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Impact of Using Wood as Material for Building Renovation – Taking Research Building in NTUST as Example

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Abstract
In response to the environmental problems of global warming, the need to save energy and carbon emissions, the energy usage in the building sector accounts for 40% of global energy consumption, and its greenhouse gas emissions account for more than three-thirds of its global emissions. In this study, the energy consumption differences between building material used were examined. A typical research building located in Taipei, Taiwan as an example for many similar cases was selected for simulation. Through building a simulating model in MIDAS and replacing partials of reinforced concrete with wood, it was able to compare the difference of energy consumption between wood and reinforced concrete. Considering Taiwan is an island located at the Pacific Rim Seismic Belt with frequent earthquakes, our project not only aims to reduce energy consumption, but also the building weight. Simulation method was used to compare the energy efficiency between the existing building and three other variations including: A. Drywall partitions replaced with wood, B. All levels of reinforced concrete floor slabs replaced with wood, and C. The upper four levels of structure completely replaced with wood. And two major study objectives were focused in this study, the difference of building weight by replacing original concrete building into partial wood building, and the difference of the energy consumption un these buildings. The simulation results showed that by replacing all non-structural walls with wood can help reduce the building's weight, Co2 emission without a drastic increase in budget and therefore would be preferable as a common methodology in Taiwan's future.

Keywords: energy consumption, carbon emissions, building weight, renovation, NTUST

Introduction
In response to the environmental problems of global warming, the need to save energy and carbon emissions, the energy usage in the building sector accounts for 40% of global energy consumption, and its greenhouse gas emissions account for more than three-thirds of its global emissions. In this study, the energy consumption differences between building material used were examined, and the method follow the previous researches which indicated the benefit of applying wood as building materials [1,2,3,4]. A typical research building located in Taipei, Taiwan as an example for many similar cases was selected for simulation. NTUST Research Building (will be indicated as RB below) is located at No.43, Keelung Rd., Sec.4, Da'an Dist., Taipei City. It includes nine floors, a basement and a rooftop; one auditorium room, and approximately a hundred and ten classrooms or offices. The main occupants of the Research Building include the Architecture Department (from seventh to ninth floor), Industrial Design (from third to fourth floor) and Computer Science Department (from fifth to sixth floor). It was simplified the interior details for a smoother model stimulation by choosing an example floor plan. All further analysis in the project will be according to the example drawing as follows.

Simulation modelling

MIDAS Gen was used for simulating different versions of structure performance in this project. It is a software dedicated to optimize solutions for structural analysis. The project's goal is to replace parts of the structure material from reinforced concrete to wood, in hope of reducing carbon footprint and building weight for a better energy performance and earthquake resistance. In accordance with the replacement degree, there will be four versions of structural diagrams generated for later comparison: (a) The original building, (b) drywall partitions replaced with wood, (c) all levels of reinforced concrete floor slabs replaced with wood, and (d) the upper four levels of structure completely replaced with wood. In this study, the parameters in terms of comparing the replacement of different parts of the target building with wood was focused. The intent is that the resulting number allow for a clear understanding of possible benefits of hybrid wood structures regarding their Co2 footprint and earthquake resilience. The versions That will be compared are defined as follows:

- Type A: Existing building
- Type B: Replacing all non-structural walls with wooden wall system.
- Type C: Replacing all non-structural walls and all structural floor plates with wooden system.
- Type D: Replacing the top 4 floors of the building with wooden system.

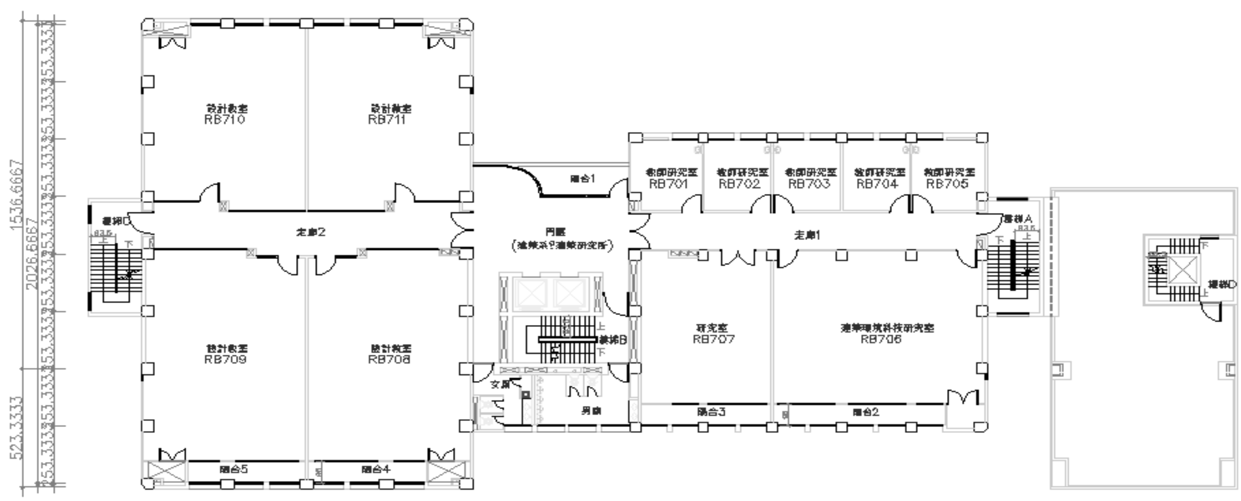

Figure 1. Typical floor plan in RB Building

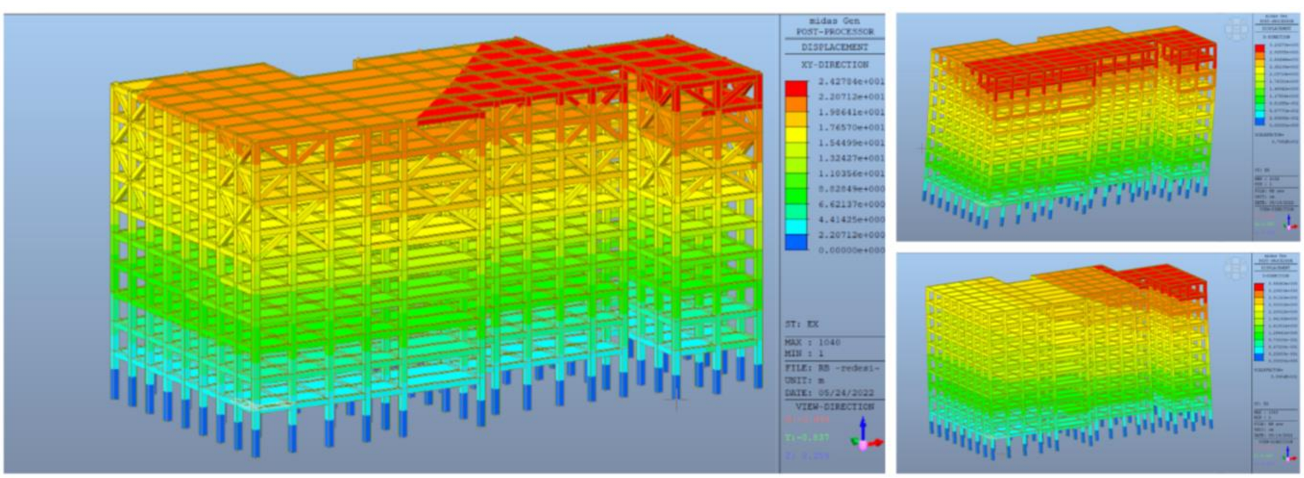

Figure 2. Earthquake response for Type D as example

Results and Discussion

In order to demonstrate the comprehensive comparison, the following parameters were chosen, which are difference of building weight, Co2 footprint, Material cost. The weight refers to the material's density in relation to its amount. Any further weight such as furniture etc. was not taken into consideration. The Co2 emission of the different materials refers to research done by PLITEQ [5]. In Order to paint a more inclusive result, the numbers do not only include the Co2 produced to produce the material but also its destruction after the life cycle of the building ends. Since Large scale wood constructions are very seldom in Taiwan, the construction cost of each material was not included into the calculation since there is no standard to be found. However, it might be added that through the much shorter construction time of wood construction the real costs for an intervention like Type D might be much closer to its predecessor than shown in the following calculations. Since Taiwan has plans to introduce a carbon taxation system similar to the one in the EU by 2023, it was also added as a parameter of comparison. Therefore, the calculations are done with the current EU tax of 2522 TWD per Ton Co2.

The resulting numbers showcase that Type C allows for the largest decrease of weight (-50%) and Co2 emission (-44%). However, it also displays the highest price increase (+123%). Type D Showcases the least inefficient reduction of weight (-29%) and Co2 emission (-18%) while still being almost as expansive (+111%) as Type C. Meanwhile, Type B gains only slightly better results in weight (-32%) and Co2 emission (-29%), slight price increase of 16% is understood, and make it the most efficient and feasible Type B according to the current local regulation.

Table 1. Parametric comparison of each typesof building

(a) Type A - Existing building

buidling part	material	total weight (T)			total CO2 (T)		Total M. Cost (TWD)	Co2 Tax cost (TWD)	Total cost (TWD)	
non structural walls	red clay brick	27916	-	-	4816	-	TWD 36,988,700	TWD 12,144,716	TWD 49,133,416	-
	reinforced concrete	31226	-	-	8262	-	TWD 76,634,790	TWD 20,836,726	TWD 97,471,516	-
colums and beams	reinforced concrete	51370	-	-	13592	-	TWD 126,069,560	TWD 34,277,864	TWD 160,347,424	-
floor plates	reinforced concrete	30576	-	-	8090	-	TWD 75,038,600	TWD 20,402,728	TWD 95,441,328	-
total ammount		**141088**			**34759**	-	**TWD 314,731,650**	**TWD 87,662,034**	**TWD 402,393,684**	-

(a) Type B - Replacing all non-structural walls with wooden wall system

buidling part	material	total weight (T)			total CO2 (Kg)		Total M. Cost (TWD)	Co2 Tax cost (TWD)	Total cost (TWD)	
non structural walls	wood (wood pillar con.)	13485	-77%	-45658	2967	-77%	TWD 202,267,500	TWD 7,481,740	TWD 209,749,240	43%
colums and beams	reinforced concrete	51370	-	-	13592	-	TWD 126,069,560	TWD 34,277,864	TWD 160,347,424	-
floor plates	reinforced concrete	30576	-	-	8090	-	TWD 75,038,600	TWD 20,402,728	TWD 95,441,328	-
total ammount		**95430**	**-32%**	**-45658**	**24648**	**-29%**	**TWD 403,375,660**	**TWD 62,162,332**	**TWD 465,537,992**	**16%**

(c) Type C: Replacing all non-structural walls and all structural floor plates with wooden system

buidling part	material	total weight (T)			total CO2 (Kg)		Total M. Cost (TWD)	Co2 Tax cost (TWD)	Total cost (TWD)	
non structural walls	wood (wood pillar con.)	13485	-77%	-45658	2967	-77%	TWD 202,267,500	TWD 7,481,740	TWD 209,749,240	43%
colums and beams	reinforced concrete	51370	-		13592	-	TWD 126,069,560	TWD 34,277,864	TWD 160,347,424	-
floor plates	wood (CLT)	6370	-79%	-24206	2790	-66%	TWD 519,792,000	TWD 7,036,531	TWD 526,828,531	452%
total ammount		**71224**	**-50%**	**-69864**	**19348**	**-44%**	**TWD 848,129,060**	**TWD 48,796,135**	**TWD 896,925,195**	**123%**

(d) Type D: Replacing the top 4 floors of the building with wooden system

buidling part	material	total weight (T)			total CO2 (Kg)		Total M. Cost (TWD)	Co2 Tax cost (TWD)	Total cost (TWD)	
non structural walls	red clay brick	12068			2082		TWD 15,990,100	TWD 5,250,123	TWD 21,240,223	
	reinforced concrete	27540	-25%	-14805	7287	-20%	TWD 67,587,750	TWD 18,376,868	TWD 85,964,618	59%
	wood (wood pillar con.)	4730			1040		TWD 70,942,500	TWD 2,624,116	TWD 73,566,616	
colums and beams	reinforced concrete	30991	-32%	-24151	8200	-28%	TWD 76,057,570	TWD 20,679,782	TWD 96,737,352	224%
	wood (GLT)	3773			1652		TWD 307,836,000	TWD 4,167,239	TWD 312,003,239	
floor plates	reinforced concrete	19193	-29%	-13754	5078	0%	TWD 47,102,330	TWD 12,806,956	TWD 59,909,286	248%
	wood (CLT)	2371			3011		TWD 193,473,600	TWD 7,594,171	TWD 201,067,771	
total ammount		**100665**	**-29%**	**-40423**	**28350**	**-18%**	**TWD 778,989,850**	**TWD 71,499,255**	**TWD 850,489,105**	**111%**

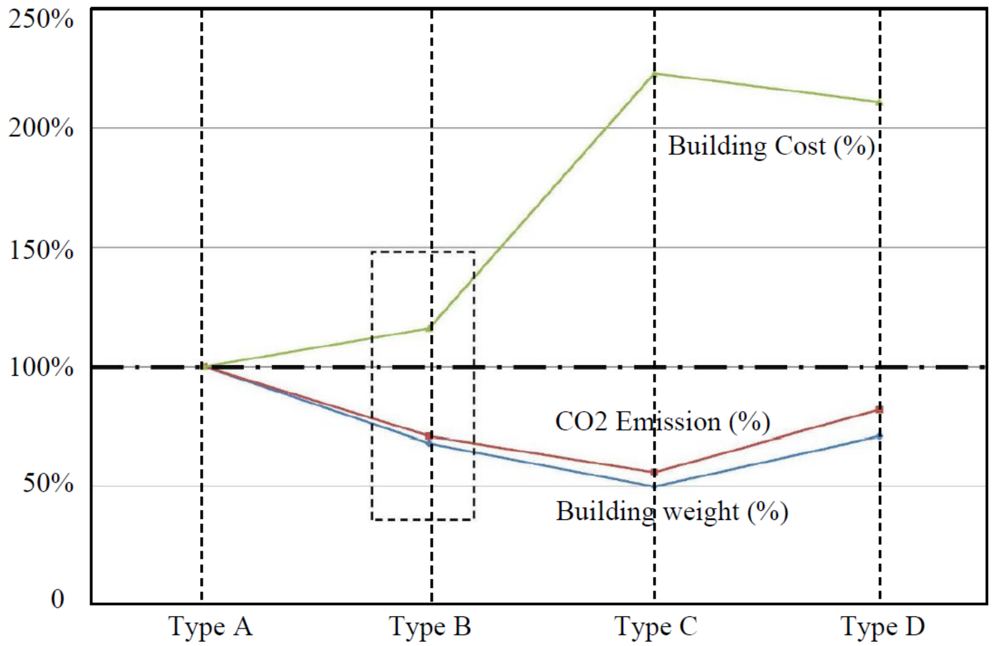

Figure 3. Comparison of impact of each building type in terms of building cost, building weight, and CO2 emission using original building (Type A) as benchmark reference

Conclusion

The comparison and calculation of the four chosen building types have shown that even a simple intervention such as the replacement of non-structural dry- and brick-walls allow for a clear reduction of the buildings weight and Co2 emission without a major budget increase. Since this type of intervention is equally possible in renovation and new build projects, does not require a different skill set than already common methods, and optimise a building's earthquake resilience. Based on the study, the proposed renovation types of buildings are preferable, and could be adopted as a common methodology in the future for the local new building project or renovation for aged buildings.

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