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Assessment of Low-Cost Housing Barriers, Materials and Technologies – A Review

Dr. Farrukh Arif and Muhammad Wasay-Uz-Zaman

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By

Dr. Farrukh Arif[1] and Muhammad Wasay-Uz-Zaman[2]

ABSTRACT

Appropriate shelter is one the demanding challenges for population of developing countries. Pakistan is one of the developing countries that are facing the challenges against economy, which ultimately affects the quality of living of people. Owning a house is even sometimes merely a dream of lower and middle-income families. It is a significant challenge to provide them shelter. However, bigger challenge is to provide cost effective housing that can be low-cost and suitable for low-income families. This paper presents a review of low-cost housing requirements, barriers, materials, techniques. Finally, discussion on review findings as well as discussion on suitable technique for Pakistan is also presented. The aim is to provide a collection of valuable information to facilitate in the selection of the best available and suitable option for ensuring low-cost housing for low-income groups.

Key Words
Housing, Pakistan, Low-Cost, barriers, materials, techniques.

Context

Housing is the basic need of humans after food and clothing and in the era, there is very less likelihood that low-income families own a house. A residential unit can be considered as low cost housing unit if low to moderate income families are able to get such a unit in 30% of total household income (E. Miles et al. 2015). Concerning Pakistan, in 1998, the housing units required were 19.2 million when the population was 132.3 Million. While in 2019 when the Population is 217.5 Million minimum 40 Million housing units are required and this can easily be achieved by using low cost housing (Pakistan Bureau of Statics). The trend to construct low cost housing is taking center stage internationally

[1] Associate Professor Department of Civil Engineering NED University of Engineering and Technology, Karachi, Phone: 92-21-99052277 Email: farrukharif@gmail.com, farrukh@neduet.edu.pk (Principal author, corresponding author)
[2] Masters' Student Department of Civil Engineering NED University of Engineering and Technology, Karachi, Pakistan.

as well as in the national interest. Pakistan. Government is also taking measures by considering housing as a basic need.

The importance of low cost housing need, is significant from governments program in which 5 million affordable housing units are planned for low-income families. Affordable Housing program should include the promotion of general welfare of the poor and low income families by providing funds and credits to all 4-provinces to alleviate present and recurring unemployment (Muhammad Ali Siddiqui n.d.). The demand of houses according to a report is approximately 700,000 per year. However, only 50% of this demand is typically fulfilled. Although the general deficit of housing is predicted to be 10 million units and increasing (State Bank 2019). Between 2012 & 2017, the gap between housing prices and incomes is widening. The prices of housing in Pakistan got doubled and rent grew by 180% while the incomes grew by 15% (Rashid 2019). Figure-1 also shows the international ratio of house price to income and among different countries the ratio is highest in Pakistan i.e. 20%.

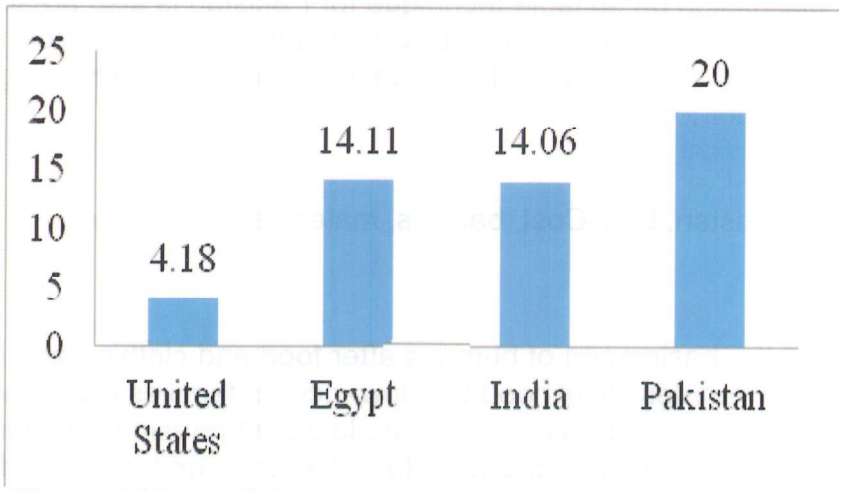


Figure-1 House Price to Income Ratio in % (Rashid 2019)

The important factors related to goal of ensuring Low Cost Housing (LCH) include, innovative and alternative construction methods, effective project management and planning, cost effective materials and low cost construction technologies. By technically focusing on these, cost of construction can be decreased and housing can be made affordable for all. Typically, such methods used i.e., for making LCH, also help to maintain sustainable environment. It is also shown from study that housing project delivery and construction materials take upto 60% of total cost of LCH project (Jaiganesh et al. 2016). With this

context in mind, this paper presents the comparative analysis of classical and innovative low cost housing technologies, based on critical review of techniques as described in prior studies. The aim is to provide a collection of valuable information to facilitate the authorities in selection of the best available and suitable option for ensuring low-cost housing for low-income groups.

Definition of Low Cost Housing

Defining Low Cost Housing is important to devise the targeted policies directed at making financially more manageable. At world level, Low Cost Housing is defined in several ways. One of the most popular and accepted definition is that from Kalpana Goplan a real estate manager. The definition states that "Affordable housing refers to any housing that meets some form of affordability criterion, which could be income level of the family, size of the dwelling unit or affordability in terms of EMI size or ratio of house price to annual income"(Gopalan and Venkataraman 2015). According to a report of Government Organization of Pakistan the definition of Low Cost Housing, which states the criteria of Low Cost Housing as follows: (State Bank 2019).

- Housing unit / apartment has maximum value up to Rs.3 Million.
- Housing unit / apartment in urban areas has maximum covered area up to 850 sq. ft.
- The maximum value of loan size is up to Rs.2.7 Million

Another definition relates Low Cost Housing to ratio of sum of monthly expenses to the monthly income per household (Aslam and Sattar 2018).

Barriers to Low Cost Housing

Although there are numerous barriers to low-cost housing, related to different aspects of low-cost housing requirements. However, with reference to the context of this paper, following are some of the barriers as found in the prior studies and listed from the experience. It must be mentioned here that these barriers are only related to the technological and execution perspective of low cost housing (Gobbo Junior et al. 2017).

- Local Contractor's don't want change in the method of doing work
- Scarcity of technical specialty
- Labor is careless and waste a lot of materials
- Lack of awareness about the technology

- Interoperability constraints
- Reliability of built structure
- Complexity in application of techniques

Low Cost Housing Materials

In order to PROMOTE Low Cost Housing, the materials that are used should be less costly and be of efficient characteristics that is both sustainable and structurally efficient. The imported materials are very expensive and cost escalated to sky if converted to the value of local currency at such exchange rates. (Climate Hot Map 2011).

As far as natural materials are concerned, Bamboo, Earth, Straw and Fiber Cement Composites are the main natural materials that can be used as low cost housing material in different forms based on regional availability. For example, bamboo can be used as reinforcement in walls and in slabs, earthen material can be used to make compressed blocks and non-erodible mud plaster, straw can be used in thatched roofs and composite fibers of cement possesses better workability, light weight and show resistance to cracking and high degree of flexibility.

With regards to man-made materials, it is evident that due to industrialization many by-products are generated out of industrial processes. Such products become problem to the environment regarding with regards to their disposal. However, at the same time some researchers found that some of these by-products possess high pozzolanic properties which make it possible to use in construction as low cost construction materials. Materials such as rice husk, fly ash, Aerocon panels and Ferro cement can also be useful (Deshmukh and Mohite 2018). Few eco-friendly and sustainable materials are sisal fiber, wallastonite, coir fiber reinforced composites and Jute fiber reinforced polypropylene composites (Mishra n.d.).

In light of the aforementioned material types, it is pertinent to mention here that the proper selection of materials plays key role to achieve low cost housing objective. Figure-2 shows one such selection criterion for the selection of low cost building material for Low Cost Housing. It should be eco-friendly and enhance the sustainable design principle. It is also common that we should have to remember the concept of 3R's (Reuse, Recycle & Reduce) so material can be selected based on the criteria depicted in Figure-2.

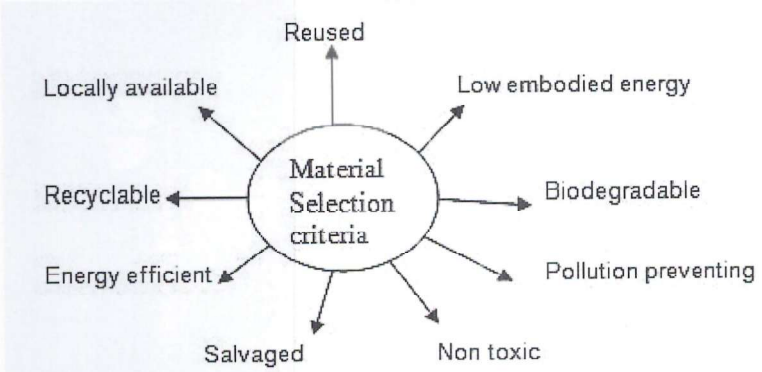


Figure-2 Selection Criteria for LCH Building Material (Mishra n.d.)

Low Cost Housing Technologies

Another important aspect is that of suitable low-cost housing technology. In order to achieve this objective of low-cost housing, it is imperative to have economic construction technologies. By economical technologies, it is meant that alternative building technologies that, apart from reducing construction costs by reducing the quantity of building materials can also be creative in improving house construction methods. Technological advancements has led to many innovations in construction techniques. Low cost housing is normally low story building which does not require high end technology or materials. Some of techniques that can be categorized as being low-cost housing technologies are discussed in detail in the following sections.

Adobe Technology

One of the most typical adopted low-cost housing technologies which is still in application of single-story houses is Adobe Construction. It is widely used in the rural areas of Asia specially in Pakistan. It is low cost and its material is easily available for construction. The technology is also used in Latin America by low-income families, however, wealthy families also adopt this technique in there luxurious houses as well as by moderate income family in Middle East (e.g. Iran) (Blondet and Garcia M. 2003).



Figure-3 Typical Adobe House (WHE Report 89, Argentina)

Architectural characteristics of Adobe houses in most of the Asian countries are alike in which; quadrilateral plan, one door and one window are principal components. Urban construction has high quality as compared to the rural area's construction. Houses made using adobe technology usually don't have foundation but those that have the foundation is made from the coarse stones whose range start from medium to large combined with mud or mortar. Likewise, walls are made using adobe blocks joined with mud mortar and sometimes straw or wheat husk also used with soil to make blocks and mortar (WHE Report 23, India). The block size is variable depending upon the region. The thickness of wall depends upon the weather condition of that region to provide comfort to its inhabitants. Roofs are generally made from wood joists acquired from the nearby available tree trunks laid down directly on the walls or supported inside the indentations on the walls top. Roof is covered with clay tiles or corrugated zinc sheets. This also depends upon the economic condition of the owner and culture of that region. The type of adobe house that shows good seismic behavior are bhonga type. Usually, the soil used for making blocks is taken from the homeowner's yard or closed proximity. Mud mortar is usually used to joint two blocks. For this type of work, a term, "non-engineered construction" is used because it doesn't require any skilled technicians any engineer or architect.

Bamboo construction

The usage of bamboo as a construction material was devised earlier in 1914 by (Dirk et al. 2015), study give the details of using bamboo in different element of structure by splitting it into two parts and make a mesh that can be used in slabs and walls as well. Bamboo can also be

used as a reinforcement in tension elements due to its excellent tensile strength (Puri et al. 2017).

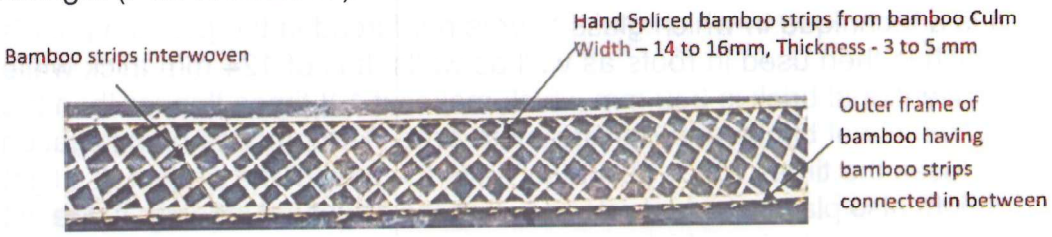


Figure-4 Bamboo mesh (Puri et al. 2017)

USING of MUD POTS

Mud is a natural material and it can be used in several ways in construction as also discussed earlier, mud is also the base of adobe technology but it can be used in innovative low cost housing technologies. It is used in the form of mud planting pots, in order to increase the thickness of slab without increasing the weight significantly we can use inverted mud pots in order to provide desired thickness with less weights. This technique also provide thermal insulation, this technique can also be used in walls as well to make them thermally insulated ("Earthen pots insulation system: Thermal comfort design - Mansi Shah" n.d.).



Figure-5 Mud pots in slab and wall ("Earthen pots insulation system: Thermal comfort design - Mansi Shah" n.d.)

GFRG (Glass Fiber Reinforced Gypsum) Building designs

It is a technique in which glass fiber is reinforced in the gypsum panels which is then used in roofs as well as walls. It is of 124 mm thick while conventional brick is 230 mm which makes it 1.8 times thinner than the conventional bricks and provide more area. The process of installation reduces the times which ultimately save the cost of the project. It's light weight also play important role reducing the structural loading. It doesn't require any plaster which saves extra cost of plastering. It is a time saving and cost reducing material and technique (Gangwar 2019).



Figure-6 Gypsum plaster, reinforced with chopped glass fibers, 300-350 mm long (.8kg/m2) (Gangwar 2019)

Panel Building System using Steel Mesh, Polystyrene Core and Chipping Concrete

Panel building system is highly effective in high seismic activity areas. It is also used in load bearing structure due to its light weight. They also possess thermal insulation characteristics. It is like a sandwich; foam polystyrene plate is in between the 2-steel meshing which is further filled by chipped concrete. It is durable and also energy efficient as it can save energy consumption and decreasing the structural cost of building.



Figure-7 Panel Building System (Gangwar 2019)

Monolithic Concrete Technology Using Poly Vinyl Chloride Formwork

Plastic or aluminum form work are very efficient in time saving in monolithic construction and it also provides a finished surface which don't require any plaster which ultimately save the cost of project. They also have self-interlocking system that means that the panels of PVC formwork connect with each other and concrete doesn't bleed from the joints. They are used for erecting walls, roofs and other structural elements. It is also efficient in providing accurate dimension, vibration in this type of work is easy which prevent form honey combing in structure. In this type of construction all services should be pre-planned and post construction alternation is not possible. Initial cost of formwork is more but could be economical for bigger projects and this form work could be used in standardized type of mass housing. These walls act as shear wall and these have better thermal resistance as compared to normal brick wall (Murillo. et al. 2019).

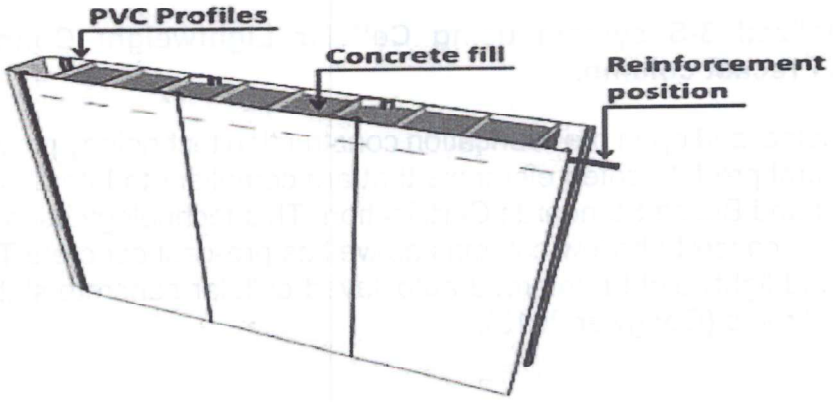


Figure-8 Cross section of Panel (A. et al. 2019)

Cement Surkhi Brick Masonry Walls & Ferrocement Clay Tiles (FTC) Hollow Roof Deck Slab

This type of structure can be built using masonry made of Surkhi Lime and Portland Cement. The binding material in this case is Surkhi-Cement, instead of ordinary Portland cement. Load bearing masonry wall are built using this material. masonry walls. While the roof is constructed using Ferrocement Clay Tile Roofing System. This kind of construction can be very cost effective in the areas where cement is not easily available and/or is costly (CWHR 2001).



Figure-9 Model Room Built With Cement Surkhi Brick Masonry Walls & Ferrocement Clay Tiles (FTC) Hollow Roof Deck Slab (CWHR 2001)

Industrialized 3-S system using Cellular Lightweight Concrete slabs & Precast column.

The industrialized open pre-fabrication construction technology provides all structural pre-fabricated elements that are compliant to International Standard and British Standards Certification. This technology uses pre-cast dense concrete hollow columns as well as pre-cast concrete T & L beams and lightweight reinforced autoclaved cellular concrete slab for floors and roofs (Gangwar 2019).



Figure-10 Precast Concrete Panels using Concrete, Welded mesh and Plates, Polystyrene Core installation (Gangwar 2019)

Prefabrication or "Prefab" is an ancient procedure and there are several diverse technologies. Following are some phases through which a typical house can be constructed using low cost housing technology. The detail procedures of each step are as follows:

1. 1st earth work of excavation and compaction is done according to the requirement, then use foundation or isolated footing casted in the factory, transport to the site and place it accurately. It is not only saving time and duration of activity but also reduces the risk of accident and good quality of construction as everything is casted in the controlled environment rather than uncontrolled environment (site).
2. Then again prefabricated panels and other elements are installed on foundation as per drawing, all they should be ready at factory. It may be of steel, cement, wood or any composite material.
3. The concept of prefabricated roofing system is used based on the principle that the lower part of simply supported beam is under tensile force and the upper part of simply supported beam is under compressive force. As these panels are very much effective against compressive and tensile forces.
4. For flooring different low cost material tiles (Irani baked, porcelain and ceramics tiles) and marbles are available at low cost in market based on the clients' preferences, based on design and quality material is used.
5. Avoid the plastering on walls

6. The frames of door and windows can be removed or replaced with low cost material as it is responsible for the half of the cost of timber used. A window without frame consists of vertical plank. It is made a simple pivotal window. Rows of pivotal planks can be used in wide span window or can be partially fixed (Arti, Singh and Tripathi 2016).

Stone-concrete Block Masonry Walls and Ferrocement Barrel Shell Roof

This type of structure is built using stone concrete masonry. Such masonry is used both for constructing foundation and load bearing walls with ferrocement barrel shell roofing system. The economic advantage of this type of construction is where low-grade stones are available (usually in rural areas) in abundance. This technique is very simple and can be used self-help.



Figure-11 Model Room Built with Stone-concrete Block Masonry Walls And Ferrocement Barrel Shell Roof (CWHR 2001)

Discussion on Review Findings

There is a wide range of technologies available for the construction of several building elements which not only save the time and cost of the project but also make sure that there should be no compromise on quality or performance characteristics. It will be highly effective if one knows the characteristics of materials, technology options and their

structural and functional characteristics with their efficiencies and significantly the appropriate methodology for specific project. The various emerging technologies discussed in this paper clearly indicate the construction practices and materials that are not only cost effective but also having sustainable properties. Few of materials and technologies discussed in this paper might be slight expensive as compared to conventional technologies and materials but this extra cost will be recovered in long run.

Suitable low-cost housing materials and technique for Pakistan

For the execution of housing projects, the short-span of the policy of emphasis on the severity has converted to state apparatus expansion. Construction of Low Housing Units in urban and rural areas one-window operation for investors will be provided by Naya Pakistan Housing Authority (NPHA).

As Pakistan is a developing country so low-cost housing techniques are suitable depending upon the region, capacity of client to spend availability of cheap low-cost material, cheap labor and availability of scenarios for adopting the innovative technology. As in the rural areas of Pakistan Adobe technology is more popular and implemented on most of the houses and in the urban areas where availability of scenarios for adopting the innovative technology is feasible "Industrialized 3-S Cellular Lightweight Concrete slabs are being used to make faster the construction process saves time and money. The use of poly vinyl concrete formwork is also beneficial for both client and contractor as it provides the finish surface so there is no requirement of plaster and it is durable so contractor don't need to buy new material for their form work after several time use, it is light weight transferring from one side to other is also convenient.

Conclusions and Recommendations

This paper provided a detailed review of low-cost housing and its definition, the barriers attached to low-cost housing, the low-cost housing materials, and techniques. It also provided discussion on findings as well as discussed suitability of low-cost housing materials and techniques for Pakistan. The paper can serve as the knowledge baseline for basic understanding of the low-cost housing requirements. However, more research that can tangibly perform simulation based assessment of different low-cost housing technologies from cost and schedule perspective as well as constructability assessment is required.

The principal author is currently working on one such study in this regards.

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