THERMAL RESISTANCE(W/m2-K)**
OUTSIDE AIR			0.04
GLASS 4 MM	1.04	0.004	0.004
AIR CAVITY 0.25 FT			0.18
GLASS 4MM	1.04	0.004	0.004
INSIDE AIR			0.12
TOTAL RESISTANCE			**0.348**
U-VALUE			**2.876**

U-VALUE OF CHURCH VENTILATORS			
MATERIAL	**THERMAL CONDUCTIVITY(k)**	**THICKNESS(l)**	**THERMAL RESISTANCE(W/m2-K)**
OUTSIDE AIR			0.04
GLASS 5 MM	1.04	0.005	0.005
INSIDE AIR			0.12
TOTAL RESISTANCE			**0.165**
U-VALUE			**6.068**

U-VALUE OF STRAIGHT ROOF OF CHURCH BUILDING			
MATERIAL	**THERMAL CONDUCTIVITY(k)**	**THICKNESS(l)**	**THERMAL RESISTANCE(W/m2-K)**
OUTSIDE AIR			0.04
12.5 MM THICK CEMENT/SAND PLASTER	0.53	0.0125	0.024
6 INCH THICK CONCRETE SLAB	1.4	0.045	0.032
12.5 MM THICK CEMENT/SAND PLASTER	0.53	0.0125	0.024
INSIDE AIR			0.12
TOTAL RESISTANCE			**0.239**
U-VALUE			**4.179**

U-VALUE OF PITCHED ROOF OF CHURCH BUILDING			
MATERIAL	**THERMAL CONDUCTIVITY(k)**	**THICKNESS(l)**	**THERMAL RESISTANCE(W/m2-K)**
OUTSIDE AIR			0.04
20 MM THICK CLAY TILES	0.53	0.02	0.038
3 MM JUTE SLAB	1.4	0.045	0.032
4 INCH THICK PLYWOOD	0.12	0.03	0.250
INSIDE AIR			0.12
3 INCH WIDE TIMBER TRUSSES SUPPORT (TEAK)	0.14	0.5	3.571
ANGLE OF INCLINATION	COS 22 DEGREES = 0.92		3.285714286
TOTAL RESISTANCE			**3.766**
U-VALUE			**0.266**

Figure 5. Showing Embodied Energy calculations of Walls, Doors, Window, Ventilators and Roof of Church

U-VALUE OF FRONT ELEVATION OF CHURCH BUILDING				
TOTAL AREA OF WALL (m2)	AREA OF DOORS (m2)	AREA OF WINDOWS (m2)	AREA OF VENTILATORS (m2	AREA OF OPAQUE WALL(m2)
128.97	5.04	11.34	0	112.59
U Front $_{wall}$ =	$U_wA_w+U_gA_g+U_dA_d$			
	$A_w + A_g + A_d$			
U Front $_{wall}$ = (inW/m2)	0.91			

U-VALUE OF BACK ELEVATION OF CHURCH BUILDING				
TOTAL AREA OF WALL (m2)	AREA OF DOORS (m2)	AREA OF WINDOWS (m2)	AREA OF VENTILATORS (m2	AREA OF OPAQUE WALL(m2)
127.26	5.04	1.62	0	120.6
U Front $_{wall}$ =	$U_wA_w+U_gA_g+U_dA_d$			
	$A_w + A_g + A_d$			
U Back $_{wall}$ = (inW/m2)	0.75			

U-VALUE OF RIGHT SIDE ELEVATION OF CHURCH BUILDING				
TOTAL AREA OF WALL (m2)	AREA OF DOORS (m2)	AREA OF WINDOWS (m2)	AREA OF VENTILATORS (m2	AREA OF OPAQUE WALL(m2)
82.08	0	0	1.35	80.73
U Front $_{wall}$ =	$U_wA_w+U_gA_g+U_dA_d$			
	$A_w + A_g + A_d$			
U Right side $_{wall}$ = (inW/m2)	0.71			

U-VALUE OF LEFT SIDE ELEVATION OF CHURCH BUILDING				
TOTAL AREA OF WALL (m2)	AREA OF DOORS (m2)	AREA OF WINDOWS (m2)	AREA OF VENTILATORS (m2	AREA OF OPAQUE WALL(m2)
58.995	0	0	0.27	58.725
U Front $_{wall}$ =	$U_wA_w+U_gA_g+U_dA_d$			
	$A_w + A_g + A_d$			
U Lefit side $_{wall}$ = (inW/m2)	0.72			

Figure 6. Showing Embodied Energy calculations of Elevations of Church

10. Analysis

Calculation of embodied energy has led to identify the problem of heat stress in the respective church; particularly in worship area. [U-values indicate the heat flow through a building element (a window, a wall, a roof etc.) to assess the thermal performance of construction materials as well as whole buildings. (The higher the U-value, the more heat flows through the building element and the greater the heat loss)]. This heat gain has observed from windows mostly. Worship area has faced thermal stress due to prayer activities (like candle lightening up etc.). Apart from that, lighting introduced in church building has contributing in producing internal heat as well. Lack of ventilation has observed. Problem of moisture trapped has also observed in washrooms and kitchen.

10.1. Recommendation

For solving the problem of moisture trapping, need is to introduce ventilators in those washrooms. Ventilators can have fitted net for avoiding the incoming of birds and nesting problems. These newly made ventilators can also help to improve air circulation in the respective areas. Alternatively exhaust fans can be introduced to tackle the situation. For solving the issue of thermal stress in worship areas, existing ventilators can be opened up for improving ventilation. Ample of artificial lighting, is one of the major causes for creating thermal stress inside the historic building. This can be solved by replacing existing incandescent lighting fixtures with energy efficient light bulbs (i.e., Fluorescent bulbs, energy saver bulbs etc.).

10.2. Conclusion and Key Findings

The range of energy savings from building reuse varies widely, based on building type, location, and assumed level of energy efficiency. "Savings from reuse are between 4 and 46 percent over new construction when comparing buildings with the same energy performance level." (*Excerpt from in-person interview*) This is due to a combination of factors, including the amount and types of materials used in a historic building. Adaptive Reuse-based impact reductions may seem small when considering a single building. However, the absolute energy-related impact reductions can be substantial when these results are scaled across the historic zone. "For example, if the historic buildings of **Old town quarter** would be subjected to adaptive reuse that it is otherwise likely to demolish over the next 10 years, the potential energy reduction would total approximately 231,00000 metric tons of embodied energy – approximately 7% of the country's total embodied energy over the next decade." (*Excerpt from in-person interview*) When scaled up even further to capture the potential for energy reductions in other parts of the country, particularly those with a higher rate of demolition, the potential for savings could be increased. Given these potential savings, additional research and analysis are needed to further strengthen the argument of adaptive reuse for the historic areas of Karachi and employ public-policy tools that will remove obstacles of historic building reuse.

Taking the same study as a base, and comparing Church building embodied energy (i.e., 71 MJ/kilo tons), it can be said that adaptive reuse concept is the best solution for maintaining the historic structures of Karachi from environmental aspect. Most of the historic buildings can be upgraded with new technologies to maximize energy performance. Historic features, such as windows can be repaired and restored for higher efficiency. New mechanical technologies are equally effective in both new and old buildings. Simple solutions like double-glazed windows, utilizing existing ventilators for proper ventilation of air, replacing normal lighting with energy efficient lighting, providing movable shades for avoiding excessive heat etc. could be helpful in reusing the historic structures.

Church Building has continued to serve as a place of worship with minimum alterations. Continuous appropriate maintenance measures are responsible for overall good condition of the respective historic building. This building incorporates modern materials also, apart from historic materials, in order to make building workable effectively. Relevant interventions, which have minimal impact on environment, have introduced for the continuous use of the particular historic building.

11. Final Words

This study explores energy's role in the preservation field, specifically, how embodied energy has calculated and support the argument of adaptive reuse for historic buildings of Karachi. Adaptive reuse of historical buildings has become highly specialized domain within architectural and conservation practice and is becoming a field of scholarly study in its own. Such practices are way advance and used worldwide but in local context of Karachi no studies or practices have ever followed. Sindh Building Control Authority (SBCA) and Culture Department Government of Sindh are jointly responsible for establishing and regulating standards for such structures according to the Sindh Historic Building Preservation Act 1994, Government of Sindh. But unfortunately these authorities have not fulfilled their responsibilities due to lack of technical expertise. Following are few suggestions which can be helpful for starting work in this direction.

1. First of all, authorizing bodies need to enhance their technical expertise and team up with relevant stakeholders including local community, conservationist, architects, and policy-makers etc. to overcome the issue of technical lacking.

2. Certain **pilot projects** should be identified (at government, private or NGO level) where the concept of adaptive reuse have practiced and disseminate the information of such projects to promote this concept.

3. Establish a 'Heritage Technical Support Cell' whose major task should be to provide support and guidance to owners of listed properties, help prepare proposals for adaptive reuse of historic buildings, and establish collaborative links with different departments and organizations (tourism, planning, city administration, etc.) involved in

management/ maintenance of historic properties.

4. Identify areas to be declared as ‘designated conservation areas/ zones’.

5. Develop an adaptive reuse guideline/ regulations manual for the historic buildings that help the owners to understand the framework within which alterations, repairs, etc. to their specific properties can be undertaken. For that sample case studies can also be make part of that manual.

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