Awareness of construction professionals from the Northern Region of Malaysia about low carbon building materials

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Abstract. Despite current global market conditions, a superior financial climate has lowered the demand for innovative low carbon building materials, with construction owners typically prioritizing project value, time, practicality, and aesthetics. This situation creates an obvious dilemma for practitioners and stakeholders, as carbon emission linked to the use of construction materials should decrease. This study presents the awareness among the construction professional in the northern states of Malaysia in relation to low carbon building materials (LCBM) via interviews and structured questionnaire surveys conducted with 93 companies of architects and civil and structural consultants. Of 76.9% valid responses, 44.6% to 51.4% claimed to be “Aware and have a good knowledge” about unfired earth bricks, prefabricated hollowcore floor system (PHFS), and prefabricated timber frame system; however, their usage remained low. PHFS provided satisfactory experiences to practitioners and ranked the highest (20.3%) in the recommendations for future projects. The sustainability and suitability of a particular LCBM is highly determined on-site, has project specific influences, and varies across structures types from project to project.

1. Introduction
The construction and building industry is accountable for 42% of global energy usage [1]. Energy consumption and greenhouse gas (GHS) emissions are involved directly in all construction stages and indirectly through the use of energy and generation of emissions linked with the production processes and ancillary materials. Thus, a need exists to carefully plan and manage building constructions so as to protect the quality of our environment, contribute to sustainable construction [2] and at least reduce short-term emission [3]. All parties involved, such as local authorities, contractors, governments, consultants and architects, must respond promptly to these changes and constraints. In 2013, building and residential subdivisions in Malaysian construction have expanded by 29.9%, directly contributed MYR 41.28 billion to the GDP, and greatly affected the national carbon budget [4].
Policy-makers have acknowledged the said condition via the introduction of regulating necessary improvements in building technology, such as the National Green Technology Policy under the Ministry of Energy, Green Technology and Water; the National Policy on Climate Change under the Ministry of Natural Resources and Energy, and the Green Building Index under private initiatives in 2009 [5]. These regulations have predominantly focused on the operational carbon emissions linked with energy efficiency and the
application of a green building index, such as for cooling and lighting systems. However, no broader direction to embodied carbon related to the earliest production of life cycle stages of sustainability of construction works is considered, that includes the building materials. The embodied carbon of construction materials is significant for energy efficient buildings from a life cycle perceptive [6]. The entire life cycle stages cover the (i) product and design stage, (ii) construction process, (iii) usage, and (iv) demolition and end life stage. The selection of appropriate building design and materials by construction consultants at the initial stage imperatively affects the embodied carbon emission to the environment.

In Malaysia’s context, information on the awareness among construction professionals about alternative building materials for carbon dioxide (CO₂) mitigation is lacking. Moreover, information on the on-site suitability of low carbon building materials (LCBM) through real experiences of these professionals is also limited specifically for the northern states on Malaysia. It remains unexplored by both academic research and industrial practices. Additionally, embodied energy is not generally considered when a building is designed, planned, and constructed [7]. This information about embodied energy is significant in ascertaining the next strategy for reducing carbon emissions. Note that as the level of awareness and suitability of alternative materials in building construction increases, the level of carbon emissions can be decreased. Therefore, the main objective of this research is to examine the awareness of LCBM among construction professionals in the northern region states of Malaysia. The specific aims of this work are to identify the knowledge of those professionals and illustrate their prevalent use and experiences with handling LCBM.

2. Literature review
Sustainability has gained popularity as the principal index for construction development. With such progress, policies and the evaluation of project sustainability have become necessary. In 2014, a team of UK professionals fought for insertion of embodied carbon as an Allowable Solution under the previously endorsed Zero Carbon Building Guidelines [8]. Other local authorities in the UK also emphasize the incorporation of the fundamental assessment of embodied carbon in proposal applications. They highlighted the use of low energy materials and those that sequester carbon over their lifetime. Comprehensive life carbon assessment has been granted extra credits in sustainability assessment strategies of large construction projects. Examples include the Building Research Establishment Environment Assessment Method, Leadership in Energy and Environmental Design in the UK, Comprehensive Assessment System for Building Environmental Efficiency in Japan, and the Green Star based in Australia.

Malaysia moved forward with an initiative by the Construction Industry Development Board in 2012 to introduce the Green Performance Assessment System in Construction for estimating carbon emissions from building construction works throughout a building’s life cycle [9]. This strategy covers the pre, during, and post construction stages, including the five elements of construction assessment, the building materials, energy, water, and waste, with carbon emission categorized into embodied carbon and operation carbon. Mitigation of embodied carbon has become part of the routine assessment for government buildings. Such mitigation entails five criteria from the Public Work Department of Malaysia including materials and resources sustainability planning and management. Since 2016, an extensive performance-based coverage standard of sustainability criteria in the Malaysian Carbon Reduction and Environmental Sustainability Tool has been adopted across the stages of a building life cycle [10] for government projects valued at MYR 50 million. The standard covers a holistic and comprehensive basis for the professional design team to identify opportunities and strategies for carbon reduction. A merging of policy prescriptions includes industry-wide awareness, creation of a regulatory framework, initiation of an energy code of practice, inauguration of a mandate for a single responsible authority, and setting a strategy for capacity expansion.

Approximately 54% of the carbon emissions are from operational stage activities and 42% of the life cycle CO₂ emissions involve embodied carbon from production and material consumption (such as of steel and concrete) [11]. Although the amount of embodied carbon is less than that of operational carbon, the former is still significant when different timeframes are considered. In this case, buildings may have a short service life (approximately 25 to 30 years) in developing countries. The contribution of embodied carbon can appear in large portions that approach approximately 50% [6]. Therefore, with the increased awareness of the embodied energy and carbon emission of buildings, the pre-design stage, which is directly related to the building materials, has grown in significance.

Various strategies for mitigating embodied carbon have focused on minimizing the consumption of materials with carbon-intensive supply chains [8]. These techniques include approaches that propose to
minimize inconsequential material usage via “light weighting,” built off-site structural optimization, extending the life of existing structures, designing new structures to be adaptable and easy to demolish, allowing the reuse of materials or components, and replacement of materials and products for alternate lower carbon supply chain management. Different alternative materials from naturally obtaining components are available, including low carbon materials made from consolidated wastes or reused substances, materials sourced for recycling from other sites, and building products that have been optimized via unique and innovative methods.

Despite support such as the investment of tax allowances by the Malaysian government for the adoption of alternative LCMB (particularly built off-site structural panels and several benefits of these prefabricated panel systems), a low acceptance turn-up is found among construction practitioners. Adoption of this system by the private sector remains low (approximately 15%) relative to the government target of 70% [12]. Many building consultants lack knowledge and remain unaware of essential elements such as modular coordination became of limited of research and development in new building systems of local materials and insufficient scientific evidence to prove the benefits of such materials [8]. This situation is prevalent among most construction firms with small hired human resources and who are limited in their research potentialities and capabilities. The unique nature of the industry necessitates shifting between short-term projects with changing stakeholders. As a result, construction professionals learnt progressing knowledge and skills from their experiences on a project-to-project basis. This unstructured process of gaining knowledge creates resistance to applying unfamiliar low carbon materials and relevant technologies. Inflexibility toward design changes arise when consultants and clients are sometimes reluctant to adopt elements from previous projects. Since the design has not frozen in the development stage, it is affected adoption of prefabrication and environmental awareness for various constructions practitioners. Non-conventional or novel materials have also been overlooked due to high cost, the scarcity of technical knowledge, lack of client appreciation, lack of economic scale, and the necessity of government intervention [8].

3. Methodology

This study adopted a mixed-method of qualitative and quantitative approach combining a survey and series of semi-structured interviews. Statistical analysis of the data was done using the Statistical Package for Social Science (SPSS). All survey respondents remained anonymous to ensure the originality and avoidance of any hidden true information.

A descriptive exploratory study was undertaken from 18 to 25 February 2019. Thirty experienced construction professionals with 10 to 20 years of experience and who were based on Perlis, Kedah and Pulau Pinang were given survey forms with questions about their knowledge and experience in using LCMB. This exploratory study provided advance guidance on where the main study could fail and was crucial in questionnaire development, in the wording and order of questions, and in the relevant range of answers [13]. The questionnaire was found to have reasonable internal consistency reliability with scores of 0.82 using the Cronbach’s alpha coefficient.

Next, the study was conducted from 26 February to 28 June 2019 within randomly total samples of 93 companies in the northern region of Malaysia consisting of Perlis, Kedah, and Pulau Pinang. The number of professional building consultants (including architects and civil and structural [C&S] engineers’ populations) was retrieved from the Treasury Malaysia Government website, 2018 [14] as this group highly influences materials selection during the pre-design stage of construction projects [8].

The questionnaires were divided into four sections, with Section A consisting of open-ended question approach to obtain demographic information. Section B on LCMB knowledge, Section C on the prevalence of LCMB usage, and Section D on experiences using LCMB apply close-ended questions to obtain quantitative data. Then, the questionnaires were distributed online by using email and through face-to-face interviews. For the demographic section, the respondents were asked to describe the organization they worked for along with their experience, the size of their companies, and the nature of the projects they were involved with over the past 10 years. This information seeks to determine the qualification of the respondents so as to obtain reliable and valid data. For Section B, the respondents were asked to describe their knowledge of LCMB in the construction industry, with responses including “Aware and have good knowledge,” “Aware,” and “No knowledge.” The questions in Section C were intended for respondents who have marked “Aware and have good knowledge” in the prior section. Four possible answers were presented in relation to the prevalence of LCMB use: “Most often used,” “Often used”, “Least often used.”
and “Not often used”. Lastly, Section D asked respondents to describe their experience with using LCBM in their projects using the following responses: “Excellent and will use again,” “Fairly positive experience,” “Fairly negative experience,” and “Negative and will not use again.”

This preliminary research focus on 15 types of LCBM, which is including precast hollowcore floor slabs (PHFS), structural insulated panels (SIP), prefabricated timber frame system (PTFS), glue laminated timber (GLULAM), ground granulated blast furnace slag (GGBS), pulverized fuel ash (PFA), unfired earth brick (UEB), ethylene tetrafluoroethylene (ETFE), geopolymer concrete (GP concrete), concrete containing construction and demolition wastes (Concrete-CDW), concrete containing agricultural wastes (Concrete-AW), adobe, rammed earth, reclaimed timber, and recycle aggregates.

4. Result and discussions

4.1. Demographic information

A total of 74 companies duly responded to the survey, a figure which represents 79.6% of the respondents over the total samples of companies from the northern states of Malaysia. Each company was represented by one construction professional. Thirty-one respondents (41.89%) answered online and 43 (58.11%) replied via survey forms. Details of the demographic information are shown in table 1.

| Respondents Profile | Frequency | Percent (%) |
|---------------------|-----------|-------------|
| Occupation          |           |             |
| Architect           | 30        | 40.5        |
| C&S engineer        | 44        | 59.5        |
| Working experience (years) | | |
| 1 – 10              | 31        | 41.9        |
| 11 – 20             | 19        | 25.7        |
| 21 – 30             | 19        | 25.7        |
| > 31                | 5         | 6.7         |
| Size of company (person) | | |
| 1 – 10              | 42        | 56.7        |
| 11 – 20             | 29        | 39.2        |
| > 21                | 3         | 4.1         |
| Nature of project   |           |             |
| Building construction| 73        | 98.6        |
| Others              | 1         | 1.4         |

4.2. Knowledge of low carbon building materials

Respondents revealed all-embracing of awareness of LCBM in the construction industry. Out of 74 architects and C&S designers identified in this study (table 2), the participants answered “Aware and have good knowledge” with 51.4%, 50.5%, and 44.6% for UEB, PHFS, and PTFS, respectively. The recorded mean values in this section are high for UEB, PHFS, and PTFS of 2.35, 2.49, and 2.42, respectively. This outcome is unsurprising as these materials are comparatively common and are conventional construction components widely used in industrial, commercial, residential, and infrastructure construction. Additionally, this result may indicate that the planner and designers possess broad knowledge and awareness of LCBM.

All respondents have mixed knowledge on reclaimed materials, customized materials, and alternative concrete materials. In this case, respondents were aware of recycle aggregates (74.3%), SIP (64.9%), reclaimed timber (63.5%), concrete containing-AW (58.1%), and concrete-CDW (58.1%). Concrete recycling is well recognized in the environmentally friendly construction world. Therefore, reusing concrete in this industry would correct its manufacturing process which is the prime contributor to GHG emissions. However, respondents have little knowledge about recycling the synthetic plastic film of EFTE that is normally used for exterior cladding material. This unawareness could be due to the fact that this industrial-strength construction plastic is considered new in Malaysia. The other less known LCBM are GGBS (51.4% of respondents), PFA (47.3%), and rammed earth (44.6%).
Table 2. Construction professionals’ knowledge on the LCBM.

| Type of LCBM | No knowledge (%) | Aware (%) | Aware and have good knowledge (%) | Mean (SD) |
|--------------|------------------|-----------|-----------------------------------|-----------|
| PHFS         | 1.4              | 48.6      | 50.0                              | 2.49      | 0.530      |
| SIP          | 5.4              | 64.9      | 29.7                              | 2.24      | 0.544      |
| PTFS         | 2.7              | 52.7      | 44.6                              | 2.42      | 0.549      |
| GLULAM       | 16.2             | 54.1      | 29.7                              | 2.14      | 0.669      |
| GGBS         | 51.4             | 37.8      | 10.8                              | 1.59      | 0.681      |
| PFA          | 47.3             | 40.5      | 12.2                              | 1.65      | 0.691      |
| UEB          | 16.2             | 32.4      | 51.4                              | 2.35      | 0.748      |
| ETFE         | 54.1             | 28.4      | 17.6                              | 1.64      | 0.769      |
| GP concrete  | 33.8             | 50.0      | 16.2                              | 1.82      | 0.690      |
| Concrete-CDW | 25.7             | 58.1      | 16.2                              | 1.91      | 0.645      |
| Concrete-AW  | 25.7             | 58.1      | 16.2                              | 1.91      | 0.645      |
| Adobe        | 40.5             | 32.4      | 27.0                              | 1.86      | 0.816      |
| Rammed earth | 44.6             | 44.6      | 10.8                              | 1.66      | 0.668      |
| Reclaimed timber | 23.0   | 63.5      | 13.5                              | 1.91      | 0.601      |
| Recycle aggregates | 12.2 | 74.3      | 13.5                              | 2.01      | 0.510      |
| GP concrete  | 50.0             | 21.6      | 14.9                              | 13.5      | 1.92      | 1.095      |
| SIP          | 68.9             | 13.5      | 8.1                               | 9.5       | 1.58      | 0.993      |
| PTFS         | 55.4             | 20.3      | 13.5                              | 10.8      | 1.80      | 1.047      |
| GLULAM       | 71.6             | 16.2      | 9.5                               | 2.7       | 1.43      | 0.778      |
| GGBS         | 86.5             | 9.5       | 2.7                               | 1.4       | 1.28      | 1.222      |
| PFA          | 86.5             | 9.5       | 2.7                               | 1.4       | 1.19      | 0.541      |
| UEB          | 52.7             | 21.6      | 9.5                               | 16.2      | 1.89      | 1.130      |
| ETFE         | 81.1             | 13.5      | 5.4                               | -         | 1.24      | 0.544      |
| GP concrete  | 83.8             | 6.8       | 8.1                               | 1.4       | 1.27      | 0.668      |
| Concrete-CDW | 82.4             | 10.8      | 4.1                               | 2.7       | 1.27      | 0.668      |
| Concrete-AW  | 83.8             | 8.1       | 5.4                               | 2.7       | 1.27      | 0.668      |
| Adobe        | 74.3             | 6.8       | 6.8                               | 12.2      | 1.57      | 1.061      |
| Rammed earth | 86.5             | 10.8      | 1.4                               | 1.4       | 1.18      | 0.506      |
| Reclaimed timber | 83.8   | 13.5      | 1.4                               | 1.4       | 1.20      | 0.523      |
| Recycle aggregates | 86.5 | 12.2      | 1.4                               | -         | 1.15      | 0.395      |

4.3 Prevalent use of Low Carbon Building Materials
Section B responses indicate that the predominantly used LCBM involve UEB (16.2%), followed by PHFS, and PTFS at 13.5%, 10.8%, respectively (Table 3). The recorded mean values for Section B are 1.89, 1.92, and 1.08 for UEB, PHFS, and PTFS, respectively. UEB has many advantages, including being economically favorable, requiring less skilled labor, contributing to energy conservation, providing acceptable fire resistance, the environmentally sustainable nature of earth construction, and the abundance of earth in bulk quantities in most regions [15]. By contrast, sun-baked and fired clay bricks that are traditionally used for ordinary wall construction suffer from the rising prices of energy usage and CO2 emission. Similarly, extruded concrete PHFS and PTFS which are normally casted for flooring and wall panels provide building consultants with a versatile and innovative concrete system [16] for fast on-site installation [17] of a self-supporting system with satisfactory lower surface finishes.

Table 3. Prevalent use of low carbon building materials.

| Type of LCBM    | Not often used (%) | Least often used (%) | Often used (%) | Most often used (%) | Mean (SD) |
|-----------------|-------------------|---------------------|----------------|---------------------|-----------|
| PHFS            | 50.0              | 21.6                | 14.9           | 13.5                | 1.92      | 1.095      |
| SIP             | 68.9              | 13.5                | 8.1            | 9.5                 | 1.58      | 0.993      |
| PTFS            | 55.4              | 20.3                | 13.5           | 10.8                | 1.80      | 1.047      |
| GLULAM          | 71.6              | 16.2                | 9.5            | 2.7                 | 1.43      | 0.778      |
| GGBS            | 86.5              | 9.5                 | 2.7            | 1.4                 | 1.28      | 1.222      |
| PFA             | 86.5              | 9.5                 | 2.7            | 1.4                 | 1.19      | 0.541      |
| UEB             | 52.7              | 21.6                | 9.5            | 16.2                | 1.89      | 1.130      |
| ETFE            | 81.1              | 13.5                | 5.4            | -                   | 1.24      | 0.544      |
| GP concrete     | 83.8              | 6.8                 | 8.1            | 1.4                 | 1.27      | 0.668      |
| Concrete-CDW    | 82.4              | 10.8                | 4.1            | 2.7                 | 1.27      | 0.668      |
| Concrete-AW     | 83.8              | 8.1                 | 5.4            | 2.7                 | 1.27      | 0.668      |
| Adobe           | 74.3              | 6.8                 | 6.8            | 12.2                | 1.57      | 1.061      |
| Rammed earth    | 86.5              | 10.8                | 1.4            | 1.4                 | 1.18      | 0.506      |
| Reclaimed timber | 83.8              | 13.5                | 1.4            | 1.4                 | 1.20      | 0.523      |
| Recycle aggregates | 86.5       | 12.2                | 1.4            | -                   | 1.15      | 0.395      |
By given with low percentage of “Most often used” and “Often used”, at range of 8.1% to 16.2%, it can be reflected of the participating building consultants, on average, having fewer years of industry experience, which 67.6% of them work between 1-20 years (table 1). Another reason could be due to unfamiliarity with these types of alternative materials and the fact that they have not yet been successfully adopted by construction practitioners. The LCBM rarely used in the construction industry include rammed earth, recycle aggregates, GGBS, PFA, and concrete-CDW with uses ranging from 83.8%–86.5%.

4.4. Experience with using low carbon building materials

Respondents were asked to describe their experiences with LCBM, and many provided details during face-to-face interviews. Four types of LCBM positively affected the materials which participants will choose to use in future, although they have only used them in one of their projects (table 4). The PHFS ranked highest (20.3%), followed by UEB (16.2%), PTFS (13.5%), and SIP (12.2%). The mean values recorded for Section C are 4.16, 4.03, 4.30 and 4.53 for PHFS, UEB, PTFS, and SIP, respectively. These positive ratings may reflect the sample fairness inherent in the non-bias self-selection process for survey respondents.

Meanwhile, participant ratings of “Fairly negative experience” and “Negative and will not use again” revealed concern about the high costs such as for reclaimed timber (12.2%) and adobe (4.1%). In the same category, PFA (6.8%) and adobe (4.1%) were highlighted as unfavorable alternative materials because of unfamiliarity, inadequate performance, inconsistent quality, impact over the construction process, and problem in product sourcing at scale. Participants also expressed the need to hold manufacturers at a substantial level of responsibility when addressing the issue of material defects and supply chain issues.

Table 4. Experiences of using low carbon building materials.

| Type of LCBM       | Negative and will not use again (%) | Fairly negative experience (%) | Fairly positive experience (%) | Excellent and will use again (%) | Mean   | SD    |
|--------------------|------------------------------------|-------------------------------|--------------------------------|---------------------------------|--------|-------|
| PHFS               | 1.4                                | 1.4                           | 27.0                           | 20.3                            | 4.16   | 0.966 |
| SIP                | -                                  | -                             | -                              | -                               |       |       |
| PTFS               | -                                  | -                             | 28.4                           | 13.5                            | 4.30   | 0.887 |
| GLULAM             | 2.7                                | 2.7                           | 20.3                           | 2.7                             | 4.38   | 1.069 |
| GGBS               | -                                  | 2.7                           | 8.1                            | 1.4                             | 4.74   | 0.723 |
| PFA                | 6.8                                | -                             | 4.1                            | 1.4                             | 4.70   | 0.840 |
| UEB                | 2.7                                | -                             | 35.1                           | 16.2                            | 4.03   | 1.033 |
| ETFE               | -                                  | 2.7                           | 14.9                           | -                               | 4.62   | 0.839 |
| GP concrete        | 2.7                                | 1.4                           | 12.2                           | -                               | 4.61   | 0.948 |
| Concrete-CDW       | -                                  | 2.7                           | 10.8                           | 2.7                             | 4.68   | 0.778 |
| Concrete-AW        | -                                  | 5.4                           | 8.1                            | 2.7                             | 4.65   | 0.851 |
| Adobe              | 4.1                                | -                             | 16.2                           | 9.5                             | 4.42   | 1.034 |
| Rammed earth       | -                                  | -                             | 10.8                           | -                               | 4.78   | 0.625 |
| Reclaimed timber   | -                                  | 12.2                          | 1.4                            | -                               | 4.74   | 0.663 |
| Recycle aggregates | -                                  | -                             | 10.8                           | 2.7                             | 4.76   | 0.637 |

5. Conclusion

Current industry awareness and understanding of embodied carbon and material selection is still underestimated. Most participants in the northern state of Malaysia have good knowledge of and can even recommend the LCBM of UEB, PHFS, and PTFS for future use, especially for residential, institutional, commercial, and industrial building construction. However, usage remained low. Over the recent years, knowledge of basic terminology substantially improved among industry professionals. Nevertheless, none of these participants have participated in embodied carbon assessment during the pre-design phase. Thus, effective marketing, dissemination of information on new LCBM, supportive performance data, and full-size exhibition projects for this professional group should be considered. Better training for manufacturers and installers is essential to enhance familiarity with a wider range of LCBM. Moreover, practice is needed for better installation and finish quality. Therefore, the central challenge entails improving knowledge of
alternative materials, understanding embodied energy theory, perceiving appropriate design concepts, and engaging all stakeholders throughout this highly fragmented industry in Malaysia.

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