CHAPTER 6

Alternative Building Materials for Low Cost Housing

Introduction

Building materials account for 70-75% (Table 1) of the total cost of construction. Due to large-scale construction programmes in the country, the demand for conventional building materials like cement, steel, bricks and timber has outstripped their supply. Moreover, the exponential population growth and the existing housing shortage have made the situation even more alarming. There is a general shortage of conventional building materials like cement, steel, bricks and timber in different parts of the country. In 199[illegible], there was an estimated shortage of 55,000 million bricks, 17 million tonnes of cement, 285 million tonnes of stones, 2.7 million tonnes of steel and 13 million cu.m. of timber. It is thus quite obvious that the present available stock of building materials in the country is not in a position to meet the evergrowing demand of housing. In the present situation, the country has very little option but to rely increasingly on locally available cost-effective building materials and components. The R&D efforts undertaken in the country by various research organisations like CRBI, Roorkee; SERC, Madras; National Council for Cement and Building Materials (NCB), Ballabgarh; Central Fuel Research Institute (CFRI), Dhanbad; NBQ and BMTPC have led to development of various low cost, low energy consuming building materials using several industrial and agricultural wastes. There is considerable potential for exploitation of the agro-industrial wastes for their commercial production and large-scale application in construction programmes.

Table 1
Average cost break-up of building construction

Materials (73%)		Labour (27%)		Component-wise (100%)	
Cement	18%	Mason's wages	10%	Foundation	10%
Iron & Steel	10%	Carpenter's wages	5%	Walls	30%
Bricks	17%	Unskilled labour	12%	Roofs	25%
Timber	13%			Doors & Windows	15%
Sand	7%			Flooring	10%
Aggregate	8%			Finishing	10%

Substitute for Scarce Materials

Research findings of various research institutions like CBRI, NCB and CFRI, etc., have led to introduction of number of alternative building materials like hydrated lime, asphaltic corrugated sheets, cellular concrete, flyash bricks, plastic pipes, secondary species of timber, pozzolana cement and overhead tanks, etc. The NBO had prepared feasibility reports for setting up plants for manufacture of such building products. Application of these substitute materials have resulted in the saving of scarce materials like cement and steel. Some of the alternative materials for low cost housing are discussed below.

Hydrated Lime

It is normally assumed that 70% of the cement produced is consumed in building construction out of which 40% is used for masonry mortars and plasters. Out of this, quite a large percentage of cement can be profitably replaced by lime alone or in conjunction with pozzolana.

In recent times, the use of lime in building construction has decreased due to the varying quality of material available in the market and its inherent defect such as slow-setting and laborious preparation of mortars.

An innovative process of hydration of lime has been developed which makes available hydrated lime in dry form, standard quality and ready to use form as in the case of cement. It can be stored in bags for 6 months without any deterioration. NBO had set-up a demonstration-cum-production unit for demonstrating the production of standard quality hydrated lime and lime pozzolana mix in 1976. Consequently, over 50 hydrated lime plants of total capacity of half a million tonnes have been established in various parts of the country over the past one decade. These plants include 3 plants set up by public sector construction agencies, one each at Srinagar, Itarsi and Raipur. It is estimated that 1 million tonnes of cement in building construction could be substituted by the materials produced in the aforesaid units with anticipated saving of over Rs. 20 crore per year.

Lime Pozzolana Mix

The clay pozzolana, available in the market, is known as surkhi' which is produced by grinding brickbats and is of variable quality. A new process of production of clay pozzolana has been developed in which clays of suitable specifications are caloried to the optimum temperature and then ground to a fine powder as per the IS specifications. The pozzolana, reactive surkhi, has lime reactivity 5 to 10 times that of ordinary surkhi made powdering burnt bricks.

The lime pozzolana mix conforming to LP-20 as per IS: 4098 is made by grinding the mixture of hydrated lime, and clay pozzolana with a small percentage of gypsum/sodium metasilicate, etc. to improve their early characteristics. The investment required in production of hydrated lime/lime pozzolana mix is about Rs 200 to Rs 250 per tonne as compared to a heavy investment of Rs 1,400 per tonne required for production of

Ferrocement

Ferrocement is a highly versatile form of reinforced concrete made of cement mortar and wire mesh reinforcement and possessing unique blend of strength and serviceability. The major advantages accruing from its usage include thin and light structure, the ease with which it can be cast, its amenability to repairs in case of local damage, considerable saving in formwork and saving in cost.

It is one of the possible substitutes for timber. It can be moulded into any shape by applying suitable techniques. Partitions, doors, cupboards, service core units, decorative walls, ceiling units in various designs and water tanks are some of the items which could be made using ferrocement without any difficulty.

Designs have been developed by SERC, Madras for ferrocement water tanks (Fig. 6.1) of 800 litres, 5,000 litres, 7,500 litres and 10,000 litres capacity. These tanks are economical compared to the traditional brick-walled water tanks upto the extent of 30%. They have been successfully tried out in many locations in India. It is estimated that about 5,000 ferrocement water tanks are being produced every year in Madras alone both in public and private sectors using the SERC technology.

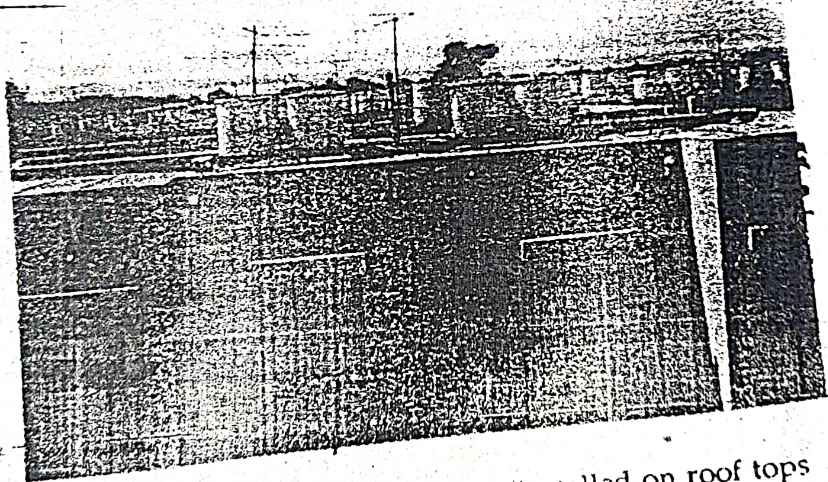

Fig. 6.1 Ferrocement water tanks installed on roof tops

Of late, ferrocement is also being experimented for the production of cyclone and earthquake resistant core units.

Gypsum Boards

Gypsum board is ideal substitute for conventional building boards in all types of buildings. It can be used in several applications like panelling, wall-covering, partitioning and false ceiling. It can give the effect of brickwork or a smooth finishing like Plaster of Paris. Gypsum board is fire proof. It weighs one-tenth of the normal brick, the actual weight being between 6.5 to 15 kg/m² depending upon the thickness.

It is easy to use as it can be nailed, cut and screwed with ordinary tools. Such boards are available in thickness of 9.5, 12.5 and 15 mm, width of 600, 900 and 1,200 mm, and length of 1,800 to 3600 mm.

Timber Substitution

There is presently an acute shortage of good quality timber due to which timber prices have been skyrocketing. This is mainly because usually only half a dozen conventional or primary species of timber such as teak, deodar, sal, shishum and rosewood, etc., are preferred in building construction on account of their durability, decorative appearance and high strength properties. The availability of primary species of timber is rapidly dwindling due to fast depletion of the forest reserves in the country and the phenomenal rise in population over the past few decades. Other factors are slow rate replenishment of the felled timber, and the increasing awareness among the people regarding the importance of maintaining ecological balance. A survey of forest reserves conducted recently reveals that about 27 million acres of the world's forests disappear every year. Half of world's original forest has already vanished. At this rate, it is estimated that global forests will completely disappear by 2020 AD. In India, in 1900, forests covered 40% of the land area. As a result of unabated deforestation during the current century, the present level of forest cover in the country has come down to the level of less than 13% of the land area.

Due to sharp rise in prices of timber, the joinery work component in construction of a new house has now a share of 20-25% in the total cost of construction. The present annual requirement of wood is estimated to be about 13 million tonnes (MT). Against this, a supply of only 6 MT per annum is available. The present demand-supply position definitely points to only towards more and more scarcity of timber in years to come.

Apart from the problems of deforestation and steep rise in the prices of wood, timber has always remained prone to attack by termites, fungi and other organisms. Most of the wood varieties used in India are susceptible to such attack. Teak, rosewood and white cedar are a few of such varieties that are durable and resistant to organism attack to an appreciable extent. However, their high cost inhibits their availability within the reach of common man.

These factors have led to the development of wood substitutes which are cheaper, curbing deforestation, environment friendly and pest resistant. Efforts in this direction have started bearing fruit. The largest construction department in the country namely the Central Public Works Department (CPWD) has already taken a bold step in this direction by banning the use of timber with effect from April 1, 1993. Some of the viable wood substitutes are described below.

i) Secondary Species of Timber

Considerable research has been undertaken in the past by the Forest Research Institute (FRI), Dehradun, regarding exploring the possibility of using lesser known varieties of timber in building construction. The FRI has identified 117 secondary species of timber which could be gainfully used in construction after proper seasoning and chemical treatment.

The NBO has promoted use of secondary species of timber in construction through their incorporation in the demonstration houses put up in different geo-climatic regions of the country, under its Experimental Housing Scheme. Some housing boards particularly Tamil Nadu. Andhra Pradesh, Maharashtra, West Bengal, Jammu & Kashmir and Karnataka have set-up integral plants for joinery, seasoning and treatment. It is estimated that 20% of the total timber used in building construction is now secondary timber.

ii) Plywood

Plywood utilises the secondary species of timber. Shelvings of secondary timbers and synthetic resin are the two basic materials. It is universally available in various grades, sizes and thickness. It is used for furniture making, wall panelling, door panels, shelves, cupboards and other household items. Plywood allows easy and quick working as compared to the conventional timber

iii) Metals

Hollow, pressed metal doors and windows have been used in India by major construction departments/agencies such as the CPWD and DDA, etc., over past one decade. These doors and windows possess the advantages of longer life, fire resistance, high fatigue strength, lighter weight, freedom from warping and swelling. Hinges, holdfasts, bolts and nuts are welded to the metal before installation. However, maintenance of such doors poses some problem. It becomes difficult for the house owners to arrange a welding set at later stage of the life span of the doors made of pressed steel.

Another improvement over mild steel doors and windows are the recently introduced galvanised steel doors and windows. Welding has been totally eliminated by assembling the joints in high precision by use of Zamac alloy and weather resistant rubbers. These doors and windows can withstand a cyclone wind velocity upto 190 km/hr.

Aluminium is yet another metal tried out for doors and windows. Aluminium door frames in conjunction with aluminium door shutters are being increasingly used in some prestigious building projects. Such doors and windows have, however, not been able to find wider application in construction of residential buildings due to their higher cost.

iv) Poly Vinyl Chloride (PVC)

Another important wood-substitute that has made inroad at least in metropolitan cities of India is the Poly Vinyl Chloride (PVC). Now PVC doors and windows are being produced in the country by the leading companies in plastic industry like Sinter Plast, the well known 'Sintex' tank producers.

The main advantage of PVC doors and windows are their attractive finish, good insulating properties, freedom from termite or fungal attack, all-out water proofing, self-extinguishing properties in the event of fire, zero maintenance, no need for painting, and longer life. Now, computer-aided design (CAD) is being used to design more stable and versatile PVC doors and windows. Concealed steel reinforcement is being provided in PVC to produce mechanically strong doors and windows. PVC doors are even unaffected by coastal saline air, typical rains or sub-zero temperatures. They are however, recommended more for indoor situations.

v) Precast RCC Frames

Precast RCC frames were first used in some buildings as far back as 1960. Due to the difficulties experienced in fixing of door shutters and the problems associated with their maintenance, their application could not catch up to the desired level of expectancy. Recently, firms like M/s Supriya Wonder Wood Pvt. Ltd., Bombay, have started manufacturing precast RCC frames wherein they claim to have sorted out most of the difficulties earlier experienced with such doors.

vi) Particle Board

Particle board, a wood-based panel product made of wooden particles and resin binder, is also being increasingly used for door shutters. It was first developed during early '40s as a substitute for timber and its primary derivatives like plywood and blockboard. Its use prohibits high wastage related to conversion of forest reserves into sawn timber or plywood. On an average 60% of a fallen tree is wasted in the process of rendering it suitable for building purposes. Use of particle board ensures 100% utilisation of the fallen tree. The particle board industry makes use of the trees belonging to the species like eucalyptus, subabool, and rubberwood, etc., planted under the social forestry programme. Such boards have uniform and plain surface; and can be easily nailed. Several factories are presently manufacturing particle boards in the country. These boards are available in a large number of sizes. They are, however, yet to be used on a larger scale for mass housing programmes undertaken by major construction departments in the country.

vii) Fibre Boards

The most promising wood substitute that possess all the good characteristics of natural wood is fibre board. These boards are manufactured by converting raw material that is 100% agro-wastes like bagasse, cotton stalks, rice husk, jute and corn, etc., into fibres, which are dried, formed into mats, pressed to give uniform distribution of fibres and then bound by a synthetic resin binder. The density that is achieved is very high, in the range between 240 to 1000 kg/cu.m. Such boards are claimed to possess excellent mechanical, moisture-resistant and termite-resistant properties.

Some of the major Indian companies have taken significant steps towards manufacture of good quality fibre-board. The Birla Group has set up a big plant. Nuchem Plastic, another group, has set up a big plant with the Swedish know-how at Tohana (Haryana) with an installed annual capacity of 13 million sq.m. (39,000 tonnes) of fibre boards. The product popularly known as 'Nuwud MDF' is a Medium Density Fibre (MDF) board manufactured from cotton stalks, binder (phenol formaldehyde) and paraffin wax. In this process, the agro-based material is chipped to graded sizes, made into fibres, added with resin binder to form mats and pressed to form MDF boards.

Fibre board is manufactured in varying densities-soft, medium and hard. Soft board can be used for thermal insulation and as a resilient material for floors. Medium density boards are suitable for panelling, wall-linings, ceilings, doors and windows. Hard boards can be used for doors/windows as these are claimed to be water and abrasion resistant. Such boards have the ability to be cut into any size like natural wood. The Bureau of Indian Standards has now evolved a code IS: 12406 for specifications of fibre boards.

Fibre board has been widely used as a viable timber substitute in the USA, Australia and Europe.

viii) Other Substitutes

Besides, the other viable timber substitutes for door/window shutters and frames include ferrocement, expanded polystyrene composite (EPS), polyurethane, polycoir, fibre-reinforced plastic (FRP), fibre glass, glass reinforced gypsum (GRG) composite boards, coircement-composite panels, eucalyptus wood shutters and frames, and cement bonded particle boards. They are still in experimental stage as far as their suitability for various indoor applications in India is concerned. The ferrocement doors have been tried out on relatively larger scale, but its weight inhibits its larger acceptance among the users.

Asphaltic Corrugated Sheet

Asphaltic corrugated sheet (Fig. 6.2) is a low-cost roofing material manufactured by using wastepaper, rags and other road pickings and bitumen. This material is lightweight, water-proof, flexible and vermin proof and available at less than half the cost of cement asbestos roofing sheets. These

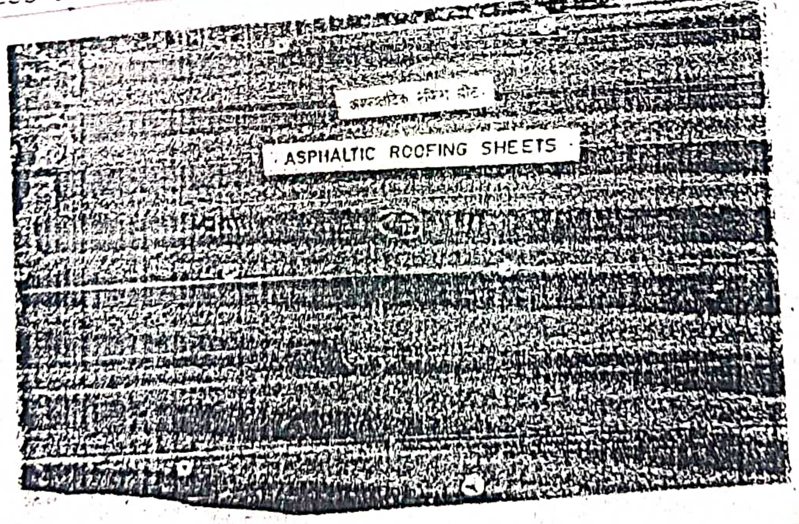

Fig. 6.2 Asphaltic roofing sheet

Industrial Wastes

Flyash

Flyash is the fine residue obtained from thermal power stations using ground or powdered coal as boiler fuel. About 40 MT of flyash (Table 3) is produced annually from as many as 70 thermal power plants in the country. This very fine industrial waste causes not only the problem of environmental pollution but also of its disposal. In India, the total installed capacity of power is around 82,000 MW (megawatts) out of which 60,000 MW is generated from thermal power plants consuming 7.5 lakh tonnes of coal daily. A thermal plant with 1,000 MW capacity for electricity generation produces about 1.5 MT of flyash every year, which is dumped over 100 hectares of land. Research and Development efforts undertaken in many countries in the West over past few decades have led to the development of appropriate technology which could be utilised in the production of Portland pozzolana cement, cellular concrete in combination with lime, lime-flyash bricks, clay bonded flyash bricks and sintered flyash lightweight aggregate, etc. The level of utilisation of flyash in the industrialised countries like France, Germany and the UK has been more than 70% of the total amount produced. Response of the Indian builders towards utilisation of flyash as useful building material has, however, been luckewarm. The poor utilisation level of 5% of the Indian flyash suggests the state-of-the-art with regard to poor utilisation of flyash in the country.

Potentials of Flyash Utilisation as Useful Building Material

The utilisation of flyash as an important building material has been accepted as an engineering reality in the industrially-advanced countries for past three decades. The position with regard to its utility as useful building material in Indian context has, however, been far from satisfactory. This is so despite the fact that the Bureau of Indian Standards (BIS) has already formulated several standards for the manifold application of flyash. Apart from BIS, several R&D organisations like CBRI, NCB, NTPC, NLC, CFRI, NRDC, NBO and BMPTC have also been instrumental in promoting application of flyash as alternate useful building material.

Among several industrial wastes which are presently being tried out for large-scale utilisation in construction activities, flyash occupies the most prominent position owing to its manifold application. Fig. 6.8 depicts the possible areas of application of flyash. A brief account of the important building materials which can be produced from Indian flyashes, is given below.

A) As Pozzolana

Most of the flyash varieties available from the Indian thermal power stations possess the chemical and physical properties required in pozzolana.

Table 3
Annual Production of Industrial and Agricultural Wastes (1993) with their Potential

Waste	Industry	Production (MT/year)	Potential Applications
Flyash	Thermal power stations	40.0	Portland Pozzolana Cement, bricks, light weight aggregate, lime pozzolana mixture
Blast furnace slag	Iron & Steel Industry	10.0	Portland blast furnace slag cement, super sulphated cement, production of lightweight concrete
Phospho-gypsum	Fertiliser, phosphoric and hydrofluoric acid industries	11.0	Gypsum plaster, fibrous gypsum boards and blocks, cement clinker, super sulphate cement
Lime sludge	Paper, sugar, fertiliser, acetylene and tannery industries	4.8	Masonry cement, sand-lime bricks and lime pozzolana mixture
Cinder	Thermal power stations and railways using lump coal	3.0	Lime cinder mortar, concrete buildings blocks
Mine tailings	Zinc, copper, gold, iron ores beneficiation plants	6.0	Calcium-silicate concrete, bricks and masonry cement
Red mud	Aluminium industry	4.0	Bricks, tiles, and lightweight structural blocks and roofing sheets
Water works silts	Water works	10.0	High strength bricks, cement, and lightweight bloated clay aggregate
Limekiln rejects	Limekilns quantity	3.0	Masonry
Coal washery reject	Coal washeries	3.0	Bricks, lightweight aggregate, fuel substitute in burning bricks
Rice husk	Rice mills	25-30	Particle boards, roofing sheets and pozzolana
Coconut husk	Coir-fibre industry	2.0	Particle boards, insulation boards, building panels and roofing sheets
Cotton stalks	Cotton plantation	10.0	Fibre boards, panels and door shutters
Bagasse	Sugar mills	5.3	Insulation boards and wall panels
Groundnut hulls	Oil mills	5.75	Particle boards, roofing sheets and chip boards
Rice straw wheat straw	Agricultural farms	Large	Roofing units, wall panels and fibre boards
Straw mill waste	Straw mills and wood based industries	2.0	Fibre boards, particle boards and insulation boards, etc.

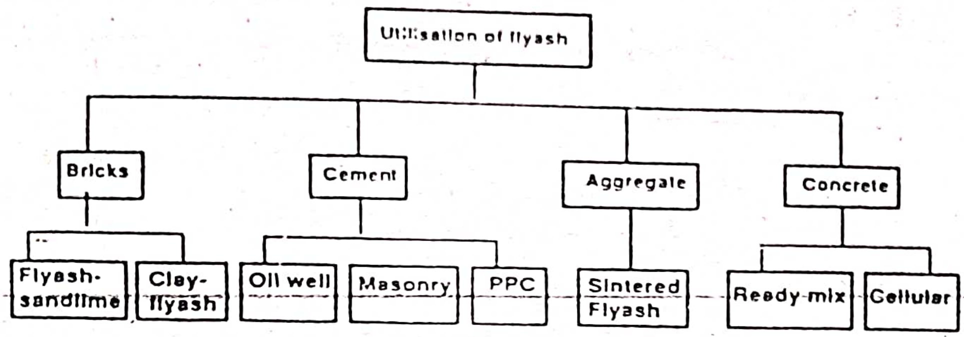

Fig. 6.8 Various utilisations of flyash

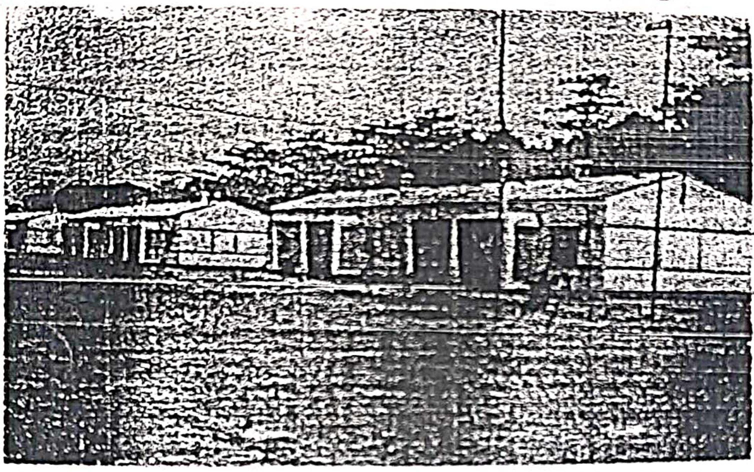

Fig. 6.9 NBO demonstration houses utilising flyash in construction at Neyveli

In fact, the use of flyash as pozzolana is not only economical, but also saves considerable quantity of cement, besides improving the workability of mortar. It has been utilised as partial replacement (upto 20%) of cement in concrete, mortar and plaster in a number of demonstration buildings (Fig. 6.9) constructed at Neyveli, Delhi and Madras under the Experimental Housing Scheme of NBO. Of late flyash has been increasingly used in production of high strength concrete in the USA, Canada and Australia.

(b) Portland Pozzolana Cement

Investigations have been carried out in the country over past thirty years to assess the techno-economic feasibility of the production of flyash-based Portland Pozzolana cement. About a dozen plants have since been producing flyash-based Portland Pozzolana Cement in the country.

The Portland-Pozzolana cement conforming to IS: 1489-1981 can be manufactured by using flyash either by intergrinding Portland cement clinker, flyash and gypsum, or by intimately blending together Portland cement and flyash in suitable proportions. The interginding method is convenient to adopt as it does not require any major addition to the plant and equipment already available at a cement factory.

Portland Pozzolana cement is suitable for use wherever Ordinary Portland cement (OPC) is usable under normal conditions. It produces less heat of hydration, increases water impermeability, reduces alkali-aggregate reaction and offers greater resistance to attack of aggressive waters than OPC. It is, therefore, particularly suitable for marine and hydraulic structures and other mass concrete constructions.

c) Ready Mixed Flyash Concrete

Portland Cement concrete in which a part of the cement has been replaced by flyash is termed as flyash concrete. When it is prepared and supplied to consumers in a plastic, unhardened, ready-for-use state, it is called ready mixed flyash concrete. The process of producing ready-mixed flyash concrete consists of two operations namely (i) proportioning of flyash concrete mix, and (ii) batching and mixing of different ingredients. The flyash concrete is so proportioned as to attain its 28-day compressive strength equal to that of the corresponding plain concrete. The batching and mixing of different ingredients is generally done at a central batching and mixing plant. Sometimes, different ingredients are taken in a truck mixer at the batching plant and so mixed either during the journey or on arrival at the site of delivery.

The ready mixed concrete has the advantage of better quality control, reduction in wastage and pilferage of materials, labour and supervision, which are normally associated with concrete prepared at site.

d) Precast Flyash Concrete Building Units

Flyash concrete has been used in the production of various types of precast building units such as concrete building blocks (solid or hollow), columns, beams, hollow core slabs, door and window frames, etc. It has also been tried out in the production of large number of precast flooring roofing units, such as cored units, channel units and cellular units by making partial replacement of cement. The strength and other structural properties were found to be comparable with those produced using plain cement concrete. In the NBO experimental projects, flyash has been used in precast reinforced channel units and RC lintels with encouraging results.

e) Clay-flyash Bricks

Brick industry is another field in which flyash can be utilised as a major raw material because both clay and flyash are of not much difference in respect of their chemical composition. Furthermore, the residual carbon content in flyashes bring about an economy in fuel consumption during firing of bricks. In the process of brick manufacture from flyash, about 25 to 80% of clay can be replaced by flyash. The clay and flyash are mixed in usual way and the bricks are moulded and fired in the usual way. The bricks thus produced are lighter as the bulk density of flyash is about one half of flyash. Clay flyash bricks have been used in the construction of number of houses at Ramagundam and Kothagundam in Andhra Pradesh. Such bricks are presently being produced on large scale by the West Bengal Power Development Corporation, Ltd. (WBPDCL) near its plant at Kolaghat. In production of Kolaghat bricks, clay and flyash are blended in the ratio of 40 : 60. Recently, CPWD has also used clay flyashs bricks in one of its projects. About 25 million clay-flyash bricks have already been produced in the country by the NTPC and other public sector undertakings and other private brick manufacturers.

Not all the clays and flyashes are suitable for the production of bricks. As regards requirements of flyash for brick manufacturer, it should have oxide composition similar to clay, the SiO_2 content should be over 40%, Al_2O_3 not less than 15%. Fe_2O_3 not less than 50% and sulphide and soluble sulphite content being insignificant.

Recently, M/s Bhanu International, Visakhapatanam, have developed a process of blending flyash, lime and calcined gypsum or phosphogypsum for making concrete hollow blocks, patronised at Fal-G concrete hollow blocks. In Fal-G, the flyash content varies bewteen 65 to 75%, while lime sludge and calcined gypsum together constitute the remaining 25-35 per cent. The Fal-G technology enables production of bricks/blocks with simple process steps of mixing, pressure-free moulding and water curing. It is claimed that apart from the technology being environmental-friendly, the costs are comparable with the conventional products. Over a million Fal-G bricks have recently been used in the construction of 200 houses in Andhra Pradesh.

Fal-G could also be used as a substitute of OPC mortar and concrete. As a thumb rule,1 ½ units of Fal-G cement is to be used against one unit of OPC.

The Government of India has recently finalised plan for setting up of three lime flyash brick plants at Dadri, Delhi and Ahmedabad.

f) Lime-Flyash Cellular Concrete

Lightweight aerated concrete or cellular concrete can be manufactured by a process involving mixing of flyash, quick lime and gypsum in a high speed mixer to form a thin slurry. A small amount of foaming agent such as aluminium powder is added and mixed into the slurry liberating hydrogen gas. The aerated slurry is poured into steel moulds and allowed to set. The blocks are then removed after initial set and autoclaved at steam pressure. After autoclaving, the blocks are allowed to cool and stacked for use.These are considered excellent products for walling blocks and prefab floor slabs. The bulk density of product ranges from 500 to 1,300 kg/cu.m. Such blocks are suitable for load bearing walls in buildings upto 2-3 storeys and partition walls in multi-storeyed buildings. They can be sawn, Chiselled, planed, screwed and nailed like wood. Due to lightweight and high strength to weight ratio of cellular concrete products, their use leads to appreciable economy in consumption of cement and steel. Flyash-based aerated lightweight concrete products are manufactured by the Ballarpur Industries Ltd. at Palwal (Haryana).

Flyash has of late also been used in production of reinforced cellular concrete members. The problem of corrosion of reinforced cement in these units has also been sorted out. The material is suitable for flooring, roofing and walling in common dwellings and multistoreyed buildings.

g) Sintered Flyash Lightweight Aggregate

Conversion of flyash into lightweight aggregate is one of the potential ways of bulk disposal of flyash in an economical manner. Sintered Flyash Lightweight Aggregate (SFLA) with a bulk density of 640-750 kg/cu.m. has been produced in a pilot plant at CBRI. The production of SFLA from the Indian flyashes which was successfully carried out in the pilot plant suggests that the aggregate is suitable for use in the production of structural lightweight concrete and precast lightweight concrete building units for use as load bearing and non-load bearing elements. It has good potential in places where flyash is locally available and stone aggregates are costly.

SFLA is produced by (i) pelletisation of the flyash, and (ii) sintering the flyash pellets at 1,100-1,200°C in a vertical shaft kiln or on a moving grate sintering strand. The technology of production of SFLA and the quality and use of the lightweight aggregate are well tried and proven in the industrialized countries like the USA, Germany, the UK and Switzerland, and may be advantageously adopted in India. This material has bright prospects. It may be worth mentioning here that SFLA has been in use in Europe since its first production under the trade name of 'Lytag' in the UK.

The West Bengal Power Development Corporation Ltd. (WBPDCL) has recently entered into technical collaboration with a Japanese firm for installation of SFLA unit near its plant at Kolaghat.

h) Flyash-Sand-Lime Bricks

Another way to supplement the present shortfall of the traditional clay bricks could be to use flyash for production of flyash-sand-lime bricks commonly known as 'Calcium Silicate' bricks. The production of such bricks is a technically sound proposition and is of particular advantage in areas where good quality brickmaking clay is not available. Costwise, the bricks have, however, been found to be costlier than common burnt clay bricks. This type of building material is very common in many developed countries like Germany, Russia and the Netherlands. Germany has more than 200 factories producing Calcium silicate bricks whereas in India only two factories produce such building material. One is situated near Cochin producing flyash-sand-lime bricks from completely imported know how and machinery. The second plant is located near Calcutta which produces such bricks on small scale with indigenous know-how and machinery. Calcium silicate products consume about 60-70% flyash in their manufacturing process.

The production of flyash-sand-lime bricks consists of four main operations namely (a) preparation of new materials; (b) mixing; (c) shaping or pressing, and (d) curing. The ultimate strength of these bricks depends upon various factors. And the notable among them being (i) nature of raw materials; (ii) moulding pressure, and (iii) steam curing in autoclaves the steam pressure and duration of curing. Initially, flyash and sand are mixed dry and then to this is added hydrated lime in the proportion of 80:10:10 to 60:30:10 by weight, respectively. A small quantity of water is added to the mixture. The slurry so formed is next transferred to the moulds of the press where a moulding pressure of 20-30 N/mm^2 is applied. The green bricks are taken off the press table and loaded on trolleys for onward transmission to the autoclaves (steam curing chambers) for curing at 1.0-1.4 N/mm^2 of steam pressure for 4-6 hours. The cured bricks are then taken out of the autoclave and sent for use.

In April 1994, a flyash-sand-lime brick plant with an installed capacity of 24 million bricks per annum has been set-up at Tribeni (West Bengal).

The plant is to utilise 200 tonnes/day of flyash produced at the Bandel Thermal Power Station.

j) Other Applications

Large quantities of flyash can be gainfully used in laying of sub-base for roads, reclamation of low lying land, filling of mines, treatment of polluted waters and unsuitable soild for agriculture, and embankment. It could also be utilised for mass concreting in construction of concrete dams.

Flyash can be used as land-fill by city authorities. It has been extensively used for the reclamation of low lands at the Farakka thermal project. It can also be used for creating mounts topped with soil for growing grass in landscaping.

Constraints in Large-Scale Utilisation of Flyash

Despite much of R&D efforts undertaken in several research laboratories in the country, the actual utilisation of flyash as useful building material has not been to the extent desired. Some important factors contributing to this phenomenon are listed as below.

i) A major impediment in the large-scale use of flyash is the non-availability of flyash in dry form. As per the practice adopted in most of the thermal power stations, the flyash collected in the Electrostatic Precipitators (ESP) is removed hydraulically. The flyash slurry is sluiced to settling ponds or dumping areas near the plant. The pozzolanicity of the freshly formed dry ash particles is seriously affected once the particles have been wetted. In some thermal power plants where flyash arresting devices such as bag filters and cyclones are non-existent, the ash spreads over a large area through the stacks.

ii) Large variations in the quality of flyash collected from different thermal power plants with consequent adverse effects on its performance.

The nature and quality of flyash generated are greatly influenced by percentage of ash in coal, fineness of grinding and nature of combustion system. In most of the thermal power plants flyash, which does not contain unburnt carbon, is allowed to be mixed with bottom ash. Presence of carbon affects pozzolanic activity of flyash.

Degree of pozzolanic activity in flyashes determines its suitability for use as pozzolana in the production of Portland Pozzolana cement or a part replacement of cement in mortars and concrete at the construction sites. The pozzolanic activity is generally found to increase with an increase in the fineness.

iii) Transportation and handling of flyash from thermal power plants over longer distances pose another serious constraint in its large-scale application.

iv) Non-availability of adequate data regarding quality of flyash

v) High initial investment in setting-up flyash based building material units

vi) Non-incorporation of flyash based building materials in the existing Schedule of Rates and specifications of the construction departments/agencies in the country is also an impediment in its large-scale utilisation.

vii) Widespread reluctance to use of flyash in civil engineering applications is also due to the fact that thermal power plants have not yet accorded recognition to bottom ash and flyash as two distinctly different resource materials for other industries. Once this recognition is accorded, their disposal would acquire a dignified status in the sense that bottom ash and flyash collected from different locations would not be indiscriminately mixed together, and would be suitably collected in the manner as would not destroy their characteristic features, viz, their pozzolanic characteristics and reactivity with lime.

Blast Furnace Slag

Blast Furnace slag is the only industrial waste which so far has found the most accepted application. It is a waste product from steel plants. Presently, India produces more than 10 MT of blast furnace slag out of which 3.5 MT are being granulated for the manufacture of Portland blast furnace slag cement whose present production stands at around 3.15 MT. Small quantities of blast furnace slag are used to manufacture slag wool. It is also used in the road construction in steel plants.

In addition to the manufacture of blast furnace slag cement, granulated slag can be utilised in the manufacture of super sulphated cement which possesses high sulphite resistance. Air cooled slag is suitable as an aggregate in concrete. Slag fines may be used as a substitute for sand without any deleterious effects. One of the important uses of foamed slag which is produced by rapid discharge and treated water jets, finds application in the manufacture of lightweight concrete with a bulk density of 800 to [illegible] kg/cu.m. These foamed slag concrete blocks are used in load and non-load bearing walls. Though potential for utilising blast furnace slag for making foamed slag exists, the field trials have yet to be undertaken. Moreover, the commercial production of the blast furnace slag cement can be increased by increasing the granulation capacity of the slag at the steel plant itself.

Apart from improving the workability of fresh concrete, blast furnace slag cement has high resistance to chemical attack, and its capacity of protecting steel reinforcement makes it suitable for use in reinforced and prestressed concrete.

Red Mud

Alumina red mud or bauxite reject is one of the important inorganic waste materials obtained in large quantities from the aluminium production plants. It is estimated that over 2 MT of red mud is produced annually in the country from the various aluminium plants. The CBRI, Roorkee, has undertaken laboratory and field trials for making building bricks out of red mud supplied from three different aluminium plants in the country. The test results have demonstrated that the physical properties of these bricks made by hand moulding or extrusion are similar to normal building bricks. In many cases a very high compressive strength was obtained due to better fluxing action produced by the red mud. The bricks made from red mud can be made and dried in the traditional manner, and fired in any of prevalent types of brick kiln.

Red mud composition gives bricks pal brown, orange or golden yellow colour depending upon the composition of raw material and firing temperature. They have thus good architectural value as facing bricks in high-rise constructions. Moreover, presence of 4-5% of alkali in the red mud provides good fluxing action resulting into good plasticity and better bond characteristics in brickwork. Production of red mud bricks on commercial scale is however, yet to commence in the country.

Red Mud Plastic (RMP)

The Red Mud Plastic, made by combining polymer (PVC) and red mud waste (from aluminium industry) is an innovative product which overcomes the negative aspects of usage of PVC namely its brittleness and short exposure life. The Red Mud waste is the sludge left after bauxite is refined to aluminium oxide. The Red Mud waste and PVC are combined in the ratio of 25% : 75% to form RMP. Possessing a better heat stability, the material is claimed to possess extra fire and thermal insulation. The inorganic oxides present in RMP add to the flame retarding nature of the base material. RMP is also claimed to be weather proof with a long exposure life. RMP sheets have been successfully adopted in Japan, China and tropical countries.

RMP's characteristics make it a suitable material for roofing and cladding. It has made inroads into Indian market only recently. Half a dozen organisations in the country have acquired the requisite technology for its manufacture. However, only two or three companies in the country have commenced actual production of RMP corrugated roofing sheets since 1986. Its present production is around 4 MT. These sheets are light in weight (2 kg/cu.m.) and available in 1 mm thickness and standard width of little over 1 metre.

Lime Sludge

Lime sludge, which essentially contains Calcium Carbonate with varying amounts of free lime is a waste product from sugar, paper, fertiliser and Calcium Carbide industries. The annual production of lime sludge is approximately 4.8 MT. The utilities of lime sludge for the manufacture of cement and lime have been investigated for commercial exploitation. Besides, lime sludge mixed with rice husk may be used as a cementing material. Further investigations and field trials are required for proper burning of lime sludge in the commercial downdrought kiln and vertical shaft kiln.. Based on the CBRI technology developed for production of masonry cement from lime sludge, three entrepreneurs have been licensed to set-up lime-sludge, base industries in Bihar, Uttar Pradesh and Maharashtra.

Phosphogypsum

Among several alternative building materials available in the country, Phosphogypsum (calcium sulphate contaminated with phosphate) holds a great promise as a substitute building material for building construction. Phosphogypsum is a by-product produced as a solid waste from and fertiliser and phosphoric acid plants. It is the second largest pollutant in the country after flyish. In India, the annual production of phosphogypsum from one dozen phosphoric acid and fertilisers plants is of the order of approximately 5 MT.

Phosphogypsum contains impurities of phosphates, fluorides, alkalies, and organic matter which adversely affect the setting and strength development of plasters/cements produced from it. These impurities exist in phosphogypsum as water-soluble, lattice bound and insoluble forms. P_2O_5, F and organic matter are generally found in the range of 0.40 to 1.5%, 0.44 to 1.5% and 0.11 to 0.60% respectively. For effective utilisation of phosphogypsum, it is essential to develop process for reducing these impurities or to make them innocuous to enable proper and effective utilisation of phosphogypsum as building material.

The CBRI, Roorkee, has evolved several methods ranging from washing and thermal to chemical treatments to reduce/ inactivate the impurities. Wet-sieving of phosphogypsum through micron IS sieve helps in removing the major part of impurities through the rejection of coarse particles in phosphogypsum.

The use of phosphogypsum primarily depends on the extra cost involved in its purification and drying. In the Indian fertiliser industries, companied like Southern Petrochemical Industries Corporation (SPIC), Fertilisers and Chemicals, Travancore (FACT), and FDIL have developed suitable purification techniques and produced useful building materials from phosphogypsum. A small quantity of phosphogypsum is currently used as cement retarder and a larger quantity of it is used as landfull.

The most important application of phosphogypsum is as a raw material for cement and sulphuric acid plants. Beside this, it can be used efficiently for making light weight fibrous gypsum plaster boards and blocks, panels for wall partitioning, slotted tiles for wall cladding, decorative boards for artificial ceilings and for making super sulphated cement. Recently, a durable water-resistant gypsum binder has been developed from calcined phosphosypsum and other additives for use in masonry work, blocks, fibre reinforced boards and plastering for external and internal applications.

The Union Ministries of Chemicals and Petrochemical, Environment and Forests, and Urban Affairs and Employment have joined hands to promote the use of phosphogypsum as a building material in a big way. The first such project is being set-up at Visakhapatnam with the German know-how. Initially, the phosphogypsum-based products are to find their application in official and residential complexes.

Apart from reducing environmental pollution, the gainful application of phosphogypsum as a useful building material as envisaged in the aforesaid project will go a long way in instilling confidence among the entrepreneurs and users in respect of larger application of phosphogypsum based products in building construction.

Cements produced from phosphogypsum have delayed setting and slow rate of strength at early ages, but strengths at later ages (28 days and beyond) are comparable with those of Ordinary Portland Cement (OPC).

Agricultural Wastes

In the rural areas 370 MT of agro-waste is available of which 50 MT comprise cotton stalks, jute stalks, maize stalks and other such crop wastes. Another 50 MT comprise rice husk, bagassse, raw-dust groundnut shells and such small wastes. These could be gainfully utilised as viable building materials.

i) Rice Husk

About 25-30 MT of rice husk is produced annually in the country. The highly reactive pozzolana produced from rice husk and clay may be used for making masonry mortar and plaster of different grades. Rice husk is obtained as a waste material from rice mill.

Investigations have been undertaken with a view to utilising them as a pozzolanic material. Technical know-how has been developed and pilot plant trials carried out at various research institutions in the country like RRL, Jorhat; NCB, Ballabhgarh; and IIT, Kharagpur. The CBRI, Roorkee, has developed a method of production of rice husk based building materials which can be used as a substitute for cement in many ways. Besides, it can also be used for making building blocks and boards with suitable binders. Plants of 2-5 tonnes per day capacity have been set-up in the small scale sector in the rice-producing States in the country for the production of rice husk pozzolana lime binder.

Rice husk being predominently siliceous in nature, has been utilised as on additive with highly plastic soils in reducing the losses during drying of bricks. Experiments undertaken on red and mixed black red soils overlaying Andhra Pradesh, Orissa and Tamil Nadu show that good bricks from these soils which are apparently highly sensitive to drying can be produced by the addition of rice-husk ash upto 30%, and firing the bricks in the temperature range of 1000±20°c.

The National Building Research Station, Karachi (Pakistan) has successfully tried out rice-husk ash (RHA) in combination with lime in production of hollow load bearing blocks, mortar and plaster for construction of low cost houses undertaken by the Institute. Thirty per cent of Portland cement was substituted by RHA in construction of precast lintels and roof beams.

ii) Coir Waste (ناریل کا جٹ)

The production of coconut wast in India is estimated at 2 MT. About 50% of the coconut is used for making coir/mats/cushions, etc. The remaining raw material is mostly used as fuel. The CBRI, Roorkee, has developed a process for making corrugated roofing sheets utilising coir, waste or wood-wool waste and cement. These sheets are light and tough, and possess good-bonding strength having good thermal insulation properties. They are about 50% cheaper in comparison to asbestos cement sheets. So far, two entrepreneurs have been issued licences for production of such sheets in India.

Bagasse

Bagasse is the fibrous residue from sugarcane processing. The estimated annual production of bagasse in the country is around 5.30 MT. Due to its fibrous components, bagasse can be utilised for production of insulation boards and building wall panels with the use of a suitable organic binder. Field trials have been carried out for making insulation boards from this waste material, and indigenous technology is available for production of bagasse-based building products in the country. However, the economy of manufacturing insulation board from bagasse on a commercial scale is yet to be worked out. There is great potential for utilisation of bagasse in manufacture of insulation board in view of the large scale availability of the main raw material which is one of the prerequisites for establishment of the waste based industry.

Other Agricultural Wastes

Furthermore, about 10 MT of cotton stalks, 4 MT of jute stalks, 5.75 MT of groundnut hulls, 2 MT of sawdust (saw mill waste) and 1 million of coconut pith are available in the country for their exploitation as viable building materials. The R&D efforts have been undertaken in the country for the development of building materials, especially for production of roofing units and walling boards by utilising these wastes. However, no indigenous technology has been developed in the country for commercial production of building components based on these agro-wastes.

Future Strategy for Promotion of Alternative Building Materials

Industrial and agricultural wastes like flyash, phosphogypsum, blast furnace slag, red mud, rice husk and coir waste, etc., hold great promise as building materials. Several governmental efforts have been undertaken in recent years the country to popularise use of such materials. Some of the measures initiated in this regard are listed as below:

i) The National Hocusing Policy (NHP) announced by the Government of India in May 1992 has emphasised on economising the use of scarce building materials and promoting use of cost-effective and environmentally appropriate technology and indigenous resources. It also calls for providing an impetus to larger use of materials based on industrial and agricultural wastes by public and private construction agencies. The housing policy also lays stress on incorporation of low cost specifications laid down by the state/central construction agencies. The CPWD has already inducted flyash in their schedule of specifications. Moreover, the NHP advocates earmarking 10% of the total construction by public construction agencies over the use of cost effective technologies and materials.

ii) With a view to providing fiscal incentive to the entrepreneurs willing to undertake manufacturer of building products based on industrial wastes like flyash and phosphogypsum, the Government of India has been announcing fiscal incentives in the past three union budgets. Excise duty has been exempted on materials and components using these industrial wastes as a raw material.

iii) In the Union Budget proposal for 1992-93, further concessions were announced in terms of custom duty reduction on important plant and machinery required to be imported for manufacture of flyash and phosphogypsum based building materials and components. Excise duty was also waived for production of bricks/tiles with 25% or more of red mud (a waste product of aluminium industry) light concrete blocks/components. The excise duty on pre-fabricated building components is also proposed to be reduced to the extent of 5-15% encouraging further use of flyash and phosphogypsum etc., to effect economy in consumption of cement.

iv) Flyash should be accorded the status of a national resource material for the building industry. Presently, clay brick industry is destroying the top fertile soil to the extent of 50,000 acres every year. Gainful utilisation of flyash in production of bricks/blocks could serve the dual purpose of conserving valuable agricultural land and augmenting brick production in the country. Over past few years, there is a renewed awareness with regard to larger application of flyash as useful building material in construction activities. Increased production of clay flyash and lime-flyash bricks/block over recent years bears testimony to the above fact. A Working Group on Flyash Utilisation constituted by the Government of India has strongly recommended commercial utilisation of flyash through manufacture of building bricks. Under the National Policy on flyash utilisation, six flyash brick units are to be set-up in the vicinity of Rajghat and Badarpur thermal power stations in Delhi U.T. The Government of India has recently also finalised a plan for setting up three flyash brick units at Dadri, Delhi and Ahmedabad under the Indo-Dutch co-operation programme.

vi) With a view to promoting use of flyash based products in the country, no new licences for burnt clay kilns should be given within a radius of 50 km. of thermal power stations, unless brick manufacturers start using flyash to replace natural soil, which is fast depleting. A switch-over to flyash-based brick will help save at least 30 to 35% of the useful top-soil.

vii) The HUDCO and NHB are promoting new building materials production units based on agricultural and industrial wastes by participating in the equity of new units. The HUDCO is also extending term-loan support to entrepreneurs for setting-up industry for production of building components based on agro-industrial wastes.

viii) While technologies for making clay bonded sand-lime and phosphogypsum based building products have been developed at the CSIR laboratories, the BIS has either developed or is in the process of developing national standards on such bricks and other applications of flyash and phosphogypsum in construction works.

ix) The Building Material and Technology and Promotion Council (BMTPC), under the Ministry of Urban Development (MUD), has undertaken identification of potential technologies which could help larger utilisation of industrial wastes like flyash, phophogypsum in construction industry. The Council has prepared technical profiles in respect of clay flyash burnt bricks, flyash-sand-lime bricks, cellular concrete components, cement fibre roofing sheet, alumina-red mud bricks and phosphogypsum based buildings components for their larger exploitation in building activities. The Council also incorporates proposals for foreign assistance in areas of building technology. It has also taken initiative in respect of encouraging larger entrepreneurs' interface with financial institutions.

CHAPTER 7

Low Cost Infrastructure Services

Introduction

Housing is far more than shelter. It is both a dwelling and basic community service and facility so essentially required for a wholesome family and community life. The quality of life in human settlements depends on environment, available facilities and resources. The basic needs for human settlements are ample clean air for breathing, potable water for drinking and efficient system of solid, sullage and waste disposal for hygienic and sanitary surroundings. Provision of infrastructure services catering to above basic needs of human settlements forms an integral part of any programme related to housing development both in urban and rural areas.

Present Status

The present position with regard to available infrastructure services in both cities and villages in most of the Third World countries is far from satisfactory. Large population growth and excessive influx of the poor migrants from villages to cities have to a large extent, degenerated civic life in major cities. The pressure of population and acute housing shortage in cities have overstrained the existing infrastructure services in cities, specially in metros.

According to the World Health Organisation (WHO), over 1.3 billion people in the developing world gained access to safe water for the first time in the preceding decade during the International Drinking Water Supply and Sanitation Decade (IDWSSD) launched by the United Nations with the primary objective of providing impetus to the programmes of water and sanitation worldwide. Some 750 million gained access to improved sanitation facilities during the said period. Yet in 1990, over a billion rural and urban residents were still without safe water supply, and nearly two billion lived without proper sanitation. According to the ESCAP report on 'State of Urbanisation in Asia and Pacific,' only 42% to adequate sanitation. In slum areas, these percentages plummet to 20% for water, and 11% for sanitation. Surveys carried out by the National Institute of Urban Affairs (NIUA) indicate that one-fourth of the urban residents in India do not have direct access to safe drinking water, and over half lack access to safe sanitation. According to the WHO Commission on Health and Environment, only 210 of India's 3,768 towns and cities have partial sewage and treatment facilities with only eight having the privilege of full facilities. Moreover, about 20% of the urban population is still without provision of water supply.

The position in villages is still worse. In 1988, drinking water supply through tap was available to only 15% of the households. Inadequacy of services in the countryside is further evidenced by the fact that according to the 44th Round of NSS (1988-89), around 89% of the rural households did not have sanitary latrines.

Technological Options

Over past three decades many cost-effective technological options have been evolved in several developing countries in respect of supply of potable water, provision of sanitary latrines in homes, drainage of waste water sewerage system, collection and disposal of garbage and improvement of environment in housing and human settlements. Brief description of the available cost-effective technological options which could lead to environmental upgradation in housing and human settlements is given below.

Low Cost Sanitation

The modern technological solutions offered for improving sanitation and environment for built-up areas and new settlements in metropolitan cities, small and medium towns, and villages are varied in nature and magnitude. A study published in 1980 by the World Bank identified over 20 systems for sanitation, varying from simple on-site latrines to water-borne sewerage. Out of 20 only three systems have been found appropriate for adoption on mass scale in India. Water-borne sewerage represents a high level of user convenience but it is extremely costly, and demands large quantities trouble-free operation. Sanitation, more than any other infrastructure services, offers prospects for reducing costs through the use of alternatives conventional sewerage.

As a result of the sustained research undertaken in the field of low cost sanitation, within and outside the country, different types of low cost sanitary latrines have been developed which can be adopted depending upon their appropriateness to local situation. Criteria for selection of a particular type of sanitary latrine for a specific community is guided by certain factors such as soil conditions, cost, technical assistance, housing condition, and cleaning material, and at times the requirement for mannure. Pour-flush latrines and twin leach pit (Fig. 7.1) systems have proved to be among the most successful of the low-cost sanitation systems. Unlike other wet on-site systems of sanitation, such as aqua privies and septic tanks, they are inexpensive. They are widely used and promoted in the South Asian countries including India, and efforts to introduce them in parts of urban Africa have had encouraging results.

Sulabh International, a non-governmental organisation (NGO) engaged in the cause of liberation and rehabilitation of scavengers in the country has constructed over 7,50,000 Sulabh Shauchalayas (pour-flush tanks) in towns all over the country. Under a low-cost sanitation programme

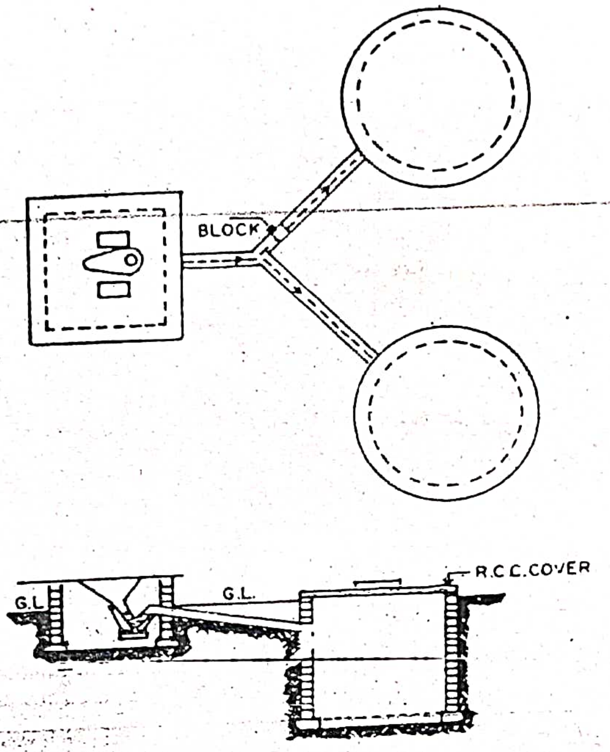

Fig. 7.1 Sulabh Shauchalaya (Double-pit pour flush latrine)

launched by the Central Government, under the aegis of HUDCO in 1989, some 2,34,066 dry latrines are being converted into pour-flush water seal latrines thus leading to liberation of 16,431 scavengers. Under 'Bhangi Kashta Mukti Yojana,' launched in Gujarat in 1968, more than 1,50,000 service latrines have so far been converted into pour-flush water seal toilets with leach pits for treatment of human excreta. Such toilets have worked well over a period of 16 years, and have stood the test of time.

Septic tanks, despite their high costs, have been widely adopted in high-income areas in developing countries, and the use of a single tank to serve many households has been found to reduce considerably the cost of this form of this form of sanitation.

Community toilets have been tried in many developing countries. Public motivation and education programmes are often necessary to ensure the success of such toilets. The Sulabh International has put up more than 3,000 community toilet-cum-bath complexes in 625 towns spread all over the country. The 'pay-and-use' concept of community toilets promoted by 'Sulabh International' has been recommended by the World Bank for adoption in 19 countries in South-East Asia, Africa and Latin America. 'Sulabh (Fig. 7.2) is an ordinary pour-flush latrine to look at, but for especially designed slopy pan which requires no more than two litres of water to flush exereta against 12.5 litres required in case of a normal flush toilet. The two covered pits receive the excreta in rotation so that only one is used at a time. This twin-pit combination is claimed to last for at least 100 years.

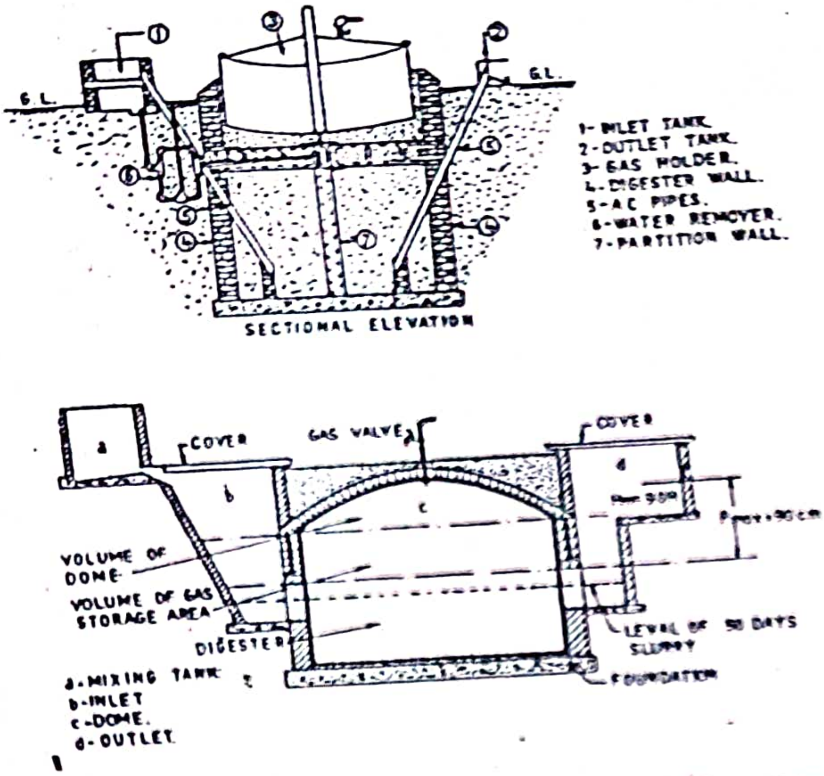

Fig. 7.2 Common designs of biogas plants

Among the other notable developments in the field of low-cost sanitation is the 'Shallow-sewer' system for urban slums, which was initially developed in Brazil for its application in a high density squatter settlement. The system consists of sewers laid at a shallow depth (30 cm) cover and away from imposed vehicular loading) with small inspection chambers used to replace manholes. Such a system has been successfully operated in many squatter settlements in Brazil and Pakistan. The Orangi (Karachi) Project involving community participation has successfully made use of the 'Shallow-sewer' system under its slum upgradation programme. Orangi is Karachi's largest squatter settlement with a population of nearly 1 million. Almost 75% of the households in Orangi have sanitary latrines connected to an underground disposal system-a low cost design costing less than US $50 per household, and built by the resident's with supervision from a community development group. The above project has served as a model for other slum upgradation programmes undertaken by several municipalities in Pakistan.

In Delhi, over 100 mobile toilet vans (MTVs) have been installed in several slum pockets to improve sanitation in such areas. Each of these vans is equipped with some 10 WCs, each WC, in turn, being capable to handle about 100 persons.

Domestic Waste Disposal

Proper collection and disposal of domestic waste and garbage are essential for preventing the environmental degradation in any human settlement. Many refuse-collection systems are in vogue in different parts of the world. The level of refuse-collection also varies considerably. Door-to-door collection facilities are often provided in high income areas, while communal storage facilities are the norm in low-income settlements.

The characteristics of a particular refuse determine the appropriateness of collection vehicles and the system for its treatment and disposal. A variety of containers are used for storing domestic refuse, varying from plastic and paper bags through bamboo or straw baskets, to metal containers, cardboard boxes, and the like in different parts of the world.

Masonry storage facilities are a popular method of collection of domestic wastes in developing countries. Large capacity (5-10 cu.m.) roll-off containers capable of being loaded directly on to the refuse vehicle have been successfully used as an alternative masonry storage facilities, and a range of such vehicles and containers has been introduced in many developing countries.

Open dumping accompanied by incineration is the most prevalent form of disposal in developing countries. Of the various processes available for waste treatment and disposal, only sanitary landfill and, in some cases, composting are economically feasible in most developing countries. The high organic content of developing country refuse (which reach upto two-thirds of total weight) makes composting a feasible option. In Bangalore and Delhi vermicompost is produced out of organic wastes through their decomposition by earthworms. The compost thus produced is a rich manure for better agricultural yield.

In India, pellets made out of organic wastes have been tried out as an alternative source of fuel. Plants producing such pellets have been set-up in Madras, Bombay, Bangalore and Baroda.

Water Supply

Provision of safe and adequate drinking water is not only essential for survival but also for healthy living. Pressure of overurbanisation in our urban centres especially the metros has led to the situation of extreme inadequacy on water-supply front. This is borne out by the fact that against the per capita water requirement of 225 litres daily, the actual per capita supply of potable water to residents of Madras is only 78 litres daily. In Delhi and Bombay, level of water supply is of the order of only of 172 litres and 136 litres respectively. In the overall scenario, in Delhi, against the requirement of 2838 mld (million litres daily), there was supply of only 2498 mld in 1994, leading to a shortfall of 340 mld. Bombay had a supply of 2538 mld against a demand of 3360 mld. Ahmedabad gets only 432 mld against a demand of 535 mld.

Population growth of cities has already led to exhaustion of available water resources. Over-exploitation of surface and ground water resources have forced the authorities to look for distant sources. In Bombay, water is supplied from various sources located 29 km to 120 km away from the city. The acute water shortage in the city of Madras has affected its growth and development. A special train named 'Water Express' brings water for the citizens of Madras.

Discharge of untreated industrial and domestic waste water into water bodies has deteriorated the quality of water resources. The city of Delhi has already exhausted the water of river, Yamuna and converted it into a 'perennial drain'. During 48 km journey of Yamuna through Delhi, 1198 million litres of water is withdrawn from the river, and as much as 1489 million litres of sewage gets dumped into the river every day.

In keeping with the spatial expansion of cities, the water supply network has also been expanding. In some parts of cities, especially the old city areas, the pipes are very old and get corroded and develop cracks over a period of time. Consequently, the city sewage enters the water supply system contaminating the water flowing through it. Every year there are a number of incidents of cholera, gastroenteritis and other water borne diseases. The city authorities that are already lagging behind in meeting the demand of potable water, find it difficult to replace the old pipes. Recently, the Municipal Corporation of Delhi (MCD) has set aside Rs 6 crore for replacing pipes in the walled city of Sadar-Paharganj areas.

Accelerated Urban Water Supply Programme (AUWSP)

With a view to improving the position with regard to supply of potable water in the less privileged smaller towns, the Government of India introduced Accelerated Urban Water Supply Programme (AUWSP) during the Eighth Five-Year Plan (1992-97) for towns having population of less than 20,000 (1991 Census). The cost of implementation is to be shared between the Centre and State in the ratio of 50:50. There are approximately 2,251 towns in this category and the provision of funds required on pro-rata basis is estimated at Rs. 2,000 crore approximately. As against this, the provision of Central assistance earmarked for this scheme during the Eighth Plan is Rs. 50 crore.

Rural Water Supply

As regards rural water supply position, only 41 per cent of the rural population on global scale have convenient access to safe drinking water supplies. In most of the developing countries in Asia, the percentage of rural population covered with provision of safe water supplies is a meagre 26. Open wells, ponds, streams and rivers still continue to be the traditional sources for water supply in majority of the Indian villages.

According to the IMRB study in India, the traditional open dugwells continue to be the primary source of water for all purposes including drinking water. The handpump comes next. The dugwell-handpump-tap is generally the order of preference. Nearly 10 per cent of the households collect drinking water from exposed sources such as ponds, lakes and canals.

Accelerated Rural Water Supply Programme (ARWSP)

With a view to meeting the requirement of water supply in the villages without no safe sources, the Central Government introduced the Accelerated Rural Water Supply Programme (ARWSP) in 1972-73 to assist States and Union Territories with 100% grant-in-aid to implement schemes in su villages. This programmes continued till 1973-74, and when in 1974-75, the Rural Water Supply Programme was introduced under the Minimum Needs Programme (MNP), the ARWSP was discontinued. In 1977-78, when the progress of supply of safe drinking water to identified problem villages was not as per expectations, the ARWSP was reintroduced to augment efforts under MNP.

In order to ensure maximum inflow of scientific and technical input into the rural water supply sector and thus to deal with quality problems of drinking water, the National Drinking Water Mission (NDWM) was launched in 1986. The government has since renamed the National Drinking Water Mission as the Rajiv Gandhi National Drinking Water Mission (RGNDWM).

As a result of top priority being accorded to the rural drinking water supply programme which meets one of the basic needs of the rural people, the outlay in the eighth plan has been kept at Rs. 5,100 crore under the Central Sector and Rs 4,954.52 crore in the State Sector MNP. The concerted governmental efforts have led to provision of at least one safe source (of water) in majority of the villages (total 5,83,003) in the country.

Energy

There is an increasing pressure on the conventional sources of energy due to steep rise of population growth in developing countries. Moreover, there is also the question of affordability of the available traditional sources of energy for the poor in rural as well as urban agglomerates. Recent techno-

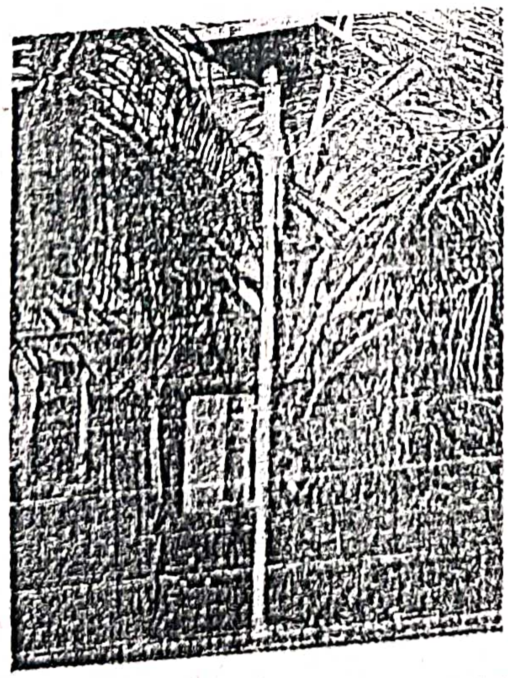

Fig. 7.3 "Stand-alone" street light for rural area (*Source*: PHEL, New Delhi)

logical advancements have provided some solution in this regard. There have been number of innovations in the field of non-conventional sources of energy which could be gainfully utilised by both the rural poor and the urban poor as well. Some of the viable sources of energy suitable for adoption by households in villages and towns are described below.

i) Biogas Plant

The normal method of disposing of animal dung is to dry it into cakes for burning it, as fuel which not only leads to insanitary conditions in the house and the neighbourhood but also deprives the agricultural land of an excellent inorganic manure. Animal dung contains ingredients which could be exploited for fuel and manurial values. In recent years, over 2 million biogas plants have been installed in a large number of villages across the country. The gas produced out of such plants is used as fuel for cooking food in homes and also for the purpose of street-lighting (Fig. 7.2). As fiscal incentive, the Union Ministry of Non-Conventional Energy Sources (MNES) makes available a Central subsidy to the tune of 25-40% of the cost for installation of family-size biogas plants.

The Sulabh International has also experimented with human excreta. The gas produced in biogas plants containing human excretas has been utilised for street light of a major thoroughfare in Patna. The organisation has since set-up 61 night-soil based biogas plants in different parts of the country.

Since the launch of the National Project on Biogas Development in 1981-82, over 2.1 million biogas plants have been set-up across the country. Uttar Pradesh, Maharashtra and Andhra Pradesh are promoting mainly night soil-based biogas plants.

ii) Solar Energy

Solar energy keeps life's clock tickling on earth. And in today's times with the energy crunch, eyes are increasingly turning to the giant power house in the sky—the Sun. An awesome source of power, solar energy equivalent to almost 75,000 trillion* KWH hits the earth every day. And a mere 0.1% of this staggering figure is sufficient to meet the world energy needs.

In recent years there has been increasing application of solar energy for domestic and community needs. The solar energy can be gainfully used for varied applications such as street lighting in villages and hamlets where transmission costs of electricity from the grid are high, rural domestic and community lighting, water pumping in problem villages—far away from the power grid and installation of solar power plants for whole villages. Solar power is widely used in the remote villages of Madhya Pradesh, Karnataka and Tamil Nadu. By the end of March 1993, nearly 60,000 solar photovoltaic energy systems had been deployed in India's remote areas and the countryside, all designed and made indigenously.

There is a countrywide programme for demonstration and utilisation of solar photovoltaic systems, especially in rural areas. The most common

* 1 trillion = 10^{12}

systems being promoted are 'Stand-alone' street lights (Fig. 7.4) developed by the Bharat Heavy Electricals Ltd. (BHEL). They stand alone without any need of costly overhead or underground transmission lines. This also caters to domestic lighting in villages which are formally covered by rural electrification programme, solar lanterns, solar-powered TV sets and lighting of public buildings like community centres, primary health centres and places where adult literacy classes are held usually at night.

According to the annual report (1992-93) of the Ministry of Non-Conventional Energy Sources (MNES), the target for village street lighting systems which was kept as 5000 was exceeded by 900 upto December 1992, while that for villages power plants of 100 kilowatts was nearly met by setting up plants at 87 kilowatt capacity.

Solar photovoltaic lanterns are gradually becoming a more popular source of domestic lighting. According to an estimate, there are at present (1995) 700 solar lantern users in Maharashtra. The current price of a solar lantern is around Rs 950, which considering that there are no recurring expenses or maintenance charges, and the life of a lantern, if properly handled, is five years at a minimum, is not unreasonable. Even the poorest household incurs more expenditure on lighting during the same period.

Beside this solar heaters and cookers are also being used for domestic application. Application of solar heaters result in saving of conventional sources of energy such as wood, kerosene oil and electricity. The Solar cookers are pollution free. Under a government-sponsored programme initiated in 1982 to address the rural energy problems and commissioned by the MNES, the solar cookers are being promoted in different parts of the country. Till date as many as 3 lakh solar cookers are reported to be in use in different parts of the country.

Smokeless Chulha (Hearth)

Cow dung, charcoal and firewood which are most commonly used as fuel in Indian villages produce a lot of smoke which is very injurious to health. To avoid this nuisance, at the behest of the NBO exhaustive investigations on efficacy of the existing chulhas were undertaken by the Planning Research and Action Institute, Lucknow in 1964. The study had identified some performance-efficient chulhas which could work without causing any smoke hazard. Such chulhas being pollution free, women find them much convenient for cooking. The NBO has promoted such chulhas in the country through their incorporation in cluster demonstration rural houses put up in 81 villages lying in different geo-climatic regions of the country. Each improved chulha saves 700 kg. of fuelwood a year. In recent years, the MNES has been actively implementing the scheme for installing smokeless chulhas in the villages. 19.5 million rural households in the country have already been covered under this scheme. Another 5 million additional households are proposed to be covered during the Eighth Five Year Plan.