

Understanding the advantages of earth construction in urban housing in the United Kingdom

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Research

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Abstract

Earth building material is beneficial in urban housing in the United Kingdom, particularly with regard to the promotion of environmental sustainability. Due to higher demand to achieve sustainable development around the world, researchers and innovators are increasingly turning their attention to efficient ways to address climate change and excessive CO₂ emissions. Contemporary earth construction certainly contributes to reducing current global CO₂ emissions and achieving environmental sustainability. Existing literature documents numerous benefits to constructing in earth, yet a critical review of the literature shows that, in many cases, these benefits are empirically unsubstantiated. Moreover, some benefits found in literature seemingly conflict and are often context and/or project specific. This paper aims to address some of these incongruities through an in-depth analysis of the advantages of earth construction in the development of UK urban housing. To achieve this aim, an interpretivist research philosophy was employed, including an up-to-date state of art literature review on the topic, and validation through the Delphi technique and in-depth interviews of construction professionals in the field of earth construction. The results show that earth building is very safe for the environment, it saves energy, promote self-help construction and significantly contribute achieving all aspects of environmental sustainability in the United Kingdom.

1. Introduction

Sun-dried earth blocks was used in construction approximately 8000 B.C and it is estimated that earth-based shelters house about 50% of the world's population [22]. Earth has been most widely used construction material in many developing countries and continues to be the major means of construction [18]. According to Schroeder & Lemke [25], earth building materials has less negative impact on the environment, they are inherently energy efficient compared to other building materials, and less risky on people health. Earth construction, for example, consumes less non-renewable energy than fired masonry, concrete blockwork and heat/humidity buffering [4]. According to Reddy et al [23], in modern interpretations, earth as a construction material has negligible life-cycle impact, is completely recyclable, and it contributes almost zero-carbon footprint.

Earth is not only environmentally viable; it is also cheaper, available in large quantities and easy to work with especially forming into building components [1]. In other words, earth construction carries many economic benefits and a primary reason for adopting contemporary earth construction is that it can address urban housing crises, especially in developing countries where it is readily embraced [29]. Interest in earth construction in developed countries, by contrast, is more often driven by potential environmental gains as opposed to its economic value. In order to achieve overarching purpose of this study of informing the diverse benefits of earth material to construction practitioners, this study aims to identify and explore the wide range of benefits associated with earth construction in UK urban housing. Considering the exploratory nature of these aims, the study begins with a critical review of relevant literature on the advantages of earth material as a primary construction material. Furthermore, the paper analyses and validates these benefits through empirical research methodology including the Delphi technique and in-depth interviews - a process in which findings in literature are compared and contrasted against the perspectives of professionals in the field (i.e. construction professionals) through questionnaires and interviews.

According to Houben & Guillaud [11], through modern construction methods, earth is typically stabilised through three major processes:

- Physically by modifying the percentage of mixed soil particles and texture of the earth by varying soil ingredients.
- Chemically by mixing chemicals (stabilisers, such as, cement, lime, gypsum, fly ash, etc.) or other materials to modify the properties of the soil.

- Mechanically by applying force directly onto the soil compressing or ramming. It alters the permeability, density, durability, strength, compressibility, and porosity of the earth.

Therefore, earth stabilisation must not be understood as only mixing cement with it. However, the benefits of using earth as building material are many, as summarised in Table 1, which presents an in-depth summary of the generic benefits of earth material as identified in literature.

Table 1
Advantages of earth as building material [30, 31].

Benefits/Advantages of earth as building material (summarised review of the literature)	Authors
1. Use of earth is economically advantageous.	[8, 28, 20, 13, 5, 27, 10, 18, 1, 17, 19, 14, 11, 12, 3, 21, 9]
2. Earth construction use simple tools and unskilled labour.	
3. It promotes housing construction in the form of 'self-help'.	
4. Earth can build extra secured and strong structures.	
5. Earth material has low embodied energy; therefore, considered as energy saver.	
6. Naturally balance interior temperature and humidity in an earth building.	
7. It is fire resistant.	
8. It creates employment opportunity.	
9. Earth is considered as sustainable building material.	
10. Earth walls preserve organic materials, such as timber.	
11. Pollutants are absorbed by earth wall.	
12. Designing with earth is easy and can produce building with high aesthetic value.	
13. Earth wall possess high insulation property, therefore, excellent in controlling noise.	
14. Earth is local building material; therefore, it promotes heritage, tradition and cultural practice.	
15. It is available worldwide in abundance.	

As shown in Table 1, a major focus of research to date has been on economic benefits associated with contemporary earth construction. However, researcher Sanya [24] stated that economic advantage of earth is not always be achieved. Given conflicting views on the economic viability of earth construction, it is pertinent to investigate this benefit in more detail. Environmental benefits also dominate current literature sources, particularly with regard to certain contexts. In India, for example, studies have shown that one m² CSEB construction of masonry consumes five times less energy than one m² of wire cut fired brick masonry and fifteen times less than country fired bricks [17]. Maini [17] also states that CSEBs are eco-friendlier than fired bricks and consume less energy and pollutes less air during manufacturing than

fired bricks. Further to this, Adam and Agib [1] emphasize how processing and handling soil requires low energy input; the author referred to a study (Desert Architecture Unit) and stated that 36 MJ (10 kwh) energy is consumed in the production of one m³ of earth, whereas 3000 MJ (833 kwh) energy is consumed in the production one m³ of concrete.

Schroeder and Lemke [25] systematically explain and illustrates how earth construction can become self-sustaining. The soil is collected/extracted from the ground with its natural state; preparation such as classification, pulverisation, drying is done with its aim to be used in the construction. Thereafter, the soil is used to complete the building. The earth building last long time, however, in the case of demolition the earth building goes back to the ground, thereafter can be reused and recycled as earthen materials. This is how the life cycle of earth becomes self-sustaining. In this way, earth material is ecologically advantageous. As research emphasizes, contemporary earth construction is often more economically and environmentally sustainable than conventional building materials (i.e. fired brick and concrete) and may play a fundamental role in cutting excessive CO₂ emissions in the urban housing projects. A critical review of existing literature, however, reveals that sparse research so far carried out that identifies, explores and analyses the advantage of earth material specifically in the case of UK urban housing. Benefits mentioned by various construction professionals and authors in literature are also, more often than not, anecdotal and based on individual perceptions; thus, empirical data is lacking and refining of data via rigorous scientific processes. Responding to the need for informing the benefits of contemporary earth construction to UK professionals, therefore, this study aims to identify the benefits in UK context.

2. Methodology

To understand the benefits of using earth material in the UK, this study followed a four-stage, methodological framework as shown in Fig. 1.

- Stage One (Formulation of research aims and methodological framework in light of the literature review): This phase involved a critical and comprehensive analysis (review) of literature on the advantages of earth construction within the context of urban housing. A thorough search on the literature uncovered that the scientific investigations, to date, on the topic of identification and understanding the benefits of earth as building material, particularly in the UK is very few. After careful consideration of the nature of the research problem, an interpretivist philosophical stance was adopted to achieve the aim of the study.
- Stage Two (Exploratory phase – the Delphi technique): This phase employed the Delphi method where an expert panel of participants responded to questionnaires in two rounds to achieve a consensus to finalise the advantages of using earth material in urban housing. Specifically, this method was chosen as an initial research technique to accumulate scientific data to support the advantages summarised from the literature review (Table 1). The data collected from the Delphi technique, combined with the comprehensive literature review, resulted in an extensive list of benefits associated with earth construction and provided data from which a robust interview schedule was constructed for the validation phase (Stage Three), i.e. in-depth interviews with experienced experts working in UK earth construction.
- Stage Three (Validation Phase of in-depth interviews): This phase employed a number of in-depth interviews with the objective of identifying and validating the advantages of earth as building material in UK urban housing. This validation phase played a central role in identifying distinctive, unique benefits and hidden agendas (such as the condition upon which the earth construction is beneficial are not well explained) particularly within the context of the UK. The accumulation of this validated data allowed the researcher to make a strong foundation of understanding the diversified, known, and unknown and conditions of benefits and then refined the generic benefits to understand them better in UK context.

- Stage Four (Synthesis of the research process): The aim of the final phase was to synthesize the research findings; summarize and discuss the contribution of knowledge the results make to academia and the construction industry; recommend future research and acknowledge limitations. This concluding phase facilitates an overall holistic understanding of the advantages of earth material in UK urban housing. Considering the exploratory nature of this study, a methodological framework of four stages was employed. Each stage collected key data that assisted and contributed to the development of the subsequent stages.

2.1 Justification and process of execution of the Delphi technique

As indicated, two major methods were used to collect data. Namely, the Delphi technique and in-depth interviews were employed due to their ability to explore the benefits of earth material. If there is a problem of getting information about any issue/phenomena and there is incomplete knowledge about it, the Delphi method can be used to acquire information [2, 7]. Through this technique information can be generated from the subjective judgments of experts on a collective basis and this method is suitable investigating problems that do not lend themselves precise analytical techniques [2]. Therefore, Delphi technique helped understanding the advantages of earth material, explored areas about the advantages of earth building material that may have been overlooked, areas where there are conflicting ideas and that do not have sufficient data to generalize.

As mentioned, the literature review concluded that sparse research produced evidence validated via structured scientific processes with regard to the benefits of earth construction. The Delphi technique, therefore, was selected as an initial study method because it offered a more rigorous, informed and grounded way to explore the potential benefits of contemporary earth construction. The Delphi technique was able to capture a more in-depth analysis of the benefits of earth construction from a carefully selected group of construction professionals. The data produced by the Delphi technique provided several clarifications and substantially contributed to knowledge in the field with regard to the type of conditions that may need to be met in order for earth construction to be beneficial.

The Delphi method consisted of two rounds of questionnaires, where the second questionnaire was built from the questions and experts contributions summarised from the first round of questionnaires. The aim of the questionnaire in the first round was to extract advantages of earth in urban housing. In the second round of the Delphi, the benefits identified from the first round were listed and ranked according to the number of experts who identified each benefit. These results (list of benefits) were then presented back to the experts for their second thought, reconsideration and coming up with final list.

Of the few of professionals specialised on earth material all over the world, the most renowned of this population were selected as participants for the Delphi method. In total, thirty-four international experts who were considered to have the up to date knowledge and exposure for the study were communicated. Fourteen international experts, resulting in a 41% response rate, responded and agreed to participate. Of the fourteen participants, all of them were practitioners but also researchers. The panellists required only two rounds of questionnaire to reach a consensus. Figure 2 illustrates the methodological process adopted to execute the Delphi technique in this study.

2.2 Justification and process of execution of the in-depth interviews

To formulate a semi-structured questionnaire for in-depth interviews conducted in phase three the researcher used the results of the Delphi technique. The data acquired from the in-depth interviews with UK construction professionals were used to validate the consolidated or generic list and generate a list of the advantages of earth material in UK. In depth

interviews are appropriate qualitative method for encouraging participants to talk about their personal feelings, opinions, and experiences [16]. Interview method help to gather hidden information or data from sensitive topics that people might be reluctant to discuss in a group setting. Therefore, in depth interviews helped exploring areas about the benefits that may have been overlooked, areas where there are conflicting ideas and that do not have sufficient data to validate the advantages of earth material in UK. The methodological processes used (and the results) of the Delphi technique and interviews are discussed in turn.

The data collected from the Delphi technique combined with the literature review resulted in an extensive list of benefits and helped direct the construction of the interview schedule for the validation stage (Phase Three). Specifically, the third phase incorporated in-depth interviews with experts experienced in earth construction in the United Kingdom. This phase played an important role in highlighting any distinctive factors and hidden agendas (such as certain local conditions upon which the benefit is depending upon) in the UK. The accumulation of these data also allowed the author to build a grounded foundation of knowledge from which to explore the benefits of earth material in urban housing of UK. According to Loosemore [15], the researcher must make sure that the research techniques used in any interviews should be able to communicate most effectively between themselves and the expert participant. Therefore, in a research, feedback is essential convergence. It is the knowledge transferring to the researcher from the participant. Such knowledge can be obtained from verbal and written formats, facial expressions and body languages. Interviews are excellent methods in theory building, not only because interviewers they can elicit perceptions of key concepts from experts, (i.e. industrial practitioners in the case of this study), but also because the data is contextualized through the stories and experiences of those interviewed [6].

All the interviewees were an average of over thirty-five years experienced in earth construction. They fulfilled the following set of criteria used to recruit participants with sufficient knowledge and experience in the field:

- British natives and locally trained construction professionals with knowledge in earth construction who may shed light on local factors affecting benefits of earth construction in the UK.
- Professionals who are active members of various UK based international associations related to earth construction.
- Migrated construction professionals trained in the UK and have international experience, with the ability to clarify local factors affecting earth construction considering their global exposure.

In the third stage (interviewing), after establishing rapport, the experts were asked to discuss what they considered to be the advantages of earth material in UK, if any. In this stage all the experts gave their own list of benefits; they were then shown the list of benefits established from the results of the Delphi phase and asked to validate by comparing between their own list. However, they were further asked to discuss and explain if there is any mismatch between the two lists. Each interview session lasted between half an hour to one hour. The interviews were recorded in audio and video tape to facilitate verbatim transcription. The fourth stage involved transcribing where the author transcribed the audio and/or video in answer to each question. The transcripts were then analysed in the fifth stage (analysing). This stage determined the meaning of the data collected to fulfil the aim of the research and indicated whether more questions were needed in order to clarify any points related to the research aim. The sixth stage, verifying, involved analysing the credibility and validity of the information gathered. Verification of the credibility and validity of the information was carried out by sending summarised final list of the benefits and all interview transcriptions together back to the all interviewees for their checking and final comments (if any). The last stage included reporting the outcomes of the in-depth interviews in light of the overall aims of the study.

3. Results

3.1 Results from Delphi Technique

The experts were asked to identify the benefits (if any) of using earth material in urban housing and all fourteen participants replied accordingly. Eleven experts (79%) unconditionally agreed that earth material is advantageous in urban housing. One expert (7%) indicated that earth may possibly be advantageous, and two experts (14%) posited that earth construction is beneficial, but dependent upon the following conditions:

- The type of urban housing (terraced, semidetached, flats, etc.). For example, multi-storeyed (high-rise) flats might not be economically or structurally possible. Single storied houses are more economically sustainable than double storied terraced or semidetached houses.
- The suitability and availability of local soil. Earth that is sourced from a great distance will result in increased expenses due to transportation costs.
- The nature of the climate in the town/city. Although contemporary stabilized earth structures have a high success rate globally with regard to resisting natural disasters, un-stabilized earth structure naturally vulnerable to flood and earthquake zones.
- The rationale and/or philosophical goal of the designer, client and/or occupant. For instance, earth construction may be chosen for urban housing for many reasons, such as environmental and/or economic sustainability, or the promotion of local technology and culture, for example. Therefore, the benefit of using earth construction will depend on the designer or client's intentions or the goal of the project.
- Type of stabiliser. For example, un-stabilised earth may prove to be environmentally more beneficial than cement stabilised earth. In addition, many experts are opposed to cement stabilised earth construction because it lacks environmental and economic sustainability.

The above summary provides an important list of conditions that need to be considered when assessing the advantages of any earth construction project in urban housing. These conditions were not identified in the aforementioned review of literature. Table 2 presents 15 of the benefits of earth construction identified from literature (see Table 1) and twelve benefits mentioned by the expert panel in the first round. The results show that the participants identified all but three of the benefits mentioned in literature review. They did not identify any new benefits that were not previously mentioned in literature. The benefits are ranked according to the number of experts who mentioned them in the first phase of the Delphi survey.

Table 2
Benefits of earth construction as identified in literature through the Delphi Method [30].

Benefits of earth as building material gathered in first round of Delphi	Number of experts
1. It saves energy (low embodied energy).	Ten (10)
2. Naturally balance interior temperature and humidity in an earth building.	Nine (09)
3. It is environmentally sustainable.	Eight (08)
4. It is economically beneficial.	Seven (07)
5. Earth construction use simple tools and labours with inferior skill.	Three (03)
6. It promotes housing construction in the form of 'self-help'.	Three (03)
7. It supports strong, secure structures.	Three (03)
8. Designing with earth is easy and can produce building with high aesthetic value.	Three (03)
9. It promotes local culture, heritage, and materials.	Three (03)
10. It is available worldwide in abundance.	Three (03)
11. It creates local job opportunity.	Two (02)
12. Earth has fire resistant properties.	One (01)
13. Earth walls preserve organic materials, such as timber.	None
14. Pollutants are absorbed by earth wall.	None
15. Earth buildings provide better noise control.	None

3.2 Results from In-depth interviews

As noted, during interviewing phase the experts were first asked to share their views on what they believed to be the benefits (if any) of earth construction. In general, all the interviewees agree on a number of conditions upon which the benefits are dependent upon but also had differing views on the economic benefit of earth construction in the UK.

Expert 'A' explained that in order to consider the benefits of earth construction, it is first important to recognize that there are several, hundred, different types of soil available in the UK, and some soil will work with stabilizer, some without stabilizer and in some cases excessive stabilization may be required. Soil in the UK varies acre to acre or hector to hector; and, in order to reap the benefits of earth construction, much will depend on the type of soil available. Expert 'A' further explained that there were two major reasons why clients chose an earth building, i.e. either they 'want a green project for the sake of environmental sustainability, or simply for aesthetic reasons'. In either case, the expert suggested that the decision of whether to stabilize the soil or not would be made during the design process. For instance, if clients chose earth because they wanted a green project, then the earth would not be stabilized, (especially not with cementation material). If the client, however, wanted to use earth material for aesthetic reasons, then that was a "completely different situation". The client would need to see how adding stabilizer would change the appearance of the building wall elevation before the actual construction starts. The practitioner would need to create a test wall before actual construction to fulfil client's aesthetic reasons. During one particular class assignment aimed at designing earth

buildings, the expert 'A' shared how she sensed a lack of interest in stabilized earth among students. Many, she explained, felt that it lacked sustainability, which "is a big issue for the UK".

Expert 'C' similarly suggested that un-stabilized earth construction provides many benefits whereas stabilized earth construction brings very few, if any. A major issue with urban housing procurement and construction, he explained, is funding; "therefore, it all comes down to the cost of industrial input". Expert 'B' also felt that earth construction was beneficial in the UK but not universally so. He suggested that each project needed to be weighed up against alternatives with respect to: the current cost and availability of materials, the labour market, and the level of familiarity the design team has with earth building and their skill set. Overall, he summarized his thoughts by saying, "The broad answer is 'yes' it is beneficial but it is project specific. Potential benefits have to be weighed against what the alternatives are".

Overall, the experts unanimously agreed that earth material is advantageous in urban housing, but dependent on certain conditions. Three of the experts also suggested that un-stabilised earth is more beneficial than stabilised earth in the UK, and, again, dependent on certain conditions. The conditions, as mentioned by the experts, are summarized as follows:

1. There are different soil types in the UK. One has to characterise different types of soil to understand which of them will work with stabiliser, which will not and which requires excessive stabilisation.
2. Projects involving earth construction must be weighed up against alternatives in terms of the current cost and availability of materials. Therefore, the benefit of using earth construction is project specific.
3. Un-stabilised earth construction provides many benefits whereas stabilised earth construction brings very few, if any. A major issue with urban housing procurement and construction is funding; therefore, cost is important.
4. The decision to use stabilizer will depend on the goal of the client, i.e. whether they are focused on creating a green project for the sake of environmental sustainability, or whether they are building for aesthetic purposes.
5. Soil needs to be excavated locally and brought to the construction site easily.
6. Skilled labour needs to be locally available.
7. The design team needs to be skilled in earth construction.

The experts were then asked to discuss what they considered to be the advantages of earth material in UK urban housing, if any. All the experts gave their own list of benefits. The experts were then shown the consolidated list of benefits (Table 2) summarised from the literature review and the Delphi technique and were asked to compare with their respective lists and validate whether those advantages of earth building were applicable to urban housing in the UK context. Table 3 presents the result of the validation.

Table 3
Advantages of using earth material in UK urban housing validated by experts.

Summarised advantages of earth building in UK
1. Earth building use simple tools and labour with less skill.
2. It supports strong, secure structures.
3. Earth material has low embodied energy; therefore, considered as energy saver.
4. It characteristically controls humidity and heat by reducing peaks and drops.
5. Earth produces fireproof buildings.
6. Earth construction creates job opportunity in the UK.
7. Earth material is easy to recycle and degrade; therefore, it is environmentally sustainable.
8. Designing with earth is easy and can produce building with high aesthetic value.
9. It produces structures that have sound insulation characteristics.
10. It is local building material; therefore, it promotes heritage, tradition and cultural practice.
11. It encourages self-help construction.
12. It is available in most regions in abundance and ready for use in UK.
13. It contributes money to the local economy

4. Discussion

As shown in the earlier review of literature, much research, to date, has focused on the monetary advantages of earth material (dependent on certain conditions); whereas the results from the Delphi technique and panel of experts show that environmental benefits dominate as the major advantage of earth construction. The results also emphasize that the benefits of earth construction are likely dependent upon certain conditions and circumstances.

There were also many conflicting perspectives in the literature review, and between the literature review and findings from the Delphi survey, which may suggest that current literature on the advantages of earth may be lacking in empirical evidence. For example, according to the literature review, earth masonry units may be manufactured investing less capital following the same manufacturing process except firing or burning phase. However, literature also shows that the process of manufacturing CSEB is distinctive. Similarly, literature states that the thermal conductivity of earth is nearly zero (0), but technical guidelines show that the thermal conductivity of dry earth is 1.5 K-(W/ mK) [26]. Experts in this study agreed that the process of manufacturing CSEB is distinctive and that the thermal conductivity of earth is not zero. Moreover, according to the literature review, a benefit of earth walls (loam) is that it preserves organic materials such as timber and pollutants are absorbed by earth wall. In the Delphi technique, none of the experts mentioned these as benefits of earth construction. However, this benefit of earth walls absorbing pollutant is not certainly overlooked by the experts of Delphi panel but in fact; there is lack of scientific evidence in the literature review of proving that earth walls can absorb pollutants.

The major contribution of this study is that it validates and extends upon the benefits of earth construction as previously identified in literature. Initially, this study identified fifteen benefits of earth construction from literature, and thirteen of those benefits were corroborated through the empirical research employed in this study. Specifically, the Delphi technique identified twelve benefits similar to that found in research. In-depth interviews also validated twelve

benefits and further isolated one benefit not recognized in research (i.e. that earth construction contributes money to the local economy). Table 4 presents a comparison of the advantages of using earth material in urban housing (in the UK context) as extracted from the literature review, through the Delphi technique and in-depth interviews.

Table 4: Comparison of advantages of earth material in urban housing.

Advantages	Literature review	Delphi technique	In-depth interview (UK context)
1. Use of earth is economically advantageous.	☐	☐	☐
2. Earth construction use simple tools and unskilled labour.	☐	☐	☐
3. It promotes housing construction in the form of 'self-help'.	☐	☐	☐
4. Earth can build extra secured and strong structures.	☐	☐	☐
5. Earth material has low embodied energy; therefore, considered as energy saver.	☐	☐	☐
6. Naturally balance interior temperature and humidity in an earth building.	☐	☐	☐
7. Earth has fire resistant properties.	☐	☐	☐
8. Earth construction creates job opportunities.	☐	☐	☐
9. Earth is considered as sustainable building material.	☐	☐	☐
10. Earth walls preserve organic materials, such as timber.	☐	☐	☐
11. Earth walls absorb pollutants.	☐	☐	☐
12. Designing with earth is easy and can produce building with high aesthetic value.	☐	☐	☐
13. Earth wall possess high insulation property, therefore, excellent in controlling noise.	☐	☐	☐
14. Earth is local building material; therefore, it promotes heritage, tradition and cultural practice.	☐	☐	☐
15. It is available worldwide in abundance.	☐	☐	☐
16. Earth construction contributes money to the local economy.	☐	☐	☐

Of note, this study may suggest a shift in attitude with regard to the leading factor as to why earth is advantageous in urban housing. Namely, where literature in the past isolated cost to be the dominant advantage, results from the Delphi technique suggest that energy saving may play a greater role in promoting the benefits of earth construction. According to the experts in this study, environmental benefits are the leading benefit to earth construction in the UK.

However, the type of conditions that may influence the benefits of earth construction, as identified in literature, have, to date, focused predominantly on issues of cost. An in-depth analysis of the results from this study (including findings from the Delphi technique and interviews with experts in the field of earth construction) reveal a much more comprehensive inventory of the type of conditions necessary upon which earth construction may be beneficial in urban

housing in the UK context. Table 5 presents a summary of the conditions and circumstances upon which contemporary earth construction is beneficial as identified from literature and from the methodology employed in this study. Taken together, these conditions and circumstances provide an extensive list of key factors that need to be considered when assessing the benefit of earth construction in UK urban housing.

Table 5: Conditions and circumstances upon which earth building is advantageous.

Conditions and circumstances upon which earth construction is beneficial.	Literature review	Delphi technique	In-depth interview (UK context)
<p>1. Type of urban housing (terraced, semidetached, flats)</p> <p>Multi-storeyed (high-rise) flats might not be economically and structurally possible. Single storied houses are more economically sustainable than double storied terraced or semidetached houses.</p>	☐	☐	☐
<p>2. Suitability and availability of local soil</p> <p>Earth sourced from afar results in increased costs in transportation. Therefore, Soil should be dug locally and should be suitable for stabilisation.</p>	☐	☐	☐
<p>3. Nature of the town, city and climate</p> <p>Although contemporary stabilized earth structures have a high success rate globally with regard to resisting natural disasters, un-stabilized earth structure naturally vulnerable to flood and earthquake zones.</p>	☐	☐	☐
<p>4. The rationale and/or philosophical goal of the designer, client and/or occupant</p> <p>Earth construction is chosen for urban housing for specific reasons, such as environmental and/or economic sustainability, or the promotion of local appropriate technology and culture, for example. Therefore, the benefit of using earth construction will depend on the designer or client's intention or goal of the project.</p>	☐	☐	☐
<p>5. Type of stabiliser</p> <p>Un-stabilised earth may prove more beneficial than cement stabilised earth, as it requires little modification. As a rule, it is only essential to change the natures of earth for special uses. In addition, many experts are opposed to cement stabilised earth construction because it lacks environmental and economic sustainability. Moreover, appropriateness of the earth for stabilisation, soil types, nature and amount of stabiliser needed for each type of soil. Sometime, increasing sand ratios will solve problem if the soil has an excessively high linear shrinkage instead of unnecessarily mixing stabiliser. All these factors influence how much benefit one gets from using earth material.</p>	☐	☐	☐
<p>6. Project expenditure in relation to other locally available construction techniques</p> <p>The project needs to be compared with the other locally available construction techniques in terms of cost (especially with regard to stabiliser). The benefit of earth construction is therefore project specific.</p>	☐	☐	☐
<p>7. The availability of skilled, local labour</p>	☐	☐	☐

8. The level of skill the design team has in earth construction	□	□	□
9. The location of the construction of the blocks (i.e. village or city), scale of project and equipment needed, and quality of finished building required	□	□	□
10. Up to date wage rates and labour productivity.	□	□	□

It is important to note here that experts in earth construction are relatively few and only small numbers of contemporary British earth building practitioners have worked in the past or are working now in the UK. Nonetheless, four British practitioners were face to face interviewed and the data was generated from the transcriptions of the interviews.

5. Conclusions

The UK experts in this study agreed that earth is extremely beneficial to UK urban housing development under certain conditions although the use of earth as construction material in the UK is not yet widespread. The environmental benefits of earth construction, in particular, are a major advantage and can address excessive CO₂ emissions in the development of UK urban housing. Thirteen major benefits of earth construction in total were identified, validated and summarized from the feedback of experts in this study that, overall, corroborate all but two of the fifteen major benefits of earth construction previously mentioned and extracted from literature.

With innovative approaches, the utilization of earth will greatly benefit urban housing in the UK. The utilization of earth material as alternative to the conventional ones is extremely valuable in that it is extremely helpful in the achievement of sustainable environment and development (i.e. reduced CO₂ emissions) and promotion of self-help construction. However, benefit number 10 and 11 in Table 4 were not stated by any of the earth construction professionals of this research. However, these benefits were taken from the existing literature. Therefore, for future research it is pertinent to investigate and find out through scientific study on the capabilities of earth walls of absorbing pollutants, preserving timber and other organic material used in construction.

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Author's contributions

The author read and approved the final manuscript.

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Availability of data and materials

All data generated or analysed during this study are of my own work and it is my pleasure to be available publically.

Competing interests

The author declares that he has no competing interests.

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Figures

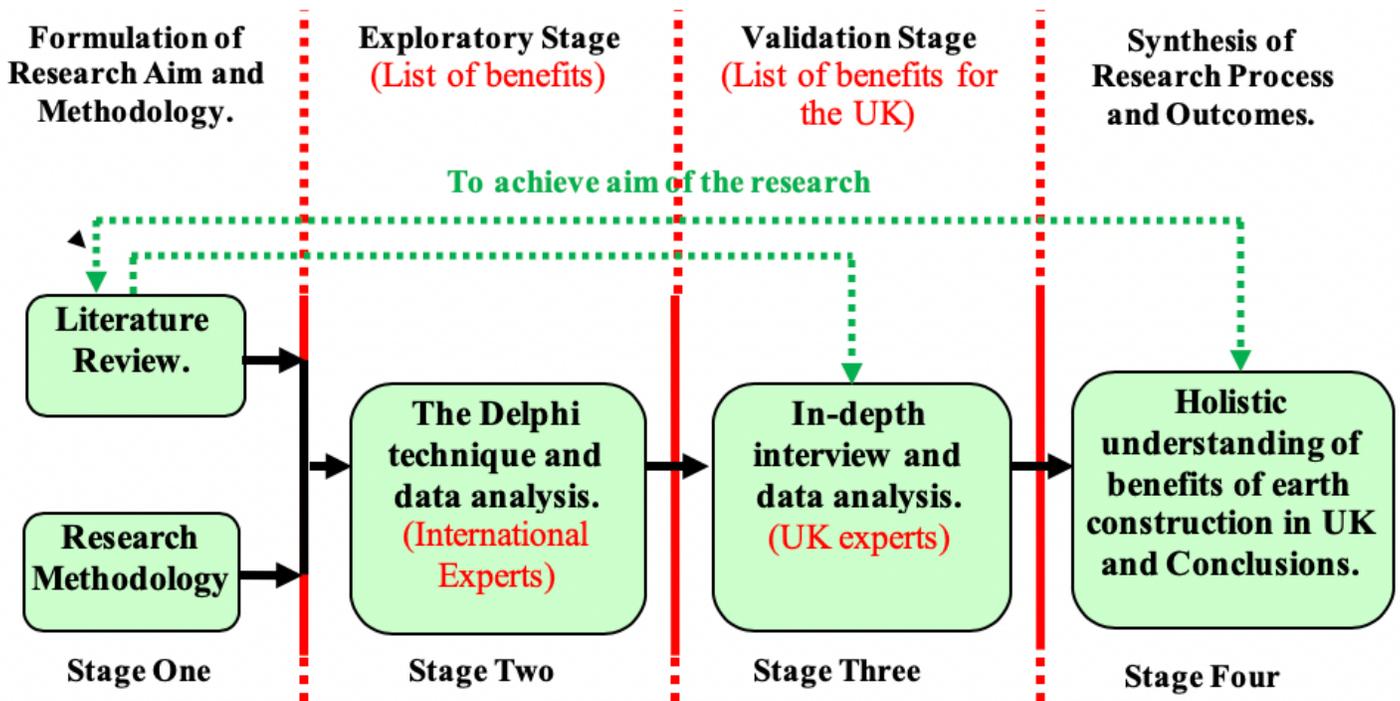


Figure 1

Methodological framework: A graphic representation of four interconnected stages and three techniques used in the study.

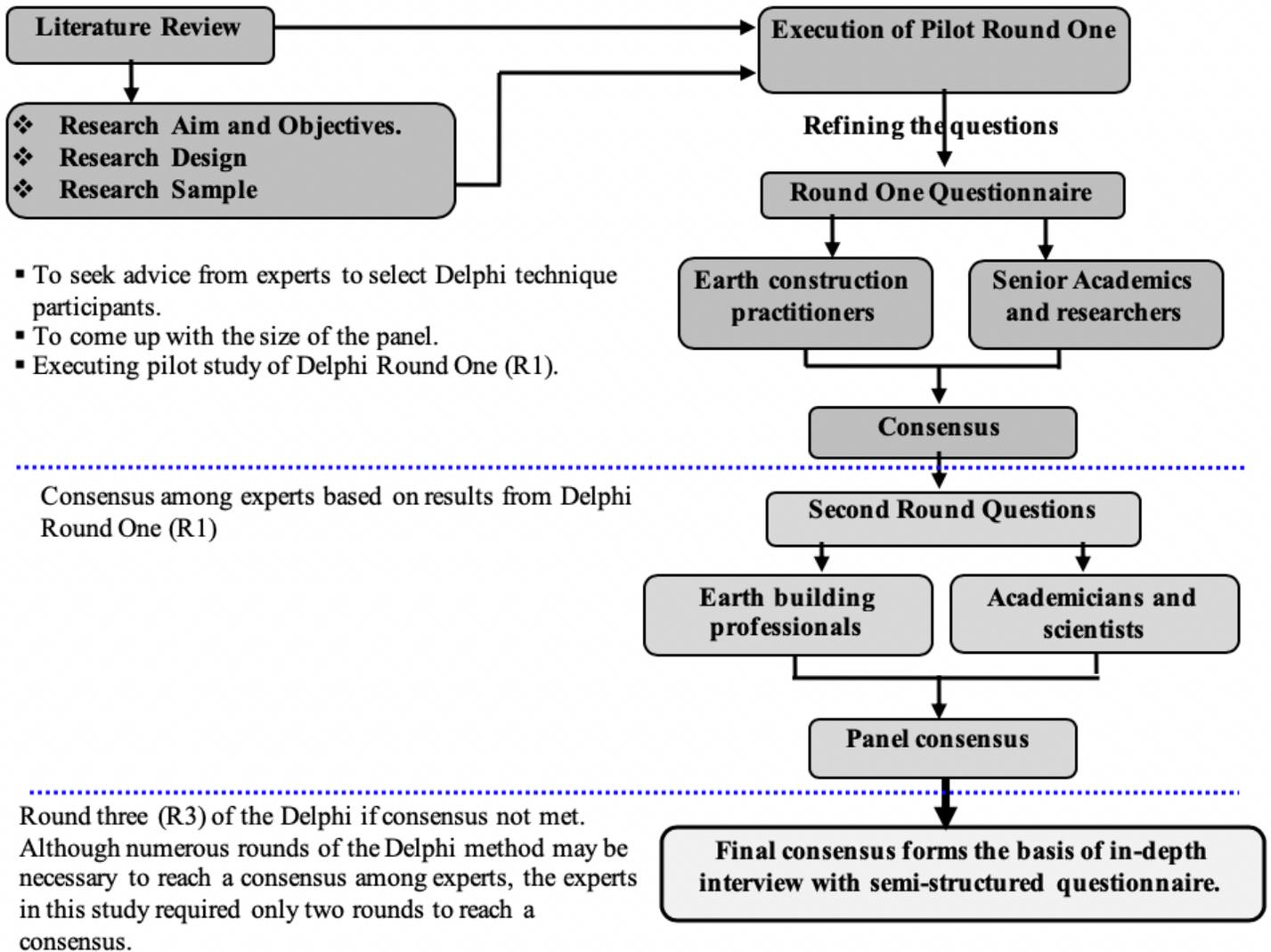


Figure 2

The process of the Delphi technique adopted in this study.

- Expert opinion needed on the advantages of earth building in UK.
 - In-depth interviews chosen as a means of understanding the benefits of earth construction.
 - Key information needed to be gathered from the in-depth interviews included the advantages of earth building in UK.
-
- Constructing interview guide that included: face-sheet, questioning route and post interview comments sheet.
 - Questions were derived from the literature review and Delphi technique and piloted on four experts to check questions.
 - Example of question: What are the advantages of earth building in urban housing of UK?
 - Face-sheet designed to record time, day and venue of interview. Interviews were conducted in the UK because the experts lived in the UK.
 - Post interview sheet designed to include researcher's feelings, interpretation of any particular issues and comments about the interviews.
-
- Established rapport with interviewees through introductions.
 - Guided discussion about the aim of the interview.
 - Interviewing followed methods necessary to conduct a successful interview.
-
- Reported on the advantages of earth building in UK based on transcribed tapes, the comment sheet, highlighted notes and text.
-
- Determined the significance of data collected to fulfil the aim of the research.
 - Isolated themes, similarities and mappings to work out meaning of the data.
 - More interviews may be carried out in case of inadequate data collected, to answer research questions towards fulfilling the aim of the study.
-
- Verified the authenticity and soundness of the data collected. Verification of the credibility and validity of the information was carried out by sending summarised final list of the benefits (Table 4) and all interview transcriptions together back to the all interviewees for their checking and final comments.
-
- Findings on the advantages of earth building in UK and prepare formal written report.

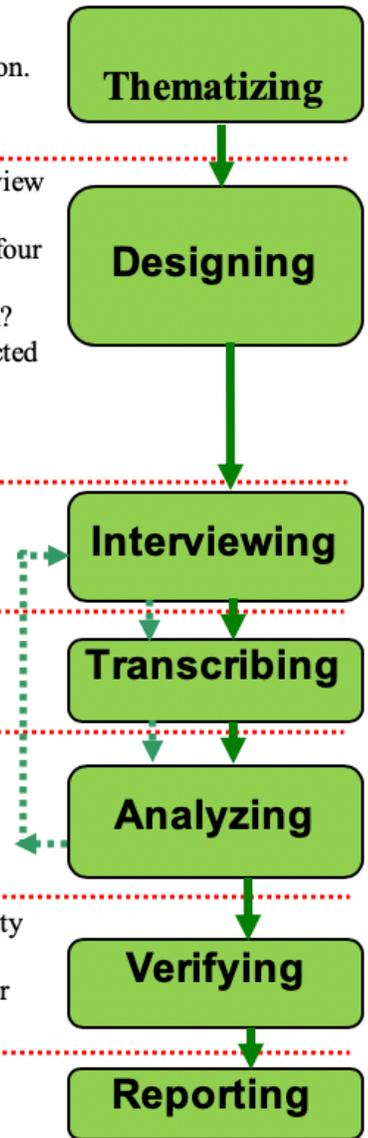


Figure 3

In-depth interview process adopted in this study.

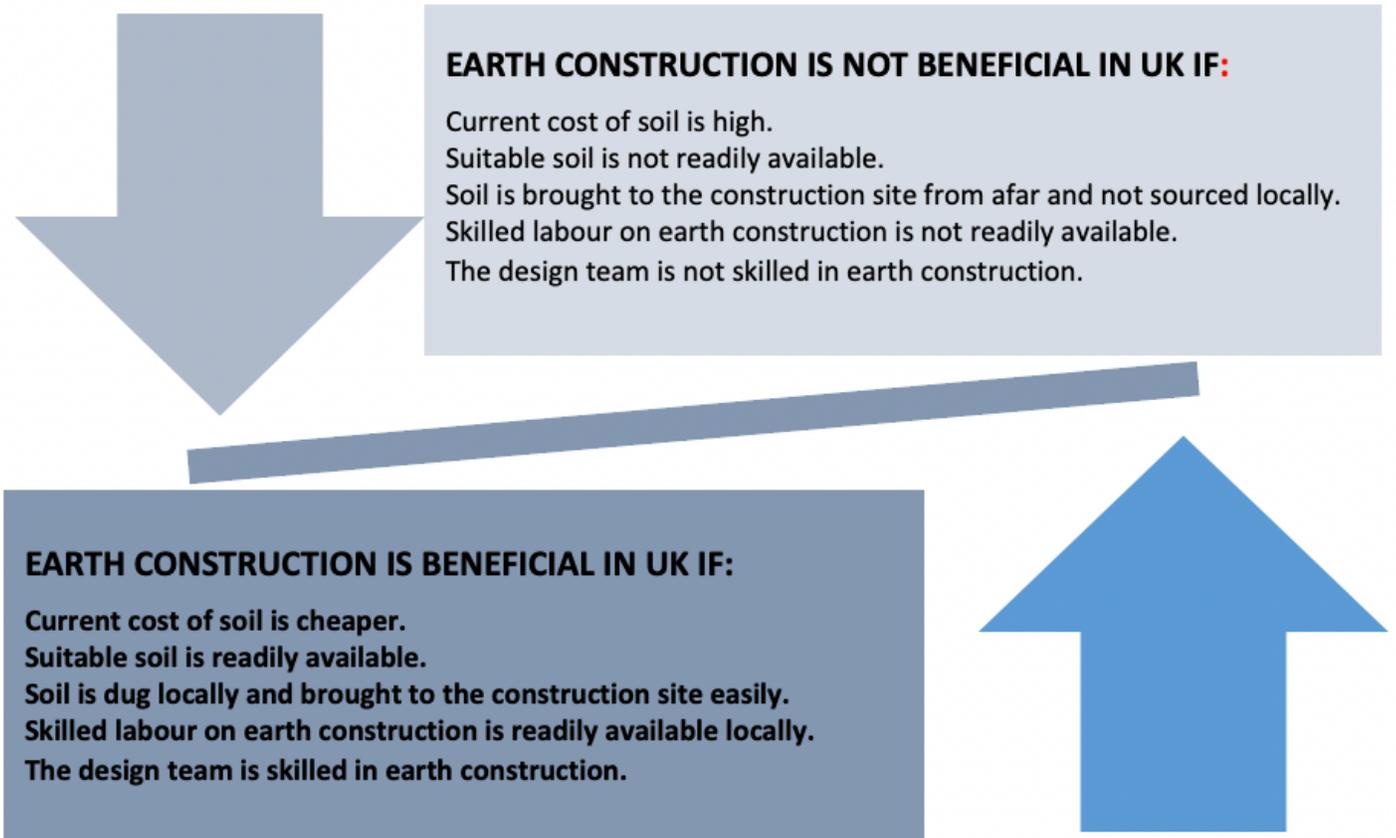


Figure 4

Factors that may influence the benefits of earth construction in UK. Author, 2020.