A review on wooden formwork for concrete casting

Mohamad Shazwan Ahmad Shah1*, Norhazilan Md. Noor1, Ahmad Beng Hong Kueh1 and Mohd. Nasir Tamin2

1 School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
2 School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

*Corresponding author: mohamadshazwan.ahmadshah@gmail.com

Abstract. This paper discusses about the advantages of using wooden formwork to cast concrete. The type of wood focused in this paper is BBCC plywood. The discussion on the wooden formwork arises when it is being compared to the steel formwork. The fact that steel-type formwork has bigger virtues over wooden formwork is undeniable. However, it should be understood that in making decision and judgement on formworks application, one must consider few important factors like cost and suitability. Wooden formwork has its own uniqueness and by some modifications, wooden formwork could be as good as steel formwork or even better from it. The advantages of using wooden formwork, specifically plywood-type will be explained from three perspectives; the cost, performance, and safety of wooden (plywood) formwork. Based these three perspectives, the paper presents positive arguments and facts to accentuate the wooden formwork if to compare to the steel formwork, with regard to the situation and environment of their usage. Based on the discussion in the paper, wooden (plywood) formwork is as dominant as steel formwork, especially if it is used in research and laboratory environment.

1. Introduction
Formwork functions as a mould by casting the concrete into the anticipated structural design in the project [1]. After a certain period of time depending on the duration of concrete gaining a minimal strength to withstand, the formwork will later be disassembled [2]. Similarly, industries use formwork to fulfil specific requirements of each project. Formworks are made up of different materials depending on several potent factors in construction such as cost, time, and quality of the concrete components. As long as the formwork criteria are fulfilled, then the formworks are considered operational. The basic criteria that need to be satisfied for formwork are quality or buildability, safety, and cost [3,4].

In some sense, material of formworks chosen should be suitable with the projects or jobs to be catered. For example, wooden formworks are suitable to mould smaller structure and light-weight. Wooden formwork costs much lower than steel formworks. Steel formworks on the other hand although they are costly but they could be re-usable for many times. However, in construction industry or in research, cost really plays an important measure in a successful project [3].

Thus, in this paper the discussion will generally discusses on the advantages from the perspective of cost and quality of concrete components using wooden formwork, in term of academic research.
1.1. Timeline in developments of formwork

- First concrete formwork used by Roman engineers.
- During 15th century, formworks being used in almost every types of concrete building.
- 16th - 17th century, formworks were used in majority of concrete building structures.

Formworks supported by vaults, domes, and arches.

This method is easier compared to stone-based building.

Development and improvisation in formworks material used

20th century onwards, formworks have become a mass production in every concrete construction.

Figure 1. History of formworks [5].

2. Steel formwork and wooden formwork review

Materials used to make formworks are dependent on several factors as mentioned earlier. Thus, in this paper only two most used materials will be layout – steel and wooden formworks.

Table 1. Advantages and disadvantages of steel and wooden formwork respectively.

| Steel Formwork | Wooden Formwork |
|----------------|-----------------|
| When properly maintained, makes steel formwork an effective long-term solution for construction needs [6,7]. | Cheaper in the short term [6]. |
| Steel formwork does not warp or absorb moisture from poured concrete [6]. | For larger or more time-consuming jobs, wood is a less ideal choice due to its tendency to warp, shrink, and swell [6,7]. |
| High ability to carry heavy load [7]. | Must be braced safely and effectively, which can be problematic on larger jobs sites [6]. |
| Easy to be fixed [7]. | Time spent cutting and drilling wood forms can impact labour costs, which can offset the lower cost of the material [6]. |
| Uniform size and surface [7]. | Wooden formwork can be used only five to ten times before it needs to be discarded and replaced [6]. |
| Limited size or shape. | Easy handling because it is light weight [7]. |
| Excessive loss of heat. | Easy to disassemble [7]. |
| Smooth surface would give problems for finishing process. | Damaged parts can be replaced with new one[7]. |
| High strength [7] | Very flexible [7]. |
| The cost of wooden formwork proven to be cheaper in certain cases [8]. |
Disadvantage of wooden formwork absorbing moisture might be actually an advantage to the moulded concrete. When the concrete is hardening, at the same time the moisture is being absorb by the wooden formwork minimally, it might prevent bubbles and void to form which actually the voids will weaken the concrete. However, as one knew about the weakness of using wooden formworks, the wooden formwork could be covered by cellotape making it as good as water-resistance material. Again, covering the formworks with cellotape is workable for smaller size of concrete especially in research works. It will be not practical if the covering method used in industry involving with bigger concrete structures.

For research purposes which normally uses smaller specimens, it is wiser to use wooden formwork for more cost-effective. Mentioning about cost-effective or reducing cost, not only the material itself has lower price – but say if the dimensions of the beam differs from one batch to another, thus the previous formworks can be used by simply add a wood-piece and screw or nail them together so that the formworks sized as needed. On the other case, if steel formworks are quite costly to fabricate few dimensions steel formworks. On top of that, the cost will be even higher if the order is just to cater small amount of concrete mix.

In research, normally the size of concrete specimen can be scaled-down based on proven facts and the testing specimens are not as many as the real building structure components. Thus, as mentioned steel formworks are more suitable and effective in term of cost and reusability for large projects and construction [9]. Meanwhile, as for academic research purposes, to cast concrete, wooden formworks are good enough.

3. Benefits in Using Wooden Formwork to Cast Concrete

3.1. Costing of wooden formwork
Formwork might consumes a huge percentage of total cost of a project – the cost of formwork itself sometimes might be more than the cost concrete and steel bar combined [3,10]. From a client perspective, having a lower total project cost with higher quality are always preferable. But there are always three parameters which influence the profile of a project; time, cost, and quality or performance [11] – it could be shown in a triangle below:-

![Figure 2. The project triangle [12].](image)

In simple words explaining the “Project Triangle”, if the project needs to be fast and cheap meaning that reducing time and cost respectively, the quality or performance might not be that promising. On the other hand, if the project wants to have a quick completion with good structures which also means decreasing time and higher performance, the cost will eventually be higher or vice versa [13].
There are few methods in reducing cost of formworks – one of it is considering the minimum size and least weight of permanent concrete structure. Although formworks were meant to support the temporary concrete structure after casting, this methods somehow jeopardize the permanent structure of concrete [3]. Scaling down the concrete structure (although the strength was proven high) does have critical arguments among experts. Generally, the size of concrete components should not be simply subsidies and diminished because there were numerous researches testified changing the concrete specimen size may results instability in strength [14,15,16]. Henceforth, the cost should not be decreased by risking the size or concrete used in structures [17,18].

Discussing on formwork costing, it could be divided into three which are (i) cost of the material, (ii) cost of labour – fabricating, erecting, and dismantling the forms, and (iii) cost of equipment involved to grip the formworks [19,20,21].

Thus, especially in Malaysia with limitation in term of financial support in engineering research, for huge quantity of specimens, the usage of wooden formwork seems to be more feasible and practical [22]. For smaller projects or research, wooden formworks are appropriate [7,8].

3.2. Performance of wooden formwork

Wood that was often used to build formworks are lumber, plywood, consist of several types of plyform [23]. To be specific, the discussion is meant to understand BBCC plyform type of formwork and equivalent. Plyform is a engineered plywood functions as forming concrete structures [3]. This type of plyform or generally known as plywood, is suitable to be used as formworks essentially because it can withstand high pressure [23].

![Figure 3. BBCC plywood.](image)

Plywood is consist of few odd layers of ply might be with the same or different grade of woods, glued internal and externally making it a good formwork – and the glue is definitely water-proof [3]. Plywood usually sized rectangular 4-ft width and 8-ft length right angle.
In any event, formworks should able to hold the concrete poured in it. For the wooden formworks, it must be hard or rigid enough to avoid the wood from damaging while containing concrete [24]. The shape of plywood as mentioned in previous paragraph is efficient making it resisting bending, shear, and deflection [25].

As a temporary structure, formworks should also have certain capabilities to cater minimal live load and dead load, while awaiting the concrete structures becomes harden [26]. Thus, before ordering the timber/wooden formworks, there are several factors that have to take into account such as load-duration, wet-service, beam stability, temperature and buckling adjustment factors. Wooden formwork design and recommendations might be referred from American Forest & Paper Association in National Design Specification (NDS) for Wood Construction year 2005 [3]. Specifically for plywood, the strength and manufacture, it always obey the Voluntary Product Standard PS 1-95 approved by The Engineered Wood Association.

Temperature and moisture of concrete mix poured in also have significant effect to the wooden formworks and concrete mix itself [27]. Moisture if being in contact with the hygroscopic material like normal timber will easily swell which causes internal stress and damage [28]. In the other hand, temperature might not be a direct factor for plywood. However, temperature might enhance chemical process and biological activities on the plywood, which indirectly harms them [29].

**Figure 4.** 5-layer typically about 18-mm thickness BBCC plywood.

**Figure 5.** Examples of swollen and warped wood due to being exposed to humid environment and moisture, respectively.
Henceforth, to ensure the stated incidents prevented, all BBCC plywood for formwork purposes must be treated and coated, internal and external respectively [30]. These issues will not occur if the project uses steel formworks. However, again, wooden formwork has bigger advantages in term of workability, cost-saving, and insulation. On top of that, tested concrete strength results between concrete moulded by steel and plywood has only small difference, which about only 5-7% [31].

3.3. Safety of wooden formwork
In year 1997, OSHA has reported that 5.83% of accidents happened due to the flaw and failures in either formworks or construction temporary structures itself. From the given percentage, 21.2% calamities were involving wooden framing and formworks [32].

As mentioned in earlier section, wooden formworks has limited cycles of usage – ergonomic studies revealed that majority cases involving wooden formworks were due to the repetitive works such as sawing, lifting and hammering which leads to an obvious vibration occurred onto the wooden formworks [33].

Thus, some bodies have made some researches in order to cater the safety issues in using wooden formworks for constructions. The researches include incurring few important factors in calculating the criteria needed by wooden formworks. The factors are such as load duration, bearing area, moisture, flat application, safety factor for formwork accessories, repetitive factor of member utilization, manufactured wood products, and adjustment factor for plywood stresses [34].

However, the detailed calculations and factor considerations are mainly meant to the construction industry which involves with real scale and big structures. Whereby, in research where the specimens are down-scaled and lighter, precautions are consumed but not as critical as on-site manner [35].

4. Conclusion
As the construction industry develops with many technologies and advancements, nowadays wooden formworks have been modified to cater problems as said above. Plywood has undergo numerous improvements such as having a higher strength and panel shear, more flexible, made to resist moisture, chemical, impact and fire, and better insulation.

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