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Environmental Impact of Timber Slabs in Residential Buildings in Egypt

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Abstract— **Sustainability refers to the ability to be used without being used up or destroyed; methods that do not completely use up or destroy natural resources; able to last for a very long time (Merriam Webster). Generally, there are three pillars of sustainability, economic, environmental, and social, which are informally referred to as profits, planet, and people respectively. Most Middle Eastern countries, such as Egypt, lack the thought and the implementation of alternative building materials that can be cost effective, durable, and most importantly sustainable. In order to save energy as well as resource, the use of natural resources building material should be urgent to be carried out. There are various ways to apply sustainability in construction, one of which is by using natural resources.**

This research paper explores the environmental effect when replacing concrete slabs in Egyptian construction with timber. As timber is a natural and renewable building resource, this replacement could bring an environmental benefit. It is also much lighter than concrete, meaning it may be possible to reduce the amount of steel used in a building. The most critical measuring criteria were anticipated to be ensuring adequate robustness, durability, and fire resistance. The aforementioned requirements are explored and the ability of timber slabs to perform sustainably was evaluated using comparative study supported by literature review.

The potential environmental benefits were investigated, and a comparative study was performed to measure the relative performances of the timber and concrete systems. The comparative study looked at how the amount of steel required in the slab, the loads, the cost, and the environmental impact would change when making the substitution. It found that the environmental impact of using timber slabs is more detrimental to the environment, however it would be an expensive option.

Keywords— Timber slab, Concrete slab, Natural building resources, Sustainability, Environmental impact, Residential building, Egypt

I. INTRODUCTION

A. Background

In many countries, sustainability, environmental effect, and efficiency are becoming the main focus of rising concern of contemporary life. Governments all over the world are implementing more strict regulations on industrial activity because it is widely considered that human activity can have a detrimental impact on the natural environment, such as carbon emissions. Construction processes accounts for a substantial portion of global carbon emissions (55% from cement alone [2]).

Wood is not just a building resource that is used in the skeleton of buildings, interior furniture, or insulation., but also a sustainable substance, Wood (timber) was frequently used in the construction of temples and buildings in ancient civilizations such as ancient Egypt, Greece, and Rome [1]. After stone, lumber (chopped wood or timber) is considered the second most important building material [2]. However, in the construction of buildings, wood has been replaced and associated with man-made common hard materials such as steel and concrete, which are associated with higher carbon emissions and lower sustainability. Yet, as environmental stewardship has grown in reaction to high carbon emissions in cities, the use of sustainable materials in buildings has become a major focus. Even though it has just been used in skyscrapers, wood or timber is being reintroduced into contemporary building as a sustainable constructed material as it's highly renewable, nontoxic, and has a low embodied energy. Furthermore, stakeholders are encouraged to incorporate timber in all types of buildings and reinvest in the sustainable material for its recognized insulation, durability, flexibility, affordability, and aesthetic nature, not to mention the benefits of wood to urban dwellers in improving their emotional and physical connection with their occupied space.

The essence of this paper is to compare the usage of timber slabs instead of precast concrete in residential buildings in terms of durability, fire resistance, and sustainability. The idea is that a performing timber slab will be significantly lighter than a concrete slab, allowing for reduced, less expensive section sizes in the construction framework. As a result, the environmental effect of a timber-floored structure will be decreased because the embodied carbon of the steel frame will decrease as section sizes decrease, and the major embodied carbon in concrete will be eliminated entirely. Simultaneously, the cost of the structure will drop due to reduced framework and foundation expenses, as well as faster construction rates. Another positive aspect, both economically and environmentally, is that structures constructed using this approach may be demolished and the slabs (and even frame parts) reused rather than wasted at the end of their working lives. If this system can be proven to be possible, it will be a cost-effective and ecofriendly option for future steel building design.

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B. Objective

The main objective of this paper is to test the environmental effect of replacing concrete slabs with timber slabs in the Egyptian construction of residential houses by comparing robustness, durability, and fire resistance of both materials.

C. Research Methodology

The study's methodology is based on a comparative analysis approach, which includes a review and assessment of old and new experiences with integrating timber as a sustainable construction material, as well as a relative analysis using critical criteria to assess the impacts on the built environment.

II. LITERATURE REVIEW

A. History of Wood Usage in Construction

For millennia, people and their forefathers have used and exploited the characteristics of wood. It has been used for human houses for thousands of years, with evidence of wooden struts supporting shelters reaching back 300,000 years in China, where they were coated in mud to preserve the wood from fire.

It has been used since the beginning of recorded history. The ancient Egyptians, for example, utilized wood for furniture, decorations, and coffins, while the ancient Greeks used it for beds and boats.

Timber was first utilized to produce bows in the Middle Ages, and then for home construction in the United Kingdom. Timber was widespread as a building material at the beginning of industrialization, but numerous devastating fires in timber framed industrial buildings began to affect the idea of timber for construction. It was reduced to holding roofs and flooring in smaller domestic settings as time passed. Nonetheless, Timber was extensively applied elsewhere, such as for the railway network.

Timber has witnessed a comeback in popularity due to its sustainability and natural properties - it is anisotropic, hygroscopic, prone to biological attacks and flaws. It is, nevertheless, significantly strong for its weight, robust, and heat and sound insulation. It is also a sustainable, renewable material resource when derived from managed forests. Technological advancements have also resulted in more useful wood-based goods, expanding the potential applications of timber beyond what it could achieve in its original form.

Engineered wood products, such as Glue Laminated Timber (GluLam), Laminated Veneer Lumber (LVL), and Cross-Laminated Timber (XLT), now allow for more predictable behavior and applications for timber.

B. Wood in Egypt

The Egyptians built the first houses and one-room huts out of wood and mud from the Nile River. Later, the ancient Egyptians began to use bricks to build better houses, not only because bricks are more durable than wood, but also because there were no forests in Egypt and wood was limited to palm and acacia trees. Ramsis and the ancient Egyptians imported cedar wood to be used in bigger structures such as the funerary temple during Ramsis' period. Other buildings from the same period are thought to exist, including the Maya culture center.

Timber has been used for ages to show the continuous thinking of builders and artisans throughout history, including the Islamic era. Wood's role as a sustainable construction material has been examined in terms of several characteristics such as environmental friendliness, durability, waste disposal, recycling, and having a lower carbon footprint than other building materials. The most major environmental advantage of timber is its capacity to regenerate and biodegrade. The historic timber structures continue to be a paradigm for reducing building energy usage. It is the architectural structure's stiffening and powerful features that carry pressure loads and disperse them, making the building simpler and safer than steel or concrete construction.

There are no main woodlands in Egypt due to its geographic position and temperature. Egypt's regenerated woods cover an area of 19,990 hectares and may be found in two locations: The first is Gebal Elba, which covers an area of 19,600 hectares, and the second is Mangroves, which is located on the Red Coast and covers an area of 390 hectares. (FAO,2010). The Egyptian woods have over 8,000,000 m3 of growing trees and bushes, generating roughly 268,000 m3 of industrial wood output while consuming around 384,000 m3, therefore the difference in demand is imported from outside. (FAO,2010). The features and extent of Egypt's woods are summarized in Table 1.

Main Characteristics	Area (ha)
Primary Forests	-
Naturally Regenerating Forests	19990
Planted Forests	127155
Reforested Areas	40055
Afforested Areas	87100

Table 1: Forests characteristic and Areas in Egypt. (FAO,2010).

C. Types of Wood Used in Construction

The table below compares different traits in two categories of wood, softwoods and hardwoods, where to be found, and used mostly in which type of construction.

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SOFTWOODS					
CEDAR	**CYPRESS**	**FIR**	**HEMLOCK**	**PINE**	**SPRUCE**
- Reddish-brown wood - Light weight - Ability to resist insects and fungi attacks - Good density - Used for wall coverings and landscapes.	- Doesn't rot easily - Ability to resist insects and fungi attacks - Used in building construction decks	- Reddish-brown wood - Used to produce plywood and lumber - Used in fencing - Low resistance to decay - Found in North and Central America, Europe, and North Africa	- Light weight - Average strength - Low resistance to decay - Not preferred for construction as it is full of knots -Used in landscaping, rail road construction, and construction of lumber, doors, and subflooring - Found in North America, Canada, and England	- White wood - Cheap - Light in weight - Resists swelling and shrinkage - Found in India - Used in a lot of construction projects from craft to home constructions	- Light weight - High strength - Low resistance to decay - Found in North America, Canada, Asia, and Europe -Used in housing projects
HARDWOODS					
ASH	**BALSA**	**BEECH**	**OAK**	**MAPLE**	**ELM**
- Heavy weight - High resistance to splintering and breaking under pressure - High strength and elasticity - Not expensive - Used in building structural frames	- Light weight - High strength - Low density - Ability to be shaped and glued easily - Absorbs shocks and vibrations - Found in North and South America - Used to build structural models such as bridges in the design and testing phase	- Heavy weight - High strength - Not expensive - High resistance in splitting - Found in North America, Asia, and Europe - Used in plywood, flooring, and frames	- High strength - Durable - High resistance to organic and insects' decay - High resistance in moisture - Found in North Africa, Asia, and Europe - Used in building structural elements such as frames, trusses, beams, and pillars	- High strength - High durability - High resistance in splitting and shock - Found in North America, India, Europe, and North Africa - Used in pathways construction and finishing	- High strength - Wide variety of colors - High resistance in splitting - Used in flooring and landscaping

Table 2: Wood types and characteristics (Author,2022).

III. COMPARISON STUDY

A. Slab Sizing

6m x 9m	TIMBER				CONCRETE	
STEEL USAGE [kg]						
Residential	1967	1478	2630	2885	1967	1478
Office	2926	1478	3568	3588	2926	1794
Classroom	2956	1794	4088	3588	2956	1794
Lecture Hall	3374	1855	4118	4546	3374	1855
6 kN/m²	3700	slab	5341	5679	3700	2426
8 kN/m²	4557	slab	5851	6646	4557	2813
10 kN/m²	Slab data	Slab data	Slab data	Slab data	5657	2946
FOUND. LOAD [kN]						
Residential	60	73	58	58	214	241
Office	70	73	68	65	223	244
Classroom	80	89	76	65	223	261
Lecture Hall	84	94	78	74	228	261
6 kN/m²	95	slab	99	85	263	337
8 kN/m²	108	slab	108	101	272	341
10 kN/m²	Slab data	Slab data	Slab data	Slab data	282	342

Primary Beam — Reason: denotes inability to span
Secondary Beam — ####: best performing
Tie Beam — ####: worst performing
Fig. 5.1 Layout optimization 6m x 9m grid

Table 3: Layout optimization 6m x 9m grid (K. A. Okutu,2012).

9m x 9m	TIMBER			CONCRETE		
STEEL USAGE [kg]						
Residential	2824	3884	4893	3344	4444	4893
Office	4118	5627	5494	4118	5627	5494
Classroom	4118	6881	7125	4118	6881	6351
Lecture Hall	4118	7727	7992	4557	7727	7992
6 kN/m²	slab	9684	10438	5454	9684	10438
8 kN/m²	slab	10785	12854	6086	10785	11896
10 kN/m²	slab	13028	16177	7992	13028	18716
FOUND. LOAD [kN]						
Residential	91	70	78	260	238	242
Office	106	91	84	267	250	248
Classroom	112	103	100	267	262	257
Lecture Hall	117	113	108	285	270	273
6 kN/m²	slab	141	132	364	289	297
8 kN/m²	slab	157	157	370	300	311
10 kN/m²	slab	179	194	389	322	378

Primary Beam — Reason: denotes inability to span
Secondary Beam — ####: best performing
Tie Beam — ####: worst performing
Fig. 5.2 Layout optimization 9m x 9m grid

Table 4: Layout optimization 9m x 9m grid (K. A. Okutu,2012).

12m x 12m	TIMBER		CONCRETE		
STEEL USAGE [kg]					
Residential	11366	11233	9358	13150	11825
Office	15240	16728	9694	14373	16728
Classroom	16514	18053	10968	16514	18053
Lecture Hall	20846	21692	14037	20846	21692
6 kN/m²	27737	29613	18073	27737	29613
8 kN/m²	36371	Primary	Primary	36371	Primary
10 kN/m²	Slab data	Slab data	Primary	Primary	Primary
FOUND. LOAD [kN]					
Residential	153	140	402	323	310
Office	196	196	406	355	359
Classroom	213	213	418	356	372
Lecture Hall	256	248	448	399	407
6 kN/m²	330	328	534	499	485
8 kN/m²	423	Primary	Primary	551	Primary
10 kN/m²	Slab data	Slab data	Primary	Primary	Primary

Primary Beam — Reason: denotes inability to span
Secondary Beam — ####: best performing
Tie Beam — ####: worst performing
Fig. 5.3 Layout optimization 12m x 12m grid

Table 5: Layout optimization 12m x 12m grid (K. A. Okutu,2012).

The load/span charts provided by slab manufacturers were used to accomplish preliminary slab sizing. Other factors influence slab size, therefore preliminary slab choices are checked against the following criteria: bearing failure, robustness, and fire resistance.

Some grid configurations were not practicable owing to inadequate data from the manufacturers or because the available slabs would not cover that distance under the required loads. This phase primarily acts as the preliminary slab size for the detailed design since the ideal beam arrangement will be carried over into the detailed beam verification.

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The scope of the cost analysis is limited to the contribution of the structural framework and foundations to the overall cost of the structure. The cases analysed are only those where the timber solution has been shown to be more economical in terms of steel usage. Using the steel usage data and the floor areas, the cost of the structural framework can be approximated using material costs. The overall cost of constructing the superstructure can then be derived. A relative cost of foundations compared to superstructure yields a cost ratio that is applied to the concrete slab case. Finally, the assumption is made that foundation cost is proportional to foundation volume.

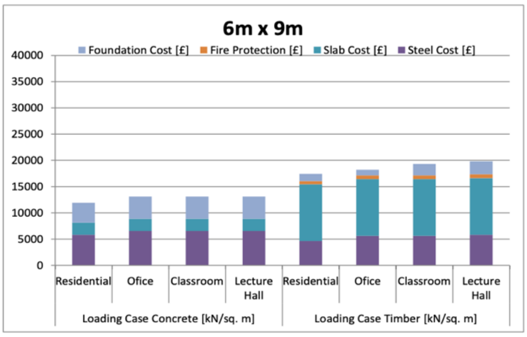

Table 6: Cost (per bay) breakdown and comparison 6m x 9m (K. A. Okutu,2012).

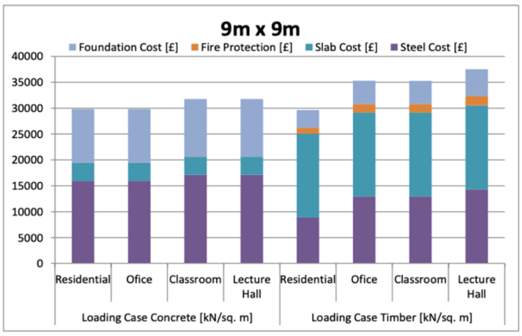

Table 7: Cost (per bay) breakdown and comparison 9m x 9m (K. A. Okutu,2012).

With limitations on time and the degree of detail it is possible to go into, this cost model gives only a general sense of the contributory factors to cost. There are other aspects that it does not consider, such as duration of works due to ease of construction, labour costs and transport costs. In addition, the derivation of foundation costs makes liberal approximations that may not accurately reflect the real cost. The costs used for the model are also not as accurate as could be desired due to the absence of readily available and up to date data. For the timber case evidently the cost of the slab is a critical determiner of overall cost, however the suppliers of the timber slabs were not forthcoming with information on their pricing so the value quoted is for generic engineered laminated timber panels.

Because of these limitations, the model is unlikely to precisely predict the cost of a structure constructed with timber or concrete slabs; nonetheless, it does allow for comparisons between the systems and highlights the essential aspects. A more thorough cost study and comparison might provide different results than the one shown here, which would be useful for clarity. Economic is a major consideration when selecting on a structure's structural shape, thus unless the cost efficiency of timber slabs can be demonstrated or improved, it may not be considered.

B. Environmental Impact

The effect of a structure on the environment may be quantified in a variety of ways, but the criteria evaluated are embodied CO2 and embodied energy. Only the steel frame and slabs are considered in this case, with embodied features being those at the time of purchase. Table 8 lists the material's qualities. For this part, a glue laminated timber is the

Material	**Embodied Energy (MJ/kg)**	**Embodied Carbon (kg CO^2/kg)**
Concrete	1.11	0.159
Section Steel	21.5	1.42
Glue Laminated Timber	12	0.87

Table 8: Material properties for environmental impact (K. A. Okutu,2012).

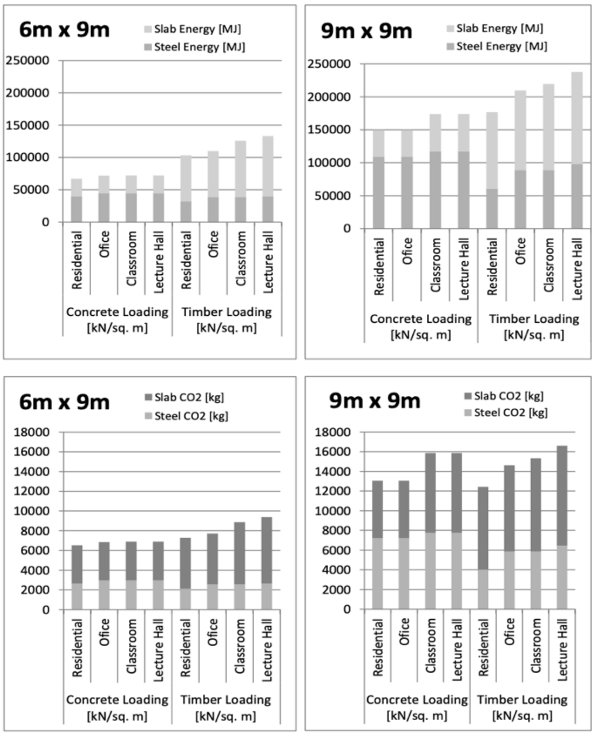

Table 9: Environmental impact summary (K. A. Okutu,2012).

Table 9 shows the results of the embodied energy and carbon calculations. Despite employing a higher quantity of the carbon and energy heavy steel component, the concrete solution has a lower embodied energy and lower embodied CO2 in all situations except one. In terms of carbon and energy costs, the slab itself reigns supreme, as it did in the cost study. The quantity of processing necessary in their creation is likely owing to the high embodied energy and CO2 of the timber - tree trunks must be sawn multiple times, edges and surfaces sanded before glueing, and heat treatment is performed before delivery. There are additional transportation expenses to consider from the woods to the processing plant.

IV. FACTORS AFFECTING TIMBER AND CONCRETE IN CONSTRUCTION

A. Robustness

The collapse prevention requirement is the most difficult requirement on the slab in terms of robustness. In terms of design, this means that the slab must be able to sustain an applied load that is at least equal to the slab's self-weight, so that any collapse of the floor above is not propagated by the failure of the floor below. Other robustness measurements for timber have no effect on the stress on the steel frame or the consequent size of the components and foundations. In the case of concrete, however, using an in-situ topping on precast modules helps to bind the structure together by creating a continuous slab element.

B. Durability

When comparing timber to reinforced concrete, we can observe that both materials have almost equal strength parallel to the grain, with the exception of hardwood being slightly stronger and softwood being slightly weaker. In compression, however, lumber cannot be compared to high-strength concrete technology. Compared to concrete and steel, timber is less stiff and has a lower density. Ramage and colleagues (Ramage and colleagues, 2017).

Wood was utilized in the construction of high-rise structures at the beginning of the past decade, although not all types of wood were utilized. In the approach of using wood in high-rise projects, cross laminated timber was utilized. Because low-rise buildings have less pressures to resist, lateral loads are resisted by bending tensions in the walls, which generate a vertical cantilever. By putting the cores outside walls in tension and compression, this wall may be used to create a more efficient core. Another solution, such as the 14-story building in Norway, where the internal core is replaced by a frame encircling the building to load all elements uniformly in tension and compression, can be used in the event of a taller structure.

C. Fire Resistance

The final feature to be confirmed in timber is fire resistance, which follows the technique to the fire-resistance in design is the value in the integrity check, which is determined by the kind of joint between slabs. To maintain the integrity of the system, more elaborate joints must be prescribed in specific cases. Though fire resistance varies depending on the environment and loads, the slab is built for a 90-minute resistance to maximize reusability while being cost-effective. The timber can potentially protect the steel beam for a length of time, but because the degree of performance is uncertain and study is needed, a fire protection provision for the ASB is provided without regard for the existence of the timber slab.

If the pre-stressing strands are covered by at least 30mm, the concrete slab will be fire resistant for the requisite 90 REI rating. The ASB must, however, be encased with at least 30mm of concrete over the top surface of the upper flange and 50mm of in-situ topping over the concrete slabs itself to provide optimum protection. This is to assure the beam and slab's composite behavior, and a 50mm topping is assumed in the slab size tables - a maximum of 100mm topping is practicable. The nature of the minimum topping depth requirement means final slab design is derived iteratively in combination with the beam design– the difference between the slab depth and the beam depth must allow for a topping within the prescribed limits, and said beam must be able to support any additional load if the topping is deeper than the assumed 50mm.

When the temperature climbs from 20 degrees to 100 degrees, timber loses roughly half of its strength and rigidity. (BSI,2015). However, due to the existence of the char layer, lumber still performs better at high temperatures than steel, whereas steel has a high thermal conductivity, meaning it heats up rapidly. (UKTFA,2013). This is done in structures that use cross laminated wood by assuming a char's rate for timber and presuming that the cross section of the timber would stay after the specified period. (Wells,2011).

D. Disassembly and Reuse

The building business is confronted with many difficulties concerning man's relationship with the environment and its resources. Greenhouse gas emissions (most notably CO2) are now widely acknowledged as producing unexpected but noticeable changes in the global climate, and these emissions are the result of our ever-increasing usage of fossil fuels, mostly for electricity. However, the deposits are finite, and because the largest reserves are located in politically unstable places, their availability has become less certain, resulting in unpredictable pricing.

The extra energy and emissions from the recycling process are saved when things are reused, and selling for reuse is more profitable for the building owner than selling for scrap. The advantages of reuse and recycling may be exploited to minimise the embodied figures for the material in issue, allowing the consumption to be more properly reflected. Material reuse might save 45 percent of embodied energy in a single-family home, according to a study.

Dodoo, Gustavsson, and Sathre discovered that recycling and reusing timber building components was more useful than recycling concrete from a recycling standpoint. Concrete may be recycled after initial use by crushing it and using it as aggregate, however owing to the recycling process, it is difficult to use and would corrode reinforcing steel, limiting the quality that can be reached and the variety of uses. Currently, timber is either recycled into new wood products or burned as a biofuel. While wood combustion emits CO2, it is healthier for the environment than fossil fuels since trees absorb CO2 during photosynthesis and store it for many years, and it is also a renewable energy source.

The environmental advantage of utilising timber slabs instead of concrete is contingent on the slabs' capacity to be reused at the end of the host structure's life, which is contingent on the slabs' durability. According to Eriksson et al, increasing demand for timber, which may arise from broad adoption of the suggested method, would put further strain on forest reserves. The lower use of lumber in this system, however, minimises the extent of the increased strain on forest reserves compared to Eriksson et al's estimates, which assumed that virtually entirely timber buildings would be employed. The standard assumed working life of most structures is also 50 years.

The timber slab may be designed to have visually pleasing surfaces and can be utilised as a work surface. Treatments to prevent the wood from degradation are available to boost the recycling potential. There are several types of preservatives available to protect against fungal and other biological assault, including water based, micro emulsion, and organic solvent preservatives. Preservatives can also be applied in a variety of methods, depending on the qualities of the wood being preserved and the intended use, such as immersion, spraying, or, most successfully, pressure impregnation. TRADA paper WIS 2/-33 "Wood Preservation – Chemicals and Processes" contains more information on this subject.

The suggested system has a huge chance of having a good environmental impact if it replaces concrete as a construction material. The XLT-ASB hybrid's reusability adds to what research says is a significant environmental benefit of employing wood rather than concrete. The reusability of the slabs and the steel frame is dependent on maintaining their durability – if the frame is properly protected against corrosion and the slab is treated against biological attack and water infiltration, component reuse could be near total, especially given the shortening working lives of structures.

V. CASE STUDY

Timber is currently used mostly for short span roof trusses on sand crate block/concrete constructions in Nigeria. However, the current issue is that the continued use of the old and conventional method to building construction is unable to fulfil the rising demand of society. Timber is commonly used as load bearing elements for residential structures in North America, Scandinavia, and other developed regions of the world due to the material's economy, high speed of construction, dryness of form, and less site operations, among other beneficial features that bring down building costs.

Table I
Cost summary of structural elements of the models

S/N	Elements	Timber Model (₦)	Concrete Model (₦)
1	Slab	985000	1660838
2	Beams	359000	945239
3	Columns	283000	630159
4	Total	1627000	3234904

Table 10: Cost summary of structural elements (K. A. Okutu,2012).

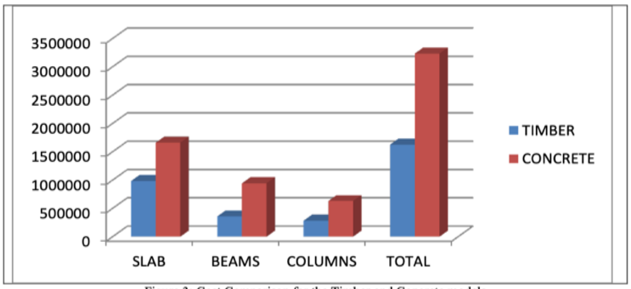

Figure 3: Cost Comparison for the Timber and Concrete models

Table 11: Cost comparison for the timber and concrete (K. A. Okutu,2012).

The results show that the timber model has a lot of promise for future mass residential building projects in Nigeria and other Sub-Saharan African countries. With the costs acquired, the timber model outperforms the concrete model in terms of cost. As a result, using timber to construct residential structures, especially on a big scale in Nigeria, will be less expensive. The use of timber as a load-bearing material for residential structures in Nigeria might give a long-term answer to the country's housing demands.

All standards must be satisfied, and the structures must be correctly planned, constructed, and maintained for timber to be completely embraced as a construction material for residential buildings in Nigeria. In the construction business, retraining and certification of craft workers and operators will be required. For the building sector to always have an adequate supply, the government will have to take the lead in forestation and continual growth of sufficient wood. Optimization of timber design and construction processes is required, since this will aid in the establishment of these methods in the Nigerian sector.

Table 11 provides the BQQ cost summary for the timber and concrete models, directly comparing the costs of the framed superstructures (slab, beams, and columns) that serve as the comparison object. The entire cost of the concrete model's structural frame is $7837.63, whereas the timber model's cost is $3941.95, roughly half that of the concrete model.

Figure 3 depicts a cost comparison of the two competing models, namely the timber structural model and the concrete structural model, to emphasise the economic convenience.

When an automated large-scale manufacturing process is used to fabricate the parts of the wood model, the influence of this cost gap between the two models will be felt strongly. The conventional concrete model is difficult to automate. As a result, the timber model has a leg up over the concrete model. Because of the light weight of the timber model's superstructure, walls, and finishes, the building's foundations will be saved by at least 50%. When all of these savings are added together, the overall cost of the timber model building will be less than half that of the concrete model.

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VI. CONCLUSION

A cross-laminated wood slab may serve the same function as a precast concrete slab unit. The timber method eliminates the requirement for steel in a limited number of circumstances (below 4kN/m2 applied load and less than 9m column-to-column spacing). The difficulties of fire resistance and robustness have essentially been handled, but the link between the timber slab and the steel beam is still a mystery. Methods were established to compare the cost and environmental impact of using timber versus concrete, but their usefulness and reliability were hampered by a lack of valid input data.

In a review of several papers, Nassen et al [42] found that replacing concrete with wood resulted in a significant reduction in CO_2 emissions associated with the structure, and that as a result, timber as a building material becomes much more competitive when CO2 emissions are expensive, and that demand for timber would increase accordingly.

Of course, the environmental advantage of lumber is restricted. If there is a move toward lumber as a construction material, the amount of forestry maintained for sustainable development and good output will need to rise. Dodoo, Gustavsson, and Sathre, citing Ericksson et al., say (2007),

"If harvesting levels are increased, age class structure would change towards younger age classes and growth increment would increase. Intensification of forest management on at least part of the forest area, through e.g. fertilization or optimization of thinning operations, would further increase the growth increment, within ecological constraints"

To conclude, replacing concrete slabs with timber in residential buildings in Egypt has proven efficient and sustainable in fire resistance and robustness, but the cost, as the wood used is not naturally found in the region, is not the most affordable alternative.

VII. ACKNOWLEDGMENT

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