ENERGY EFFICIENCY CRITERIA FOR COMMON BUILDING STRUCTURE SYSTEMS: AN OVERVIEW

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ABSTRACT

Making decisions about the selection of energy efficiency building construction is one of the sustainable construction key. Therefore it is crucial to identify criteria that can influence the choice of energy efficient common building structure systems. The main purpose of this paper explores the energy efficiency criteria for common building structure systems. Thus, the paper adopts a conceptual approach by using current literature on energy efficiency. The paper shows a wide range for the energy efficiency criteria for common building structure systems. This range in reported figures is due to the use of common different building structure systems through different LCA methodologies and different boundaries. For that reason, this paper contributes to the literature by providing deeper insights into the energy efficiency criteria influencing the selection of energy efficiency common building structure systems. The paper also present a new approach that will support energy efficiency termed ‘energy efficiency common building structure systems’. And this will opens several interesting avenues for future research.

Keywords: Energy efficiency, Environmental impact, Constructive system, Embodied energy.

1. INTRODUCTION

Nowadays, it is becoming increasingly difficult to ignore the Climate Change issues. It quickly becoming a global issue for the United Nations. Many researchers recognised Climate Change as major issues in sustainable development [1-5]. Energy efficiency plays significant roles towards sustainable development [6-8]. Since building sector is one of the most widely energy consuming. Buildings consume 40% of overall energy consumption [2, 9-13]. In order to promote the energy efficient buildings. We must link the energy efficiency to the actual energy consumption [14]. Thus it is important to design the building to be more efficient.

Building construction can be built of several element (e.g. Structural Frame, Slab, Roof, Internal Wall, External Wall and Staircase). However, all these element can be constructed with deferent type of construction systems such as Precast Concrete, Structural Steel, and Cast In-Situ Concrete etc. Therefore the major question in this paper is: What are the criteria that having a strong influence on the choice of energy efficient of common building structural systems? In order to defining energy efficiency criteria, a combination of reviewing academic research, existing methods and energy codes. Assigning energy efficiency criteria related to the common building structural systems in whole building life cycle. Thus the paper aims to identify energy efficiency criteria of common building structural systems and explore the alternative of common building structural systems in order to reduce the environment effect.

2. COMMON BUILDING STRUCTURAL SYSTEMS

The common building structural systems mean existing building structural in large numbers. Construction systems can be grouped based on the interest of construction users [15]. Thus, this stage replies the question “what are the Structural systems that commonly used” Therefore, we need the data related to the construction industry including the building Structural systems. Balubaid, Zin [16] published a paper in which they described and answered that question as shown in Table:
Table 1 common building Structural systems in Malaysia [(surce Balubaid et al 2014)16]

| Group            | Sub-group                                      |
|------------------|-----------------------------------------------|
| Structural frame | Cast in-situ concrete frame                   |
|                  | In-situ concrete load bearing wall            |
|                  | Precast concrete frame                        |
|                  | Structural steel frame                        |
| Slab             | In-situ RC flat slab                          |
|                  | In-situ RC slab                               |
|                  | Precast slab with in-situ topping             |
|                  | Steel deck with in-situ concrete topping      |
| Internal wall    | Cast in-situ concrete wall                    |
|                  | Light weight brick                            |
|                  | Light weight panel                            |
|                  | Precast concrete wall                         |
|                  | Traditional brick and plaster wall            |
| External Wall    | Block wall with applied finished              |
|                  | Brick wall with applied finished              |
|                  | In-situ concrete wall                         |
|                  | Metal cladding                                |
|                  | Precast concrete wall with Pre-installed windows and finishes |
| Roof             | In-situ concrete roof                         |
|                  | Prefabricated steel roof truss                |
|                  | Steel decking with in-situ Concrete topping   |
|                  | Steel truss roof with Composite decking       |
|                  | Timber truss with roof tiles                  |
| Staircase        | Cast-in-place                                 |
|                  | Prefabricated                                 |
|                  | Steel                                         |

3. DEVELOPMENT OF CONCEPT OF ENERGY EFFICIENCY (EE)

It is necessary here to clarify exactly what is meant by Energy Efficiency (EE). Various definitions of efficiency are found. This shows a need to be explicit about exactly what is meant by the word efficiency. The word efficiency have been widely used in different fields (sociology, economy, engineering, etc.) with different meanings [7]. The word efficiency generally means achieve a desired result within minimum resources [4]. The term efficiency can be defined as any stimulus that can be doing more with less [17]. In broad of engineering terms, efficiency can be defined as “the ratio of the desired output (useful effect) to the required input (used resources) of any system” [7, 18].

Thus, the definition of energy efficiency is, the ratio of the energy you get from energy transformation process to the energy used by that process [4, 7, 19]. It can be referring to use less energy (input) in order to produce the same amount of services (output) [7, 20, 21]. Basically, the energy efficiency of a building is difficult to be calculated or measured or quantify, since a building is not an energy transformation process and consist a multiple services [7, 22]. Thus, a broader definition could be used, which is amount of energy used to provide a given construction system.

4. ENERGY CONSUMPTION IN BUILDING

Generally, there are two types of energy consumption in buildings. The first one is embodied energy, which goes into production, fabricating, transportation, and erecting of the building materials. The second type is the energy for operate, maintenance/servicing of a building during its useful life [23, 24]. Since this research deal with the construction systems so it will be link with the first type.
5. ENERGY EFFICIENCY CRITERIA FOR COMMON BUILDING STRUCTURAL SYSTEMS

A great deal of energy efficiency criteria is understanding and suggesting solutions to suite deferent structural systems. Deferent structural systems has deferent energy efficiency criteria. In fact, each structural system have their own energy efficiency criteria. However, solutions cannot be suggested unless the problem is fully analysed, and this involves a thorough understanding of the common energy efficiency criteria for most of structural systems. Some of the common energy efficiency criteria that may find useful for explaining the common structural systems is listed below:

Table 2 energy efficiency criteria for common building Structural systems

| References                  | low embodied energy material | Reducible structure material | Reusable structure material | Recyclable structure material | Durability structure material | Use of local structure material | Usage structure efficiency | Produce less waste | Adopting an efficient technology and construction technique | Simplifies the production process | Transportation of building structure material to the site |
|-----------------------------|------------------------------|-----------------------------|-----------------------------|-------------------------------|-----------------------------|-------------------------------|-------------------------|-------------------|------------------------------------------------|--------------------------|-----------------------------------------------|
| Chen, Okudan [9]            | Y                            | Y                           | Y                          | Y                            | Y                           | Y                            |                         |                   |                                              |                          |                                                |
| Bakhoum and Brown [25]      | Y                            | Y                           | Y                          | Y                            | Y                           | Y                            |                         |                   |                                              |                          |                                                |
| Riduan. Yunus [26]          | Y                            | Y                           | Y                          | Y                            | Y                           | Y                            |                         |                   |                                              |                          |                                                |
| Sattary and Thorpe [2]      | Y                            | Y                           | Y                          | Y                            | Y                           | Y                            |                         |                   |                                              |                          |                                                |
| Šijanec Završ, Žarnić [27]  | Y                            | Y                           | Y                          | Y                            | Y                           | Y                            |                         |                   |                                              |                          |                                                |
| Yang, Li [28]               | Y                            | Y                           | Y                          | Y                            | Y                           | Y                            |                         |                   |                                              |                          |                                                |
| Burdová and Vilčeková [24]  | Y                            | Y                           | Y                          | Y                            | Y                           | Y                            |                         |                   |                                              |                          |                                                |
| Natee, Pheng [29]           | Y                            | Y                           | Y                          | Y                            | Y                           | Y                            |                         |                   |                                              |                          |                                                |
| Yunus and Yang [30]         | Y                            | Y                           | Y                          | Y                            | Y                           | Y                            |                         |                   |                                              |                          |                                                |

5.1. Low Embodied Energy Material

Embodied energy comprises energy inputs that needed to extract, process, manufacture and transport the materials emblems of the Building structural [31-37]. It consist all types of the indirect energy (such as energy used during manufacture of structural materials) and direct energy (such as energy used during transportation and installation of structural materials) [3, 13, 38-43]. The embodied energy has been suggested in a building structural materials in Australia. It is contained 20 to 50 times
the annual operational energy needed for the building structural materials [44]. Sattary and Thorpe (2011) argues that the embodied energy in in building structural materials is a significant component of the overall energy reduction in the building life cycle. Further associated studies have illustrated that low embodied energy material is an important issue in the climate system [43, 45, 46], it is linked with reducing carbon emissions of construction materials. Thus it is plays a key role in reducing energy consumption. [9, 25, 26, 47]. Low embodied energy materials can be achieved by:

- using long life materials,
- Less energy intensive and
- Engineering structural solutions.

5.2. Reducible Structure Material

According to Green Building Council of Australia, Building waste in Australia 40% [47]. Using new method of reinforcing and new materials (such as eco-cement concrete) will reduce wastage of construction materials and this will lead to reduce the cost. Reducible element means reduce resource requirements which will lead to reduce the embodied energy that needed to extract, process, manufacture and transport the materials emblements of the Building structural [9, 25, 26].

5.3. Reusable Structure Material

By understanding similarities and differences between structural systems, we can increase our understanding and learn more about structural systems. This usually involves a process of analysis, in which we compare the specific parts as well as whole [2]. Comparison may also be a preliminary stage of evaluation. For example, by comparing reusable elements of Precast concrete frame and Structural steel frame, we can decide which is more reusable [9, 25, 26].

5.4. Recyclable Structure Material

Recyclable structure material has a significant impact on the comparability of the structure material energy. Recycle resource requirements which will lead to reduce the embodied energy that needed to extract, process, manufacture and transport the materials emblements of the Building structural [2, 9, 25, 26].

5.5. Durable Structure Material

In reviewing the literature, use of structure materials with less embodied energy and use of durable materials are the most important factors for reduce embodied energy. Buildings will not be durable in the future unless improved the durability of building structure materials which will result in reduced embodied energy [47].

5.6. Use of Local Structure Material

Building structural with local materials means to reduce the environmental impact of construction. Morel, Mesbah [48] found that the energy used in building will be decreased up to 215% just by using local materials.

5.7. Produce Less Waste

In order to reduce the impact of the waste of building structural materials, the best way is simply to avoid producing waste [30, 49-53]. All the studies reviewed on waste minimization so far, however, suffer from the fact that building structural materials have many types and shapes.
5.8. **Adopting an Efficient Technology and Construction Technique**

Using new and energy efficient technology of construction could affect energy values and could bring large differences to embodied energy [13, 54]. We need to rethink the way we consume energy of construction. Using energy efficient technology and machines in construction become as one of energy efficiency measures [8]. Adopting energy efficient technology of construction industry has a positive implications beyond energy savings such as [8]:

- Increased productivity,
- Reduced production costs (including labor, raw materials),
- Reduced waste disposal costs
- Improved worker safety (will result in reduced insurance costs).
- Reduced operations and maintenance,
- Improved product quality,
- Improved capacity utilization.

5.9. **Simplifies the production process**

A considerable amount of literature has shown that the embodied energy of construction processes is almost equivalent to 15 years of operating energy. Thus, simplifies the production process in the construction process has now come into focus as a way of reducing carbon dioxide emissions and global warming. Impacts generated by production processes of construction such as energy consumption, raw material use, waste generation, water use and land use; and are significant [2]. Development and simplifies the production process to map energy usage for better understanding input, output, for each process at a relatively early stage [8].

5.10. **Transportation of building structure material to the site**

Meanwhile, Transport the materials emblems of the building structural and construction methods mostly play a role for selecting building structural materials [9, 30]. Take, for instance, vehicles have greater fuel efficiency and a different fuel structure.

6. **CONCLUSION**

The selection of building construction system has to be made carefully as each construction system has different impact on energy efficiency. Development of tools to select energy efficient construction systems is considered timely as it may help less experienced designer with limited energy efficiency knowledge to make decisions in the same way as experts. This paper reported an on-going research aimed to develop a decision support model for selecting energy efficiency structural system. From the perspective of the designer by examining the relationship between energy efficiency criteria and common building structural systems. The next stage of this research will evaluate energy efficiency criteria and common building structural systems using Analytic Hierarchy Process (AHP) Method.

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