Comparison Between Timber Concrete Composite Slab and Solid Slab for Residential Buildings

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Abstract:- This research aims to compare Timber concrete slabs (TCC) with solid slabs (RC) to show that TCC may be used to minimize building weight and construction costs. Moreover, the purpose of this project is to use CypeCAD software to design a one-way TCC slab and a two-way solid slab, analyze the data supplied in the software, and compare the findings according to the Eurocode standard. The results illustrate that although the timber concrete composite slab is a new constructive solution and is little used in many constructions, it is less expensive compared to the conventional solution adopted in many countries around the world. This system (TCC Slab) accounts for 62% of the total cost of constructing a solid slab with the same size and architecture. Overall, the TCC slab is cost-effective compared to the solid slab with beams, which can reduce 38% of the total cost of construction. Additionally, the results showed that the TCC slab represents a phenomenal potential to be utilized in residential structures from an economic standpoint, as it is less expensive than a two-way solid slab with a beam (RC slab).

Keywords: *Timber-Concrete Composite Slab, Two-Way Solid Slab, One-Way TCC Slab, Eurocode, Cypecad Software.*

I. INTRODUCTION

Timber has been used as a building material for ages, and several mid-rise buildings have also been constructed. Manufactured wood materials, i.e. glue-laminated lumber, became an excellent replacement alternative to steel in the twentieth century, particularly in large-span constructions with equal strength/weight ratio [1]. It has a high potency ratio, can transfer tension and compression stresses, and is naturally suitable for use as a flexural member. Lumber is used to create frames, columns, trusses, and girders, as well as columns, decks member, railway platforms, and concrete formwork [2]. Despite being one of the oldest building materials, timber has lately trailed concrete and steel in the construction sector due to purported issues which include limited concrete members, resilience, fire protection, and costs. Wood products are being developed to overcome these issues [3]. TCC constructions are becoming more popular as floor options. They are made up of a wooden element shear joined to a concrete slab. These hybrid structural sections might be used in future constructions to increase acoustic isolation while also increasing heat retention, in addition to existing structures to boost strength and stiffness while reducing vibration sensitivity [4]. Cross-laminated timber (CLT) and glulam, have enabled wood to be utilized for bigger buildings that were previously designated for concrete and steel construction [5]. Because the benefits of pure timber slabs are mixed with the benefits of pure concrete slabs, timber-concrete composite structures are one option for typical slab systems [6]. The link between the lumber and the concrete determines the system's durability; consequently, the connections ought to be robust, stiff, and inexpensive to build [7]. This research aims to compare Timber concrete slabs (TCC) with solid slabs to demonstrate that TCC could be employed to reduce building weight and cost of construction. Furthermore, the purpose of this project is to use CypeCAD software to design a one-way TCC slab and a two-way reinforced concrete slab with beams, analyze the data supplied in the software, and compare the findings according to the Eurocode standard.

➢ *Synopsis of Slabs*

Slabs are structural elements that compose buildings' bases and ceilings and are designed to withstand uniform forces. Slabs can be supported simply or continuously over one or more supports [8]. Slabs are characterized depending on a variety of factors [9]:

- Shapes include squares, rectangles, circles, and polygons.
- Support type: wall-supported slab, beam-supported slab, column-supported slab (Flat slabs).
- Boundary condition: Sustained, Cantilever slab, Overhanging slab, Fixed slab, or Continuing slab.
- Rib slab/Grid slab, Solid slab, Filler slab, Folded plate: cross-sectional or sectional arrangement.
- Foundation of spanning directions: one-way slab: that runs in only one direction, two-way slab: Runs in both directions.

This segment of the research will cover the overview of TCC slabs and solid slabs, advantages, disadvantages, and design.

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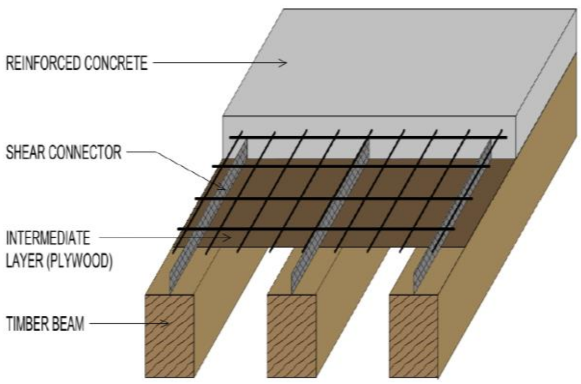
➢ *TCC Slab*

The TCC structure is a building technology that involves connecting timber beams or slabs to an upward cement flange using various connectors. Since the wood resists flexing and tensile stresses caused by loads and the concrete topping resists compression, the best properties of both materials may be employed. Floor systems with intermediate spans (7-15 m) may be developed as a result of the interlayer connection's superior structural system between two materials [10]. This method uses a connecting mechanism to transmit shear loads between a solid, glued laminated (Glulam), or laminated veneer lumber (LVL) wood beam and a reinforced concrete slab cast above it. In this connection technique, connectors such as nails, fasteners, and grooved metal plates inserted in the lumber, grooves carved from the timber, or a combination of the two can be utilized [11].

- *Design of TCC Slabs*

TCC is a tried-and-true building material for the creation of long-lasting, load-bearing floor systems. TCC sections are comprised of wood beams joined to a basic or reinforcing concrete slab by shear connections. Shear connections usually only provide a flexible connection between the lumber beams and the concrete slab [12]. There are various types of composite flooring designs, the most common of which are solid timber slab designs and beam designs. In terms of buildability, cost, strength, and aesthetics, each basic kind has advantages and cons [13]. Solid wood lumber, glulam, structural composite lumber (SCL), including CLT, or other lumber materials can be used to make the timber component. Shear connections can be discrete fasteners or shear connectors that transfer the weight to a wider surface. It is also feasible to combine many shear connections [14]. Three essential design requirements must be met for this building style to be efficient: To ensure that both components work well, the neutral axis of the TCC cross-section must be near the wood interface. Because the concrete is only pressed and the wood is regularly exposed to tensile forces, the interconnection framework should be robust and rigid enough to convey the basic tensile force while also providing additional efficient composite action [15]. Figure 1, shows the composition of the composite systems floor.



Source: [16]
Fig 1 Timber Concrete Composite Systems Floor

✓ *Glue Laminated Timber (Glulam)*

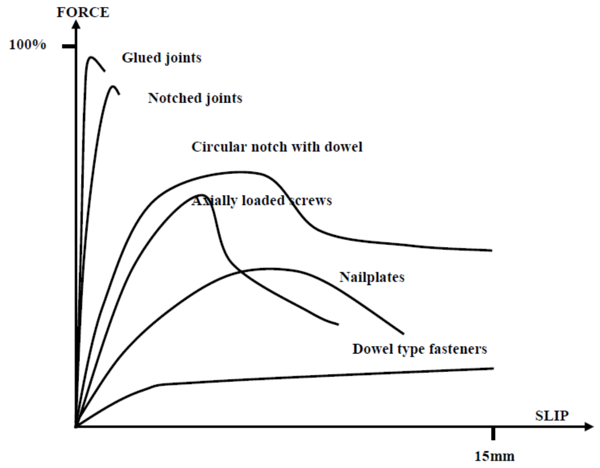
Glulam, also known as glue-laminated lumber, is a composite with more uniformly distributed and superior mechanical qualities than lumber [17]. Glulam is made up of tiny pieces of wood (called laminates) that are joined together using adhesives and planned out so that the surface of all laminates is typically aligned with the long axis. Single composites are typically 18-50 mm thick, 1.6-5.0 m long, jointed using the fingers jointing process, and then distributed along with the glulam element. Before being machined and assembled, the laminates are typically dried to a moisture level of 12-18%. After finger jointing, edge-gluing allows beams wider and bigger than commercially available sections to be made. The faces of the laminates are frequently assembled by using a precisely regulated adhesive mix. They are then put in the appropriate mechanical or hydraulic jigs, pressured at right angles to the glue lines, and kept until the adhesive has finished curing. The glulam is then cut and molded and any necessary preservative and concluding treatments are performed [2].

✓ *Plywood*

Plywood is a flat panel formed by gluing together and pressing several thin layers of veneer, known as plies (or laminates). The initial version of EWP was made of plywood. Debarked logs are steamed or cooked in hot water for roughly 24 hours. They are then rotary peeled into veneers ranging in thickness from 2-4 mm and trimmed into 2 m broadsheets [2]. Plywood is classified into numerous types: deciduous or conifer plywood - throughout the construction [18].

✓ *Connector*

There are numerous forms of timber and concrete connectors, including bonded, non-bonded, and notched connections. Notched connections are formed comprised of a groove cut from the wood piece into which the cement is poured, and a screw can be inserted into the notch for enhanced efficiency. A solid wood slab design is frequently made up of a wood frame platform formed of fastened wood planks with a concrete slab cast straightforwardly on top. Floors typically use a notched link, in which the concrete is poured into channels or ditches in the top of the wooden platform, as a result of which a highly strong and full composite connection is obtained. To produce cemented connections, steel is bonded into the wood goods and extends into the concrete slab [13]. To withstand possible tensile loads caused by stretching and to limit the breadth of the concrete fracture, steel mesh is usually formed into the slab [19]. Fasteners partly entered into pre-drilled openings in the timber, a punched steel profile pressed into the lumber, slanted rebar driven into small holes, and shear studs screwed into the wooden component are examples of non-glued connections [13]. Figure 2, illustrates the typical load-ship behaviors for numerous kinds of joints.



Source: [20]
Fig 2 Typical Load-Slip Behavior for Various Kinds of Joints

The system has a substantial impact on the operation of the TCC floor. For best structural efficiency, shear connections must be stiff and robust, resulting in the lowest number of comparative slippages among the under filament of the concrete slab as well as the peak filament of the wood beam. Despite the undeniable benefits of TCC structures, there are significant challenges that limit their widespread use [11].

- *Advantages and Disadvantages*

Wood has a lower density than concrete, they are lightweight than equivalent all-reinforced concrete systems. Lumber and concrete, when properly coupled, can even have three times the highest load capability and 6 times the flexural stiffness of standard timber floor systems. In regards to forces applied per unit self-weight; they are far more cost-effective than all-reinforced concrete structures. Although composite systems are far less structurally advantageous than all-timber systems, they are less expensive [21]. TCC systems are less susceptible to vibration, which is advantageous, especially with long spans. The non-combustible concrete layer improves the floor's fire resistance. Over time, the tightness against gas and fire extinguishing water is guaranteed. For maximum cost-effectiveness, some prefabrication is frequently pursued. Because of the pre-installed wood slab, the expense of formwork is kept to a minimum. The added weight of the concrete improves the acoustic qualities of the floor. Additional mass for acoustic enhancement may be mostly avoided [22]. The load capacity of a composite floor utilizing tubular connections is about three times that of a wood floor before reinforcement [23]. One of the most significant problems with using lumber is its low elastic modulus, which must be solved by enhancing the dept and severely limiting the use of timber components [24]. Shear loads are often nearly completely absorbed by the ribs, although bending stiffness and strength are due to both the flange and the ribs. Different mechanical fasteners, such as screws (which should preferably be slanted for greater strength and rigidity), double-sided perforated metal plates, and glue, can be utilized [25]. To begin with, the high labor costs required frequently preclude the adoption of TCC. The connecting system has a considerable impact on the overall building cost. The behavior of the connecting system has a considerable impact on the operation of the TCC floor [11]. Despite being one of the oldest building materials, timber has lately trailed steel and concrete in the industrial building industry due to perceived difficulties including small truss members, endurance, fire safety, and cost. [3]. The overall cost of the restored floor system is less than replacing the complete floor system with a concrete floor or a new timber floor system. The existing sheeting or boards serves as a permanent formwork, saving time and money. Because the concrete can be pumped to the correct place, substantial portions of the building envelope do not need to be demolished to install massive prefabricated features. The building industry is unfamiliar with the employment of timber-concrete composites and their structural behavior. The effectiveness of this kind of composite construction is strongly dependent on the properties of the shear connection type chosen. However, no acceptable design code has been developed since these features and the performance of the beams built with them have not been adequately examined [26]. TCC sections profit from the strong compressive strength of concrete, while wood carries tensile loads. To achieve that kind of force distribution, the contact between lumber and concrete should be capable of transferring shear. Traditionally, shear studs or nuts were employed to distribute shear among wood and concrete. The shear strength of screws, fastener concrete, and bolt-wood contacts limits shear transfer capacity. The standard concrete material utilized in these systems sometimes needs extra reinforcing, which is time-consuming. This, together with the usage of fasteners to distribute shear, can result in somewhat expensive construction costs [27]. TCC systems are less susceptible to vibration, which is advantageous, especially with long spans. The non-combustible concrete layer improves the floor's fire resistance. Over time, the tightness against gas and fire extinguishing water is guaranteed. For maximum cost-effectiveness, some prefabrication is frequently pursued. Because of the pre-installed timber slab, the expense of formwork is kept to a minimum. The added weight of the concrete rises the acoustic qualities of the floor. Additional mass for acoustic enhancement may be mostly avoided [28]. A concrete floor structurally associated with its supplementary timber joists via corners split from the wood or suitable mechanical fasteners provides several benefits, including preserving the previous timber structures while increasing rigidity and strength; Working to develop a rigid floor diaphragm, and improving the floor's sound detachment, heat mass, and burn resistance. In terms of strong performance, the components in TCC are well exploited, with the wood web mostly exposed to tensile and stretching, the Please concrete flange primarily exposed to compression, and the connecting system primarily subjected to shear [29]. The gains of such rebuilding enhanced procedures, which can be applied to new construction, entail enhanced stiffness and load-carrying rigidity, managed to improve soundproofing and fire resistance, and cost and environmental benefits obtained whenever the current supporting wood structure is used as a framework. [30]. The anisotropic structure of timber has made constructing connecting details problematic in the architecture of this system. It is preferred to stress lumber in contraction parallel to the direction instead of opposed to the grain to provide more strength and stiffness [31].

➢ *Solid Slab*

A solid slab is a structural solution composed of a platform supported by pillars that are employed to transfer dead and live loads to vertical sections via bending, shearing, and torsion. They are employed in a variety of settings, including buildings, bridges, and parking lots. It is a significant issue to use standard flat slabs in these locations since they require a big column-free pace [32]. Solid slabs are used in the building of floors, roofs, walls, and bridge decks. The floor system of construction might be in situ, ribbed slab, or pre-cast elements. Slabs can be supported by a huge concrete structure, a steel beam, a or wall, or they can be placed directly over columns [33].

- *Design of Solid Slab*

Concrete frame buildings are a prominent, if not the most common, type of modern architecture. As the name indicates, this kind of construction is composed of a concrete frame or skeleton. Beams are horizontal structural components of this construction, whereas columns are vertical elements. Reinforced concrete slabs can be placed in the place or fabricated. The concrete slab floor in situ is constructed using formwork, which is often comprised of hardwood planks and boards, plastic, or steel and incorporates steel bars known as reinforcement. Straight bar reinforcement is most commonly utilized, however cranked bar reinforcement is also used the reinforce, frame supports, and span proportion of a slab to determine whether it is one-way or two-way. The former is universally accepted, and the proportion of large to small time frames is greater than two. It also has a shortened proportion of less than two and is retained on all four corners. Several criteria and limitations impact the selection of the most suitable and cost-effective concrete slab, including the types of construction, building design, the appearance of the product, and size concrete slabs are available in a wide range of forms and sizes, including one-way joist slabs, plain slabs, waffle slabs, hollow core slabs, prefabricated slabs, bubble deck slabs (voided Slabs), tough slabs, and composite slabs. Because the slab may span between columns with proper reinforcing features, no support beams or girders are necessary for this situation. Solid reinforced concrete slabs are frequently constructed as one-way or two-manner slabs relying on the span duration proportion and the flexural stiffness of the slab. A span ratio larger than 2 is typical for a one-manner slab. One-way slabs are designed to span only one path. The slab extends to beams and relies on reinforcement installation to span continuously over numerous bays [34].

- *Advantages and Disadvantages*

One of the most significant advantages of a two-way flat slab over one-way or two-way slabs that transmit the weight to beams and girders is that flat slabs have lower floor-to-floor heights. When there are no beams and girders, the structure takes up significantly less space, up to a foot less on each story. This can result in many feet being removed from the overall height of a multi-story building. Reduced building height offers a variety of cost advantages, including the use of less finish material, such as building cladding and paint [33].

II. METHODOLOGY

The project entails designing and calculating a one-story house with two bedrooms, a kitchen, a great room, a dining area, and a bathroom as a total area corresponding to 95.75m^2. Moreover, the methodology applied in this research consists of designing a one-way TCC slab and a two-way solid slab using the CypeCAD software, followed by data analysis and comparing the findings according to the quantities of the materials employed in each system as well as the cost of construction for both structural solutions. The following norms and rules were applied for dimensioning: Eurocode 0 [39], Eurocode-1 [38], Eurocode-2 [35], Regulation of Reinforced and Prestressed Concrete Structures (REBAP) [36], Safety Regulations and Actions for Building Structures (RSA) [40], and Eurocode 5 [37].

➢ *Applied Approach*

- *Building Configuration*

The project's case study building is a modern house plan with two bedrooms, one bathroom a large great room with a dining area, with a modern kitchen all areas correspond to 95.75 m^2.

- *CypeCAD Software*

CYPECAD is reinforced concrete, steel, wood, and aluminum structural software that provides geographic information systems, structure elements designing, reinforcements and sections generation, and construction drawings. It examines three-dimensional structures composed of supports and floor slabs, including their foundations, as well as the automated design of reinforced concrete, steel, wood, and aluminum components. The designer has a precise and efficient tool for resolving all components related to the structural analysis of any type of concrete using CYPECAD, which is also compatible with the most recent international Codes.

- *Material Specifications*

The materials to be used must comply with the rules and regulations in force regarding their quality and operation, and these must satisfy the requirements in terms of resistance, efficiency, operation as well as the Eurocode standard.

✓ *Concrete*

The concrete to be used must satisfy the considerations mentioned in the characteristics of the materials, thus having the classes of the concrete used when designing the structure.

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Table 1 Characteristics of Concrete used in the Research

Concrete	[KN/m^3]	f_{ck} [MPa]	f_{cd} [MPa]	$f_{ctk0.05}$ [MPa]	f_{ctm} [MPa]
$C_{20/25}$ (B25)	24.00	20.00	13.33	1.80	2.20

Source: [35]

✓ *Steel*

The steel to be used must satisfy the considerations taken in the characteristics of the materials, and the classes to be used in the structure and its dimensioning will be:

Table 2 Characteristics of the Steel used in the Research

Steel	f_{yk} [MPa]	f_{yd} [MPa]	E [GPa]
S 400	400.00	348.00	210.00

Source: [36]

✓ *Glulam*

The timber to be used in this project must satisfy the following characteristics:

Table 3 Characteristics of the Glulam used in the Research

Glulam	f_{yk} [MPa]	f_{yd} [MPa]	E [GPa]
GL34H	11600	34	23.50

Source: [37]

✓ *Connector*

Lag screws, when partially inserted into the wood, can act as shear connections in TCC flooring. The lag screw that should be used for this research needs to fulfill the following conditions:

Table 4 Characteristics of Shear Connectors used in the Research

Lag Screws	F_{max} [KN]	K_{ser} [KN/mm]	Slip [mm]
Ø 12	21.5	195.5	15

Source: [37]

III. RESULTS AND DISCUSSIONS

This chapter covers the design and analysis of one-way TCC slab and two-way reinforced concrete slab using CypeCAD software to understand which of them is more effective economically and presents reduced weight.

➢ *Solid Slab (RC Slab)*

The following plan is constituted of 5 panels, 12 beams (Frames), and 16 columns. The thickness adopted for the slab is 20 cm.

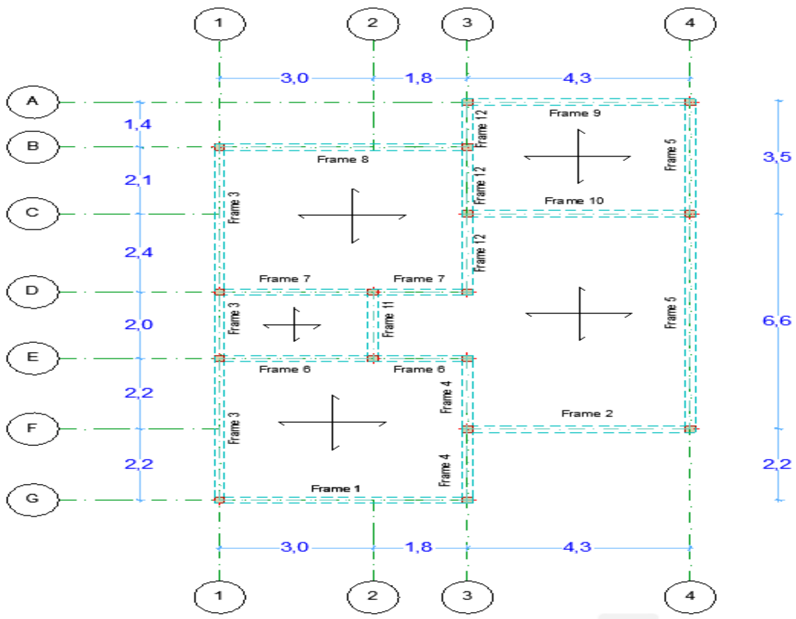

Fig 3 The Plan Consists of a Solid Slab, Beams (Frames), and Columns

- *Slab*

Table 5 Results for Solid Slab Analysis Related to Concrete Volume and Formwork

Slab ID	Length	width	Volume m³	Formwork m²
Panel 1	4,8	4,4	4,224	21,12
Panel 2	3	2	1,2	6
Panel 3	4,8	4,5	4,32	21,6
Panel 4	6,6	4,3	6,396	28,38
Panel 5	4,3	3,5	3,01	15,05
Total			19,15	92,15

- *Rebar for the Slab*

✓ *Longitudinal Reinforcement*

Table 6 Results of the Analysis Related to Rebar for Longitudinal Reinforcement at the Bottom

Slab	Dia.	No.	Lengtht(cm)	Total (cm)	S 400 (Kg)
Longitudinal Reinf.	ø8	12	350	4200	16,6
	ø10	4	620	2480	15,3
	ø10	32	450	14400	88,8
	ø8	29	500	14400	57,2
	ø8	9	620	5580	22
	ø10	7	510	3570	22
	ø8	20	510	10200	40,3
	ø8	20	460	9200	36,3
				Total	298,5
				ø8	189,64
				ø10	138,71
				Total	328,35

✓ *Transversal Reinforcement*

Table 7 Results of the Analysis Related to Rebar for Transversal Reinforcement at the Bottom

Slab	Dia.	No.	length (cm)	Total (cm)	S 400 (Kg)
Transverse Reinf.	ø8	30	450	13500	53,3
	ø8	5	210	1050	4,1
	ø8	30	460	13800	54,5
	ø8	26	210	5460	12,1
	ø8	7	690	4830	19,1
	ø8	25	360	9000	35,5
	ø8	12	690	8280	32,7
	ø10	7	690	4830	29,8
	ø8	2	1030	2060	8,1
				Total	249,2
				ø8	241,34
				ø10	32,78
				Total	274,12

✓ *Longitudinal Reinforcement in the Top (Supprts)*

Table 8 Results of the Analysis Related to Rebar for Longitudinal Reinforcement at the Top

Slab	Dia.	No.	length (cm)	Total (Cm)	S 400 (Kg)
Top Longitudinal Reinforcement	ø8	12	110	1320	2,9
	ø10	8	460	3680	32,7
	ø8	105	170	17850	39,6
	ø10	10	440	4400	27,1
	ø10	8	500	4000	24,7
	ø10	12	470	5640	50,1
	ø10	4	370	1480	13,1

	ø10	4	330	1320	11,7
	ø10	4	480	1920	17
	ø10	4	320	1280	11,4
	ø10	4	170	680	6
	ø10	4	320	1280	7,9
	ø8	4	190	760	3
	ø8	22	150	3300	7,3
	ø10	4	170	680	6
	ø10	2	220	440	6,9
	ø10	3	420	1260	11,2
	ø10	2	430	860	7,6
	ø10	2	450	900	5,5
	ø10	2	380	760	4,7
	ø10	2	240	480	7,6
	ø10	2	330	660	4,1
	ø10	3	170	510	3,1
	ø10	2	150	300	1,8
					313
				ø8	58,08
				ø10	286,22
				Total	344,3

✓ *Transversal Reinforcement in the Top (Supports)*

Table 9 Results of the Analysis Related to Rebar for Transversal Reinforcement at the Top

Slab	Dia.	No.	Length (cm)	Total (cm)	S 400 (Kg)
Top Transverse Reinforcement	ø8	12	100	1200	2,7
	ø8	8	880	3520	13,9
	ø8	105	160	7680	17
	ø8	10	730	2920	18
	ø8	8	310	1550	6,1
	ø8	12	680	11560	45,6
	ø8	4	520	2600	16
	ø8	4	240	1680	6,6
	ø8	4	470	6580	26
	ø8	4	220	2640	5,9
	ø10	4	570	3990	24,6
	ø10	4	230	460	2,8
	ø10	4	210	420	2,6
	ø10	22	870	1740	10,7
	ø10	4	1020	2040	12,6
	ø10	2	270	540	3,3
	ø10	3	820	1640	10,1
	ø8	2	250	500	2
	ø10	2	320	640	3,9
	ø10	2	690	1380	8,5
				Total	238,9
				ø8	175,78
				ø10	87,01
				Total	262,79

- *Reinforced Concrete Beam*

Table 10 Results of the Structural Analysis for Reinforced Concrete Beam, in Terms of Concrete Volume, Formwork, and Steel Bar

Beam ID	Width m	Conc. Volume m^3	Formwork m^2	Steel Bar (Kg)
Frame 1	4,8	0,614	5,28	30,7
Frame 2	4,3	0,555	4,73	29,3
Frame 3	4,4	0,542	4,84	28,4

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	2	0,245	2,2	10,7
	4,5	0,554	4,95	28
Frame 4	2,2	0,281	2,42	16,1
	2,2	0,279	2,42	12,8
Frame 5	6,6	0,813	7,26	49,9
	3,5	0,431	3,85	34,2
Frame 6	3	0,376	3,3	16,7
	1,8	0,238	1,98	13,5
Frame 7	3	0,376	3,3	16,2
	1,8	0,238	1,98	12,6
Frame 8	4,3	0,555	4,73	28,7
Frame 9	4,8	0,614	5,28	31,1
Frame 10	4,3	0,555	4,73	25
Frame 11	2	0,281	2,2	11,9
Frame 12	2,4	0,307	2,64	13,7
	2,1	0,247	2,31	15,5
	1,4	0,184	1,54	11,2
Total		8,285	71,94	523,44

➢ *Timber Concrete Composite Slab*

This structural solution is composed of TCC slabs made up of glue-laminated timber beams and glulam timber panels with concrete and reinforcement forming the structural framework for the slab.

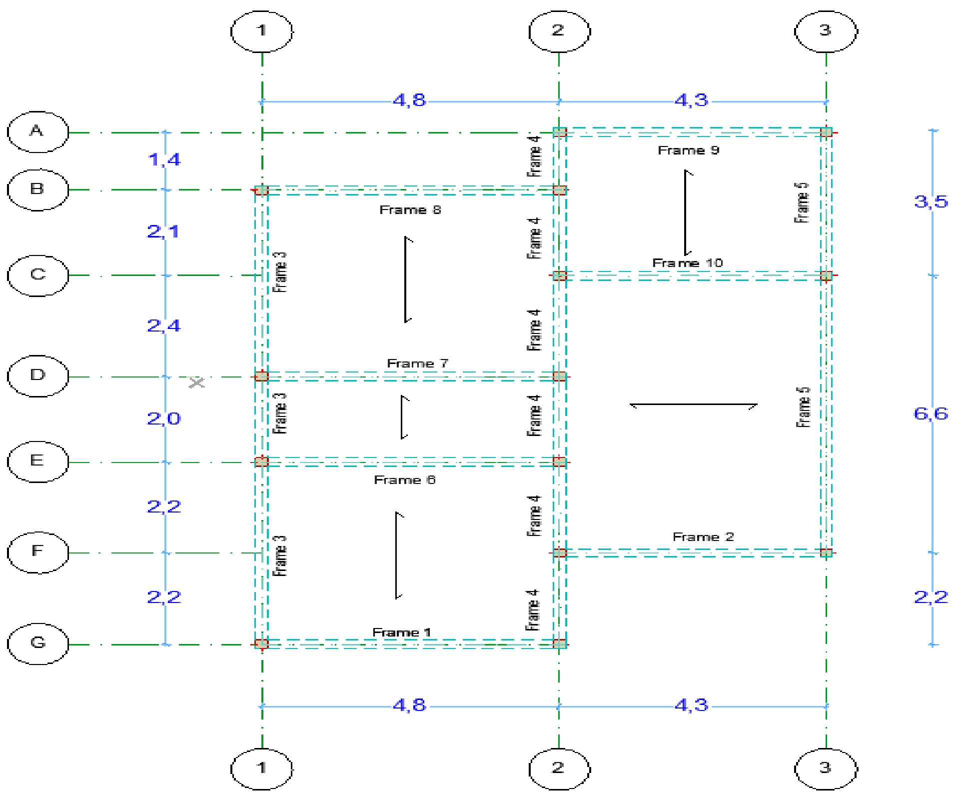

Fig 4 The Plan Consists of a TCC Slab, Timber Beams (Frames), and Columns

Table 11 Results of the Analysis Related to Timber Panels, Concrete Volume, Mesh and Screw Dowel

Slab ID	**Type**	**Area m^2**	**Conc. m^3**	**Mesh kg**	**Dowel un.**
Panel 1	GL-240x120	21,12	1,1	10,0	220
Panel 2	GL-180x120	9,6	0,5	7,4	100
Panel 3	GL-240x120	21,6	1,1	10,1	225
Panel 4	GL-180x120	15,05	0,8	8,5	193,5
Panel 5	GL-240x120	28,38	1,4	11,8	487,5
Total			4,8	47,7	1226

- *Timber Joists Quantity*

Table 12 Results of the Analysis Related to Timber Beams Quantity over the Slab

Slab ID	Type	Length m	Quant. un.	Total m
Panel 1	GL-180x120	3,3	9	30
Panel 2	GL-240x120	4,2	15	63
Panel 3	GL-160x120	1,75	1	2
	GL-160x120	2,1	1	2
	GL-240x120	4,35	10	44
Panel 4	GL-160x120	1,85	1	2
		1,9	1	2
	GL-240x120	4,25	10	43
Panel 5	GL-160x120	1,75	1	2
		1,95	10	20
Total				208

- *Timber Concrete Composite Beam*

Table 13 Results of the Analysis Related to Timber Beams in the Corner of the Slab

Frame	Type	Width (m)
1	GL-160x120	4,8
2	GL-160x120	4.3
3	GL-380x120	10.9
4	GL-380x120	12.3
5	GL-280x120	10.1
6	GL-380x120	4.8
7	GL-280x120	4.8
8	GL-160x120	4.8
9	GL-160x120	4.3
10	GL-380x120	4,3
Total		65.4

➢ *System Comparison*

This part of the research will address the comparison in terms of the quantity of material calculated and analyzed by the software.

- *Beam Comparison*

The graph below illustrates the results obtained with the structural analysis using CypeCAD Software for both structural solutions, namely TCC Slab and Solid Slab (RC Slab). Fig. 5 clearly shows that reinforced concrete slabs have approximately 95 m^2 and more than 10 m^3 as a result of formwork and concrete volume respectively. Meanwhile, for steel bars, the software provides less than 0.8 tons for longitudinal and transversal rebars. On the other hand, for the TCC slab, the results showed that for the slab it is needed 2.6 m^3 of glue-laminated timber beam.

Fig 5 Comparison between TCC Beam and RC Beams in Terms of Concrete Volume, Formwork, Steel Bar, and Volume of Timber

- *Slab Comparison*

For this section, the results showed that the TCC slab required 4,8 m^3 of concrete, and 1226 units of screw dowel to serve as a shear connector between the timber beam and slab as well as provide good interaction between both materials (Concrete and Timber). Meanwhile, for solid Slab (RC Slab) fig. 8 demonstrates that approximately 25 m^3 and 284kg of concrete and mesh respectively are needed to cover the slab with 120 m^2 of formwork to provide the form of the slab, also it possible to see that for solid slab it is necessary 1,8 ton of steel reinforcement namely bottom transversal and longitudinal reinforcement as well as top transversal and longitudinal reinforcement to fulfill all requirements needed in a two-way solid slab. From the graph below it is possible to observe that the volume of concrete in the solid slab is 5 times higher than in the TCC slab. Additionally, the timber panels play a double role, first as formwork and second as a part of the composite slab which reduces the necessity of formwork for this structural solution of slab compared to solid slab. With regards to rebar, the quantity of rebar needed for the solid slab is higher than the TCC slab.

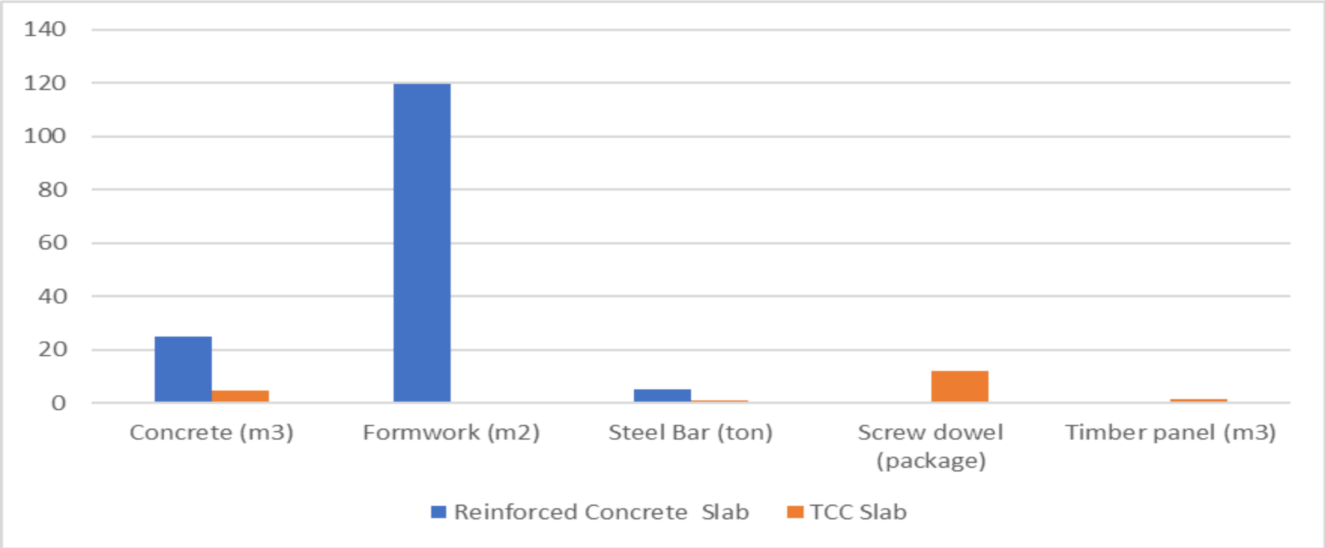

Fig 6 Comparison between TCC Slab and RC Slab in Terms of Concrete Volume, Formwork, Steel Bar, Screw Dowel, and Timber Volume

- *Cost Comparison*

The graph (Fig.7) shows the results related to the cost of construction of both structural solutions namely TCC slab and Solid Slab (RC slab). From the graph, it's possible to understand that the solid slab is more expensive than the TCC slab with a difference of 5000$. Furthermore, for the solid slab, the total cost is approximately 14000$, meanwhile, for the TCC slab the price is 8600$, which represents 62% of the total amount in the bill of quantities of the solid slab. Moreover, the graph provides a cost comparison related to the slab and beams for both structural solutions. For the TCC slab, the cost is relatively close to the solid slab with 7100$ and 8100$ respectively, which represents 1000 $ the difference for both slabs. With regards to beams, Reinforced Concrete beams are more expensive than timber slabs with 5500$ and 2400$ as well as a difference of 3000 $ between both kinds of beams.

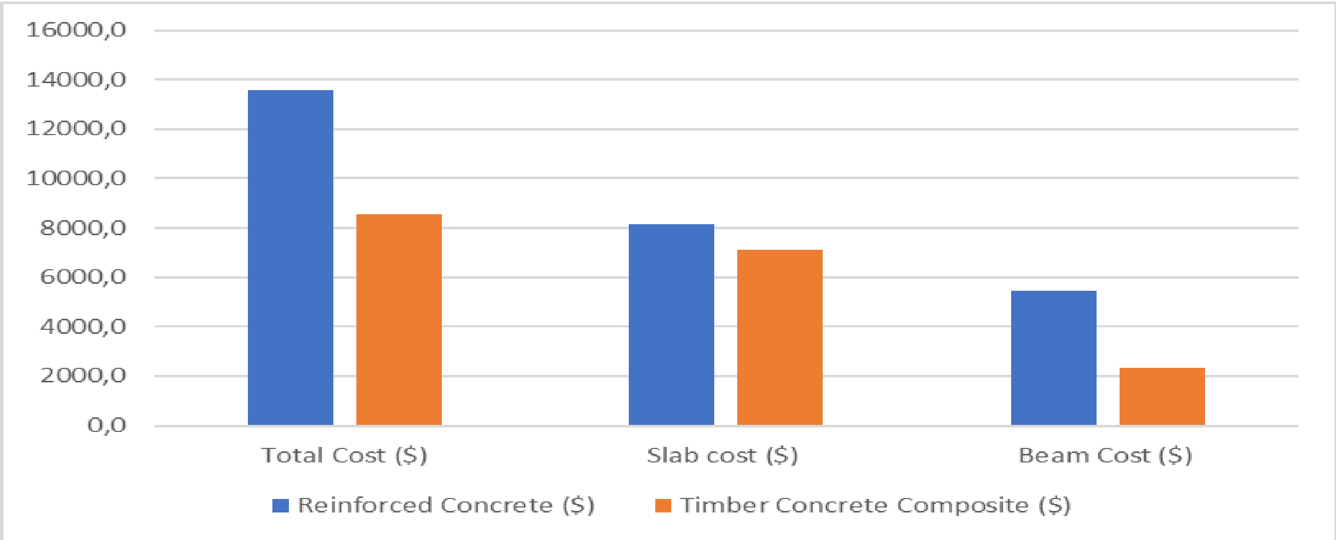

Fig 7 Cost Comparison between TCC slab and RC Slab

IV. CONCLUSION

A comparison between Timber concrete composite slab and Solid Slab (RC Slab) system was made, all designed to meet the requirements of a one-way slab and a two-way slab according to the Eurocode standard to cover a 2 rooms house with 95.75 m^2. Both structural techniques can be used for residential structures, despite their modest differences in architectural and structural layout. However, the results illustrate that although the timber concrete composite slab is a new constructive solution and is little used in many constructions, it is less expensive compared to the conventional solution adopted in many countries around the world. This system (TCC Slab) accounts for 62% of the total cost of constructing a solid slab with the same size and architecture. Overall, the TCC slab is more cost-effective than the solid slab, which can save 38% of the total construction cost, and the TCC slab represents a phenomenal to be employed in residential structures from an economic standpoint, as it is less expensive than a two-way solid slab with beam (RC slab).

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