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Performance of Sustainable Building Fabric to Replace the Traditional Cavity Wall Technique for New Housing Sector in the UK

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***Abstract*—** *UK Government confirms the important binding targets to promote low carbon construction industry such as enhancing reduction 34% by 2020 and 80% by 2050. This reduction can be adopted by different way for instance mitigating the energy use in houses. Huge numbers of houses were annually built-in construction industry, In England and Wales more than 160,000 houses are built in 2017 therefore, Promoting the improvement through airtight and insulated in building envelope can lead to high energy consumption reduction. Reducing greenhouse gas emissions is considered a significant part that related to the energy consumption requirements in terms of the operational energy of houses in United Kingdom. Reducing the energy demands can be achieved through using building materials and operational energy. Construction methods of construction can also provide impacts on the energy demands of building in terms of the materials that used during construction. Five methods of construction were selected to examine their performance in terms of the thermal resistance and factors that could affect acceptability in construction industry. The methodology was identified the behaviour of thermal performance for each method of construction through using cases study methods of previous cavity walls manufacturer. The acceptability of construction methods was carried out by collecting data of community. The main objective was to find out the optimal system of construction methods that could minimise the operational energy whilst providing comfortable houses energy.*

I. INTRODUCTION

Greenhouse gas emissions have harmful impact on environment. These emissions are leading to climate change across the world. The net effect of climate change results as an outcome of global warming. Consequently, surface temperature would significantly increase. The three significant binding targets have been set to mitigate greenhouse gas emissions in the United Kingdom. The ongoing target was set to reach a 34% cut by 2020, which was triggered as officially binding in 2009. The third target; to reduce about 80% of carbon emissions by 2050 [1].

In England and Wales, more than 160,000 houses were built in [1], considerably more than what was built in previous years. These dwellings are controlled by number of organisations that set many building regulations. However, there is slightly differences in these regulations between England and Wales, Scotland and Northern

Ireland. Nonetheless, they all cover the main aspects similarly. Controlling energy costs in properties could annually generate significant savings. Performance of building envelopes plays key role in preserving energy. Improving the envelop by using airtight thermal insulation could highly reduce energy consumption. The major issue with the currently used building envelopes is preserving the energy needed for the heating and cooling processes. Most of the procedures of energy savings are regulated by the Code for Sustainable Homes, which requires stakeholders to meet the standards by using adequate materials and efficient technologies.

Insulating concrete formwork (ICF) was initially appeared in UK in the early 1970s. ICF system uses cast in-situ concrete between two layers of insulation. However, the acceptance of this method was highly slow because brick and timber methods were considered similarly durable, as well as, they were already available [2]. Homebuilding and Renovating [3] [4] gave details for utilising the structural insulated panels system which recently accounted for about 8% of the UK house building. Throughout sustainable projects, a big challenge is the selection of best construction method. It is considered as a main factor that affects productivity and efficiency of projects [5]. There are two main techniques used in assessing environmental impacts and building design in the United Kingdom, namely; life cycle assessment (LCA) and code for sustainable homes. The code for sustainable homes is a national standard used in construction and verifies the sustainable performance of new houses by Applying building regulations. The implementation would be conducted considering many categories such as energy and carbon dioxide emissions, materials and pollution. Each category identifies the environmental impacts which could be mitigated by following certain measures.

II. LITERATURE REVIEW

Construction of new houses is considered traditional in England and Wales. Elements of housing designs and layouts are replicated over large areas. It could be due to the fact that most houses are constructed in large developments by building companies. An adequate housing design would provide efficient life for. Therefore, design and layout value of houses play very significant role by attracting and providing commercial motive for house builders, in order to adopt more innovative designs [1]. Effect of alternative construction methods on projects' execution is considered as an essential approach associated with an appropriate selection. The impact could extend to reach productivity, quality, and cost. It is highly possible to increase costumers' satisfaction when adopting efficient construction techniques. At the same time, house builders will, with no doubt, gain commercial rewarding when providing more innovative and attractive designs. Either householders or users of dwellings are taking an account of the value of innovative designs, because innovative layout would help them acquire modern houses.

In the United Kingdom, different methods of construction and materials was used in previous years. Timber- frame construction represented 40% of the homes built in Scotland in 1995, with only 3% built in England and Wales in the same year [6]. Between 2003 and 2010, the majority of UK's homes were built using masonry cavity walls that typically consist of brick outer skin and a blockwork inner skin. Moreover, all construction works in England and Wales were administrated by Building regulations that imposed rules for new buildings to ensure that structures were safe. To comply with building regulations, it was obligatory to carry out works with adequate materials, efficient construction technique and workmanlike manner. Tricker and Samantha [7] indicated that existing or new construction materials would be checked by considering its adequacy requirements in terms of weather resistance, thermal resistance, weight and structural stability and fire protection. Due to the fact that construction materials demand extensive energy to produce, selection of building materials need huge awareness. There are several advantages and disadvantages to the construction techniques used for any specific project. In 2007 about 166.000 new building homes were constructed in the UK, around 92 percent of which were built using brick and block and timber frame methods. There are plenty of alternative methods of construction that can become a preferred option for either, the house building companies or the self-builders. These alternative building systems are will become more frequently used and architects must be well-skilled when utilising them. Therefore, choosing the best system for housing requires concessions over different aspects.

Construction methods have been adopted in the UK from global experiences that integrated various building materials such as insulated concrete formwork (ICF), structural insulated panels and thin joint blockwork. ICF system is considered as an innovative modern method, due to its association with the essential strength of concrete and the outstanding thermal insulation assets of polystyrene which provide cost saving and strong structures. Standing concrete formwork would be produced using polystyrene material. Concrete offers excellent sound insulation, fire resistance and thermal insulation. This construction method was first developed in Europe during the WWII as a strong technique to reconstruct destroyed houses [2]. Nevertheless, there are

some problems that could occurred during ICF construction. For instance, during constriction, the procedures of pouring walls with concrete could sometimes be problematic. When concrete is placed at fast range, it might break through the polystyrene sheets, which can cause building delays. A skilled house builder must be aware of the adequate numbers of feet that can be placed without causing damages. Moreover, regular ICF panels are considered vulnerable to groundwater intrusion. Architect and designers should take into account the use of drainage sheeting to minimise the effect of moisture [8].

Structural insulated panels are considered as light weight, off-site, manufactured objects. The panels are typically orientated stand boards (OSB), which is composed of two skins of wood based panels and made by sandwiching a low density, cellular core rigid insulation. Using SIPs technique can provide high performance building, through enhancing the durable bond between core insulation and the skins of OSB. High level of airtightness in SIPs can be achieved by collecting all structure components in a tightly-fitted medium [9]. On the other hand, some drawbacks to the use of SIPs is that it requires very well skilled workforce during construction. The reason behind that is the fact that the orientated stand boards are considered as vulnerable to water, leak problems and moisture. Furthermore, SIPs has specific features as it is considered as lightweight construction technique. That would increase the risk of high temperatures in houses, particularly during summer. Consequently, overheating could affect the comfort and health of residents.

Thin joint blockwork technique is also considered as modern method of construction. The UK construction industry is increasing demands to utilise this method, due to its high performance. The layer of mortar that is used for blockwork is pre-blended cement that demands only further water to make it ready. That make blockwork easy to build, in sTable conditions, and reduces the amount of mortar, compared to another technique. High levels of productivity could be promoted throughout building autoclaved aerated block walls, with a thin layer mortar that allows construction in less time. Using mortar joints during construction would reduce the thermal bridging and provides more preferable U-value. Combination of efficiency for thermal mass and low conductivity in blockwork is identified as significant aspect in reducing energy consumption in houses, which can be improved when using thin joint technology. That way, it would increase the whole execution of the cavity wall, considering the amounts of heat loss [10].

Most of construction issues are related with design, manufacturing and assembly. Which, ultimately, relates to the capability to make decision within the available time frame. Some clients require specific data that could affect the phases, performance and amount of time allocated for projects. Selection of adequate materials would be relatively complex due to the difficulty in meeting the specific purposes of householders, house builders and architects. Any stakeholder must take into consideration the determination of priorities regarding the construction products. Designers also would reassess the materials related to building envelops. Choosing the correct solution for a specific situation could give benefits for householders, as well as, for house builders. It is very important to take into account the comprehensive process of greenhouse gases reduction, through operations and during the assessment of the implications of design decisions on construction. Architects, developers and house builders need to raise awareness regarding the materials that would be used from different sources, to eliminate any possible issue [11].

III. METHODOLOGY

In this research, questionnaire was used to be spread for housebuilders among UK districts. The main objective is to find out the significant factors that could affect decision making process when selecting the most suitable construction method. Moreover, to measure the acceptability of construction techniques for housebuilders in construction industry it terms of thermal performance. Furthermore, cases study of u-values will be conducting in project to find out the more about heat lose and gain for each method construction. Construction techniques in this project have been selected according to their appropriateness by comparing them with the past and the already applied construction methods. Suggesting unfamiliar techniques of the modern methods of construction and other construction methods and evaluating the feasibility of using them during the upcoming 50 years in the UK. In this research, the qualitative methods would be used to clarify of the acceptability of construction methods that used in housing construction by using questionnaire, online survey was selected to identify the statics of the factors that could affect of design-making for the house building materials. The cases study was also carried out to illustrate the thermal performance for each construction method through manufacturers in UK and to measure the U-value for construction techniques.

The satisfaction with using a certain construction method by the public is considered a critical matter. The reason is that, raising awareness and the ability to make a proper decision is the responsibility of construction

professionals. Therefore, the acceptability of construction methods would be carried out by construction industry over the reviews of house builders. This consideration should be undertaken during the planning phase. Therefore, information about existing projects in the UK was collected from industry professionals. The online survey was used to identify the factors that affect the decision-making process when selecting the most suitable construction method and to measure public's satisfaction. Kothari [12] indicates that primary data can be obtained through various ways such as observation and direct communication. This work was carried out by using questionnaire for its high advantages. Some of these advantages are; respondents would have appropriate time to give precise answers, respondents' opinion can be easily obtained, large numbers of respondents can get involved and its low cost. Other key advantage of using questionnaires is the ability to collect adequate data by covering various districts within the UK. In spite of that, Kothari [12] gave some disadvantages to the use of questionnaires. He argued that questionnaires can be used merely in one case; when contributors are participative and educative. He continues and indicates that, loss of control can occur when surveys are sent online. Moreover, he added that there is difficulty when modifying the aspects once surveys has been referred.

The practical approach of questionnaires' design is considered critical because it might work either correct or wrong. Gillham [13] suggested that, adopting modern software could make the process easier and could help presenting questionnaires in a more attractive and professional way. Nevertheless, it is important to provide plenty of space for the questions. Moreover, it is necessary to make sure that every question has adequate area. Prior to starting the designing stage on computer, specific considerations are needed for ensuring the highest quality. For example, questions' list and pilot must be made in order to reach final decision about the presented questions and its contents. Also, applying the rewarding stage through promoting the first draft of questionnaire. That would enable the operator to make some changes for defects by proof reading. The main objectives of distributing questionnaires to house builders are to specify the key factors that would affect materials' choice of the cavity wall method, measuring the number of the used construction methods in previous projects and to identify specific properties of constriction methods, to support house builders when making decision. In order to collect precise information and obtain the highest possible number of respondents, the questionnaire was written in simple language. Acceptability measure was applied by employing the yes or no answers. Respondents showed their degree of satisfaction by answering 'yes' or 'no'. For instance, one of the questions was; ''do you agree that following factors can support timber frame with brick cladding method to use in housings''. Moreover, the technical information of layers used in construction methods was briefly mentioned at the beginning of questions. The reason behind that is to ensure that respondents have clear idea about the subject matter and provide precise answers. Factors' selection was also identified, based on previous studies with similar construction methods. For instance, house builders were asked '' do you agree that following factors can help brick and thin joint blockwork method to use in housings''. The purpose here was to locate significant factors that might measure respondents' satisfaction with the used construction techniques through giving the required answers in the form of 'yes' or 'no'. The online survey was built and distributed using Bristol Online Survey, which is well-known for facilitating the design process and obtaining more precise responses Gillham [13]. Different UK companies, in different areas, have participated in the online survey. The responses were chosen based on their experience. Moreover, in order to guarantee high accuracy and efficient response, about 30 samples were collected. The distribution process was conducted by sending links via email, with summarised explanation about the project. Surveys' link was also posted using social media such as Twitter, for obtaining higher number of responses. Seven charts were created for classification through statistically analysing the significant factors of the construction methods. The analysis was presented as percentages of the most to the least significant method for house builders. The performance of construction methods was demonstrated based on key factors such as airtightness, thermal efficiency, energy consumption.

Construction methods were assessed by their construction performances, in terms of their U value and air tightness. Choices would be made in accordance to the factors that could enhance the selection process for house and public builders. U value is considered an effective way to assess heat lose and gain. It is also effective tool used in measuring the insulating properties of buildings' structure. British standards [14] identifying U values as the thermal resistances of the elements. Kingspan [15] [16] indicates that Determination of U values is dependent on the R value or the resistivity of the materials. U-Value (of building element) = 1 / (Rso + Rsi + R1 + R2 …). where: the Rso is the fixed external resistance. Rsi is the fixed internal resistance and R1, R2, etc. are the resistivity of all elements within the application including that of the cavities within the construction. R values are considered the material's capability to resist heat transfer at specific

thickness of insulation materials, which is calculated as R = L/λ where L = the thickness of the material in metres and λ is the thermal conductivity of the material in W/m^2.K. The thermal conductivity of most materials used in the construction methods were established from British, accordance to the British Standards Institution [14].

IV. RESULTS AND DISSCUSSION

Most of questionnaire respondents were house-buildeing companies in the UK with large different districts. The aim was to cover large areas with diverse views and different stages of work. Such stages included: design, planning and construction. Moreover, about 24 responses were received from these companies.

Materials' characteristics was one of the most factors in making decision to choose the construction method used and its relevant materials. There are many options of building materials available in the industry. Therefore, it would be difficult to know the best choice for houses construction. During the questionnaire, an important question was asked about the range of significant factors when choosing building materials. The factors that could affect the decision included: cost, construction speed, health and safety requirements, waste material disposal, durability and environmental impact. Moreover, the type of answers was in the form of yes or no. Percentage scores for each factor are shown in Fig. 1.

Cost had the highest level of importance, having that it could affect materials' selection. Regarding that, 100% of the participants responded 'yes'. The second highest aspect concerned house-builders was construction speed, which accounted for 91.7% with a 'yes' response. Regarding health and safety, building materials could cause leak of chemicals that can be harmful to residents' health. Therefore, during the online survey, health and safety had good level of consideration, scoring 79% of participants' concern. Cost, construction speed and health and safety requirements had high scores by the house-builders. Therefore, they need to be considered when making decision.

House-builders were asked 'has your company ever used this following methods of construction'. The answering choices were 'yes, no or maybe'. The aim of this question was to measure the acceptability of construction industry and to specify previous practices of alternative methods of construction. The results are shown in Fig. 2.

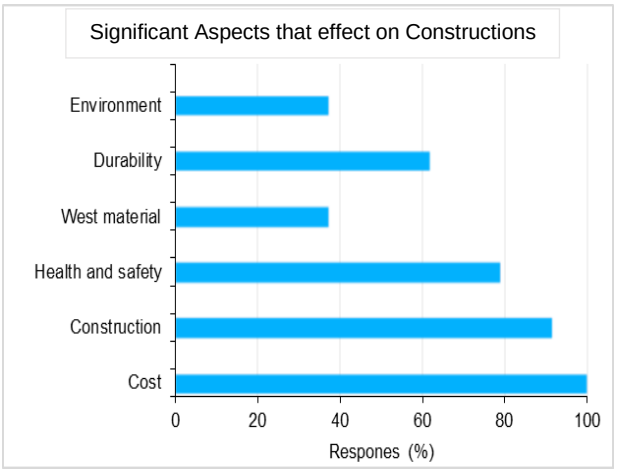

Fig. 1. Agreement Percentage of the importance of factors

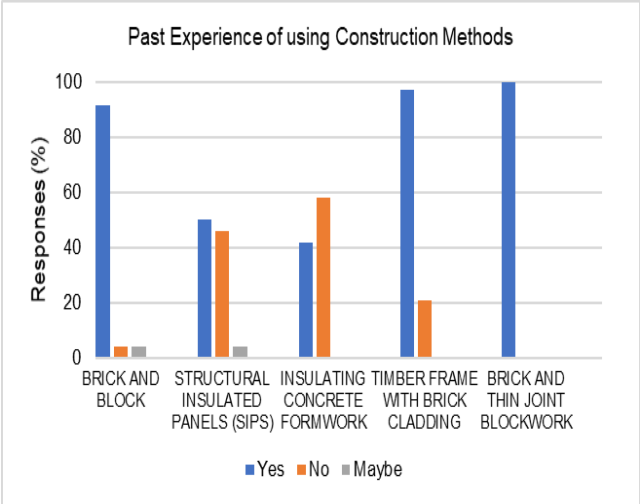

Fig. 2. Experience of using Construction Methods

The results showed that brick and thin joint block work had the maximum use, accounting for 100% of the companies that participated in the online survey. Brick and block was recognised as the second most used construction techniques for house building in the UK, with 91.70% answered 'yes' and only 4.20% responding with 'no'. These percentages were expected, due to the last figures shown in previous years. Another technique was timber frame with brick cladding, which was considered as the oldest method used in housing construction.

The method achieved high level of recognition, accounting for 79.20% of the responses. That may indicate that some house-building companies are still using timber frame, since it is faster, less expensive and lighter. Structural insulated panels and insulating concrete formwork method scored the lowest level of use in the UK, as indicated in previous studies. The figures showed us that there is acceptability, as well as awareness of utilising the most suitable construction method in housing.

Bricks and blocks are considered strong materials, formed into individual units. The walls have inner and outer skins, with a cavity in-between. The masonry was dominantly considered as the main construction material used in cavity walls for dwellings after 1990, accounting for about 88%. Brickwork and blockwork cavity wall are built by using external brickwork and internal fabric of blockwork, which are separately constructed with mortar. Air gap is used as insulation and ties for connection. Internal layers are finished by plasterboard and plaster skim layers. Calculating U-values was adopted, considering key aspects such as; thickness, thermal conductivity and resistant. The results were adopted from British Standards Institution [14] and manufacturers. Additionally, a 0.257W/m^2.K U-value was calculated from Table 2.

Table.1: Brick and Block Materials Specifications

Material	Specification
Mortared brick	clay red brick and cement sand mix
Cavity	25mm width
Wall ties	Stainless steel
Insulation	Mineral wool
Block	8MPa compressive strength,
Plasterboard	12.5mm thickness
Plaster skim	6mm skim

Table.2: R values for brick and block method materials

Material	L (m)	λ (W/mK)	R (m2.K/W)
Brickwork	0.1025	0.84	0.12
Cavity	0.025	0.18	0.14
Insulation	0.1	0.038	2.63
Blockwork	0.1	0.18	0.56
Plasterboard	0.0125	0.16	0.08
Plaster coat	0.006	0.57	0.01

Table.3: R values for brick and block method materials

Material	L (m)	λ (W/mK)	R (m^2.K/W)
Brickwork	0.1025	0.84	0.12
Cavity	0.025	0.18	0.14
Insulation	0.1	0.038	2.63
Blockwork	0.1	0.18	0.56
Plasterboard	0.0125	0.16	0.08
Plaster coat	0.006	0.57	0.01

Calculating U-values was adopted, considering key aspects such as: thickness, thermal conductivity and resistances. The results were adopted from British Standards Institution [14] and manufacturers. Additionally, a 0.257W/m^2.K U-value was calculated from Table 3.

Structural insulated panels (SIPs) is considered as light weight and off-site manufactured method. The method is constructed as an essential loadbearing element. Doan [9] indicated that, Structural Insulated Panels are built by sandwiching a low density, cellular core rigid insulation, between two sheets of wood that are placed together through orientated process, named as orientated strand boards (OSB). Efficient materials were used in the layers as insulation, for providing high performance. These materials include: Extended Polystyrene (EPS), Polyurethane (PU), Extruded Polystyrene (XPS) and Polysio-cyanurate. Construction process can be simple when using SIP as it requires less skilled workers on site and adapts to high design requirements, especially for house building. The KINGSPAN TEK building system specifies [15] [16] that the breather membrane is fixed on the external panels, in order to increase weather protection, which, in turn, contributes to the overall U-value of cavity walls. Wall ties are used to connect the external brickwork to buildings' structure, while keeping cavity for insulation. Internally, walls are finished with plasterboard and plaster skim layers [3] [4]. Construction details of SIPs are included in Table 4, according to KINGSPAN's specifications.

Table.4: SIPs materials specifications

Components	Specification
Brick	102 mm brick external leaf
Mortar	cement sand mix
Wall ties	Stainless steel wall ties
cavity	50 mm residual cavity
Breather membrane	Kingspan nilvent breather membrane fixing using steel staples
SIP panel	142mm Kingspan TEK building system panel (2x15mm OSB sheets, 112mm urethane foam)
Plasterboard	2 x 12.5mm thickness
Plaster coat	6mm skim

Structural insulating panels provide high performance in terms of resisting thermal bridges. Kingspan [15] [16] indicated that, in the worst circumstance, full cavity wall can achieve a U-value of 0.20 W/m^2.K, with no insulation foam. Department for Communities and Local

Government [17] argued that, most newly-built developments should have external walls with U-values targeted between 0.17 W/m^2.K and 0.18 W/m2.K. For calculating U-values most details were provided from manufacturers and building regulations of British standards, such as [14] [15] [16]. The U-value calculated from Table 4 was 0.16 W/m^2.K.

Table.5: R values for SIPs materials

Components	L (m)	λ (W/mK)	R (m^2.K/W)
brickwork	0.1025	0.84	0.12
Cavity	0.050	0.18	0.28
OSB	0.015	0.06	0.50
Foam	0.112	0.023	4.87
Plasterboard	0.026	0.15	0.15
Plaster skim	0.0061	0.58	0.02

On the other hand, ICF is a block technique made from two sheets of foam, expanded polystyrene (EPS) or extruded polystyrene (XPS), connected by metal or plastic ties. Wall thickness typically differs according to buildings' type, use and anticipated performance. ICF has excellent properties as its thermal mass is achieved by a concrete core and two layers of insulation. Davies [18] suggests that, structural design will determine concrete's width, limited between 100mm and 350mm. In some cases, ICF formwork may be thicker for external walls, to give additional insulation. Rebar is used for structural requirements. Generally, cavity walls are erected to a first floor level, before pouring concrete, followed by curing. Formwork would remain in place to guarantee a durable layer of thermal insulation and appropriate wall shape.

Table.6: ICF materials specifications Materials

Type	Specifications
Brickwork	clay red brick, 102.5 x 65 x 215mm
Wall ties	Stainless steel,
Mortar	cement sand mix, 10mm joints
Concrete	RC 25 concrete, 10mm aggregate
ICF	Beco Wallform manufacturer
Plasterboard	12.5mm thickness
Plaster coat	6mm plaster

The Concrete Centre [2] indicated that, providing durable cladding in ICF is significant for providing protection from environmental damages. Moreover, it is important for providing efficient materials used for cladding such as brickworks, particularly in housing construction. Connection between bricks and ICF's member is achieved through using wall ties. Needless to mention, placing the foam insulation into the air space cavity. Walls element are usually finished by using coats of plaster skim or plasterboard.

ICF is well-known for its energy. The Concrete Centre [2], ICF technique uses EPS/XPS thermal insulation, which provides about level 5 and level 6 in codes for sustainable homes. Moreover, it is a durable building technique that provides U-values of 0.10 – 0.30 W/m^2.K. Evans [19] argued that, when ICF system is used with insulation, external brick, foam leaves, plastic strip ties and cavity walls, U-values could be dropped to 0.13 W/m2.K. The U-value calculated from information given by the [14] and [2] was about 0.204 W/m^2.K.

Table.7: R values for ICF materials

Material	L(m)	λ (W/mK)	R (m2.K/W)
bricks	0.1025	0.840	0.123
Cavity	0.0151	0.180	0.083
ICF	0.313	0.0658	4.764
plasterboard	0.0126	0.160	0.078
Plaster coat	0.0061	0.570	0.011

Table.8: Thin joint blockwork materials specifications

Material	Specification
Mortar brickwork	clay red brick
Wall ties	Stainless steel
Thin joint mortar	cement sand mix
Thin joint blocks	Durox top blockwork
Plasterboard	12.5mm thickness
Plaster skim	6mm skim
Insulation	mineral wool

Table. 9: R values for thin joint blockwork materials

Material	L(m)	λ (W/mK)	R (m^2.K/W)
Brickwork with mortar	0.103	0.84	0.12
Cavity	0.025	0.17	0.15
Insulation (wool)	0.2	0.037	2.64
Blockwork	0.1	0.16	0.64
plasterboard	0.012	0.16	0.09
Plaster skim	0.005	0.58	0.02

Timber frame cavity walls are involve using various internal layers. These layers include; plasterboard, vapour control layer, air filled cavity, waterproof membrane and insulation. The system is suitable for most external cladding options, including brick for appropriate appearance. To ensure that building envelopes have durable finish, plaster skim is used National Building Technologies [14].

Table.10: Timber frame with brick cladding specifications

Materials	Specifications
Mortared brick	clay red brick with cement sand mix
Wall ties	Stainless steel
waterproof membrane	Glidevale Protect TF200 Breather Membrane
Insulation	Mineral wool
Plasterboard	25mm thickness
Plaster skim	6mm coat

The timber frame design includes insulation within composite structure. Efficient level of insulation is adopted, preventing air leakage that affects amounts of heat loss from buildings. many clients selected this method for its high performing score. Another reason was it blocks moisture and the air passing through the internal structure. Timber frame wall construction can provide high thermal performance by using durable layers, which reduces U-value to 0.24 W/m^2 K [20]. Moreover, the U-value, calculated from Table 11 was around 0.249W/m^2.K [14].

Table.11: R values for timber frame with brick cladding materials

Materials	L(m)	λ (W/mK)	R (m^2.K/W)
Brickwork	0.1025	0.84	0.12
Cavity	0.060	0.18	0.14
Wood sheet	0.009	0.03	0.30
Insulation	0.120	0.038	3.16
Plasterboard	0.025	0.16	0.08
Plaster coat	0.006	0.57	0.01

According to the online survey, most of construction techniques for cavity walls have been used in the United Kingdom. The methods of construction for housing building that were selected in this study included: brick and block, structural insulated panels (SIPs), insulating concrete formwork (ICF), thin joint blockwork and timber frame with brick cladding. Methods' properties were examined during this project, in terms of their thermal resistance and U-values. The U-values are listed in Table 12 below.

Table.12: The methods of construction

Construction method	U value W/m^2 K
Brick and block	0.257
SIP	0.16
ICF	0.13
Thin joint block work	0.18
Timber frame with brick cladding	0.249

V. CONCLUSION AND DISCUSSION

Five methods of construction of cavity wall were investigated in terms of sustainable building fabric, to mitigate energy demands in housing. The baseline method was brick and block, which is considered the most frequently used in the UK. Alternative methods of construction were applied in construction industry. Therefore, there is possibility to reach the code of sustainable homes evaluation and score accep Table levels. U-values of construction methods were examined to clarify thier thermal resistance.

The methods of construction were selected in terms of both; appropriateness and modern methods of construction, which were recently used in the industry. Therefore, the acceptability of public is considered significant to determining the best choice that could help house-builders in decision making. According to the questionnaire of the past experience of house-builders, the scale of acceptability is wide across the used techniques. Structural insulating panels and insulating concrete formwork methods represented the least methods used in housing construction. Therefore, they need to be developed. Brick and block and thin joint blockwork methods showed the highest acceptability. The differences in public acceptability were realised in results, perhaps due to studying different locations across the United Kingdom. The factors that concern house-builders and the public when selecting building materials were categorised as cost, construction speed, health and safety requirements, waste material disposal, durability and environmental impact. The factor that scored the highest was cost, which is considered the most important aspect affects method selection. Low costs of construction methods can increase acceptability for house-builders and the public, since

costing could reduce prices of building materials and energy demand.

The main aim behind using case studies was to determine the most adequate method of construction used in an envelope, in terms of its thermal resistance, heat loss minimisation and energy requirement. The differences in the scale of thermal resistance can allow using various construction methods, particularly the cavity wall. The results indicated that thermal transmittance of SIPs was most favourable when compared with other methods, as it scored the lowest U-value (0.16 W/m^2). Therefore, SIPs can be considered as the most appropriate option for achieving lower operational energy for industry's requirements. Although brick and block method scored the highest rate of acceptability in online survey, considered as the most frequently used in the industry, the method showed inefficient U-value. Hence, it needs to be developed in terms of its thermal areas. From the conducted study, it is clear that energy consumption and acceptability are important for achieving a successful housing construction.

REFERENCES

[1] Department for Communities and Local (DCL) (2007) Government the Callcutt Review of Housebuilding Delivery. [online] available from: <http://webarchive.nationalarchives. gov.uk/20101208170101/http://www.callcuttreview.co.uk/downloads/callcuttreview_221107.pdf > [12 March 2018].

[2] The Concrete Centre (2009) Insulating Concrete Formwork, a guide to use and application [online] available from < http://www.ihsti.com/tempimg/1219245-CIS888614800300566.pdf > [3 March 2020].

[3] Homebuilding and Renovating (2011) Introduction to Structural Insulated Panels [online] available from< https://www.homebuilding.co.uk/introduction-to-structural-insulated-panels/> [3 March 2020].

[4] Homebuilding and renovation (2011) A Guide to SIPs [online] available from <https://www.homebuilding.co.uk/sips-how-do-they-work/> [9 March 2020].

[5] Bansal,S., Biswas,S. and Singh, S. (2017) 'Fuzzy decision approach for selection of most suitable construction method of Green Buildings' International Journal of Sustainable Built Environment [online] 6, 122–132.

[6] Roy, R., Brown, J., and Gaze, C. (2010) 'Re-Engineering the Construction Process in the Speculative House-Building Sector' Construction Management and Economics. 21(2), 137-146.

[7] Tricker, R., Samantha, A. (2014) Building Regulations in Brief [online] eighth edition. London: ProQuest. Available from < http://ebookcentral.proquest.com/lib/coventry/detail.action?docID=1675935> [16 March 2018].

[8] Bautex (2017) Problems with ICF Construction [online] available from <http://www.bautexsystems.com/company/news-events/icf-problems> [17 April 2020]

[9] Doan, V. (2012) Integrated Design Solution of A Residential Structural Insulated Panel Dwelling [online] Doctor of Philosophy. University of Birmingham. Available from < http://etheses.bham.ac.uk/4236/ > [18 April 2020].

[10] MPA the Concrete Centre (n.d.) Thin Joint Blockwork [online] available from < https://www.concretecentre.com/Building-Elements/Walls/Thin-joint-blockwork.aspx > [19 March 2020].

[11] Emmitt, S. and Yeomans, D.T. (2008) Specifying Buildings, A Design Management Perspective [online] 2nd edn. Oxford: Butterworth-Heinema. available from < http://locate.coventry.ac.uk/primo-explore/fulldisplay?docid=TN_ingram_myilibrary 9786611273200context=PCandvid=COV_VU1andsearch_scope=Primo_Centralandtab=remoteandlang =en_US > [20 March 2020].

[12] Kothari, C. (2004) Research methodology methods and techniques [online] 2nd ed., New Delhi: New Age International (P) Ltd., Publishers. Available from <http://locate.coventry.ac.uk/primo-explore/fulldisplay?docid=COV_ALMA514622579000201 1andcontext=Landvid=COV_VU1andsearch_scope=LSCOP_COVandtab=localandlang=en_US> [29 March 2020].

[13] Gillham, B. (2000) Developing a Questionnaire. [online] London: Continuum available from < https://ebookcentral.proquest.com/lib/coventry/reader.action?docID=1749803andquery= > [20 March 2020].

[14] British Standards Institution (2017) Building components and Building Elements - Thermal Resistance and Thermal Transmittance - Calculation Methods [online] available from< http://www.ihsti.com/tempimg/5748bba-CIS888614800319386.pdf > [25 March 2020].

[15] Kingspan (2017) Kingspan TEK Building System Specification Manual [online] available from <file:///C:/Users/alsharqi/Downloads/25958_ProductBrochure_TEKSpecificationManual_UK.pdf> [26 March 2020].

[16] Kingspan (2017) How to Calculate a U-value [online] available from < https://www.kingspan.com/meati/en-in/product-groups/insulation/knowledge-base/faqs/u-values/how-to-calculate-a-u-value> [26 March 2020].

[17] Department for Communities and Local Government (2010) English Housing Survey, Housing Stock Report 2008. [online] available from <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6703/1750754.pdf> [3 March 2020].

[18] Davies, C. (2006) WORKING DETAILS / STYRO STONE HOUSE. The Architects' Journal [online] 223 (8), pp. 54-55. https://search.proquest.com.

[19] Evans, B. (2006) ''The house took around 35 trucks of structural-grade ready mix'' Concrete Quarterly [online] Vol. 223, pp.52-53 available from < https://search.proquest.com/ > [31 March 2020].

[20] Hastings, T.(2010) VC Foil Ultra Insulating Vapour Control layer. [Online] Available from < http://donaldson-insulation.co.uk/wp-content/uploads/2012/10/protect_vc_foil_ultra.pdf > [2 April 2020].

[21] UK Construction Week (2017) World In Action And Barratts The Builders| [online] Available from <https://www.ukconstructionweek.com/news/construction-buzz/1017-world-in-action-and-barratts-the-builders-construction-buzz-100> [3 March 2020].

[22] National Building Technologies (2017) Technical Manual, Timber Frame Clad System [online] available from < https://9r6oo423wkdlw0p8lrr2lmmb-wpengine.netdna-ssl.com/wp-content/uploads/technical-manual-timber-frame-clad-1.pdf > [1 April 2020].

[23] Ministry of Housing, Communities and local government (2017) House Building; New Build Dwellings, England: December Quarter 2017 [online] available from < https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/692680/House_Building_Release_Dec_Qtr_2017.pdf > [11 April 2020].

[24] Communities and Local Government CLG. (2010) code For Sustainable Homes [online] available from<https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/5976/code_for_sustainable_homes_techguide.pdf > [15 March 2020].

[25] Bragança, L., Mateus, R. and Koukkari, K. (2010) Building Sustainability Assessment. Sustainability [online] 2, 2010-2023.

[26] Shibani, A., Hassan, D., and Shakir, N., 2020, The Effects of Pandemic on Construction Industry in the UK, Mediterranean Journal of Social Sciences, 11(6), 48.

[27] Shibani, A. 2020, Adopting Building Information Modelling in Small and Medium Enterprises of Iraq's Construction In-dustry, International Conference on Industrial Engineering and Operations Management. March ed. IEOM Society, p. 457-470 14 p.

[28] Shibani, A. Arumugam, K., 2015, Avoiding Cost Overruns in Construction Projects in India : Management Studies. 3, 7-8, p. 192-202.

[29] Shibani, A., 2020, Proceedings of the International Conference on Industrial Engineering and Operations Management. March ed. IEOM Society, p. 457-470 14 p.

[30] Umar, T., Egbu, C., Ofori, G., Honnurvali, M. S., Saidani, M., Shibani, A., Opoku, A., Gupta, N. & Goh, K., Oct 2020, In: Engineering Sustainability. 173, 7, p. 325-343 19 p.

[31] Araz Agha, Abdussalam Shibani, Dyaa Hassan, Alexander Salmon, 2020, Building Research Establishment Environmental Assessment Methodology on the UK Residential Projects. International Journal of Construction Engineering and Management 2020, 9(6): 183-189. DOI: 10.5923/j.ijcem.20200906.01.

[32] Abdussalam Shibani, Omar Mahadel, Dyaa Hassan, Araz Agha, Messaoud Saidan, 2021, CAUSES OF TIME OVERRUNS IN THE CONSTRUCTION INDUSTRY IN EGYPT. International Research Journal Of Modernization In Engineering Technology And Science (IRJMETS), Vol.3 (1).

[33] Araz Agha, Abdussalam Shibani, Dyaa Hassan, Alexander Salmon, 2020, Building Research Establishment Environmental Assessment Methodology on the UK Residential Projects. International Journal of Construction Engineering and Management 2020, 9(6): 183-189. DOI: 10.5923/j.ijcem.20200906.01.

[34] Agha A, Shibani A, Hassan D, Zalans B (2021) Modular Construction in the United Kingdom Housing Sector: Barriers and Implications. J Archit Eng Tech 10:2:236.