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Low Carbon Community: Redevelopment strategies for Versova Koliwada, Mumbai.

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Abstract : This paper focuses on the Versova Koliwada community in Mumbai, which primarily engages in coastal fishing. The objective of this study is to raise awareness among the Versova Koliwada community about the significance of sustainable housing practices and the methods to redevelop their houses in a cost-effective and sustainable way. To understand the demography, morphology, and redevelopment needs of the study area, a survey was conducted. Later on, the Life Cycle Assessment (LCA) method was used to determine the environmental impact of traditional and newly constructed houses. The material data was collected manually, and the Inventory of Carbon and Energy (ICE) database was utilized to calculate the results. The study found that lime and cement were the primary sources of carbon emissions in traditional houses and newly constructed buildings, respectively. The analysis showed that traditional houses have significantly lower carbon emissions than newly constructed buildings and the materials from traditional houses can be recycled for use in the redevelopment of new houses. The findings of the study would advantageously aid local stakeholders, sustainable practitioners, and community members in identifying alternatives to cement and construction techniques. This would minimize cement usage and carbon emissions, thus making the Versova Koliwada community more sustainable and low-carbon.

Keywords - Low carbon community, LCA of building, Embodied carbon, Operational carbon, Carbon emission.

I. INTRODUCTION

The demand for low-carbon building materials is increasing due to the urgent need to reduce greenhouse gas emissions and mitigate climate change [1]. In urbanization, the building sector is the measure of CO_2 emissions. Carbon dioxide is considered a key factor that directly contributes to the acceleration of climate change and the warming of the planet, according to scientific research [2]. The production of carbon dioxide on a global scale is considerably influenced by buildings, with approximately 40% of the total emissions being attributed to them [2].

Versova koliwada is a coastal community in Mumbai [3]. The Kolis are indigenous to Mumbai, mostly fishing is the main profession of the community. The unique history of Koliwadas emphasizes their social, environmental, and economic sustainability, distinguishing them from other villages [4]. The koliwada's houses were constructed in groups along well and included fish storage and drying spaces, which were an integral part of each dwelling. These houses were originally built using locally available materials like wood, sand, stones, and clay tiles, but with the introduction of modern construction materials like cement, and steel, both the traditional identity and sustainability of the koliwada are being eroded.

The community implemented various sustainable development initiatives and low-carbon strategies, such as renewable energy, waste management, and sustainable fishing practices to improve the quality of life of its residents and to protect its natural resources [5,3].

Low-carbon community redevelopment is a strategy aimed at reducing the carbon footprint of communities through the use of low-carbon construction technologies and sustainable practices. Measuring and comparing the environmental impact of human activities needs tools and methods which help to maintain sustainability [6]. For the calculation of the carbon emissions of traditional houses and newly constructed buildings, a life cycle assessment (LCA) approach can be used. This involves assessing the carbon emissions at different stages of a building's life cycle, including transportation, construction, use, and end-of-life [7].

II. LITERATURE REVIEW

2.1 Review of Versova Koliwada Case, Mumbai

One such similar research in the context by Batra and Mahajan (2015) conducted a case study of Versova Koliwada in Mumbai, India, to explore the challenges and opportunities of implementing low-carbon community development strategies in urban areas [5]. The case study by Neha Singh and Kavita Batra (2017) examines the sustainable development of coastal communities as an increasingly important issue in context with the climate change and environmental degradation of coastal ecosystems and the communities that depend on them [3]. The case study by Joshi and Srinivas (2018) addresses the potential of fishing villages to become sustainable communities that balance environmental sustainability and economic development. Versova Koliwada has undergone a significant transformation in recent years, adopting several sustainable practices such as organic farming, waste segregation and recycling, and the use of renewable energy sources such as solar power [8].

2.2 Life cycle assessment

Life Cycle Assessment (LCA) is a widely recognized methodology for assessing the environmental impacts of a product, process, or service throughout its entire life cycle, from raw material extraction to disposal [7]. LCA has gained significant attention in recent years due to the growing concern about the environmental sustainability of human activities [7]. LCA has been used in the construction industry to assess the environmental impacts of building materials, construction processes, and building design [7]. Sharma et al. (2011) offer a critical analysis and overview of the research on the life cycle assessment (LCA) of buildings. The paper explores the different stages in the life cycle of buildings, including construction, operation, and demolition, and examines their environmental impacts. The paper also discusses the various tools and methods used for conducting LCA, including software and databases, and addresses the challenges and limitations of LCA in the context of buildings [6]. One more research [9] emphasized the importance of considering the entire life cycle of a building, from production to disposal, in order to accurately assess the environmental impact of building materials. The paper by Petrovic et al. (2019) conducts a life cycle assessment (LCA) of building materials for a single-family house in Sweden [10]. The study shows that the production phase of materials, especially steel, and concrete, contributes significantly to the overall environmental impact of the building. The use of renewable energy sources during the production phase can help reduce the impact. The study also highlights the importance of considering the entire life cycle of building materials, including transportation and end-of-life disposal, in reducing environmental impact [10].

2.3 Low-carbon building materials and techniques

Research by Cabeza et al. (2013) [9] provides a review of the use of low-carbon and low-embodied energy materials in buildings. The authors analyzed various building materials such as adobe, rammed earth, straw bale, bamboo, cork, and recycled materials, and assessed their carbon footprint and embodied energy. The study found that the use of low-carbon and low-embodied energy materials can significantly reduce the carbon footprint and embodied energy of buildings [9].

Dewalkar et al. (2016) conducted a study in Pune, India, where they developed an assessment software called "soft tool for the calculation of a building's carbon footprints" to calculate the total carbon emissions of a residential building [11]. They used the following equation to calculate carbon emissions due to building materials:

Carbon emissions due to material (kg) = carbon emission factor for material X weight of the material [11].

Noha Ahmed et al. (2020) conducted a study on the embodied carbon emissions of different building materials during the construction phase [12]. The results showed that reinforced concrete had the highest embodied carbon emissions compared to other materials. The study also found that using heavyweight cast concrete and aerated concrete as alternatives reduced embodied carbon emissions by 23% and 50% respectively.

The study conducted by Tirth V et al. (2019) analyzed three different residential buildings and found that the building materials that are most commonly used in large quantities, such as cement, steel, concrete, and bricks, have a significant environmental impact [13]. The authors suggest that using these materials in construction should be reduced or alternative materials with lower environmental impacts should be considered to mitigate the negative environmental effects.

The authors Kurian R. et al. (2021) conducted a study to estimate the carbon footprint of a residential building located in a warm and humid climate [7]. The results of the study indicated that cement is the building material that contributes the most carbon emissions compared to other building materials [7].

Saravanan and Gandhi conducted a study to compare the carbon footprint of filler slab construction with conventional slab construction [14]. The study estimated the embodied CO_2e for filler slab construction would be around 49.8 kg CO2e per cubic meter of concrete slab, which was approximately 40% lower than the embodied CO2e for conventional slab construction. The study also found that the use of filler material such as clay pots or expanded polystyrene (EPS) can significantly reduce the carbon footprint of the building compared to conventional reinforced concrete construction [14].

2.4 Research gap

Versova Koliwada, Mumbai has implemented several sustainable measures including renewable energy, waste management, and sustainable fishing practices to transform into a low-carbon community. However, it appears that no initiatives have been taken to promote low-carbon strategies in the construction industry. This study focuses on traditional houses and newly constructed buildings, building materials, and carbon emissions from a life cycle.

III. RESEARCH METHODOLOGY

The total number of households is 2500. Out of these, 1225 houses have already been redeveloped, 1050 are currently undergoing redevelopment, and the remaining 225 are temporary structures [15]. To gain insight into the demographics, morphology, and redevelopment requirements of the study area, a survey was conducted as the initial step. To study the sustainability of old houses and the use of low-carbon materials, the life cycle of the houses was analyzed and the carbon emission

of the materials was calculated from the collected data. This was done both for old traditional houses and for newly constructed buildings with new building materials to compare carbon emissions in both cases.

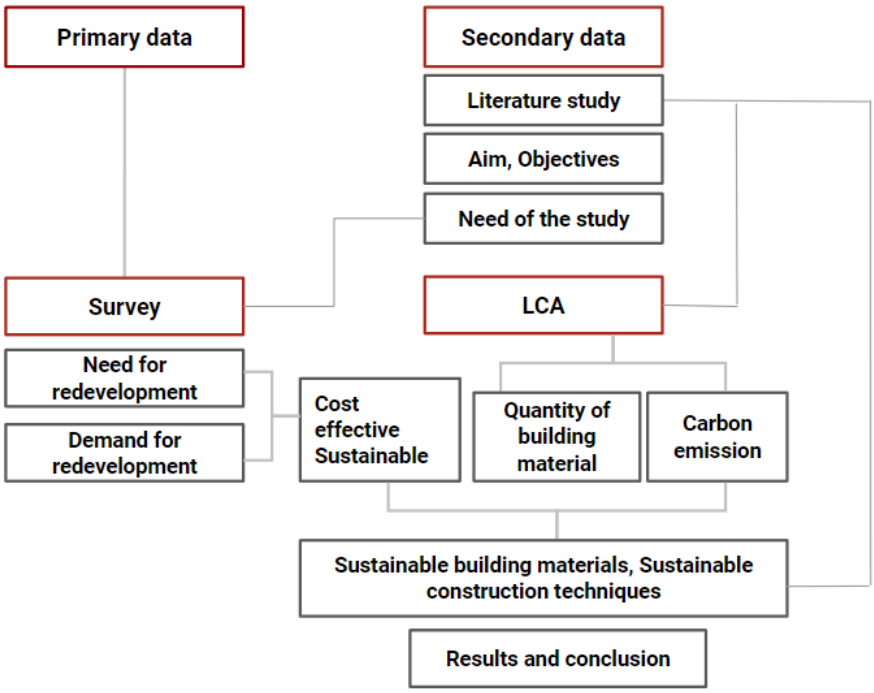

Figure 3.1: Methodology of the research.

The research was based on primary and secondary data, in primary survey was taken. From the secondary data literature study and case study was collected and detailed methodology drawn in Figure 3.1.

IV. DATA COLLECTION AND DATA ANALYSIS

The survey revealed that 40% had redeveloped their houses into 3-4 storey buildings or multi-storey houses based on the area they had obtained from the family property, while 60% of respondents had plans to redevelop their houses. The maintenance of traditional houses serves as a significant driver for redevelopment is accounted for 42.9%, followed by the need for additional income sources 28.6% and the requirement for more living space 28.6%.

In the Life cycle of the house, the building consideration of the construction stage is important when assessing its environmental impact and developing strategies to reduce its carbon footprint [16]. The quantity of all the materials is calculated manually.

Selected cases are elaborated in tabular form in Table 4.1.

Table 4.1: Details of selected traditional houses and newly constructed buildings.

	Case - 1	Case - 2
Areas	100 m^2	120 m^2
No. of storey	Single storey	G+3 storey
Type	Traditional house (approx. 75 years old	Newly constructed (approx. 10 years old)
Roof	Sloping roof, Wooden frame and cement sheets	RCC flat roof 125mm
Wall	Stone masonry 400mm	Exterior concrete block 230mm Internal brick masonry 150mm
Floor	Coba	Tiles

Selected cases detailed out in 2D plans as shown in Figure 4.1 and 4.2. Case 1, traditional house is L- shaped single storey house and case 2 is newly constructed rectangular building is G+3 storey building.

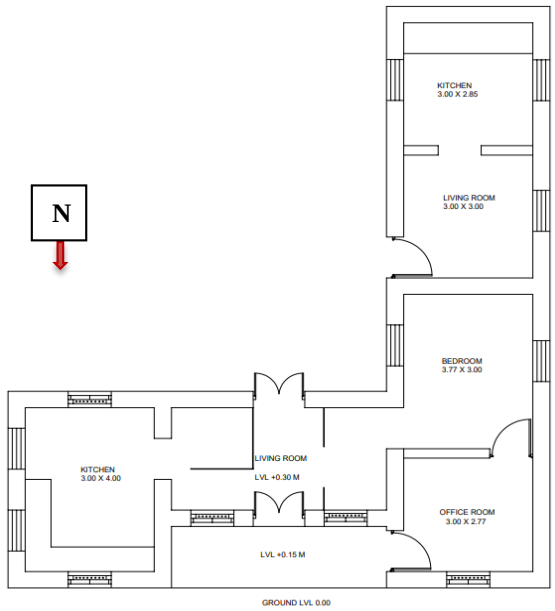

Figure 4.1: Ground floor plan of traditional house (case 1).

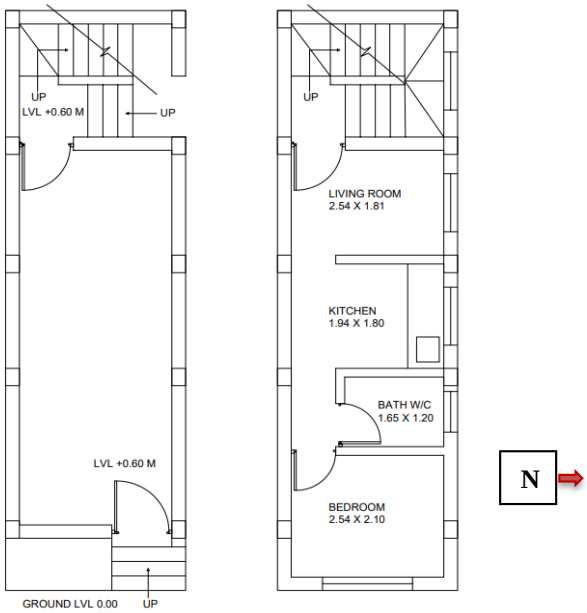

Figure 4.2: Ground, 1st, 2nd, and 3rd-floor Plans of a newly constructed building (case 2).

Carbon emissions due to material (kg) = carbon emission factor for material x weight of the material [11]. Inventory carbon emission (ICE) database is used for carbon emission calculation [7].

In order to determine the carbon emissions from transportation during construction, it is essential to analyze the amount of CO_2 emitted by the vehicles used to transport materials to the construction site. Factors that affect carbon emissions include the capacity and type of vehicles and the number of trips required. It is also essential to consider the shipping mode, which is typically road shipment [12].

The operational phase of a residential building is responsible for a more significant amount of carbon emissions than the other phases in the building lifecycle, as assessed by life cycle assessment (LCA) methodologies and electricity is the major component used [7]. Operational energy calculated by considering 80yrs. of lifespan of traditional house and newly constructed house building [7].

Traditional materials have very less/negligible emissions so they have been not considered while calculating the demolition stage period in the life cycle assessment. For newly constructed buildings, emissions are considered 10% of the construction stage [7].

Carbon emissions from the all the stages of life cycle of the traditional house and newly constructed house building shown in Table 4.2.

Table 4.2: Carbon emissions of all the stages of case 1 and case 2.

LCA	Case 1($kgCO_2$)	Case 2($kgCO_2$)
Construction stage	9175.1	48493.94
Transportation stage	99.69	655.28
Operational stage	146611.2	525772.8
Demolition stage	-	4849.39
Total emission	155879	579771.41

Total carbon emission of traditional house is 155879 $kgCO_2$ and 579771.41 $kgCO_2$ is from newly constructed building. Detailed percentages of all the stage of the case 1 and case 2 shown in Figure 4.3 and 4.4.

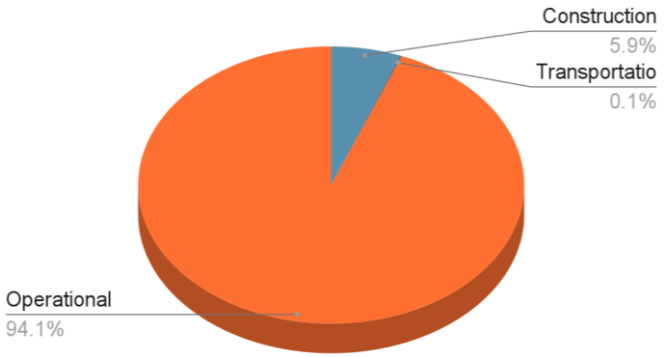

Figure 4.3: Percentage of carbon emission of all 4 stages in case 1.

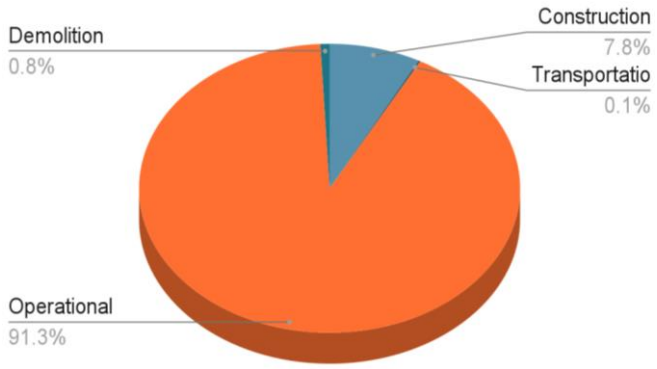

Figure 4.4: Percentage of carbon emission of all 4 stages in case 2.

Carbon emission of traditional houses of case 1, operational stage is 93.9% which is high compared to other stages. The construction stage contributed 6%. Demolition and transportation stages are almost negligible. Carbon emission of newly constructed buildings of case 2, operational stage is 93.4% which is high compared to other stages. The construction stage contributed 6%. Demolition stage carbon emission is 0.6% and the transportation stage is almost negligible compared to other stages.

According to LCA methodology, cement, and steel produce more embodied carbon emissions in newly developed buildings than lime in traditional houses. The operational stage is primary source of carbon emission in both cases.

V. LOW CARBON PRPOSALS

5.1 Alternative Sustainable building material – Adobe bricks

This study compared the used concrete blocks with adobe bricks to observe the alternative building material will reduce the embodied carbon emissions and eventually carbon emissions of the construction stage.

Adobe bricks – The size of the brick is considered 380mm x 250mm x 110mm, and its weight is 8-10 kg/adobe brick [17].

Embodied carbon factor of the Adobe brick is 0.0017 and 0.0129 $kgCO_2/kg$ [18].

Table 5.1: Alternative wall material Adobe brick calculation.

	Length of the wall (m)	Quantity of wall material used (kg)	Embodied carbon ($kgCO_2$)	Quantity of adobe brick required. (kg)	Embodied carbon ($kgCO_2$)	% of reduction in embodied carbon emission
Case 2	66.59	98092.8	8632.16	40881.06	4.15	99.95

Here in table 5.1, case 2 resent newly constructed house building, allows for a reduction in embodied carbon of 99.95% compared to concrete blocks.

5.2 Construction Technique – Filler slab

As already discussed in the literature review, the filler slab will reduce the quantity of materials which reduces the embodied carbon emission.

Case 2 was studied for alternative construction techniques like fillers lab. The reduction in the quantity of cement by using a filler slab is present in Table 5.2.

Table 5.2: Amount of cement quantity and embodied carbon reduction in the roof by using filler slab.

	Slab Area m2	Quantity of cement bags (M20)	Required quantity of cement bags (M15)	% of reduction	Required quantity of cement bags (M20)	% of reduction
Case 2	93.84	73	51	31.50	65	12.32

In case 2, the quantity of cement reduces by 12.32% by using the filler slab technique.

The reduction in the quantity of steel by using a filler slab is present in Table 5.3.

Table 3.3: Amount of steel quantity and embodied carbon reduction in the roof by using filler slab.

	RCC Slab Area (m2)	Quantity of steel Required for RCC slab (kg)	Filler Slab Area m2	Quantity of steel Required for RCC slab (kg)	% of reduction
Case 2	93.84	184.16	82.06	161.04	12.55

In case 2, the quantity of steel reduces by 12.55% by using the filler slab technique.

VI. RESULTS AND DISCUSSION

To reduce the carbon emission of newly constructed buildings alternative building material Adobe and alternative construction technique filler slab considered and studied from the calculation % of reduction tabulated in Table 6.1 and 6.2.

Table 4.1: Comparative analysis of embodied carbon emission reduction between Conventional wall materials and Adobe bricks in the construction stage

	Length of wall (m)	Embodied carbon emission at the construction stage of concrete blocks ($kgCO_2$)	Embodied carbon emission at the construction stage after using Adobe bricks ($kgCO_2$)	% of reduction
Case 2	66.59	48493.94	39865.93	17.79

In newly constructed buildings 17.79% reduction is calculated in case 2.

By using the filler slab construction technique reduction of carbon emission at the construction stage is calculated in Table 7.

Table 6.2: Comparative analysis of embodied carbon emission reduction between RCC and Filler slab in the construction stage.

	Slab Area (m2)	Embodied carbon emission at the construction stage of existing RCC slab ($kgCO_2$)	Embodied carbon emission at the construction stage after using the filler slab technique ($kgCO_2$)		% of reduction	
			M15	M20	M15	M20
Case 2	93.84	48493.94	47349.57	48057.61	2.35	0.89

This analysis found that in case 2, 0.89% to 2.35% carbon reduction happened as the perusing grade of concrete M20 and M15 respectively. From the Table 6.1 and 6.2 observed that Adobe bricks for wall reduce the more carbon emission in compare to reduction from filler slab technique.

VII. CONCLUSION

The results obtained from the research intended to study the comparative difference between traditional houses and newly constructed buildings in the use of construction materials and emissions from the construction material. Carbon emission per square meter for traditional houses case 1 is 1.55 tCO_2/m^2. In newly constructed buildings case *2* carbon emissions per square meter *is* 4.83 tCO_2/m^2 The results therefore, show that traditional houses in Versova Koliwada are low carbon houses.

Newly constructed building represented as case 2, using adobe bricks as an alternative wall material, embodied carbon emissions were reduced at construction stage by 17.79%. By using alternative construction technique of filler slab, the embodied carbon emission can be reduced at construction stage for case 2 by 0.89% to 2.35% (depending upon the concrete grade used). However, if both the options are used without compromising the strength, carbon emission are effectively reduced to great extent which would be helpful in new construction of buildings with regard to sustainability.

Strategies for achieving low carbon emission communities

Therefore, specific strategies developed as guidelines for achieving low carbon emission communities have been marked as hereunder:

1. Use of adobe with minor modifications as per the context to the area can be propagated advantageously for the benefit of the society at large not only from the point of view of low carbon emission but also for achieving sustainable development.
2. Alternative construction technology of filler slab can also be used in construction practices to effectively reduce carbon emission at construction stage only which would prove beneficial for the sustainable development of the community.
3. While redevelopment, reusing and recycling of the traditional house material can be done in new construction building which will reduce the carbon emission and also negative impact on environment. Clay tiles as a filler material in filler slab, wood for door-window frames, etc. can be used as reused and recycled material.

4. While designing, from the case study observed that use of natural resources helps to reduce the operational energy of buildings in a way of cross ventilation, natural day light. Therefore, use of renewable energy would primarily account for reduction of operational carbon emissions.
5. While selecting materials, sustainable and low-carbon materials like adobe and others will help to reduce carbon emissions and related negative impacts on environment.
6. While constructing, using construction techniques which reduce the quantity of cement and steel, embodied carbon emission of building will get reduced.

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