IMPROVING ENERGY EFFICIENCY IN CHINESE HOUSING

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ABSTRACT

In China, even though climatic conditions are severe, energy use in buildings has traditionally been very insignificant by Western standards. As a result, the Chinese have little experience with the use of energy conservation, passive solar energy or central heating. The recent increases in household energy consumption have left two options: increase household energy use at the expense of industrial and environmental gains or develop policies to conserve or restrict household energy consumption. This paper records one such effort to introduce low-cost energy conservation practices in Henan Province, China. The paper describes both the practical problems encountered in the introduction of new building materials and designs, and also the institutional barriers that inhibit the development of an energy conservation delivery system.

A major theme of this paper is how unsuitable Western solutions are for solving energy conservation problems in developing nations. For instance, the high cost and unavailability of materials requires building redesign solutions that do not utilize insulation, vapor barriers, and modern heating and cooling plants. Similarly, the coordination of worker units and government officials in developing countries for a wide-scale conservation program is vastly different from either the public or private development programs in the developed world.

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INTRODUCTION

Developing rational policy for improving building energy efficiency in developing countries involves more than applying First World solutions to Third World problems. While it is undisputed that our knowledge regarding energy conservation policy and practice has increased markedly since the Arab oil embargo of 1974, one cannot simply apply what we have learned to the developing world. As Western analysts, we must be cognizant of more than the technical fix. Rather, our knowledge of what works should be coupled with an appreciation of the social, political, economic, and cultural context in which our energy conservation policy is being developed.

The People's Republic of China provides an interesting case study to examine the development of policy to increase building energy efficiency in the Third World. China has only recently given any priority to promotion of energy conservation, with most of the emphasis on industrial opportunities. This new focus on energy conservation has been in large part necessitated by radical changes in both the organization of society and the expansion of its economy. The drive for national modernization and increases in individual disposable incomes have both increased the demand for energy. Development of new energy resources requires development of internal infrastructure in mining, production and transportation, all of which require foreign currency for purchase of equipment. For the present, China's greatest source of foreign currency is its indigenous energy resources, particularly oil. Improving energy efficiency lessens the conflicting pressures for utilization of present energy resources.

China provides a unique case study to examine the formulation of policy to encourage energy efficiency. China is perhaps the only developing country that has climatic conditions analogous to those found in the United States where substantial heating and cooling degree days exist. Despite the climatic similarities, this paper will show how difficult it is for Westerners to utilize their expertise in helping the Chinese with their energy efficiency problems.

DESCRIPTION OF CASE STUDY SITE

Zhengzhou, the capital of Henan is located in central China at latitude 34 N. The weather conditions can be quite extreme reaching -10 degrees C in the winter and 42 degrees in the summer. Average heating degree days based on 18 degrees C are 2331. Despite these severe conditions, buildings in Henan seldom have any insulation and are generally only heated by a small cooking stove. The selection of Henan as a study site has evolved due to a series of cooperative research efforts between the University of Pennsylvania and the Henan Commission of Science and Technology.

AN OVERVIEW OF CHINESE ENERGY USE

Analysis of the Chinese energy situation requires the same objectivity used in analyzing any aspect of present Chinese life. Things are not always what they appear to be on the surface. At first glance, China appears to have a very sound energy future. Presently, the country is the third largest consumer of commercial energy.[1] Blessed with vast coal reserves and to a lesser degree, petroleum, China is able to produce all of its own energy. In fact, the export of about 17.4 million tons of oil per year (25.5 Million Tons of Coal Equivalent (MTCE) about seventeen percent of Chinese crude oil production) and 5.9 MTCE of coal generates about 20 percent of Chinese exports.[2]

On a per capita basis, however, China is one of the world's poorest nations, using only 18.6 Kilajoules (KJ) per capita. According to the World Development Report of the World Bank, the average for developing countries for 1980 was 17.8 million kJ/per capita.[3] The direct comparison of Chinese per capita energy consumption to the figures for other nations is somewhat misleading. Unlike other developing countries, most of China's commercial energy, roughly seventy-two percent of the net consumption is used in industry; only fourteen percent is used in the commercial and residential sectors combined.[4] Additionally, Chinese per capita energy use is even more remarkable considering that most other developing nations do not have as many heating degree days.

For commercial and domestic use combined, China's per capita use of commercial fuels is 2.5 million kJ/year, or the equivalent of 16 gallons of fuel oil per person per year. Most of this is in the form of compressed coal dust burnt directly in stoves primarily in urban areas. The rural areas are generally not supplied with coal and must rely on agricultural wastes and biomass for cooking and heating. Various estimates note that between 200 and 250 MTCE of biomass fuels are used annually by rural households.[5] Including biomass fuels raises the per capita use for domestic and commercial uses to 9.9 million kJ/year.

The available fuel is insufficient for meeting even cooking needs. The situation is even more severe in rural areas. Zhu et. al. report that 80.2 percent of the rural households in the region that includes Beijing and Henan lack sufficient cooking fuel.[6]

Energy use in China is inefficient when compared to other countries. Present Chinese energy use per GNP output is 2.5 times the average for other developing countries.[7] Part of China's modernization plans include the expansion of industry as has been successful in other Asian countries. However, limitations in fuel supply may restrict China's ability to expand. The World Bank noted in 1980 that a growth rate of Gross Domestic Product (GDP) of 5 percent per annum through 1985 and 6 percent per annum from 1985 to 1990 is infeasible without a high savings from energy conservation and fuel switching from oil to coal.[7]

The prospects for achieving gains through conservation are not without obstacles. Chinese industry has developed without outside assistance or competition and as a result has not been exposed to modern energy saving operations. The World Bank points out that energy conservation in other countries has resulted from individual enterprises seeking to lower their costs and that at present, Chinese industry, as part of a centrally planned country, does not directly have this motivation.[9]

No discussion of Chinese energy use would be complete without acknowledgement of the serious environmental impacts associated with extensive use of coal and biomass fuels. The heavy use of largely unprocessed and unwashed coal in inefficient stoves and furnaces with no treatment facilities has lead to high concentrations of air pollutants.[10] The never ending search for fuel in rural areas has resulted in rapid deforestation, erosion and soil degradation. The dependence by most peasants on agricultural wastes for fuel has resulted in the depletion of soil nutrients and has increased the use of inorganic fetilizers derived from fossil fuels. Smil notes that the shortage of wood and lumber is so severe that a lack of timber for mine supports and in rail ties threathens China's ability to expand its coal production.[11]

ENERGY CONSERVATION POTENTIAL IN THE BUILDING SECTOR

Because the residential and commercial sectors consume so little of the commercial fuels in China, little emphasis has been given to energy conservation potential in these sectors. Yet, the rapid expansion of the Chinese economy has created pressures that may alter the traditional low energy use in homes and commercial buildings. China is undergoing an ambitious program to increase the number of housing units. Many of the newer residential buildings are more Western in style and heating approach. Furthermore, the influx of outside business people and tourists has also increased the need for modern facilities. In addition, as income levels rise for individual Chinese families, energy use in homes will increase as people buy more energy consuming appliances, switch from local/traditional fuel sources to commercial energy sources, and generally improve their standard of living. If present building and consumption trends continue, then energy demands in the building sector will increase to the point that even greater limitations on industrial use will result.

In Henan Province, residential housing construction tops 52.6 million square meters per year, with eighty-five percent of that construction being done in rural areas. In Beijing alone, over ten million square meters of new space is constructed each year. Unlike traditional buildings, all of the construction in Beijing and some of the construction in Henan is Western in style. The severe restrictions on arable land have forced the Chinese to build their new housing upward.[12] Unfortunately, having accepted the concept of building vertically with Western building style and heating approach, the Chinese have only used standard practices for insulating their buildings and equiping them with energy efficient systems on a very limited basis.

China can allow the increased use of fuels in the commercial and residential sectors, but only at the expense of its industrial expansion, or China can attempt to limit the use of these fuels by residential and commercial users by more firmly restricting their availability. China already uses strict rationing of fuels to limit residential energy use. As noted, the energy supply is already insufficient for meeting cooking requirements. If greater control of energy use in the residential sector is desired, this control will probably have to result from improvement in building energy efficiency rather than more severe restriction in energy distribution.

Recently the National Bureau of Planning and the Ministry of Urban and Rural Construction and Environmental Control have passed a Housing Design Code for Energy Conservation. The code, to be published in fall 1986 is expected to lower the energy use of homes built in 1990 by thirty percent.[13] If this code is to effective in China, it must draw the attention of diverse interests beyond the central organizations responsible for its publication. Institutions including universities, government energy research institutions, construction units, manufacturing firms, policy developers, and political leaders will all be needed to effect changes.

THE TRADITIONAL CHINESE BUILDING AND HEATING APPROACH

Given the size of China, its climatic differences and cultural diversity, no single style of construction exists. Using indigenous materials, simple shelters were constructed offering protection from the rain, snow, and wind. The houses were never constructed to be fully heated. Even today, public buildings, except those used by foreigners, are seldom heated.

The k'ang, an efficient system of keeping warm, was traditionally used by the Chinese. The k'ang consists of a platform built over the flue of a cooking stove. The flue is extended horizontally so that some of the waste heat is used to warm the platform above. The k'ang serves both the living area during the day and the sleeping quarters at night.

As a result of the new economic policies which permit peasants to chose which crops they can grow and to sell excess production on the open market, many peasants have become rich by Chinese standards. Some have managed to obtain annual incomes exceeding 10,000 Yuan ($3000) and have received the label of "Ten Thousand Yuan Families".[14] This new found wealth has resulted in some elaborate new two-story homes built in the rural areas.

In Henan, most new housing consist of three to five rooms built on a single story. Unlike almost all urban housing, the government does not pay for or own homes in rural areas. All homebuilding is paid for by the individual peasant or his work unit. These homes tend to be less elaborate than urban homes and as a result are normally even colder then their urban counterparts.

Both urban and rural homes are constructed using clay brick. The walls are two bricks thick on each side so that thickness is about 24 cm. Figure 1 shows the horizontal profile, while Figure 2 shows the vertical profile of a typical wall. Between the two columns of brick there is a centimeter of cement mortar. The inside surface of the units is covered only by a thin (1 cm) coating of lime mortar. In each room there is one window, the area of which is about one tenth of the floor area of the room. The roof of the structure is built using concrete block as shown in Figure 3.

In rural areas there are usually no windows placed on the north side of the house. Windows are made of 3 mm thick glass fixed on a 40 mm thick wooden frame. Doors are made of 5 mm thick boards attached to a 50 mm frame. There is very little quality control in the doors and windows and thus these items contribute heavily to winter heat loss. The roofs are normally supported by timber joists on top of which is spread layers of reed mat, mud, concrete and/ or tile, see Figures 4 and 5.

MODERN BUILDING IN CHINA

The pressing need for housing coupled with the limitations on arable land have forced the Chinese to build upward. While only the biggest cities are constructing apartment buildings with 16 to 22 stories, even medium size cities such as Zhengzhou, with a population of one million, are building five-story walk-up apartments. A typical floor plan is shown in Figure 6 where each floor consists of three, two-bedroom apartments. In this drawing each individual unit has its own toilet, though in most older units toilet facilities are shared by the units. For Henan, wall construction for urban housing is similar to that described in the rural section above. Windows and doors are similar and suffer from the same inefficiencies. In more northern sections of China, wall thickness is increased as the only means of raising the level of thermal efficiency. In Beijing, high-rises buildings often employ pre-formed concrete and other more advanced approaches. A factory that produces aerated concrete blocks has been imported from Europe. Presently, however, the production from this factory is limited and the blocks produced are utilized in buildings housing foreigners, the buildings where the highest indoor temperatures are maintained.

A WESTERN RESPONSE TO CHINA'S RESIDENTIAL ENERGY SITUATION

The improvement of energy efficiency in Western housing has been well documented in the three previous ACEEE Summer Sessions. From this knowledge, a framework could be developed to solve energy inefficiency in China's housing. A typical response to the situation might be as follows:

1) Technical Solutions: Given that there is presently no insulation used in Chinese housing, the inclusion of ceiling and/or wall insulation would seem warranted, especially in new construction. Western experience may also suggest that improvements to the heating system, passive solar, and attention to infiltration/exfiltration may be options to be explored in addition to insulation. Using the myriad of sophisticated computer design tools, the analyst should determine which of the above technical options is the most cost-effective for the Chinese building style and climatic conditions.

2) Widespread Promotion of Energy Efficiency Through Government Policy: In the United States, a number of programs have been developed to help promote energy efficiency. The most important of these have been tightening of building standards, tax credits and incentive programs for energy efficient measures, information dissemination, and technical assistance programs. Once more energy efficient housing styles have been developed, the next step is to convince decision makers. Given China's planned form of government, programs such as these could be easily mandated on a broad scale to encourage energy efficiency.

AN ENERGY JUSTIFICATION FOR INSULATION

The first step in encouraging greater energy efficiency in Chinese housing is to demonstrate the potential savings from using energy efficient options. Just such a report was prepared by Lawrence Berkeley Laboratory in 1984 (LBL).[15] Using DOE-2.1A, a computer simulation model, the energy use of a Beijing apartment unit built under present practices was compared to the use of units equipped with wall insulation, double glazing, and infiltration improvements. The building design utilized is very similar to the urban floor plan shown in Figure 6. The major difference between the buildings is that in Beijing (which has 30 percent more heating degree days than Zhengzhou--3043 versus 2331 at 18 degrees C) buildings use a fifty-percent thicker wall and centralized heating. Central heating in Henan is still not found in most non-foreign occupied buildings.

The LBL results indicate that improvement in the window quality is the number one improvement to be made. Reducing the air leakage from one air change per hour to one-half air change per hour would lower coal use by thirty percent, roughly 288 kg of coal (8.35 GJ per three apartment units). This savings could be accomplished for 50 Yuan ($25 by 1983 exchange rates) by instituting better manufacturing quality control and the inclusion of a flexible gasket for a better window seal.

The report also determined that the creation of a cavity wall filled with perlite insulation on the north wall of Beijing apartment buildings would have a six-year payback. The construction of a cavity wall is reasonable on the north wall because the walls are already constructed with two columns of brick. By changing the design so that a wall cavity is placed between the columns and insulation is placed inside the cavity, the only additional costs are the cost of the insulation, some steel hooks for holding the walls together, and some additional labor. The report estimated that these costs would be about 180 Yuan per three apartment units (3.4 Yuan/m^2 for the insulation and 1.6 Yuan/m^2 for the labor multiplied by 30 m^2). Coal savings would be about 6.72 GJ per three apartment units.

Two other measures were examined for their cost-effectiveness: Double glazing and adding a cavity wall to the south wall. Assuming that the northern wall cavity is insulated, the payback for double glazing would be twelve years. The payback for creating a southern wall cavity is 22 years. The major difference between the north and south walls is the fact that the south wall does not presently use a double column so that additional bricks would be needed.

While six and twelve year paybacks would be beyond the tolerance of most Chinese and Western investors, the results are conservative in that savings from a reduction in heating equipment are not included. The report concludes that the first cost reduction from the smaller heating systems more than make up for the cost of the wall cavity and the thermopane windows.

Several assumptions made by the LBL study may not be truly representative of present conditions in Beijing and may effect the conclusions drawn by LBL. The study determined that based on modelled heating loads and known coal use per unit, that present coal-fired central heating systems acheive only 40 percent efficiency. The LBL report assumed that the efficiency of the heating systems would be raised to 70 percent in the future. Indeed, the improvement in the efficiency of the heating system is a cost-effective priority for these buildings. Another assumption made is that future indoor room temperatures will rise to 18 degrees C despite the fact that present temperatures are not maintained at nearly that level. Finally, in determining payback period, the report uses a price for coal based on the international cost rather than the significantly lower internal price.

Each of these assumptions was made to determine the long-term social benefits of improved efficiency in buildings. The report calculates a value for the cost of the conserved coal which represents the opportunity cost to Chinese society for finding new coal supply. The "cost of conserved coal" (CCC) is less than the international price for the infiltration improvements, the north wall cavity and the double glazing. This result means that from a societal perspective, it is more prudent for the Chinese to invest in these building measures than it is to invest in additional coal production.

BARRIERS TO THE IMPROVEMENT OF HOUSING ENERGY EFFICIENCY IN HENAN

The case for conservation presented by LBL is sound and convincing, yet conservation in Chinese buildings still remains a rare occurence. There are a number of explanations for this lack of activity, the least of which are the technical barriers to including conservation. As noted earlier, it must be considered that China is very different from the West in culture, political and economic organization and in availability of raw materials and infrastructure. Equally important is the fact that policy developed at the national level is implemented at the provincial and local level. Recognition of and commitment to solving a problem by the academic community and policy makers in Beijing is not necessarily immediately translated into action in the rest of the country.

Some of the barriers found in China are similar to ones found in the United States. The principal obstacle in both countries remains the difficulty in securing construction funds up front, "the first cost bias". In an effort to be able to provide as much housing as possible, the Chinese Central Government has placed limits on the cost of building living units. This strict policy permits only the barest of structural necessitities, thus eliminating any possibility of adding insulation. As in the United States, this problem is exacerbated by the fact that the builder is not the eventual occupant that becomes responsible for the energy payments. In China, one ministry is responsible for designing buildings and a second builds the buildings. The eventual occupants assume responsibilitty for the energy costs. There is no mechanism for enlightened eventual occupants, if there were any, to compensate the Ministry of Construction for including energy efficiency measures in their specific units.

Further complicating the political situation is the dual nature of the decision making process. The central government is responsible for establishing policy. Each of the ministries sets directives within its narrow focus which are transmitted down to similar organizations formed at the provincial and local levels. At the same time, local organizations maintain significant authority for interpreting policy. This overlapping authority can be stifling to innovation.

Construction practices are different in China than they are in the West. The solutions suggested in the LBL report, while seemingly simple by Western standards, would be difficult to implement in China. The insulation of walls is taken for granted in the West, but may not be cost-effective in most Chinese applications. The assumption that insulation is a good idea needs to be examined further.

The materials used in Western insulation practices are not readily available in China. For instance, most US applications involve using wood studs or lathing to keep insulation in place. In China, wood is so scarce that most homes use none or only enough to span the roof.

Insulation materials are also rare. Natural materials such as corn and rice stalks are already overused by peasants for cooking. Paper, an alternative insulation material in the West is so scarce that most of it is recycled. The manufacturing of fiberglass and polystyrene would constitute a major new investment. The government has begun the manufacture of air-expanded concrete blocks, but production is very limited. The LBL study suggests the use of perlite as a insulation material. Yet the quoted price for perlite was found to be significantly higher in China than even in a country such as Kuwait, where the raw materials are imported. Mobilization of the workforce to mine and deliver perlite in the quantities required would be a massive shift in resources.

Under the circumstances, creating a cavity wall with no insulation appears to be a better solution. The wall would still be approximately twice as efficient as the existing wall structure without the added costs and delivery concerns associated with perlite.

Yet, even this option is not without its obstacles. In Henan, the construction of a cavity wall would require additional materials and skills. In order for the wall to remain flush, a longer brick is needed to compensate for the air cavity gap. Unfortunately, the suppliers of bricks are independent of the builders. Given the existing shortages in the supply of normal bricks, it may be difficult to get brick making operations to agree to produce the customized bricks. Without any profit incentive for firms, there is no guarantee that just because equipment and materials that promote energy efficiency would be cost-effective, they will become available.

A similar lack of motivation affects the workers themselves. Most building work crews are under extreme pressure to increase productivity. Yet, the workers retain control over the building process, and can refuse to accept new practices. Despite China's poulation, there is ironically a shortage of workers in urban areas creating a further disincentive towards innovation.[16] Even if a new process is understood to be advantageous and acceptable, the skill level of workers is not necessarily capable of the more exacting requirements of a cavity wall. This is an especially large concern in Henan where the walls are all load bearing.

Though the LBL report did not explicitly examine the economics of improved boiler efficiency, it can be assumed that improvement of efficiencies above the estimated 40 percent would be a priority over any insulation.[17] Not surprisingly, a major effort to promote higher efficiency stoves has been undertaken in the rural areas. The World Bank reports that over forty million stoves have been distributed.[18]

WILL ENERGY CONSERVATION IN HOMES ACTUALLY SAVE ENERGY?

The analysis done for Beijing assumes that room temperatures are maintained at a minimum temperature 18 degrees C. Not only is this temperature higher than temperatures maintained in Chinese homes, but the logic is not representative of the heating process in Chinese homes. Instead of indoor temperature being controlled by a thermostat, building temperatures are controlled by the scarcity of heating fuel. The indoor temperature is a function of how much fuel is available to burn, not by how much is needed to maintain a given setpoint.

The government uses the scarcity of coal as its means of controlling demand. The price of coal is kept below the price of international trade. Zhu et. al. note that the low price is an effort to keep the costs of fuel consumption below 5 percent of household income.[19] Yet coal is not readily available particularly outside of the urban areas.

In Zhengzhou, the government gives each family between 80-100 kilograms of processing coal per month. This is meant to be sufficient for cooking, though most families save fuel in the summer for heating in the winter. The processed coal is burnt in very inefficient stoves so that actual useful energy is probably no more than 250,000 to 700,000 kJ per month.[20] If 18500 kJ/day are needed for cooking, then Zhengzhou households will only have sufficient fuel for cooking if their stove efficiencies are above twenty-five percent.

In the winter, the government of Henan supplies each employee an additional 10 Yuan as a heating aid. The government does not supply any extra fuel so that if this money is to be used to purchase fuel, it must be done privately. At 1980 prices, this subsidy would purchase around another 180 kg of coal if it were available. The individual that wants to buy extra coal may have to spend a day or two dragging the coal back from the mine by pullcart.

The major point is that the energy savings projected from insulating a wall in Beijing may not result from insulating a wall in Zhengzhou. The greater efficiency may merely translate into a more comfortable living situation for the inhabitants. For many homes, the fuel available is insufficient to meet cooking needs, so that greater thermal efficiency will not lessen fuel use even should occupants be willing to maintain previous indoor temperatures. In fact, given that most Beijing units are not maintained at temperatures near 18 degrees C, it is likely that a portion of energy conservation done in Beijing will also result in comfort improvements rather than fuel savings. A clearer picture of the benefits of conservation will be obtained using lower setpoints and modeling indoor conditions under constrained fuel inputs.

One contrast between the traditional home and modern buildings in Beijing is the difference in the amounts of heat needed to feel comfortable. The k'ang is a good example of the effectiveness of traditional energy appliances. The inefficiency of the stove was compensated by the recovery of exhaust gases in the flue for heating the platform. In addition, the area that needed heating was minimized. The k'ang could be labelled as the precursor to today's warm room concept. In contrast, the modern apartment with a central heating system is designed to heat the air of the entire apartment. A much greater amount of energy is needed to obtain the same feeling of comfort.

Another problem in Henan is that indoor temperatures in summer sometimes exceed forty degrees centigrade. The homes become quite unlivable. No airconditioning is used in homes, though many families now have electric fans. Insulation, if combined with methods for reducing heat gains from insolation and cooking stoves, would be effective in maintaining more comfortable conditions. The typical Henan home is oriented east/west with no overhang, thus maximizing summer solar heat gain. The greater saturation of electric fans and their counterpart electric heating units which are necessitated by poor building design will probably mean more rapid growth in electricity than is projected by the government. Once electric service is connected, efforts to limit its availability are more difficult than controlling the delivery of coal. In order to limit use by residential customers, the government has set the price of electricity two-and-one half to three times the average price for heavy industry. However, because most buildings and rural areas are master metered, the direct financial stimulus is absent.

CONCLUSION

The Chinese are renown for their ability to surive hardship. Their term for this is ... "eating bitterness." Prior to 1949, eating bitterness reflected the peasants' ability to survive on marginal amounts of food. Now that China is able to supply its people with adequate nutrition levels, it is beginning to concentrate on improving housing and providing adequate fuel supply. The development of these two areas is in direct conflict with the more important goals of maintaining food supply and encouraging the development of industry. Buildings have to be built upwards to protect arable land and energy supplies must be limited for residential uses.

The concentration on energy conservation in heavy industry by the Chinese is understandable and appropriate. The lessor role that residential energy use now plays in the overall Chinese energy picture is, however, no reason to ignore this sector completely. As the West has realized, housing lasts for a long time, and inefficient housing remains inefficient for a long time. The present consumption of the sector does not represent a satisfied energy efficient sector, but rather a massive potential of future demand. China has been able to control its use of fuel by limiting its access. The continuation of this strategy faces two major obstacles: The rural poor denied access to commercial fuels will continue to destroy forest and cropland at an increasing rate, and the urban dwellers forced to inhabit new Western style apartments without attendant energy efficiency will demand greater access to energy supplies.

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20. The low end is 80 kg X 20700 kJ/kg X 0.15 efficiency, the high end is 100 kg X 24900 kJ/kg X .283 efficiency. Efficiencies reported in Zhu et. al. for bituminous coal and comb-shaped coal stoves.

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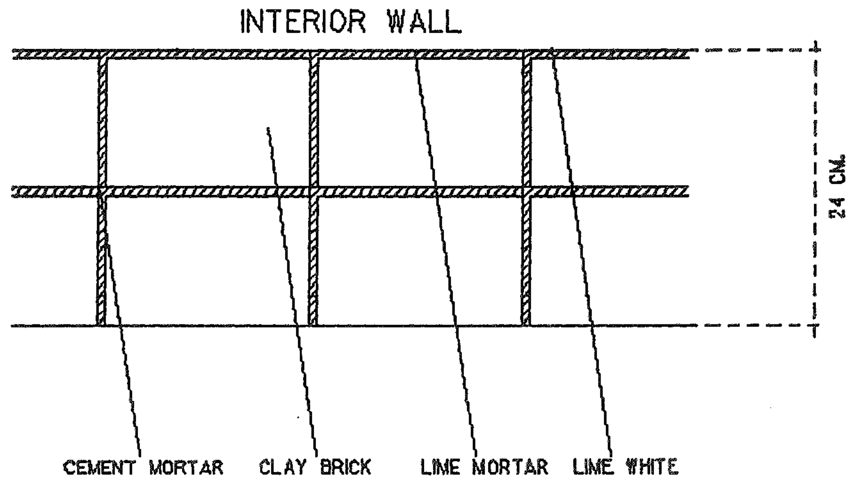

FIGURE 1. TYPICAL HENAN WALL: HORIZONTAL PROFILE

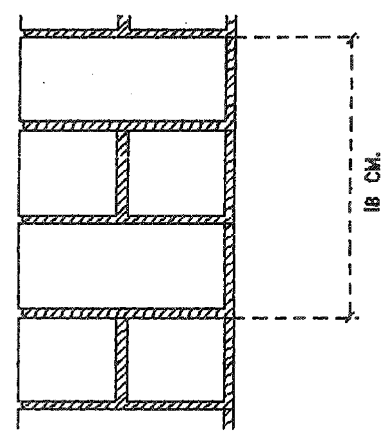

FIGURE 2. TYPICAL HENAN WALL: VERTICAL PROFILE

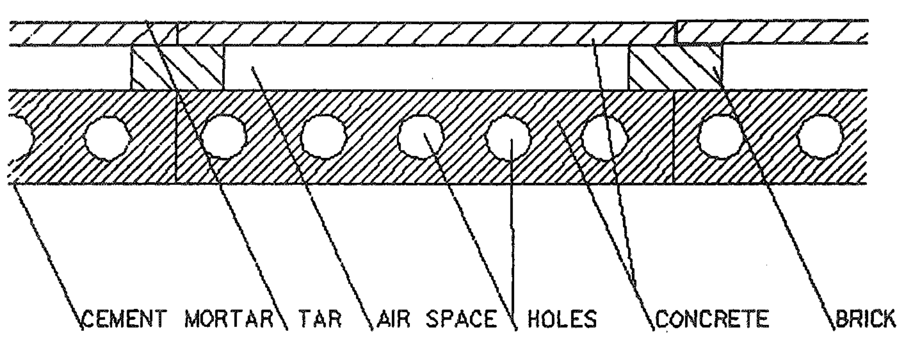

FIGURE 3. ROOF CONSTRUCTION IN URBAN HOUSING -- HENAN

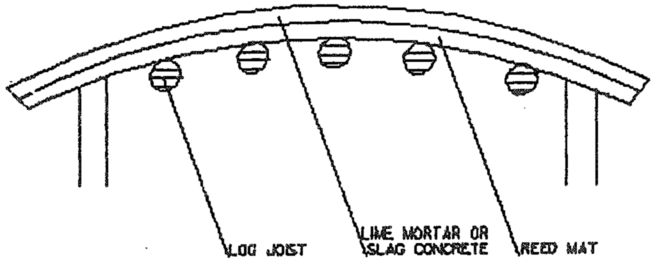

FIGURE 4. HENAN ROOF: VERTICAL PROFILE

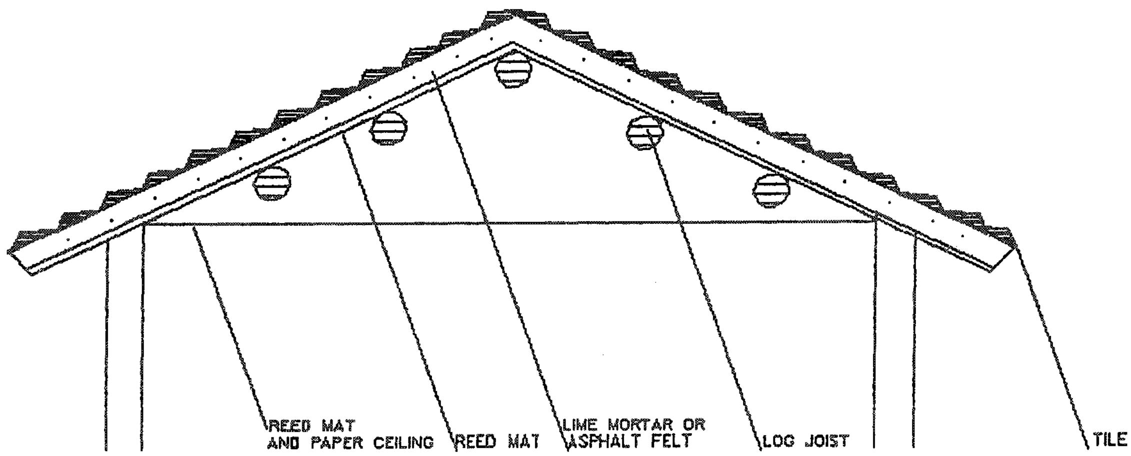

FIGURE 5. TYPICAL PEASANT TILE ROOF: VERTICAL PROFILE

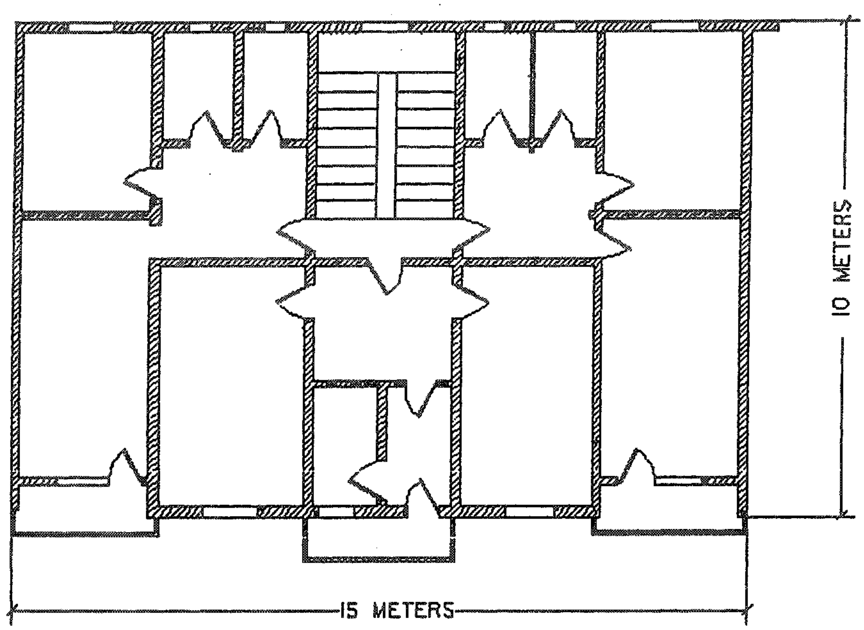

FIGURE 6. TYPICAL HENAN APARTMENT BUILDING FLOORPLAN
EACH FLOOR CONSISTS OF THREE 2 - BEDROOM APARTMENTS