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Timber Construction in Greece: Exploring the potential in thermal performance in an office

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Abstract
This research aims to investigate the potential of timber construction in the commercial sector of Greece, regarding the thermal performance. An office building in Athens was chosen as a case study and simulated as it is actually built (concrete) and in: timber frame (1), solid wood panels (2), and panels combined with concrete soffits (3), as successfully introduced by an office building in Grantham. The last two cases were simulated having the same and lower U value than the existing case. Timber frame was found to have the highest energy demand among all cases. The panels showed better performance when achieving lower U value, yet slightly worse than the existing case. The third case with lower U value showed the closest energy demand to the concrete case. This indicates that timber has the potential to achieve similar thermal performance to concrete in Greece, but when taking also into consideration the lower embodied energy and its other benefits, timber can be considered as an advantageous choice in the commercial sector in Greece

Keywords: timber construction, thermal performance, office

1.0 Introduction
Timber is gaining more and more ground in the construction sector. Greece, among many other countries, carries a long tradition in timber construction. However nowadays, due to vast use of concrete, timber construction occupies only a very small portion in the construction industry, mostly used in houses. Commercial buildings have yet to discover the new possibilities of timber. Due to that lack, this study explores the potential of timber construction in office buildings in Greece, using an office building in Athens as the basic case study.

2.0 Research background

2.1 Characteristics of timber
Timber has many significant attributes that make it competitive against other common materials, like concrete or steel. It is a *natural* and *renewable* material. Since it is plant based, it *stores carbon* during tree growth (Sutton et al., 2011), but it can also be *naturally regenerated* and therefore balance any CO_2 produced, that will be only released in case of fire or decomposition (Barboutis, 2010). Furthermore, it is vastly *recyclable*, as it can be easily reused after the main use, which means that *less waste* is produced (Mahapatra & Gustavsson, 2009).

All these explain why wood has *very low embodied energy*, much lower than concrete. Many studies have proved that fact (Adalberth, 2000, as found in Doddo et al, 2011/ Upton et al, 2008, as found in Nässén at al., 2011/ Gustavsson and Sathre, 2006). This is not a factor to disregard; since newer Building Regulations give improved standards, the operational energy drops significantly and so, embodied energy becomes more important when considering the whole-life footprint of the building (Dixon, 2010).

Wood has also *low conductivity*. The higher the conductivity is, the more quickly heat is released from where it is stored. Motesnitsa (n.d.) mentions that "wood is 9 times more insulating than concrete, 700 times than steel and 2000 times than aluminium". Low conductivity together with high specific heat and high density are features that make materials suitable for thermal mass. Concrete, brick and stone are such materials. Wood, however, is not considered favorable for thermal mass, as it has low density. Hameury (2006) studying the performance of concrete/heavy timber/light-weight timber envelopes concludes that the possible combination of heavy timber construction with concrete improves the energy consumption.

An indicative case study of this combination is the office building of Woodland Trust in Grantham, UK, from Feilden Clegg Bradley Studios. The building adopted an innovative solution of combining thermal mass of concrete in a timber building and got many awards for that. That innovation was to fix concrete panels to the soffits on the ceilings (Fig. 2). In that way, the concrete absorbs the heat coming from the internal and solar gains during the day, creating a cooling effect in the workspace, and then releases back the heat at night, when the windows are open to allow cross ventilation. The effectiveness of that solution on the energy consumption loads was tested from the author in a previous study and the results showed that it improved the energy consumption.


Fig.1 The Woodland Trust Headquarters, KLH, 2011


Fig.2 Concrete soffits on the ceiling timber panels, 2011, FCB studios, 2011

The rest benefits of timber should not be overseen. *Big structural endurance in relation to its weight, cost-effectiveness, prefabrication, good structural performance in case of fire, good sound proofing performance, and good aesthetic qualities* are also important advantages to take into consideration.

2.2. Timber construction in traditional architecture

In many parts of the world, more known in Central and North Europe, America and Canada, timber was a common choice for the main residence (Moraitis & Papadopoulos, 2011). In Finland, almost everything was built by logs up to 1930, when lightweight timber frame was introduced from abroad (Heikkilä, & Suikka, 2000). Similarly in Sweden, all cities we made out of wood until 1600 (Ekdahl, n.d.). Recent regulations allowed the increase of multi-storey timber construction (Schauerte, 2009, as found in Mahapatra & Gustavsson, 2009).

Greece also holds a long tradition in timber construction. According to some general principles, the ground floor should be built from very thick, load bearing stone masonry. Within it, horizontal timber beams were running in order to ensure the proper function of the cross walls as unified building element. In the upper floor, timber frame was used in most of the cases. The frame created trusses among which, filling-in materials were typically mud, straw and bricks (tsatmas). Alternatively, small timber laths could be used to fill in the trusses (bagdati) (Lianos, 2008).

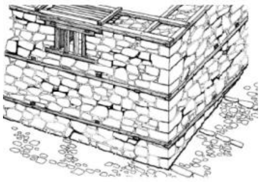


Fig.3 Ground floor construction, Lianos, 2008

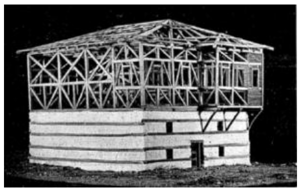


Fig.4 Physical model of a typical house in Makedonia, Lianos, 2008

2.3. Timber construction in contemporary architecture

Timber construction is gaining more and more ground in the building industry today. Although mostly used in housing, many case studies can be found in buildings in commercial, educational and industrial sector, many of which explore the possibility of going further in height.

In Greece however, timber occupies only a tiny percentage of the building industry, almost exclusively referring to houses. Most usually, these houses are made out of logs, which are often imported from Scandinavia. Timber frame also has become recently a considerable choice. Still, solid wood panels have yet to be discovered.

The only timber office building is the headquarters of a company that builds timber houses. The office stands as a prototype and is built from logs on the ground floor and timber frame on the first floor, and according to recorded temperature data, it shows satisfactory thermal performance and reduces the operational energy need.

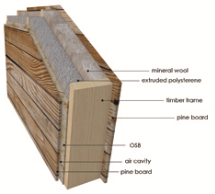


Fig.5 Detail of timber frame wall, Wands, n.d.

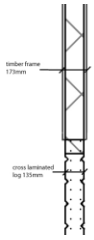


Fig.6 Detail of external wall between the two floors in the office building, Wands, n.d.

2.4. Facts and numbers about energy consumption in Greece

After the Kyoto Protocol, European Union established the Directive on the energy performance of buildings that sets rules and standards that EU countries should comply with [Directive 2002/91/EC (EPBD, 2003)]. In that frame Greece established the "Regulation of Energy Performance of Buildings (KENAK) in 2010 (FEK 407/B/09.04.2010).

According to KENAK (2010), Greece is set apart in four climatic regions, for which different standards are set. Different standards are also set according to the function of the building. However, no specific energy consumption standards are provided for each category. Some studies have been conducted on the energy consumption of the office buildings in Greece, which give a numerical indication of their performance. Indicatively, Nikolaou et al (2009) created a Virtual Building Dataset for benchmark office buildings in Greece according to energy use and thermal comfort (table 1).

Table 1. The VBD energy benchmarks for office buildings in Greece, Nikolaou et al, 2009

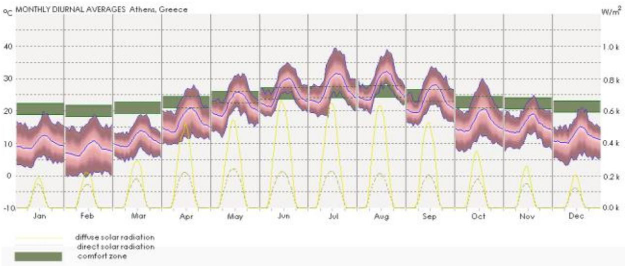
	Climatic Zone		
	A	B	C
Mean energy consumption for heating	38.7	50.0	76.1
Typical office building (50% of the stock)–heating	29.7	38.8	58.0
Best practice office building (top 25% of the stock)–heating	18.0	25.2	41.1
Mean energy consumption for cooling	108.8	110.5	97.9
Typical office building (50% of the stock)–cooling	103.7	105.3	93.5
Best practice office building (top 25% of the stock)–cooling	78.7	81.5	72.2
Mean energy consumption for heating–cooling–lighting	175.0	188.0	201.5
Typical office building (50% of the stock)–heating–cooling–lighting	168.1	179.2	188.1
Best practice office building (top 25% of the stock)–heating–cooling–lighting	135.6	145.3	152.5
Total mean energy consumption	265.9	278.9	292.3
Typical office building (50% of the stock)–total	261.8	273.0	282.7
Best practice office building (top 25% of the stock)–total	220.7	231.4	239.4

3.0 Methods

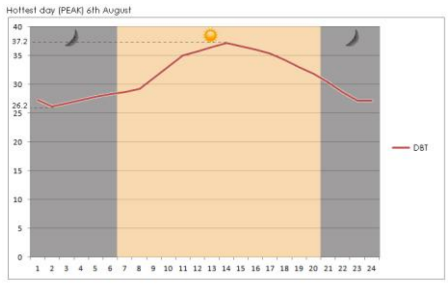
3.1. Microclimate analysis

During the research process a microclimate analysis for Athens was undertaken, in order to understand the climatic context of the case study building.

The climate in Athens is characterized by hot / dry summers and mild / wet winters. Sunshine is dominant, even in winter period. Rainfall usually takes place from October until April, but precipitation lies in very low levels (Hnms, n.d.). Graph 1 relates the diurnal temperature variation to the comfort zone and the solar radiation. Graph 2 shows the diurnal temperature variation for the hottest peak day, 6^{th} of August. Here, the maximum difference between day and night hours is 11^{o}C, which shows the potential of applying thermal mass in a building, combined with night ventilation.



Graph 1. Diurnal Temperature Variation for Athens, Weather Tool, 2011



Graph 2. Diurnal Temperature Variation for Energy Plus, 2012

3.2. Case study

The case study building was designed and occupied by an architectural firm. It was built in 2006 and won the 2nd award in “Building Green” Awards 2010 in Greece. The building is basically developed in five levels along the East- West axis with two extra levels underground. The first three levels are used as offices, while the upper two as residence. The two underground levels are used as storage and parking. The building follows some significant bioclimatic principles: a) sun-light control system with movable louvers at West façade, b) night stack ventilation through the staircase, combined with evaporative cooling through a pool at East façade, c) aluminum rainscreen cladding at North & South façade that protects from cool wind or allows it to ventilate the façade, respectively.

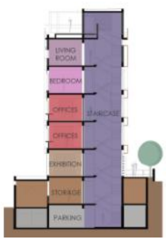


Fig.7 A-A Section, R C TECH, 2010

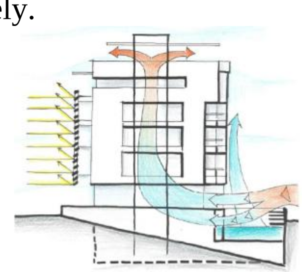


Fig.8 Evaporative cooling combined with stack ventilation through staircase, R C TECH, 2010

3.3. Thermal performance analysis

For the purpose of the research, the building was virtually simulated in TAS Bentley software. At first, it was simulated as it is actually built- which is with concrete and bricks. Then, three basic timber cases were tested: 1) timber frame, 2) cross laminated timber panels, 3) cross laminated timber panels with concrete soffits on the ceilings, as successfully introduced in Woodland Trust Headquarters (see fig. 2). The last two cases were tested both for having the same U value as in the existing case, and having lower one. For the case 1 achieving the same U value was not feasible. The database of Nikolaou et al. (see table 1) was used as reference standards.

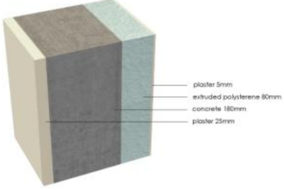


Fig. 9 Existing case wall

Fig. 10 Timber frame wall

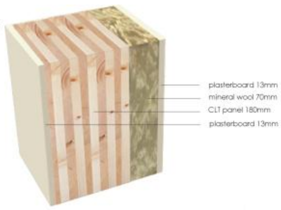


Fig. 11CLTpanel wall

Fig. 12. CLT panel with concrete soffits

Table 2. All the simulation results.

	concrete	Timber frame	CLT Same U	CLT Lower U	CLT with thermal mass Same U	CLT with thermal mass Lower U	standards
Annual Heating (Kwh)	1820.88 (4.2 (Kwh/ m^2)	736.05 (1.7 (Kwh/ m^2)	2147.28 (5 (Kwh/ m^2)	1445.75 (3.3 (Kwh/ m^2)	1955.72 (4.5 (Kwh/ m^2)	1390.25 (3.2 (Kwh/ m^2)	25.2 (Kwh/ m^2)
Annual Cooling (Kwh)	11437.32 (26.4 (Kwh/m^2)	15165.03 (35 (Kwh/ m^2)	11890.61 (27.5 (Kwh/m^2)	12336.18 (28.5 (Kwh/m^2)	12547 (29 (Kwh/m^2)	12101.98 (28 (Kwh/m^2)	81.2 (Kwh/ m^2)
SUM	13258.2 (30.6 (Kwh/m^2)	15901.08 (36.7 (Kwh/m^2)	14037.89 (32.5 (Kwh/m^2)	13781.93 (31.8 (Kwh/m^2)	14502.72 (33.5 (Kwh/m^2)	13492.23 (31.2 (Kwh/m^2)	106.7 (Kwh/m^2)

4.0 Discussion

The results showed that generally all timber cases had higher total loads than the existing case, which is due to higher cooling loads. Heating loads were found very low in all cases, as it is expected in an office where internal gains are very high. Timber frame case was found to have the least good performance. It managed to reduce significantly the heating loads, but cooling loads went far higher, which influenced the total amount. Cross laminated timber panels, when given the same U values in the building elements as in the existing case, showed higher loads both in heating and in cooling. This indicates the benefits of thermal mass, since timber has much lower density and therefore, cannot store heat for so long as concrete. When lower U value was achieved, the heating loads were reduced, but the cooling loads went even higher, however, the difference from the existing case became lower. When the solid panels were combined with thermal mass the heating loads were reduced; yet they are higher than the concrete case, similar to the cooling loads. In the last case where lower U value was achieved, heating loads were found lower than in the concrete case. Cooling loads were again higher; however, the total loads have the smallest difference from the concrete case among all timber cases. It should be mentioned that evaporative cooling through the swimming pool was not feasible to be simulated; this means that in reality, the cooling loads are probably lower.

5.0 Conclusions

The study showed that timber cannot override concrete, but it can achieve an almost equal or slightly weaker thermal performance. Thus, as revealed from literature, timber also carries a number of significant other advantages against concrete, among which, low embodied energy stands as the most important. In conclusion, we could say that timber *can achieve almost equally good thermal performance as concrete in an office building in Greek climatic context. Adding its other major benefits, it can be considered a beneficial choice in the construction of Greek offices.*

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