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A Proposal for Low Cost Energy Efficient Public Housing Scheme in Pakistan

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Abstract

The rapidly growing world energy usage has raised concerns over supply difficulties, depletion of energy resources and heavy environmental impact. It is estimated that the energy consumption of buildings is between 35%-40% of the total energy consumption. Moreover, growth in population, increasing demand for building services and comfort levels, together with the rising amount of time humans typically spent inside the buildings, assure that upward trend in energy demand will continue in the future. Therefore, there is a need to find out more energy efficient and cost saving alternatives so as to maintain urbanization of houses at a price affordable to people. This paper presents a proposal for a low cost energy efficient public housing society in Pakistan. The housing scheme called *Ashiana Housing Scheme* (AHS) with a strict control over cost allows the low income groups to enjoy livability deriving from energy and cost saving technology. In this research the building components focused for imparting energy efficiency are building's walls. The study includes introduction of Rat Trap bond for building masonry walls of homes and illustrates how this construction technique improves energy efficiency and reduces overall cost of the building.

Keywords

Energy efficiency, Low cost housing, Rat Trap bond, Public housing, Masonary construction

1. Background

The residential sector in Pakistan is consuming a major chunk of electricity produced. This is partially due to lack of implementation of energy efficient design and construction practices (Hamna *et al.*, 2016). Land and Urban growth in Pakistan is under enormous pressure from uncontrolled urban extension, failing environmental laws and lack of basic services in housing societies. Considering these facts, the Government recently took a step in the right direction by deciding to make Low cost and Energy Efficient housing societies in the Punjab province of Pakistan. This project called *Ashiana Housing Scheme* (AHS) is proposed for several cities in Pakistan. The purpose of this scheme is to deliver reasonable and decent housing units to the people from the low-income group. These societies include housing units of 450 sq.ft and 675 sq.ft (see Figure 1). The project team visited some units that were already completed and inhabited. Based on the informal conversations with the residents, the following design and/or construction issues were identified (Hamna *et al.*, 2016):

- Some units do not receive any direct sunlight.
- There are no shades upon windows.
- When it rains, the rain water penetrates inside.
- Water storage system is placed at terrace without any shades so it receives direct sunlight and water gets hot in summers and cold in winters making it difficult to use.
- Roof and walls have developed cracks.
- In winters, warm clothing and coal is used for heating. In summers, fans and room coolers are used for cooling. According to the residents, the electricity bills shoot up in the summer. The room coolers do not work efficiently in the months of August and September due to high humidity.
- Room ventilation is poor and not considered in the design.

Yet due to their low cost the residents were somehow satisfied with the comfort level of their homes. According to them, despite these problems a house of their own is more than enough for them. However, the design and construction needs amendments to provide the best level of comfort to the residents.

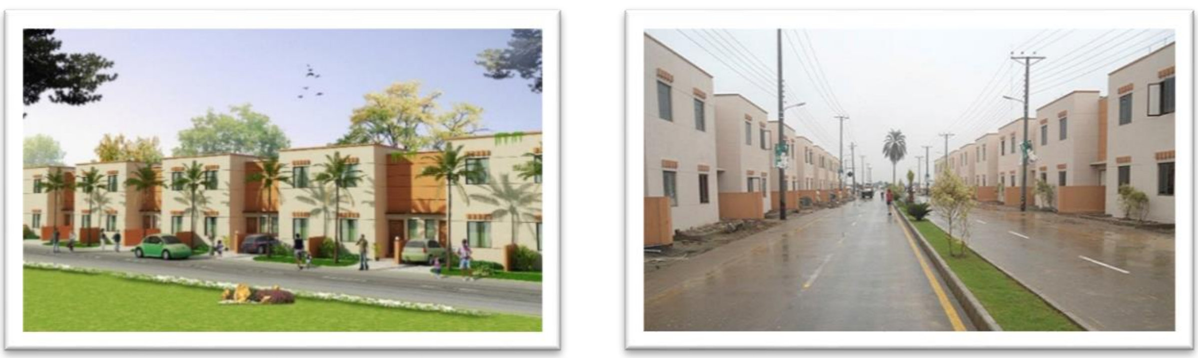

Figure 1: Ashiana Housing Scheme

2. Objectives and Scope

The objectives of this study are as follows:

a) To propose energy efficient measures for the *Ashiana Housing Scheme* (A.H.S) while keeping the project cost as low as possible.
b) To set up a trend that new construction techniques and energy efficiency measures can run hand in hand to keep utility costs minimum while maintaining the necessary comfort level.

This study is limited to developing energy efficient solutions for buildings by improving their walls construction. Moreover, this project focuses on construction cost to keep it as minimum as possible.

3. Methodology

Following are the major methodology steps for this project:

a) Site visits and surveys are performed to gain basic knowledge about the scheme and to critically analyze the existing issues.
b) New space design is proposed and compared with the existing space design for energy efficiency.
c) Energy simulations and cost analysis are performed using the software *Ecotect®* for two schemas:
   1) Analysis of the existing housing unit with conventional construction.
   2) Analysis of the proposed housing unit with revised space design and Rat Trap masonry joints.
d) Main findings are highlighted and suitable recommendations are provided.

4. Rat Trap Bond – An Innovative Masonry Technique for Energy Conservation

This study proposes to apply "Rat Trap Bond", an innovative brick masonry construction technique that can improve energy efficiency of the buildings and cost saving in terms of materials and energy consumption. Rat-Trap bond construction can be made in cellular light weight concrete also (A.K. Marunmale, A.C. Attar 2014). However, in Pakistan Brick is the most common material for construction of housing units in private and public sectors. In case of brick, a Rat-Trap bond is a kind of wall brick masonry bond in which bricks are laid on edges irrespective of header or stretcher position. In this arrangement the shiner and rowlock are visible from both inner and outer sides of the wall. The whole arrangement forms an internal cavity in wall bridged by the rowlock. In Pakistan the most common brick size is 9″ x 4.5″x 3″ which permits 3″ cavity in wall with Rat-Trap bond as shown in Figure 2. The cavity in wall saves materials significantly. The Rat-Trap bonding system of walls provides sustainable option against conventional solid brick wall masonry and thus relates to green architecture.

To take maximum advantage of the method, it is desirable that the masonry is deliberate in a modular pattern at the design stage itself, after the prevailing brick size available for use has been decided. For best rat-trap brickwork, there should be no half/quarter bricks used in brickwork, unlike their common use in the conventional brickwork. This will distract the staggering of joints in rat-trap brickwork and affect the reliability of brickwork. The strength of Rat-Trap bond wall is equally comparable with solid brick wall. However, the major difference between traditional and Rat –Trap bond wall is saving of materials and achieving indoor thermal comfort resulting energy efficient character to the building. The materials like brick, cement and sand can be saved 28%, 37% and 40 % respectively. Further as the bricks are aligned from both side of the walls externally therefore plastering can be avoided except few areas and if required on all areas it will cost less as compare to traditional wall (S. Nilanjan and R. Souvanic-2013). The cost of foundation is also on lower side in case of Rat-Trap bonding wall in comparison to traditional wall on the bases of their weight (Ali Haider Jasvi and D.K. Bera 2015)

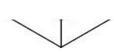

Figure 2: The Rat Trap Model, Reproduced
(Source: S. Saileysh Sivaraj *et al*., 2012)

Rat- Trap bounded wall has better sound insulation and thermal properties as compared to traditional wall because of its cavity (Rafiq et al., 2014). The compressive strength of Rat- Trap bond prism (Figure-4) was investigated through experimental studies with cement mortar proportion 1:4 and 1:5. The result of this investigation are shown in table 1 and 2. As shown, the compressive strength of Rat-Trap bond prism of "C.M. 1:5" is 0.87 MPa (126 psi) and "CM 1:4" is 1.30 MPa (188 psi). This indicates that bricks set-in a richer mortar is stronger than that in thinner mortar. The second one is almost 49 percent stronger than the first one. These test results concluded that the Rat Trap construction is comparable and sometimes even stronger than the conventional masonry construction. It also reveals from research that walls with slab are stronger against earthquake forces than those without roof. However, Rat–Trap bonded walls can be safely used in the proposed housing scheme (S. Saileysh Sivaraj *et al*., 2012). To improve earthquake resistance, the Rat-trap masonry walls can be covered with steel bars at all junctions, around beginnings (door and windows), T-junctions and occupied with a M20 concrete. The diameter of reinforcement depends on number of floors, floor height, seismic zone, importance of building and soil type. It should not be less than 12mm. Figure 3 illustrates the typical joints and reinforcement details in Rat Trap construction.

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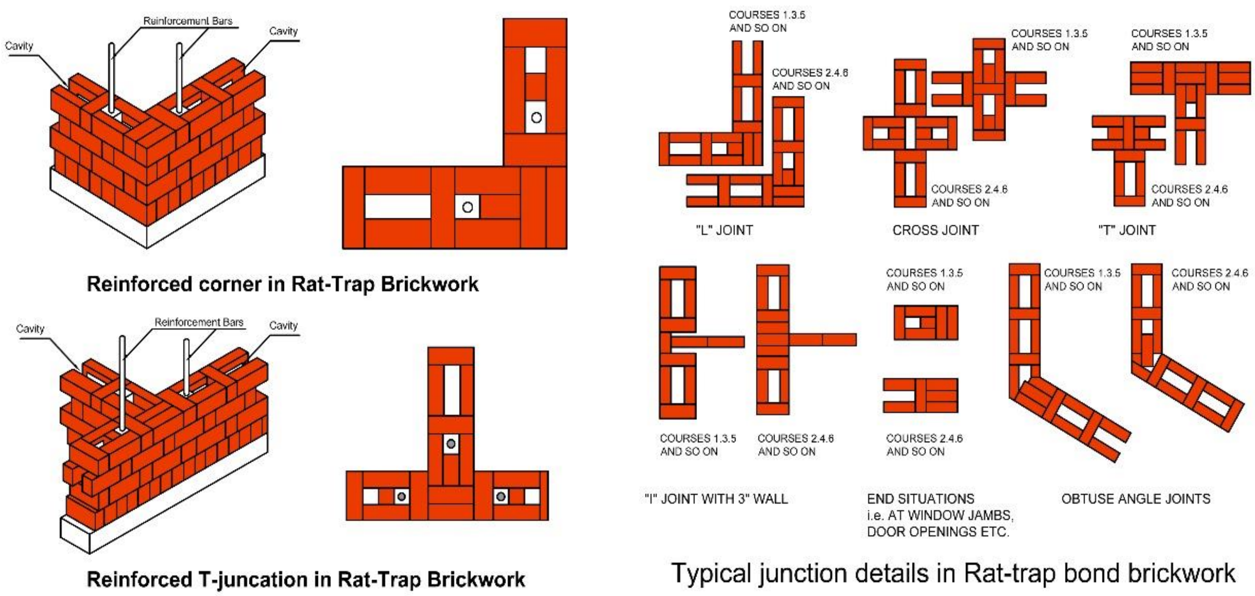


Figure 3: Joint and Reinforcement Details in Rat Trap Bond: Drawing Reproduced by Authors (Source: S. Saileysh Sivaraj *et al*., 2012)

To verify the required compressive strength, prisms of Rat Trap bond were tested under compression load as shown in Figure 4.

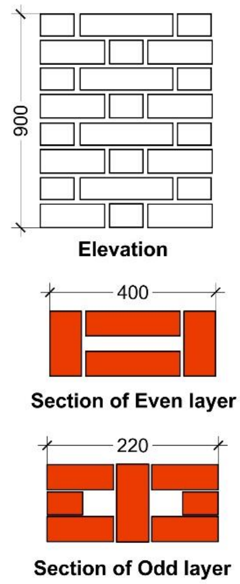


Figure 4: Rat Trap Bond Prism (900mm x 400 mm x 220 mm**) for Compressive Strength Testing: Drawing Reproduced by Authors (Source: S.** Saileysh Sivaraj *et al*., 2012**)**

The test results are shown in Table 1 and 2. (**S.** Saileysh Sivaraj *et al*., 2012)

TABLE 1
COMPRESSIVE STRENGTH ON RAT-TRAP BOND PRISM OF CM 1:5

SI. No.	Size of Prism mm x mm x mm	Mortar Proportion	Ultimate Load (N)	Cross section area (mm^2)	Compressive strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	900 x 400 x 220	1:5	7.5×10^4	400 x 220	0.85	0.87
2	900 x 400 x 220	1:5	7.2×10^4	400 x 220	0.82	
3	900 x 400 x 220	1:5	8.4×10^4	400 x 220	0.95	

TABLE 2
COMPRESSIVE STRENGTH ON RAT-TRAP BOND PRISM OF CM 1:4

SI. No.	Size of Prism mm x mm x mm	Mortar Proportion	Ultimate Load (N)	Cross section area (mm^2)	Compressive strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	900 x 400 x 220	1:4	9.6×10^4	400 x 220	1.09	1.3
2	900 x 400 x 220	1:4	10.8×10^4	400 x 220	1.23	
3	900 x 400 x 220	1:4	13.8×10^4	400 x 220	1.57	

5. Energy Simulation Results

The energy simulations are performed using the software *Ecotect*® for two schemas as follows:

a) Analysis of the existing housing unit with conventional construction as shown in Figure 5.

b) Analysis of the housing unit with proposed space design and using the Rat Trap bond technique. In this scheme, apart from incorporating the Rat Trap bond, some changes to existing 675 sq.ft. unit are proposed as shown in Figure 6. These changes include patio location in the middle instead of backside of unit and terrace in front side of unit as opposed to rear side. The purpose of these changes is to maximize ventilation and minimize heat gain in the summer.

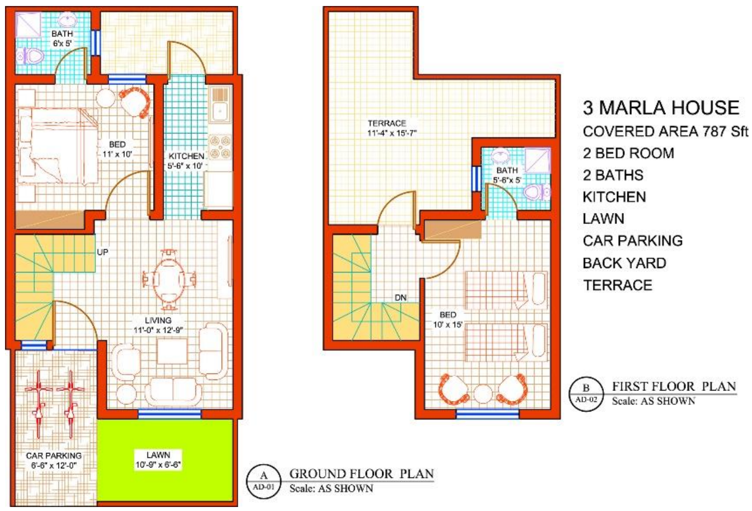


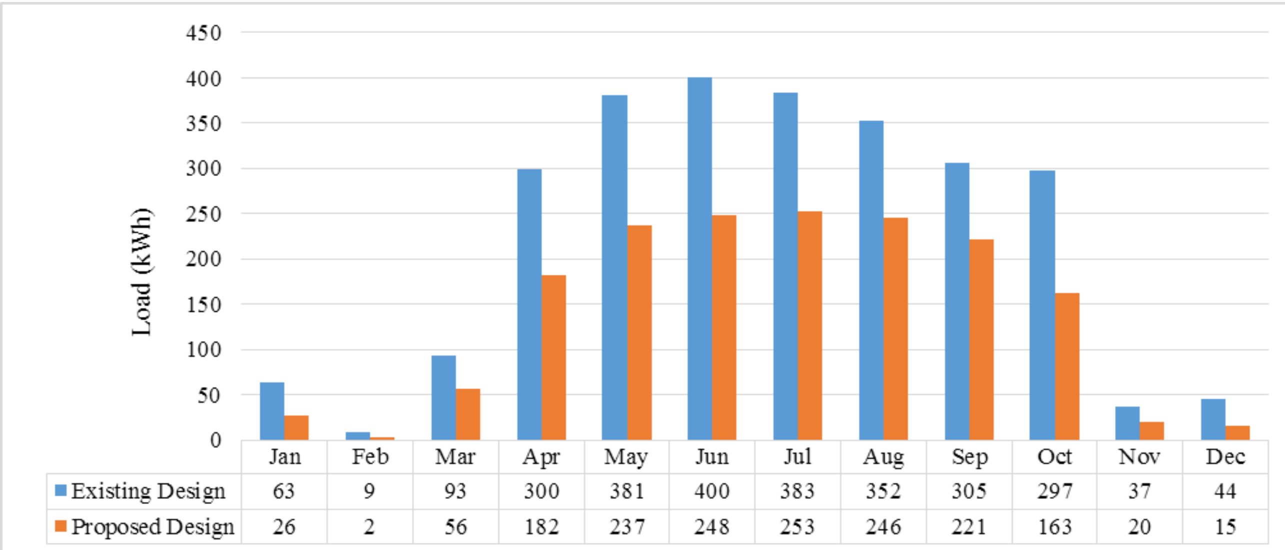
Figure 5: Existing Plan of 675 ft^2 Unit: Drawing reproduced by Authors

Source : Office of the Punjab Land Development Authority Government of Punjab Lahore

Figure 6: Proposed Plan of 675 ft2 Unit: Designed by Authors

Autodesk *Ecotect*® is selected for conducting thermal load analysis. This software is not restricted to material specification which means different materials can be placed at the same surface. Moreover, it provides thermal load calculations at different times of the year and has ability to incorporate any required orientation. The location of unit used in the analysis is Lahore, Pakistan. Lahore features a composite climate with rainy, long and extremely hot summers, dry and warm winters, a Monsoon and dust storms. The weather of Lahore is extreme during the months of May, June and July, when the temperatures soars to 40-48°C (104-118°F). From late June till August, the Monsoon season starts, with heavy rainfall throughout the province.

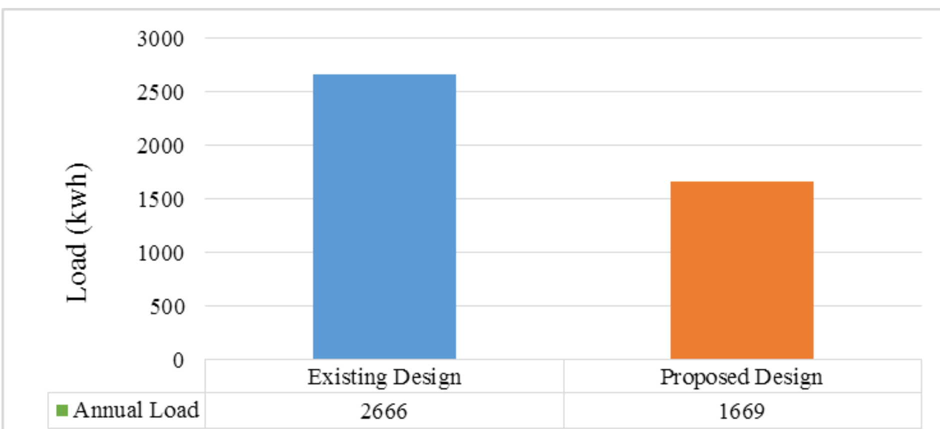
Figure 7 shows the results of thermal loads for both designs.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Existing Design	63	9	93	300	381	400	383	352	305	297	37	44
Proposed Design	26	2	56	182	237	248	253	246	221	163	20	15

Figure 7: Thermal Load Comparison

The annual thermal load of conventional house is 2467.78 KWh per year to achieve the internal temperature of 18^0-26^0 whereas to achieve the same conditions, 1669.3 KWh is the load of proposed design incorporating the Rat Trap bond and updated layout as shown in Figure 8.



	Existing Design	Proposed Design
Annual Load	2666	1669

Figure 8: Annual Thermal Loads Comparison

The difference of thermal loads of both schemes is 865KWh. If each house saves 865 KWh per year then the whole housing society which has 2500 units can save 2,162,500 KWh annually which represents substantial savings.

In addition, another energy simulation analysis is performed to compare the energy savings in conventional and the Rat Trap masonry construction. The results are shown in Figure 9.

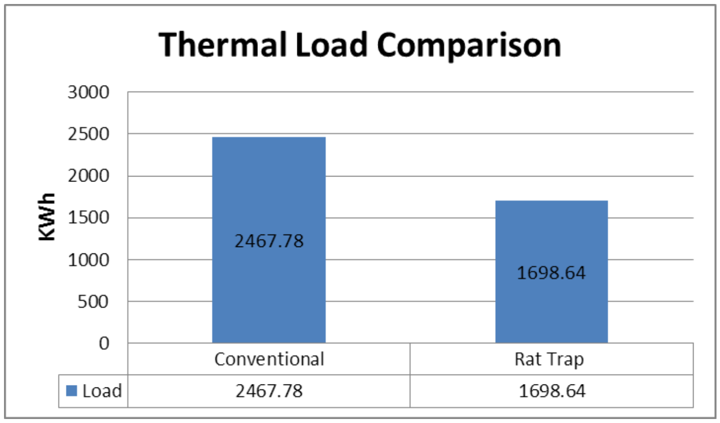


Figure 9: Overall Thermal Load Comparison of Conventional and Rat Trap Units

It is found that the overall thermal load of conventional house is 2467.78 KWh per year to achieve the internal condition of 18^0-26^0 whereas the 1669.3 KWh is the thermal load of Rat Trap bond house to achieve the same conditions. This indicates that the Rat Trap bond alone contributes to substantial energy savings.

6. Cost Comparison Analysis

Material and labor cost analysis is performed for both existing and proposed designs. It includes material quantities of brick masonry, cement and sand. Labor includes cost for masons and laborers according to number of days they work. Results are shown in Figure 10.

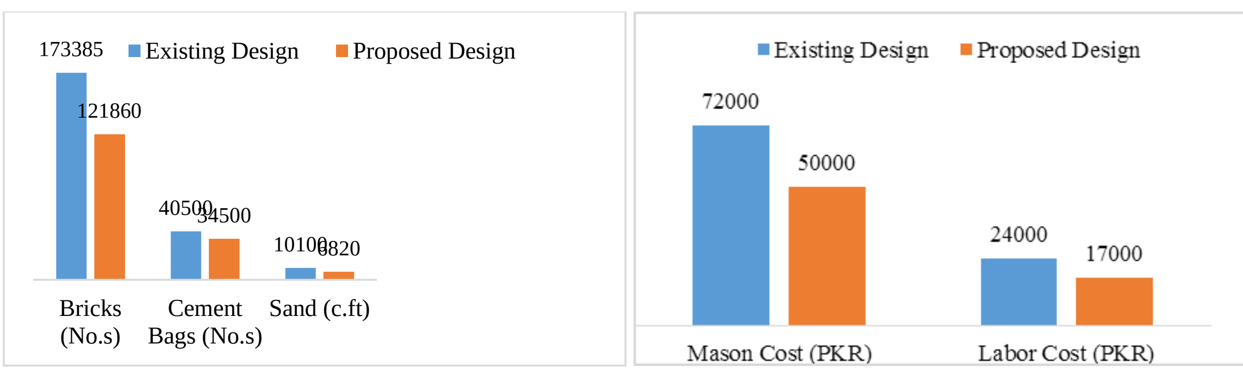


Figure 10: (a) Material Cost Comparison; (b) Labor Cost Comparison

The overall cost of original design came out to be Pak Rs. 319,985 whereas the cost of the revised design is Pak Rs. 230,180 which is 28% less than the original design.

7. Conclusions

The study concludes that construction of residential dwellings with brick masonry under Rap–Trap bond is more economical as compared to traditional construction with English or Flemish bond in Pakistan. Further the Rat-Trap bond is more effective in reducing energy consumption in residential dwellings. In addition the energy conscious planning of houses also plays an important role in reducing energy burdens on residents of low cost housing. By slightly revising the layout plans of homes we can save a significant chunk of energy. In view of the findings of study there is an urgent need to reconsider planning and construction methods in Pakistan for housing like Aishana where objective is to provide accommodation at macro scale to the low income group of the society with minimum cost.

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