ENVIRONMENT-FRIENDLY LOW-COST HOUSING OPTIONS FOR LOW-INCOME COMMUNITIES

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ABSTRACT

Bangladesh is one of the most densely populated countries in the world. About 80% of its population live in rural areas and about 50% of its total population still are below the poverty line. Most of the people living in the villages or in urban slum areas do not have a habitable dwelling house along with safe water supply and sanitation facility which are the basic needs of human being. The use of indigenous materials dominates the country's present housing pattern. But the houses built of these materials lack in structural stability and durability which in turn depend largely on judicious selection of materials and sound structural design. Thus these houses can not provide a cost-effective return to the poor users. Again, due to country's varying hydrogeological and socio-economic condition, different localities need different technologies to get access to potable water supply and sanitation facility as well. The paper closely examines all these issues and suggests a number of low cost options of housing with safe water supply, and sanitation facilities for the low-income communities of both rural and urban slum areas taking into consideration the following essential parameters: durability, structural stability, affordability and local construction & maintenance competence aspects. Although the scope of the paper does not entail the cyclone prone southern coastal area where the design criteria and considerations will be different, it takes into account about 80% of the total geographical area and population of the country. Last but not the least, the paper presents a replicable model for the communities of similar socio-economic pattern.

1. INTRODUCTION

Habitable shelter is one of the basic needs of human being. The housing pattern of a community largely depends on its socio-economic conditions, availability of raw materials and environmental factors. The low-income profile of a population is naturally forced to choose a low cost option to raise their dwellings. However, these houses need to be structurally stable and durable to provide a cost-effective return. A minimum level of provision for safe water supply, sanitation, fuel and lighting facilities are also associated with these dwellings. Such a shelter together with all these basic amenities within an affordable range of low-income communities can significantly contribute to promote their standard of living.

With this background, the paper reviews the prevailing socio-economic condition, housing pattern, water supply and sanitation situation of Bangladesh, a densely populated country with very low per capita income. Based on this review, the paper suggests a number of low cost options of housing integrated with potable water supply and sanitation facilities for the low-income communities of both rural and urban slum areas. Some essential parameters such as durability, structural stability, affordability and competence of local construction & maintenance have been considered prior to suggesting these low cost options. The paper, however, does not entail the cyclone prone southern coastal area, where the design criteria and considerations will be different. Nevertheless, it covers about 80% of the total geographical area and population of Bangladesh.

2. PRESENT SOCIO-ECONOMIC CONDITION OF BANGLADESH

Bangladesh is a developing country with an area of 147570 km^2. According to the last census, the country's population stood at 111.4 million in 1991 with an annual growth rate of 2.17%. The density of population of Bangladesh stands to be one of the highest in the world. In spite of concerted efforts of the government, non-government organisations, social development bodies and external support agencies, to alleviate poverty, about 50% of rural population and 46% of urban population (mostly in slum areas) are still below the poverty lines (Fig. 1). The percentage of urban population is 20.1, while that of rural population is 79.9. The per capita annual income (about Tk. 5500, Tk. 46 = 1 USD) is one of the lowest in the world with a very slow trend of rise (Fig. 2).

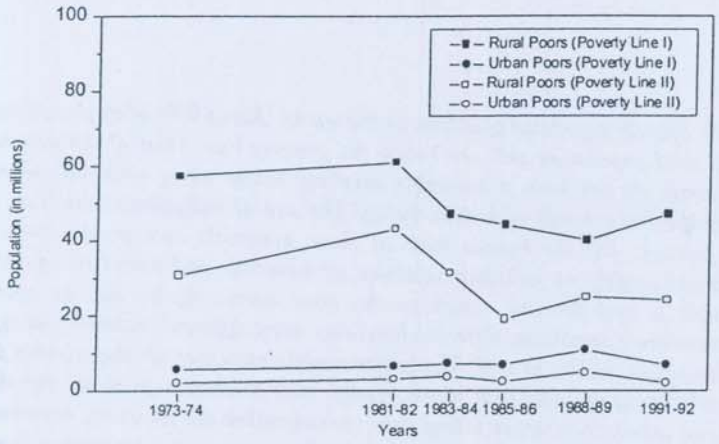


Fig. 1 Number of Population Below Poverty Lines (BBS 1995)

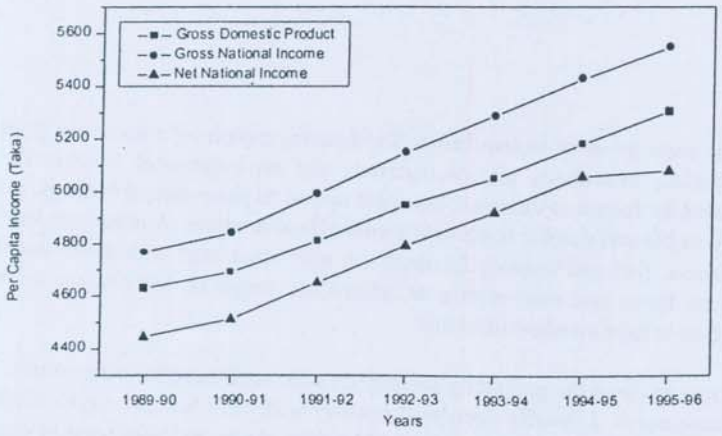


Fig. 2 Per Capita Income of Bangladesh and Its Trend of Change (BBS 1995)

Poverty Line I = Recommended calorie intake 2122 calories/day/person
Poverty Line II = "Hard Core" Poverty 1805 calories/day/person

The country's economy is predominantly agro-based with a land-person ratio continually following a declining trend. The rural-urban migration of poverty stricken people for better jobs and living opportunities is distinctly apparent. This phenomenon of rural-urban migration gives rise to urban slums that are increasing in numbers and size as well. Apart from many other issues, these slums are causing alarming environmental hazards primarily for lack of appropriate water supply and sanitation systems.

Fig. 3 shows the growth of urbanisation in four major urban centres, where a sharp growth rate is apparent. Such a rapid urban growth demands corresponding increase in housing facilities integrated with water supply and sanitation services. But due to the socio-economic and demographic backdrop, the challenge of reversing this appalling situation is enormously big.

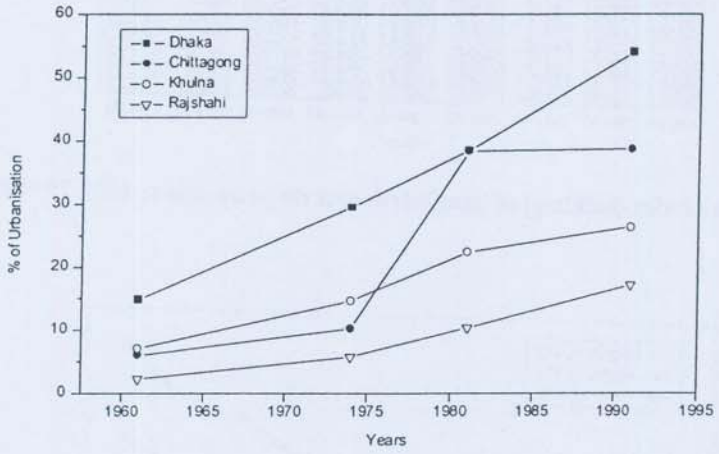


Fig. 3 Trends of Urbanisation in Four Major Urbanised Districts of Bangladesh (BBS 1995)

3. PRESENT HOUSING CONDITION OF BANGLADESH

3.1 Economic Factors

The cost of a new house mainly includes the costs of building materials, wage/labour, and transportation apart from the cost of land. Fig. 4 summarises the component wise cost indices, all of which in general show a sharp rising trend. The continuously increasing construction cost coupled with higher rate of migration of rural poor people to the urban centres is also causing the house rent to go up (Fig. 5) affecting the low income communities most.

3.2 Use of Construction Materials

The low per capita annual income of the people of Bangladesh forces the majority of its people to use low cost indigenous materials to build their dwellings. Table 1 shows general housing pattern of the country and its change in three years (1991-1994). The figures indicate that the use of locally available materials like straw, bamboo, mud, unburnt brick, wood, etc. influences the total housing pattern of the country. However, in urban areas the uses of brick, cement-mortar and reinforced cement concrete (RCC) are relatively more, as the people are relatively better off.

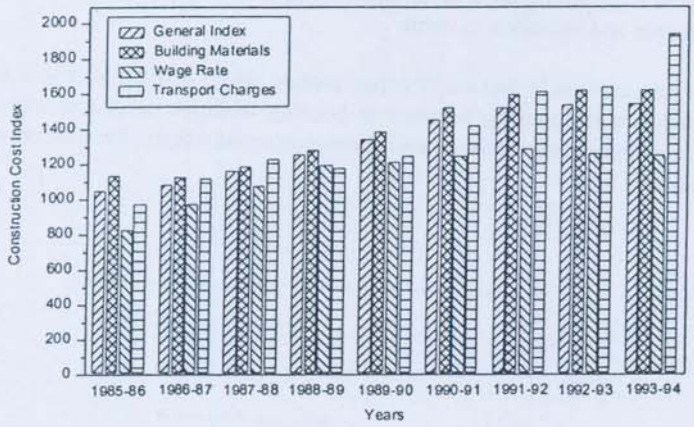


Fig. 4 Construction Cost Index (building) of Bangladesh over the years (Base : 1969-79=100), (BBS 1995)

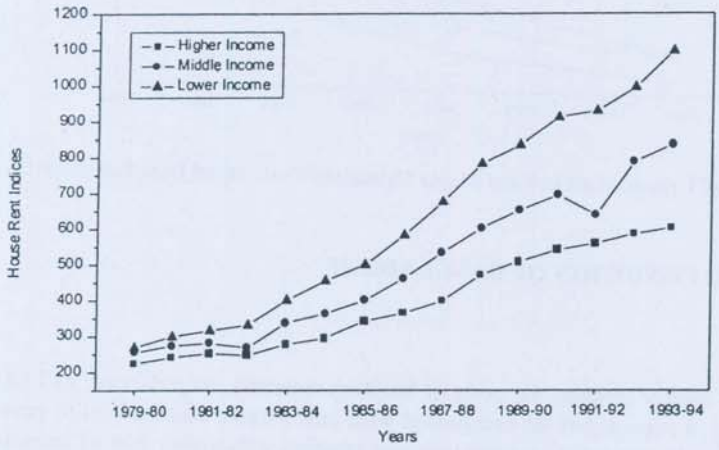


Fig. 5 House Rent Index of Bangladesh over the years (BBS 1995)

Higher Income: Pucca house having 608 sft and above plinth area with gas (if available in the city); electricity and water connection have been considered to be rented by middle income group of people.

Middle Income: (1) Pucca house having 183 to 608 sft plinth area with gas (if available in the city); electricity and water connection; or, (2) Pucca house having 183 to 239 sft plinth area with electricity and water connection but without gas; or, (3) Semi-pucca house having 240 to 359 sft plinth area with gas (if available in the city); electricity and water connection have been considered to be rented by middle income group of people.

Low Income: (1) Semi-pucca house having 183 to 359 sft plinth area with electricity and water connection but without gas; or, (2) Katcha house having 182 sft or below to 239 sft plinth area with electricity and water connection, but without gas have been considered to be rented by middle income group of people.

The changes of household pattern over three years (Table 1) indicate that in rural areas the use of brick or RCC houses (Category 1) is increasing in a slower rate than that in the urban areas. In case of houses made of mixed type materials (Category 2) the rate of increase is more significant in urban areas. This is an indication of the increase of urban slums. For houses made wholly of indigenous materials available in nature (Category 3), the situation is more or less constant in rural areas, whereas in the urban areas it shows a sharp decreasing trend. All these changes are likely to be related with the change of per capita income of the users/owners of the households within the time frame.

Table 1. Change of percentage distribution of household by wall & roof materials (BBS 1995)

Categories of housing material	Rural		Urban	
	Year		Year	
	1991	1994	1991	1994
Category 1	0.94	1.43	17.92	32.35
Category 2	2.15	3.22	11.74	17.78
Category 3	96.91	95.35	70.34	49.87
Total	100.00	100.00	100.00	100.00

Category 1: Both Wall and Roof are made of Brick and RCC.
Category 2: Combination of Straw, Bamboo, mud, unburned brick, wood, corrugated iron sheet, etc. with brick, cement-mortar, RCC, etc. are used.
Category 3: No brick, cement-mortar or RCC are used.

3.3 Water Supply and Sanitation Situation

Commendable progress in the provision of water supply services in the rural areas has been made with a coverage of around 98%, but only in terms of low service level (Table 2). Although near about 98% of the rural population have access to potable drinking water sources, the use of safe water for other domestic purposes has still been limited to only 30% because of poor service level. It is apparent that this situation will not improve unless water points are brought near the household and considered as an integral part of the respective cluster households.

The rural sanitation coverage is only 16% (Fig. 6) with home made latrines. However, this figure goes up to a level of 42%. This home made latrines will be kept out side the provision of the paper as these are not considered to be sanitary.

The urban water supply and sanitation coverage are both around 50%. All the figures of both water supply and sanitation as mentioned above are related to national coverage, where the prevailing unhealthy situation in the un-served and under-served low-income communities can easily be perceived.

Rural Water Supply Coverage is presently defined as percentage of population living within 150 meters of a tubewell.
Rural and Urban Sanitation Coverage is presently defined as one sanitary latrine per household.
Home-made Latrines are defined as pit latrines without water seal pans and without pit linings.
Urban Water Supply Coverage is presently defined as one house connection per household or one stand post per 100 people.

Table 2. Percentage distribution of household by source of drinking water and by locality (DPHE 1997)

Year	Locality	Source of drinking water		
		Potable		Non-potable
		Tap	Hand Tubewell	
1997	Rural	0.25	98.00	1.75
	Urban	50.00	49.00	1.00
1994	Rural	0.22	91.31	8.47
	Urban	44.01	54.46	1.23
1991	Rural	0.14	77.56	22.31
	Urban	22.48	67.75	9.76

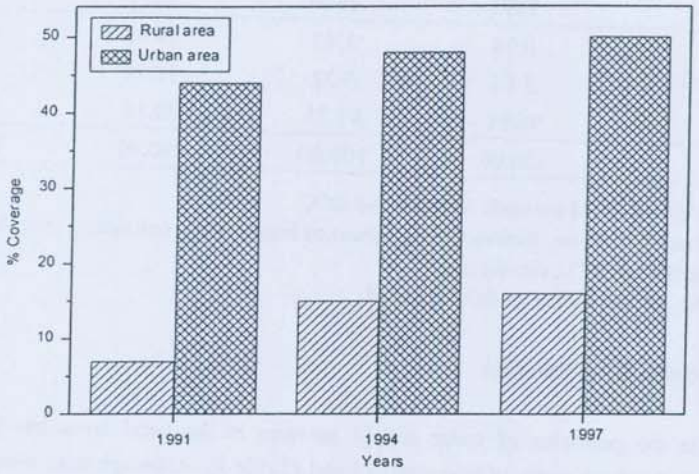


Fig. 6 Percentage distribution of household by sanitary toilet facility and by locality (DPHE 1997)

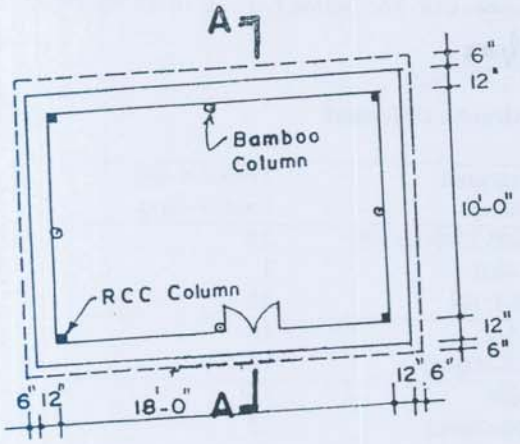
4. PROPOSED LOW COST OPTIONS

4.1 Structure of the House

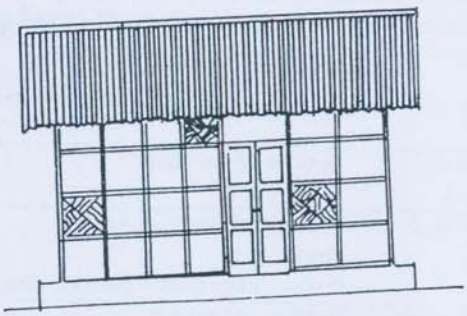
The basic structure of a house consists of column, beam, wall and roof elements. These elements can be made of different types of materials. But the choice of materials is determined primarily on the basis of their cost, availability, durability and social acceptability. Table 3 presents the unit prices of different available materials (as per the present market survey) along with their probable lifetime. After a judicious selection of the materials for different structural elements, a sound structural design is needed in order to provide structural stability to sustain both dead and live loads (HBRI 1990). With this background, this section presents three options of structural systems with their cost involvement.

4.1.1 Option I

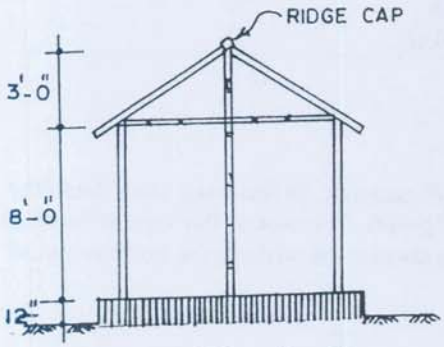
In this option, the corner columns of the house can be made of reinforced cement concrete (RCC), while beams are made of bamboo. To minimise the mid span deflection of the bamboo beams, intermediate bamboo columns are to be provided (Fig.7). The introduction of RCC columns improves the overall stability and durability of the



PLAN



FRONT ELEVATION



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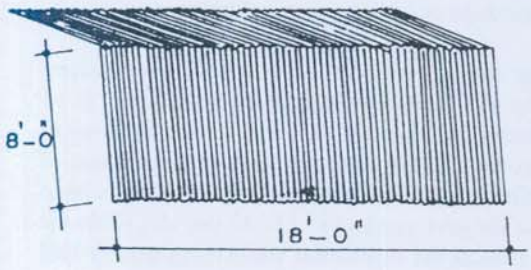
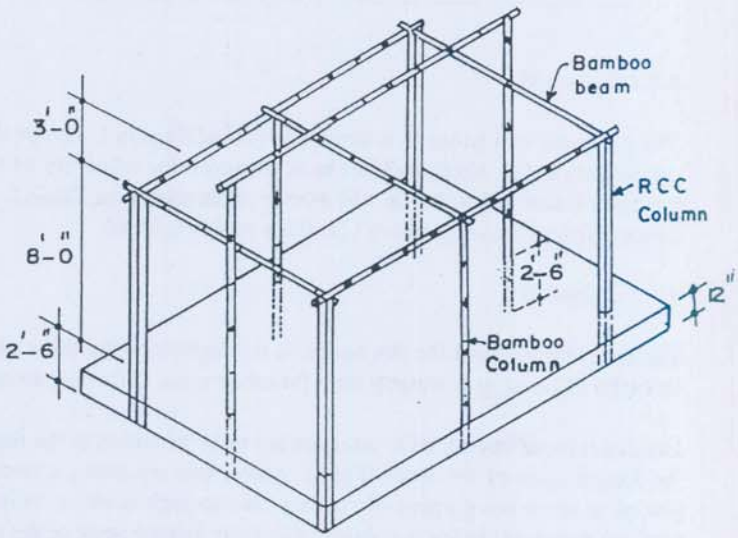


DETAIL OF ROOF



STRUCTURAL FRAME

FIG. 7 DETAILS OF OPTION I

whole structural system and also allows time to time repair & maintenance operations without disturbing the whole structure. CI sheet has been selected for roofing purpose, while terza (made of bamboo strips) for wall materials. Alternatively, very low cost straw can also serve the purpose as roof and wall materials, but these are not considered on account of very low durability and high maintenance cost. For Option I, a cost of Tk.96.00 per sft has been estimated for a single room house of 150 sft in Table 4.

Table 3. Cost of different available structural element

Structural elements	Options of materials	Unit price (Taka)	Probable life time (Years)
Roof covers	Corrugated Iron (C.I.) sheet	3000-3500/bundle	25
	Straw	4-6/sft	1
	Ferro-cement folded plate (1" thick)	40-45/sft	25
Roof structures	Bamboo (4" thick)	3-5/ft	10
	Wood (2" x 2.5")	300-400/cft	12
Beams	Bamboo tie (4" thick)	3-5/ft	10
	Wood tie (2" x 2.5")	300-400/cft	12
	RCC beam	200-225/cft	25
Columns	Bamboo (4" thick)	3-5/ft	5
	RCC pre-cast column	225-250/cft	25
Walls	Terza	4-6/sft	2
Doors & windows	Terza	4-6/sft	2
	Tin sheet	25-30/sft	20
	Wood	300-400/cft	12

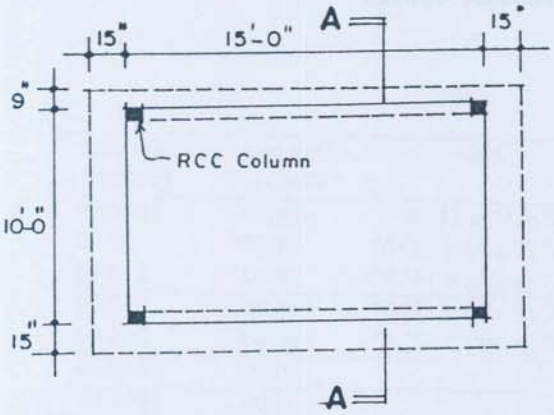
4.1.2 Option II

The principle of Option II is similar to that of Option I, except the wall materials. In this case, from durability consideration C.I. sheet wall has been proposed for relatively better off people. The cost of this type of housing has been estimated to be Tk. 161.00 per sft as shown in Table 5. From the cost calculation, the involvement of almost 50% of the total cost in C.I. sheet wall is evident.

4.1.3 Option III

The cost involvement for this option is the highest of the three with more durability than other two options, but this type of housing is suitable only for urban areas from the consideration of construction competence.

For this type of option, RCC columns are to be provided at the four corners connected by two RCC beams along the longer span of the room (Fig.8). Above this structure, a composite ferro-cement folded plate roof is to be placed to serve the purpose of roofing. Due to high moment of inertia and resultant stiffness of this lightweight roof, no structural beam is required along the shorter span of the room. For the same reason, the requirement of intermediate columns as those of Option I and Option II is also eliminated. Five-inch thick brick wall has been proposed for this structural system which increases the total cost of the structure to Tk. 237.73 per sft (Table 6). However, for interim purpose, C.I. sheet can also be used, which reduces the cost of the wall component to half as compared to brick wall.



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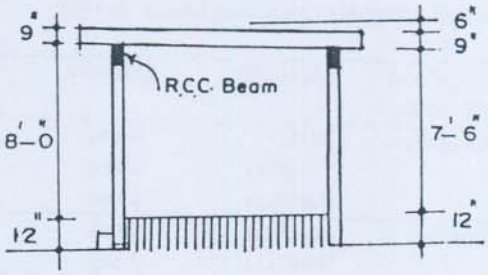

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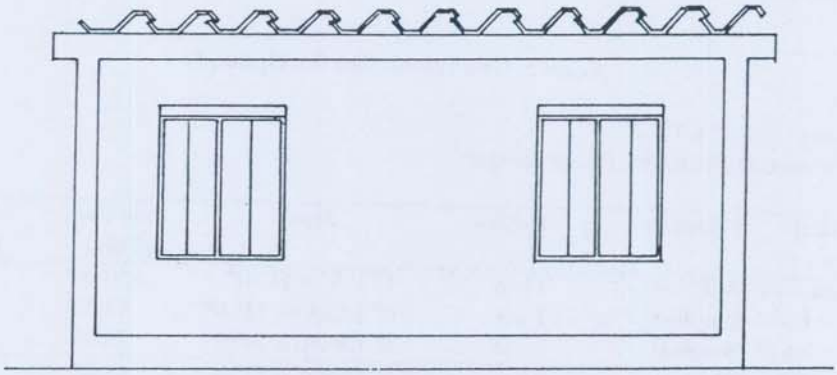
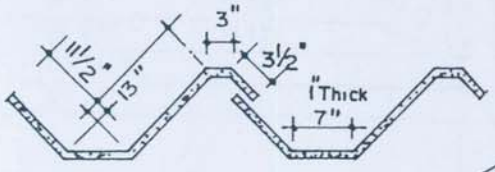


BACK SIDE ELEVATION



CROSS SECTION OF F.C. FOLDER PLATE

ISOMETRIC VIEW OF A F.C. FOLDER PLATE

FIG. 8 DETAILS OF OPTION III

Table 4. Cost calculation for Option I

Plinth area: 10'-0" x 15'-0"
Cost of materials (including labour charge):

Structural elements	Materials	Quantity	Size	Unit cost (Taka)	Total cost (Taka)
Columns	RCC	4 nos.	5" x 5" x 11'-0"	450.00	1800.00
	Bamboo	2 nos.	4" (thick) x 11'-0"	44.00	88.00
	Bamboo	2 nos.	4" (thick) x 14'-0"	56.00	112.00
Beams	Bamboo	3 nos.	4" (thick) x 11'-0"	44.00	132.00
	Bamboo	3 nos.	4" (thick) x 17'-0"	68.00	204.00
Roofs	CI sheet	288 sft.	---	30.00	8640.00
Walls	Terza	393 sft	---	5.00	1965.00
Doors	Wood & Tin	1 nos.	3'-6" x 6' – 6"	725.00	725.00
Windows	Wood & Tin	2 nos.	3'-6" x 3' – 0"	375.00	750.00
Grand Total					14416.00
Cost/plinth area (Taka/sft)					96.00

Table 5. Cost calculation for Option II

Plinth area: 10'-0" x 15'-0"
Cost of materials (including labour charge):

Structural elements	Materials	Quantity	Size	Unit cost (Taka)	Total cost (Taka)
Columns	RCC	4 nos.	5" x 5" x 11'-0"	450.00	1800.00
	Bamboo	2 nos.	4" (thick) x 11'-0"	44.00	88.00
	Bamboo	2 nos.	4" (thick) x 14'-0"	56.00	112.00
Beams	Bamboo	3 nos.	4" (thick) x 11'-0"	44.00	132.00
	Bamboo	3 nos.	4" (thick) x 17'-0"	68.00	204.00
Roofs	CI sheet	288 sft.	---	30.00	8640.00
Walls	CI sheet	393 sft	---	30.00	11790.00
Doors	Wood & Tin	1 nos.	3'-6" x 6' – 6"	725.00	725.00
Windows	Wood & Tin	2 nos.	3'-6" x 3' – 0"	375.00	750.00
Grand Total					24241.00
Cost/plinth area (Taka/sft)					161.00

4.2 Water Supply

The hydrogeological consideration divides the country into four major categories, i.e. low water table areas, shallow water table areas, coastal saline areas and Chittagong Hill Tract areas. In general, most of the plain lands of the country fall under low and shallow water table areas. The cyclone prone coastal area falls under saline zone which is not under the purview of the paper.

Due to this sharp division, different technologies are required for water supply in these areas of four categories. Some of these technologies are simple, easy to implement and inexpensive, while others are expensive and difficult to install. In this situation, the water tables and the water qualities are primarily found to dictate the selection of options. Again, there are areas where conventional technologies are not applicable. Research and Development (R&D) activities in the recent years resulted in a few innovations to meet the requirements of these

areas. The following sections present appropriate technologies for different hydrogeological situations along with their capital and O&M cost (Table 7).

Table 6. Cost calculation for Option III

Plinth area: 10'-0" x 15'-0"
Cost of materials (including labour charge):

Structural Elements	Materials	Quantity	Size	Unit cost (Taka)	Total cost (Taka)
Columns	RCC	4 nos.	5" x 5" x 11'-0"	450.00	1800.00
Beams	RCC	2 nos.	5" x 6" x 15'-0"	660.00	1320.00
Roofs	Folded plate	210 sft.	---	45.00	9450.00
Walls	Brick wall	393 sft	5" thick	55.00	21615.00
Doors	Wood & Tin	1 nos.	3'-6" x 6' – 6"	725.00	725.00
Windows	Wood & Tin	2 nos.	3'-6" x 3' – 0"	375.00	750.00
Grand Total					35660.00
Cost/plinth area (Taka/sft)					237.73

Table 7. Capital and operation & maintenance (O&M) cost of different water supply options (DPHE 1997)

Technologies	Capital costs (Taka)	O&M cost/year (Taka)	Remarks
Shallow hand tubewell	5500.00	50.00	Each unit of these options can provide water to a maximum of 15 households
Deepset tara handpump	12500.00	100.00	
Deepset hand tubewell	40000.00	50.00	
Iron removal plant	8000.00	300.00	

4.2.1 Shallow Hand Tubewell

This is suction mode hand pump tubewells popularly known as 'No. 6 Hand Pumps' that can be used in shallow water table areas where water table remains within 22 feet below the ground level. These are the simplest and cheapest type of technologies that are in use in the rural water supply systems.

4.2.2 Deepset Hand Tubewell

This technology can be deployed in the areas where ground water table lies deeper than 22 feet below ground level for the supply of potable water. The conventional deepset pump is very expensive and requires a mobile maintenance crew to keep it operational. Through R&D activities a less costly and easier to maintain new type of pump, known as 'Tara Handpump' has been developed and is being used in large scale since 1988.

4.2.3 Iron Removal Plant

It has been observed that in areas where water contains more than 5 ppm of iron, people are reluctant to use such water as it stains clothes, imparts a metallic taste to drinking water, colour rice that is cooked in it. Through R&D activities a simple design of iron removal plant applicable for hand pumped water supply system has been developed. This technology can be used in the areas with acute iron problem.

4.2.4 Urban Water Supply Network

Apart from the above mentioned low cost technologies, the existing water supply system in urban areas may also dictate the selection process to some extent as water supply in the urban centres of the country is generally done

through piped water supply systems usually consisting of production wells, pumping main, overhead reservoirs, distribution networks, house connections, stand posts, etc. Table 8 (DPHE 1997) presents economic aspects of domestic water supply networks. However, slums located in urban fringe areas, shallow or deep set hand pumps can also be used in parallel to meet the demand of potable water supply.

Table 8. Connection fees and monthly water use rates for different domestic water supply connections

Diameter of water connection	Water connection fees (Taka)	Monthly water use rates (Taka)
½ inch	1400.00	80.00
¾ inch	1800.00	120.00
1 inch	3600.00	200.00
1½ inch	5600.00	350.00

4.3 Sanitation

Sanitation, i.e., the excreta disposal in rural areas of Bangladesh is still more or less traditional. The methods that are being practised at the moment are open defecation, some sort of pit latrine, lined single and twin pit latrines. To improve this situation different low cost appropriate technologies have been developed in the country through R&D activities. The following sections, Table 9 and Table 10 highlight some of these technologies and their cost involvement (DPHE 1997), which are most appropriate in all respects including social acceptability.

4.3.1 Direct Pit-Pour Flush-Water Seal Latrine

The system consists of a slab made of reinforced concrete or ferro-cement. The pan is essentially from ferro-cement and includes water seal. Reinforced concrete rings are used as lining materials for the pits to ensure stability.

4.3.2 Pour Flush-Water Seal-Offset-Twin Pit Latrine

This is also a low cost technology, but as compared to direct pit-pour flush-water seal latrine this system is more expensive and cost involvement is almost double. The main advantage of twin pit system lies in the alternate use of the pits once one is full. In that case, the other one is put into operation allowing sufficient time to the previous one for full decomposition of its sludge. Generally, in a period of 18 months, the sludge gets decomposed fully and converted into safe and pathogen free organic manure suitable for enhancing soil fertility.

4.3.3 Septic Tanks

The technology and raw materials for building septic tanks are also available, but are popular only within a thin profile of rural population. These are very capital intensive systems and the affordability factor predominantly limits their uses in the rural areas.

4.3.4 Urban Sanitation

At present, only 18% population of Dhaka metropolitan is now under the coverage of conventional central sewer system. The capital intensive nature and high operation & maintenance cost of the system limits its viability only within the affluent section of the population of the metropolitan. Septic tank system, although popular is very costly and therefore its uses are also limited within the affluent class of the non-sewered part of urban population. However, sector professionals and planners are gradually getting convinced in regard to the viability of small bore sewer system as community based intermediate technology for relatively less affluent urban society, maintaining level above poverty line. But from cost consideration, the options of direct pit-pour flush-water seal

latrine or pour flush-water seal-offset-twin pit latrine (Section 4.3.1, 4.3.2) appear to be most suitable for the urban people living in slum areas.

Table 9. Capital and operation & maintenance (O&M) cost of different sanitation options

Technologies	Capital cost (Taka)	Remarks
Direct pit-pour flush-water seal latrine*	900.00	• It can only serve a simple household. • It requires a maintenance cost of about Tk. 200/- during emptying of pit once in about 4 years.
Pour flush-water seal-offset-twin pit latrine*	1800.00	• It can only serve a simple household. • It requires a maintenance cost of about Tk. 200/- during emptying of pit once in about 4 years.
Septic tanks	15000.00	• It requires a maintenance cost of about Tk. 300/- during emptying of pit once in about 5 years.

*Including super structure

Table 10. Connection fees and monthly sewer system use rates for different domestic connections

Type of Sewer system	Connection fees (Taka)	Monthly use rates (Taka, per capita/year)
Conventional sewer system	3000.00	600.00
Small bore sewer system	2000.00	400.00

5. CONCLUSION AND RECOMMENDATIONS

5.1 General

- Population density and rural and urban settings of the country demand distinctly different options of housing.
- To ensure minimum environmental consideration,water supply and sanitation services are to be seen as integral components of housing unit.
- Housing options of various standards are to satisfy the minimum requirements like availability of raw materials, durability, structural stability and local competence of constrauction & maintenance ensuring overall cost effectiveness.
- Housing options are to be designed in such a way that enough flexibility is there for upgradation of housing units in line with progressive socio-economic development of the user community.
- A section of population in abject poverty will continue with the present practices in raising their dwellings, although these are not worthy to consider as viable options at present. It is expected that in future affordability of this class of people will gradually increase through intensive poverty alleviation drive of government, non-gonernment and external support agencies allowing them to choose one of the options according to their willingness to invest. However, the water supply and sanitation (WSS) options particularly for rural areas are expected to be well within the reach of the user community as these options can provide services to a multiple housing units.
- Although, provision of a single water point per household will be the ideal case, the natural phenomena of affordability and willingness to pay will dictate choosing requisite service levels of WSS. However, from convenience and privacy points of view a single unit of sanitary latrine is recommended for each individual household.

- There remains a scope for further detailed socio-economic, structural and financial analysis of the options suggested in this paper.
- A continuous R&D efforts must be there to develop more viable options on low cost housing including WSS.

5.2 Options for Rural Area

- A single water point (No. 6 handpump) and pour-flush waterseal single-pit latrine is recommended for Option I of housing unit in shallow water table area.
- A shared water point (Deepset/Tara handpump) upto a maximum of 15 households and a pour-flush waterseal single-pit latrine is recommended for Option I of housing unit in low water table and iron problem area.
- A single water point (No. 6 handpump) and pour-flush water seal twin-pit latrine is recommended for Option II of housing unit in shallow water table area.
- A shared water point (Deepset/Tara handpump) upto a maximum of 10 households and pour-flush water seal twin-pit latrine is recommended for Option II of housing unit in low water table area.

5.3 Options for Urban Area

- A shared water point (stand post) and pour-flush water seal twin-pit latrine is recommended for Option II of housing unit in non-sewered locality.
- A single water point (house connection) and pour-flush water seal twin-pit latrine is recommended for Option III of housing unit in non-sewered locality. However, in sewered area (small bore sewer connecion) a single sewer connection for a cluster of 5 housing units is recommended.

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