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RECYCLING OF SILT FROM STORM WATER DRAINS, SLUDGE FROM WATER TREATMENT PLANT/SEWAGE TREATMENT PLANT AND ASH FROM WASTE TO ENERGY PLANT FOR BUILDING CONSTRUCTION

Submitted to

DEPARTMENT OF ENVIRONMENT
NCT GOVERNMENT OF DELHI

Environmental Science & Technology GROUP
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DISCLAIMER

The Project on RECYCLING OF SILT FROM STORM WATER DRAINS, SLUDGE FROM WATER TREATMENT PLANT/SEWAGE TREATMENT PLANT AND ASH FROM WASTE TO ENERGY PLANT FOR BUILDING CONSTRUCTION carried out by Central Building Research Institute (CBRI), Roorkee. The responsibility of CBRI is limited to the technical advice only on the matter referred to in this report. All procedural, legal or operational concerns, including implementation, supervision and execution at site will be the sole responsibility of the party using this report.

RECYCLING OF SILT FROM STORM WATER DRAINS, SLUDGE FROM WATER TREATMENT PLANT/SEWAGE TREATMENT PLANT AND ASH FROM WASTE TO ENERGY PLANT FOR BUILDING CONSTRUCTION

Awarded by

DEPARTMENT OF ENVIRONMENT
NCT GOVERNMENT OF DELHI, DELHI

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FOREWARD

Municipal and industrial wastes arising from human activities are increasing day by day due to increase in population and urbanization and industrialization. These wastes are generated at a much higher rate in the metropolitan cities like Delhi. In addition to the municipal solid wastes, urban areas in Delhi generated million tons of various other wastes such as silt from storm water drains or nallah cleaning, sludge from municipal water/sewage treatment plant/industrial effluent treatment plants, ash from waste to energy plants etc. These waste get mixed up with MSW at collection or disposal points leading to many problems during their disposal. Further, the indiscriminate disposal of these wastes on land deteriorate the fertile surface soil as well as contaminate ground and surface water, causing threat to both human and animal life. Therefore, effective management and handling of hazardous waste become of paramount importance for protection of human health and environment. Considering the seriousness of the same, the Ministry of Environment & Forests, Government of India, notified the Hazardous Waste (Management & Handling) Rules, in 2008. The objective for introduction of such Rules is to ensure safe management of hazardous waste, generated from different industrial sources. As a disposal option, landfills are also becoming increasingly expensive because of the rising costs of construction and operation.

The importance of utilization of industrial waste used in building sector as ecofriendly building material is widely recognized and reflected by increasing emphasis being placed to reduce pollution and health hazards produced by them. Serious efforts have been made in the past few decades to improve productivity, efficiency and performance of the traditional materials and also to develop new alternative materials. The recycling of industrial solid wastes as substitute for building materials is not only environment friendly but also cost effective alternative way to sustain a cleaner and greener environment.

The present report is based on the utilization wastes like bottom ash from waste to Energy Plants, sludge from STPs/CETPs and drain silt for development of building products like paving blocks and bricks by cold process. The paver blocks and cement bricks have been developed and tested as per Indian standard using OPC as a binding material. The Toxicity characteristics Leaching Process (TCLP) studies has also been carried out as per USEPA for field applications of the products developed.

Hopefully this report will be highly useful for pollution control boards, regulatory bodies, industries, WTEPs, STPs/CETPs, MCDs, IF&C, PWD and other concerned departments responsible for wastes management.

Date: **(Dr. N. Gopalakrishnan)**
Place: Roorkee **Director, CSIR-CBRI**

EXECUTIVE SUMMARY

The environmental problem arising from unscientific and indiscriminate disposal of industrial solid waste is a real menace for the whole society. Solid waste management includes all activities that seek to minimize the health, environmental and aesthetic impacts of solid wastes. Recycling and recovery (treatment/processing) play a large role in solid waste management. It decreases the burden on collection services as well as on treatment and final disposal facilities.

In addition to the municipal solid wastes, urban areas in Delhi generated million tonnes of various other wastes such as silt from storm water drains or nallah cleaning, sludge from municipal water/sewage treatment plant/Industrial effluent treatment plants, ash from waste to energy plants etc.The present investigations deals with utilization of these wastes as replacement of natural fine aggregates and cement as binding materials for development of value added building materials like road paving blocks and bricks. Wastes samples were collected from various plants/area of Delhi, processed, characterized for physical and chemical parameters as per standard methods. Various mix compositions were tried and it was observed that these waste could be utilized in the range of 8-45 % of overall mix composition (13-100 % as replacement of natural fine aggregates) for development of building products as per respective Indian Standards. The toxicity test (TCLP) have also been performed as per US EPA procedure and results show there is no leaching of toxic. All the heavy metals get immobilized in the cement matrix after 28 days of curing and products are found suitable for field applications.

The developed building products at different cement and aggregate content were utilizing wastes have been compared for cost with the conventional products in the market. The cost estimation shows that the selling price of paving blocks in the market is comparable to the products developed. The results also show that the quality of the product in terms of strength is better as compare to the market product. Besides this, the product developed is ecofriendly utilizing waste as fine aggregate which will not only help to reduce the consumption of natural resources but also it will help in conservation of the environment. Further, utilizing waste as building materials will reduce the burden on landfills, helpful keeping the cities pollution free and clean.

CHAPTER I

INTRODUCTION

1.1 GENERAL

The industrialization of the country is associated with generation of large quantities of hazardous wastes (HW) which need to be properly handled and disposed to avoid contamination of soil, ground water and other components of the environment. Therefore, effective management and handling of hazardous waste become of paramount importance for protection of human health and environment. As per CPCB, Delhi, in 2009, there were 36,165 nos. of hazardous waste generating industries in India which were generating 62,32,507 Metric Tonnes of hazardous wastes every year. The category-wise classification of this quantity is as follows:

- Land-fillable HW : 27,28,326 MTA (Metric Tonnes/Annum)
- Incinerable HW : 4,15,794 MTA
- Recyclable HW : 30,88,387 MTA

It is obvious that the recyclable portion of HW is in the range of 49.55 % and is more than other two categories. The land disposable portion and incinerable portion are in the tune of 43.78 % and 6.67 % respectively.

Out of this recyclable waste, major portion (million tonnes) of semi-solid/solid sludge is generated by industrial effluent treatment plants (ETPs), common effluent treatment plants (CETPs) and sewage treatment plants (STPs) during the treatment process comprising of chemical coagulation and flocculation followed by biological treatment and solid/liquid separation. This sludge degrades the environment and poses hazard to both human and animal life, thus causing concerns for their disposal. The indiscriminate disposal of the sludge from effluent treatment plants (ETP) deteriorate fertile surface soil as well as contaminate ground and surface water, which become an important environmental and public health issue. Considering the seriousness of the same, the Ministry of Environment & Forests, Government of India, notified the Hazardous Waste (Management & Handling) Rules on July 28, 1989 under the provisions of the environment (Protection) Act, 1986, which was further amended many times. Recently the Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 were notified by MoEF for effective management of hazardous waste (HW), mainly solids, semi-solids and other industrial wastes, which do not come under the purview of the Water (Prevention and control of Pollution) Act, 1974 and the

Air (Prevention and Control of Pollution) Act 1981 and also to enable the Authorities to control storage, transportation, treatment and disposal of waste in an environmentally sound manner. Under the guidelines for Management and Handling of hazardous wastes, land fill disposal is recommended for inorganic sludge from wastewater treatment plants (MoEF, 1991). The objective for introduction of such rules is to ensure safe management of hazardous waste, generated from different industrial sources. The Rules define various categories of hazardous waste, based on the process listing (waste streams) and concentration of hazard components.

Besides collection, transport and storage of wastes, construction of secured land fill sites pose problems of land acquisition, high land and construction cost, closure of site, environmental monitoring etc. Therefore, it is now a global concern to find a socio, techno-economic and eco-friendly solution to dispose industrial/municipal solid wastes. The recycling of these solid wastes as substitute for building materials is not only environment friendly but also cost effective alternative way to sustain a cleaner and greener environment. The usage of sand, silt, stone, gravel, lime, clay, gypsum, etc. as building materials and manufacture of other building materials such as brick, cement, etc. depletes the existing natural resources and damage the environment due to continuous exploitation. Considering the environmental concern, the use of industrial solid wastes, especially, use of ETP sludge as a partial supplement to building materials plays an important role and it is gaining a great momentum.

1.2 STATUS OF WASTE GENERATION AND MANAGEMENT IN DELHI

Delhi is located in North India between the latitude of 28^{o} 24'17" to 28^{o} 53' 00" North and longitude of 76^{o} 50 '24" to 77^{o} 20' 37" East. The population of New Delhi has increased tremendously from a figure of 400,000 in year 1901 to around 19,072,564 in 2017. According to 2011 census of India, population of Delhi was around 16,753,235. The municipal Corporation of Delhi (MCD) is amongst the largest municipal bodies in the world providing civic services and has been divided in to five zones. As per the data of Delhi Pollution Control Committee, total municipal solid waste generated from these zones is about 10757.26 TPD (approx. 4.0 million tonnes per annum) and details are given in Table 1.1. A study carried out by WTERI (Waste-to-Energy Research and Technology, 2012) has estimated that Delhi generates 11,500 TPD or 4.2 million TPA solid waste which is the highest among union territories. The per capita generation of MSW in Delhi is approximately 0.5 Kg/capita/day. Apart from MSW, about 1.5 million tonnes per annum of construction and demolition (C & D) waste is also generated in Delhi.

Table 1.1: Municipal solid waste generated from different zones of MCD

Sr. No.	Name of Zone	MSW generated (MTD)
1.	North Delhi Municipal Corporation	4000
2.	South Delhi Municipal Corporation	3600
3.	East Delhi Municipal Corporation	2800
4.	New Delhi Municipal Council	300-350
5.	Delhi Cantonment Board	57.26
		Total = 10757.26-10807.26

For proper handling and management of these wastes, many facilities have been created, installed and under operation in Delhi. The details of these facilities are as follow:

I. Sanitary Landfill Sites

There are total 03 No. of landfill sites in Delhi which are used for disposal of MSW, silt from drains, silt from C & D waste processing facilities, sludge from sewage treatment plants, sludge from effluent treatment plants, bottom ash from waste to energy plants and inert waste from compost plants etc. The status of these sites is shown in Table 1.2.

Table 1.2: Status of landfill sites in Delhi

Location	Year of operation	Area in acres	Height in Meter	Total Legacy Waste in million tonnes
Ghazipur	1984	70	62	Over 14
Bhalswa	1994	40	45	Over 13
Okhla	1996	32	55	Over 5

II. Compost Plants

The status of composting using organic matter from MSW as raw materials has been shown in Table 1.3.

Table 1.3: Status of compost plants in Delhi

Agency/ Department	Existing Capacity with nos of plants	Under Procurement/ process with no. of plants
South DMC	200 TPD- 1 no Compost plant at Okhla	5 TPD- 4 nos 1 TPD- 4nos (6 months) *(biding is in progress in GEM portal) 200 + 200 TPD at Najafgarh (within 15 months) 1 tender called on (04.04.2018) for 200 TPD at Nangli
North DMC	354 pits in 312 parks	UDF-I 1TPD- 6nos (9 months) 5 TPD- 4 nos. (10 months) *(biding is in progress in GEM portal) 100 TPD- 1 no (15 months)
East DMC	113 pits in 113 parks	UDF-I 1TPD- 10nos (9 months) 5 TPD- 2 nos. (10 months) *(biding is in progress in GEM portal) 100 TPD- 1 no (15 months)
New Delhi Municipal Council	Compost plant at Okhla and 102 nos compost pits in various gardens/Parks and four RDF plants with one biomethanation plant of 500 KPD capacity	1 TPD- 1 no Organic waste converter (1 month)
DCB	Composting of horticulture waste in all 17 parks of DCB.	Pilot plant for decentralized composting of Solid waste has been installed with 125 kms/ day

III. Waste to Energy (WTE) Plants

There are 03 Nos. of WTE plants operating in Delhi for processing/disposing off the municipal solid waste and generating power. The status of WTE plants is given in Table 1.4.

Table 1.4: Waste to Energy Plants (WTE) in Delhi

Sr. No.	Name and location of the site	Designed capacity per day (MTD)	Capacity of electricity generated
1.	M/s Timarpur- Okhla Waste Management Company Pvt. Ltd., Okhla	1950 (operated by JITF ECOPOLIS)	16 MW
2.	M/s East Delhi Waste Processing Company Ltd., Ghazipur, Delhi,	1300 (operated by ILF&S)	12 MW
3.	M/s Delhi MSW Solutions Ltd. Narela Bawana Road,	3000 (operated by Ramky Group)	24 MW

IV. Construction & Demolition (C & D) Waste Processing Plants

The status of construction and demolition waste generation and processing in Delhi is shown in Table 1.5. At present there are 02 Nos. of C & D waste processing plants in Delhi which are processing about 2500 TPD of C & D waste for manufacturing value added building materials like bricks, road paving blocks, tiles etc.

Table 1.5: Status of construction and demolition waste processing in Delhi

Agency/ Department	Existing waste Generation	Proposed waste Generation by 2024	Existing Waste processing facility	Proposed Waste processing facility (Expansion/New) with timeline
South DMC	1000 MT	1500 TPD	N.A.	500 TPD at Bakarwala Dec 2018 (Expandable upto 1000 TPD) 500 TPD at Tajpur Pahari by March 2019
North DMC	2000 MT/day approx.	3500 TPD	2000 MT/day at Burari	1000 MT/day (Expandable) at Ranikhera. Likely to be made operational by the concessionaire within 4-5 months.
East DMC	700 TPD	1000 TPD	500 TPD at Shastri park	Additional 500 TPD by June., 2018
New Delhi Municipal Council	100-125 TPD	125 - 150 TPD	Sent to East MCD plant for processing	No Land available for new plant
DCB	40 - 50 MT/ month	N.A.	Sent to East MCD plant for processing	N.A.
PWD	N.A.	N.A.	N.A.	500 TPD at Libaspur & Tikri border

1.3 STATUS OF OTHER WASTES GENERATED IN DELHI

In addition to the municipal solid wastes, urban areas in Delhi generated various other wastes such as silt from storm water drains or nallah cleaning, silt from C & D waste processing, sludge from municipal water/sewage treatment plant/Industrial effluent treatment plants, ash from waste to energy plants etc. The Table 1.6 shows the status of these urban wastes (other than MSW) generated in Delhi. The status of drain silt generation from different departments in Delhi is also shown in Table 1.7.

Table 1.6: Estimates of ash/silt/sludge generated in Delhi

Sr. No.	Type of waste	Quantity (MT Per Annum)	Remark
1.	Silt from drains	404000	MCD, I&FCand NDMC
2.	Silt from C & D waste processing	450000	50 % from 2500 per day C & D waste processing
3.	Sludge from STP/ETP	400000	Estimated on the basis of data received from plants
4.	Bottom Ash from WTE plants	460000	20 % of 6230 MT RDF processed per day
5.	Silt from reclamation of landfill	1800000	60 % of the 30 Million Tonnes accumulated waste in 10 years

Table 1.7: Status of drain silt generation in Delhi

Agency/ Department	Existing silt Generation/ annum	Implementation Status of recommendation of CBRI/NEERI study report	Existing Usage of silt	Any R&D study proposed
South DMC	25000 MT	N.A.	Being dumped at SLF/ Low lying areas	Being entrusted to NEERI for approx 48 lacs
North DMC	11000 MT	Report of CBRI to be given by 25.08.18	Covering of MSW at Bhalswa	CBRI is carrying out
East DMC	60000 MT	N.A.	Dumping of silt at Singhola near Khampur.	N.A.
New Delhi Municipal Council	8000 MT per annum including mechanical road sweeper, silt collection	N.A.	At Okhla sanitary pit	N.A.
IF&CD	300000 MT	N.A.	Is presently used for filling up of low lying area and drain embankment	N.A.

These urban wastes are disposed off in dumpsites/water bodies/low lying areas in the city and most often get mixed up with MSW at collection or disposal points leading to many problems like waste processing, choking/siltation of water bodies, contribution of heavy metal to downstream water users posing suspected threat of Alzheimer's disease etc. Organized processing, recycling/reuse activities are virtually absent for the above wastes and there is an urgent need to find out a techno-economic solution of the problem for utilization/recycling of these wastes to wealth. Therefore, a project entitled "RECYCLING OF SILT FROM STORM WATER DRAINS, SLUDGE FROM WATER TREATMENT PLANT/SEWAGE TREATMENT PLANT AND ASH FROM WASTE TO ENERGY PLANT FOR BUILDING CONSTRUCTION" was formulated by Department of Environment, NCT Govt. of Delhi and quotations were invited along with detailed project report with practical solutions of the problem. CSIR-CBRI, Roorkee has the expertise to utilize industrial solid wastes for the development of building products and submitted the proposal. CBRI proposed to utilize all such wastes as a replacement of natural aggregates for the development of building products (bricks and paving blocks) as per Indian Standards by cold process.

1.4 MAJOR OBJECIVES

The major objectives of the project includes:

- Visit and collection of samples of drain silt/sludge from WTP/STP/CETP/ash from WTE plant
- Physical, chemical and biological characterization of samples
- Feasibility studies for development of building and road construction materials along with suggestion regarding utilization of the silt/sludge/ash by cold process
- Testing of Engineering Properties of the products as per Indian standards
- Leaching studies of the products as per standard procedure (US EPA : TCLP)
- Comparison of the products developed with conventional products available in the market
- Writing of brief techno-feasibility report

CHAPTER II

RAW MATERIALS AND EXPERIMENTAL METHODOLOGY

2.1 RAW MATERIALS

To develop the building products like road paving blocks and cement bricks, main raw materials required are Ordinary Portland Cement (OPC), coarse aggregates and stone dust as fine aggregate/waste materials. The details of characterization of these raw materials are given below:

(i) ORDINARY PORTLAND CEMENT

Ordinary Portland Cement of 43 Grade conforming to IS: 8112: 1989 has been used as binder for development of paving blocks and bricks. The physico-chemical properties of the OPC have been analysed as per IS: 4031(1988) and 4032 (1985) and are shown in Table 2.1.

Table 2.1: Physico-chemical analysis of cement (43 Grade)

Parameters	Values
Physical Properties	
Loss on ignition	3.8 %
Consistency	31.5 %
Soundness	1.0 mm
Bulk density	1.4 g/cm^3
Initial setting time	170 min
Final setting time	305 min
Specific Gravity	3.14
Compressive strength (28 day)	49.0 MPa
Chemical Properties	
SiO_2	21.50 %
Al_2O_3	5.10 %
Fe_2O_3	3.66 %
CaO	61.31 %
MgO	2.9 8 %
SO_3	3.02 %
Insoluble residue	4.36 %

(ii) CHARACTERIZATION OF COARSE AGGRAGATES

The locally available natural crushed stone, generally of quartzite type has been used as coarse aggregate of maximum 12.5 mm size for development of paving blocks. The particle size distribution, physical and mechanical properties of coarse aggregates determined as per IS 2386:1963 are given in Table 2.2. The grading curves of coarse aggregates along with minimum and maximum limits of IS 383:1970 are also shown in Fig. 2.1. Oven dried aggregates has been used though out the studies.

Table 2.2: Physical and mechanical properties of coarse aggregate

Sr. No.	**Properties**	**Value**
1.	Flakiness index	9.1 %
2.	Elongation index	12.5 %
3.	Water absorption	0.40 %
4.	Specific gravity	2.70 %
5.	Bulk density	1.560 g/cm^3
6.	Crushing value	13.2 %
7.	Impact value	9.5 %
8.	Particle size distribution **Size** 20 mm 12.5 mm 10 mm 4.75 mm 2.36 mm 1.18 mm 600 µm 300 µm 150 µm	 **Passing (%)** 100 92 22.4 1.4 0.1 0.1 0.1 0.1 0.1
9.	Fineness modulus	6.84

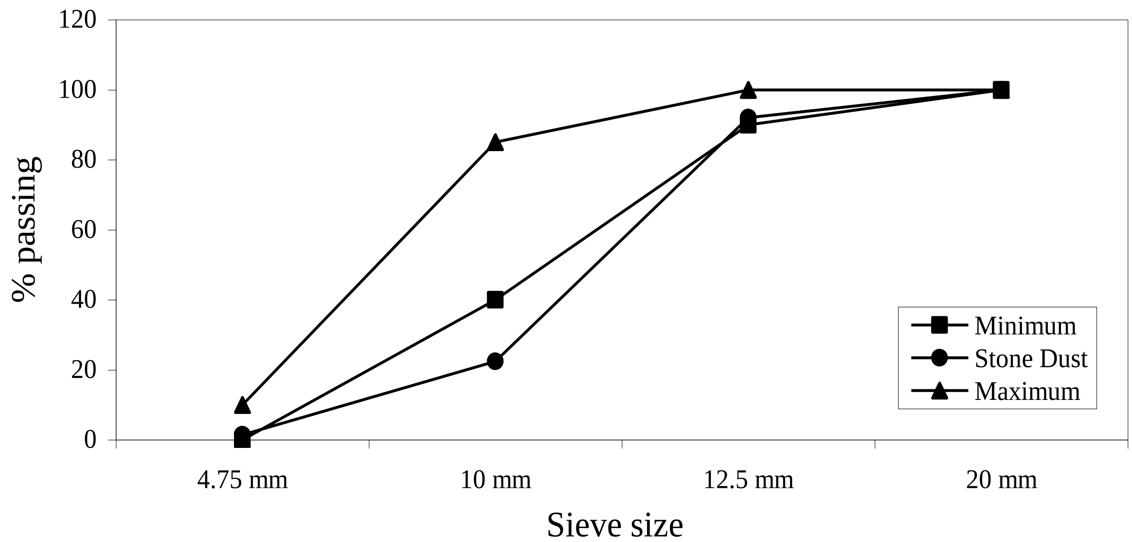


Fig. 2.1: Grading curves of coarse aggregates

(iii) CHARACTERIZATION OF FINE AGGREGATES

Stone dust as a local material complying with the particle size requirements of IS 383: 1970 has beeen used as natural fine aggregates (NFA) for fabrication of blocks and bricks. The physical properties (IS 2386:1963) and particle size distribution of stone dust are shown in Table 2.3. The grading curves of stone dust has also been shown in Fig. 2.2 along with minimum and maximum limits as specified in IS: 373: 1970. It also indicates that stone dust is within the limit of IS: 373 and falls in Grading Zone II.

Table 2.3: Physical properties of fine aggregates

Sr. No.	Properties	Value
1.	Specific gravity	2.7
2.	Water absorption	4.50 %
3.	Bulk Density	1.5 g/cm3
4.	**Particle size distribution**	
	Size	**Passing (%)**
	10 mm	100
	4.75 mm	99.75
	2.36 mm	76.65
	1.18 mm	54.35
	600 µm	44.5
	300 µm	33.0
	150 µm	16.55
5.	Fineness modulus	2.7

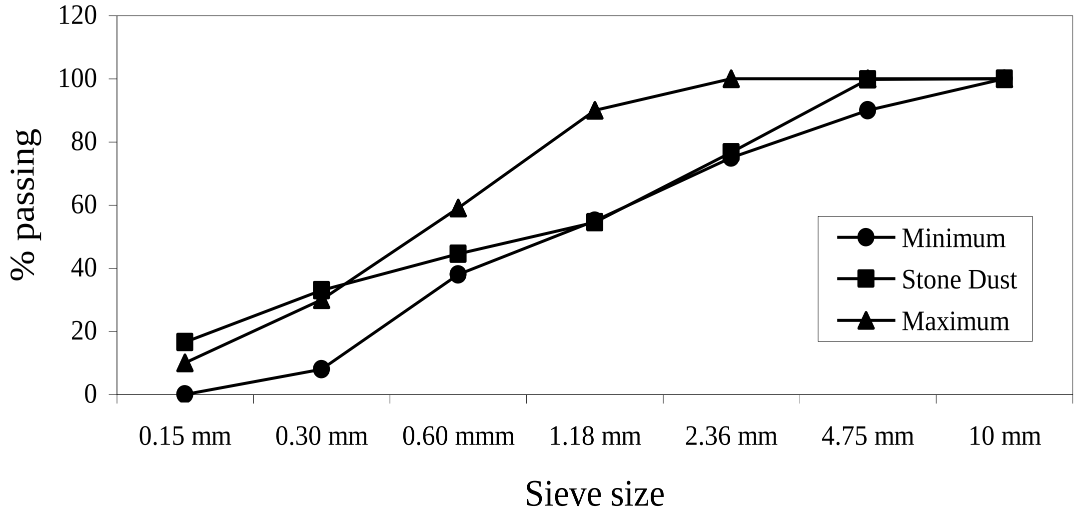


Fig. 2.2: Garding curves of fine aggregate (stone dust)

(iv) WASTE MATERIALS

The characterization of waste materials like waste to energy (WTE) plant ash, sludge from sewage treatment plants (STPs), and sludge from combined effluent treatment plants (CETPs), and silt from drain used as fine aggregates are given in respective chapters.

2.2 DEVELOPMENT OF ROAD PAVING BLOCKS

The fabrication of road paving blocks has been carried out using compaction method following the procedure and specifications described in IS: 15658: 2006: Precast concrete blocks for paving-specifications. Since zero slump concrete is used in production of paver blocks, the quality of blocks will depend upon various parameters like the capacity of compaction and vibration of machine, grade of cement used, water content, quality of aggregates used, their gradation and mix design adopted, handling equipment employed, curing methods adopted, level of supervision, workmanship and quality control achieved etc.

Two layered paving blocks has been fabricated using cement, coarse aggregates, stone dust as fine aggregates and water. The top layer consists of cement and stone dust in the proportion of 1:2 with 9.0 % of water content. The composition of top layer has been kept constant in all the mixes through out the study. For fabrication of bottom layer, various trial mix have been done using cement, waste materials (ash, sludge from CETP's and STPs plants and drain silt) as partial replacement of fine aggregate (stone dust) and coarse aggregate. Water was added as per requirements. The details of concrete mixes are shown in respective chapters.

2.2.1 Mixing, Fabrication and Curing

For fabrication of 200 x 160 x 70 mm block, the desired quantity of cement, stone dust and water was mixed and filled in the mould to achieve the thickness in the range of 4-6 mm. For fabrication of bottom layer, the weighed quantities of cement, coarse and waste material used were poured in the drum mixer and allowed to dry mix for one minutes. Subsequently half of the total required quantity of water was added to the mixture and allowed for two minutes mixing for coating of cementitious layer around the waste particles. Now the measured quantities of coarse and fine aggregates were added in the drum along with balance half of the water and mixed for next 2 minutes. This mix was poured in the mould and compacted using a hydraulic pressure of 50 tonnes for 15 seconds. After demoulding, block was cured for 28 days at a relative humidity of over 90 % and temperature of 25 ± 2^{o}C. The control specimens (A0, B0 and C0) of blocks were prepared without replacement of fine aggregate with waste.

2.2.2 Engineering Properties of Blocks

The physical and mechanical properties of paving blocks like water absorption and compressive strength were determined after 28 days of curing.

(i) Determination of Water Absorption

Water absorption is the measure of permeability and porous nature of hardened concrete and is determined as per method described in IS: 15658:2006. The blocks were completely immersed in water at room temperature for 24 h. After removal from water, blocks were allowed to drain for 1 min by placing them on a 10 mm wire mesh, and visible water was removed with a damp cloth and immediately weighed. Subsequent to saturation, the blocks were dried in ventilated oven at 105±2^{o}C for 24 h. The blocks were weighed after cooling at room temperature to calculate the percentage water absorption. The average value of three specimens tested has been reported.

(ii) Determination of Compressive Strength Blocks

Mechanical property like compressive strength was determined according to the procedure described in IS: 15658: 2006 after 28 days curing. The average value of three specimens tested for each mix has been reported. Before determination of compressive strength, all the specimens were kept for 24 h in water at room temperature of 25±2^{o}C, air dried and tested using a CTM. The maximum load applied was recorded and the apparent compressive strength was calculated by dividing the maximum load by plain area of the block. The corrected compressive strength has been calculated by multiplying the apparent strength with correction factor for thickness and arris/chamfer of paving block according to IS: 15658. The mix having a compressive strength of minimum 20 MPa and water absorption of maximum 6.0 % has been recommended

2.3 DEVELOPMENT OF CEMENT BRICK

The fabrication of cement bricks has been carried out as per specification of IS: 1077: 1992 using OPC, fine aggregates (stone dust) and waste material in various proportions. All the mix were expected to achieve a minimum compressive strength of 5.0 MPa at the age of 28 days. The control (E0) specimens of bricks were prepared without replacement of fine of aggregate with waste.

2.3.1 Fabrication of Bricks and Curing

The bricks of 225 m x 110 m x 70 mm size were fabricated by mixing desired proportions of cement, fine aggregates, waste and water in a drum mixer for 5 minutes. The moulds were filled up and fabrication was carried out using vibro-compaction method with a vibration time of 15 sec. The bricks were removed from the mould, placed at room temperature for 24 h and then cured at a relative humidity of over 90 % at 25±2^{o}C for 28 days.

2.3.2 Engineering Properties of Blocks

The properties of bricks like water absorption and compressive strength were determined following the procedure laid down in IS: 3495 : 1992.

(i) Water Absorption

For determination of water absorption, brick was dried in a ventilated oven at a temperature of 105±2°C till it attains substantially constant mass. After cooling the specimens to room temperature it was weighed and immerse in water for 24 hours. After removal from water, it was allowed to drain for 1 min by placing them on a 10 mm wire mesh, and visible water was removed with a damp cloth and immediately weighed. Water absorption, percent by mass is calculated and the average of three specimens was reported in Table 5.2.

(ii) Bulk Density

The bulk density in g/cm^3 was also calculated by dividing the weight of the specimen with the overall volume.

(iii) Compressive Strength

Mechanical property like compressive strength was determined after 28 days curing and the average values of three specimens tested for each mix were reported. Before determination of compressive strength, all the specimens were stored for 24 h in water at room temperature of 25±2°C, air dried and tested. A compression testing machine was used for determination of compressive strength and the sample was placed horizontally. The upper face of the bricks was capped by 2 sheets of 3 mm thick plywood sheet of size larger than the blocks by a margin of 5 mm from all the edges. he maximum load applied was recorded and the compressive strength was calculated by dividing the maximum load with area of the brick.

2.4 LEACHING CHARACTERISTCS OF BUILDING PRODUCTS

A leaching test involves bringing a waste material in contact with a liquid to determine the components that will be dissolved from the waste. The purpose of leaching tests is to either classify a waste for disposal or to determine leachate quality. Leaching tests are divided into two broad categories depending on whether the leachate is renewed or not:

(i) Batch-leaching test

These tests are also called as extraction test and in these tests, the leachate is not renewed and a specific amount of waste is brought in contact with a specific amount of leachant for a specified period. At the end of test, the liquid is separated from the waste and analysed. These tests are short term, have good reproducibility, are simple to perform, and are often used to simulate the worst case scenario for leaching of the waste. All regulatory leaching protocols specify batch-leaching test (TCLP).

(ii) Column-leaching test

These test are also called as dynamic tests in which the leachant is continuously or intermittently renewed to maintain a constant driving force for leaching. These tests are performed by packing the material to be evaluated in a column and passing a given volume of leachant through the material. These tests provide information about the kinetics of waste dissolution, and they are generally considered to be more representative of the field conditions.

2.4.1 Toxicity Characteristics Leaching Procedures (TCLP)

The leachability of trace elements from the concrete and its products is determined according to U.S. EPA Testing Method 131-Toxicity Characteristics Leaching Procedure (TCLP). This test is recommended by regulatory bodies to estimate the toxicity of the metals viz. Cr, Zn, Mn, Fe, Ni, Co, Pb and Cu for the sludge generated from effluent treatment plants, wire and metal plating industries on environment constituents like ground water, surface water and land. In the present studies, TCLP has been employed to investigate the leachability characteristics of metal contaminants from wastes used for development of building components.

2.4.2 Methodology of TCLP

The TCLP tests were carried out for 28 days cured sample. To conduct the test, a slice of approximately 9.5 mm thick was cut from the mid height of the product. A part of each slice weighing approximately 100 g was crushed carefully using a hammer so that all the particles were <9.5 mm, but the variation on the particle size distribution was not significant. Leaching studies were carried out in severe acidic conditions (pH=~2.88). 200 ml of acetic acid solution were added to the 10 g of sample (liquid to solid ratio 20: 1) in a high-density polyethylene bottle. The bottle and its contents were agitated in a rotary shaker at 30 rpm for 18 h. The leachates were filtered through a 0.45 μm membrane filter to remove suspended solids and the leached solutions were used for determination Cr, Ni, Mn, Zn, Cd and Pb by Inductive Couple Plasma spectrophotometer. Each leachate was analysed in duplicate and average values were reported

CHAPTER III

DEVELOPMENT OF BUILDING PRODUCTS USING WASTE TO ENERGY PLANT WASTE

3.1 STATUS OF WASTE TO ENERGY (WTE) PLANTS IN DELHI

Information collected from Delhi Pollution control Boards (DPCC) shows three Waste to Energy (WTE) Plants have been installed in Delhi and details are shown Table 3.1. A perusal of the table shows that about 6250 MT of MSW is processed per day and approximately 15-20 % bottom and fly ash is generated as a by-product of electricity generation. The management of this ash is going through a critical phase, due to the unavailability of suitable facilities to treat and/or dispose off in Delhi.

Table 3.1: Data pertaining to Waste to Energy Plants

S. No.	Name and location of the site	Designed Capacity	Waste generated
1.	M/s Timarpur- Okhla Waste Management Company Pvt. Ltd., Okhla, Delhi	1950 MT/D (operated by JITF ECOPOLIS), 16 MW Electricity	350-400 MT/day
2.	M/s East Delhi Waste Processing Company Ltd., Ghazipur, Delhi,	1300 MT/day (operated by ILF&S), 12 MW Electricity	230-250 MT/day
3.	M/s Delhi MSW Solutions Ltd. Narela Bawana Road, Delhi	3000 MT/day (operated by Ramky Group), 24 MW Electricity	580-620 MT/day

3.1.1 Silent Features of Waste to Energy Plants

Integrated waste processing facility offers a safe, technologically advanced means of waste disposal while also generating clean, renewable energy, reducing greenhouse gas and in particular methane gas emissions and supporting recycling through the recovery of metals and other recyclable materials. The silent features of WTE plants are as follows:

(i) Sustainable solution to waste management problems

(ii) WTE facilities burn waste in specially designed boilers to ensure complete combustion. The facilities use state-of-the-art pollution control equipment to scrub emissions, preventing them from releasing into our environment. The result is clean, renewable energy.

(iii) WTE facilities divert the waste from landfills each day preventing ground water contamination as well as preventing methane gas emissions (20-25 times more potent than carbon dioxide) from decomposing garbage.

(iv) Source of clean renewable energy and global climate benefits

(v) Full compliance with Emission standards (100% safe)

(vi) Keeping waste out of landfills, more open space and less risk of leaking toxins into Ground-water and releasing harmful air emissions.

(vii) WTE facilities also recycle metal that would have otherwise been land filled.

3.1.2 Visit and Survey of WTE Plants

A team of CBRI scientists visited Delhi for collection of ash samples from two WTE plants viz. M/s Timarpur- Okhla Waste Management Company Private Ltd and M/s. East Delhi Waste Processing Company Ltd after discussion with Deptt. of Environment, GNCTD. During the visit, survey of the plant was carried out with special emphasis on the installed capacity, nature of MSW processed, points of waste generation, quantum and type of wastes generated, recycle/recovery process adopted, actual efficiency, method of disposal of inert waste etc. Photographs of plants are shown in Fig. 3.1-3.2. The disposal of ash from these plants is an environmental problem and requires attention for its utilization as building material.

Fig. 3.1: Timarpur- Okhla Waste to Energy Plant, Okhla, New Delhi

Fig. 3.2: East Delhi Waste to Energy Plant, Ghazipur, Delhi

3.1.3 Collection of Samples

After survey of the each WTE plant, following samples were collected:

(i) Approximately 100 kg of bottom ash from M/s. Timarpur- Okhla Waste to Energy Plant.

(ii) Approximately 100 kg of bottom ash from M/s. East Delhi Waste to Energy Plant, Ghazipur, Delhi.

(iii) Collection of 100 kg of fly ash from from M/s. East Delhi Waste to Energy Plant, Ghazipur, Delhi.

(iv) **3.1.4 Characterization of Bottom Ash**

The samples collected were moist, containing C & D wastes and other coarse waste materials. Before characterization, these samples were sun dried, grinded in ball mill and sieved through 4.75 mm size sieve. The various physical properties of bottom ash are shown in Table 3.2. The particle size distribution curves of bottom ash are shown in Fig. 3.3 and Fig. 3.4 for Okhla and Ghazipur plants respectively. Chemical characterization and elemental analysis of bottom ash are shown in Table 3.3. The bottom ash has been used as replacement of fine aggregates for the development of building products like road paving blocks and cement bricks. The process flow chart for making paving blocks and bricks using bottom ash is shown in Fig. 3.5.

Table 3.2: Physical properties of Bottom ash

Sr. No.	Properties	Values	
		Bottom Ash Okhla WTE Plant	Bottom Ash Ghazipur WTE Plant
1.	pH	10.40	10.30
2.	colour	Dark brown	Light grey
3.	Specific gravity	2.40	2.52
4.	Water absorption	25.20 %	23.74%
5.	Compact Bulk Density	1.84 g/cc	1.86 g/cc
6.	LOI	6.4 %	5.4 %
7.	**Particle size**	**Passing (%)**	**Passing (%)**
	10 mm	100	100
	4.75mm	100	99.45
	2.36mm	99.10	94.14
	1.18mm	88.73	82.56
	600 µm	84.70	90.10
	300 µm	79.43	86.98
	150 µm	76.23	77.57
8.	Fineness modulus	1.60	1.77

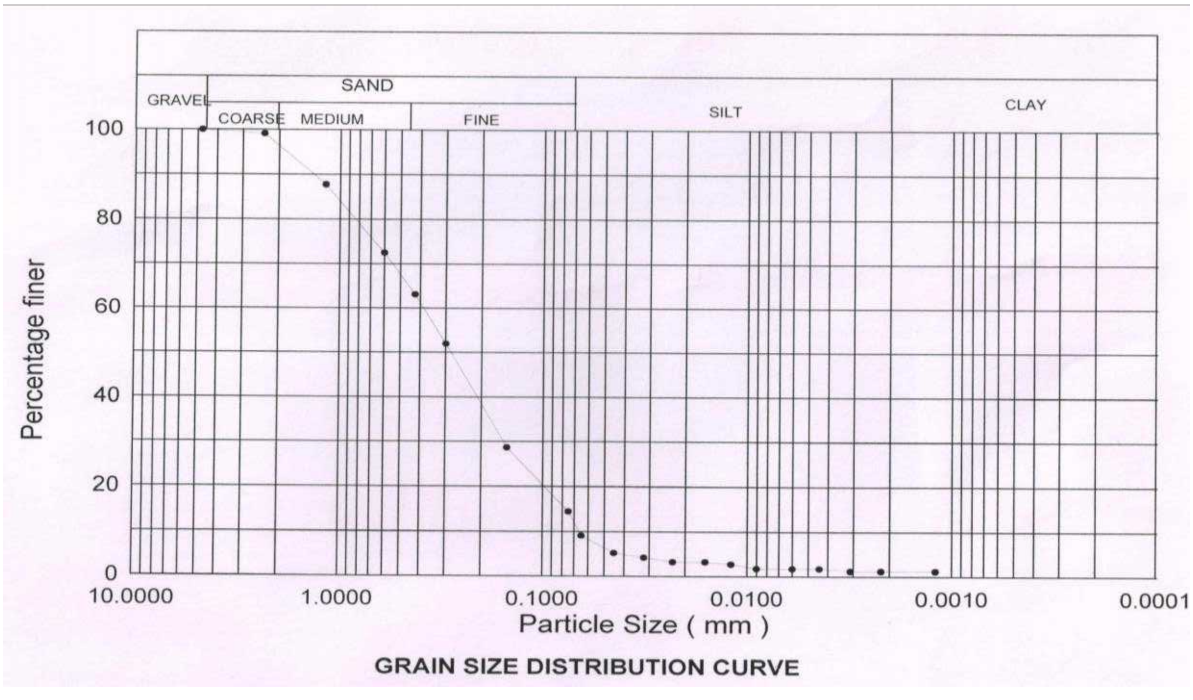


Fig. 3.3: Grain size analysis of bottom ash of Okhla MSW processing plant

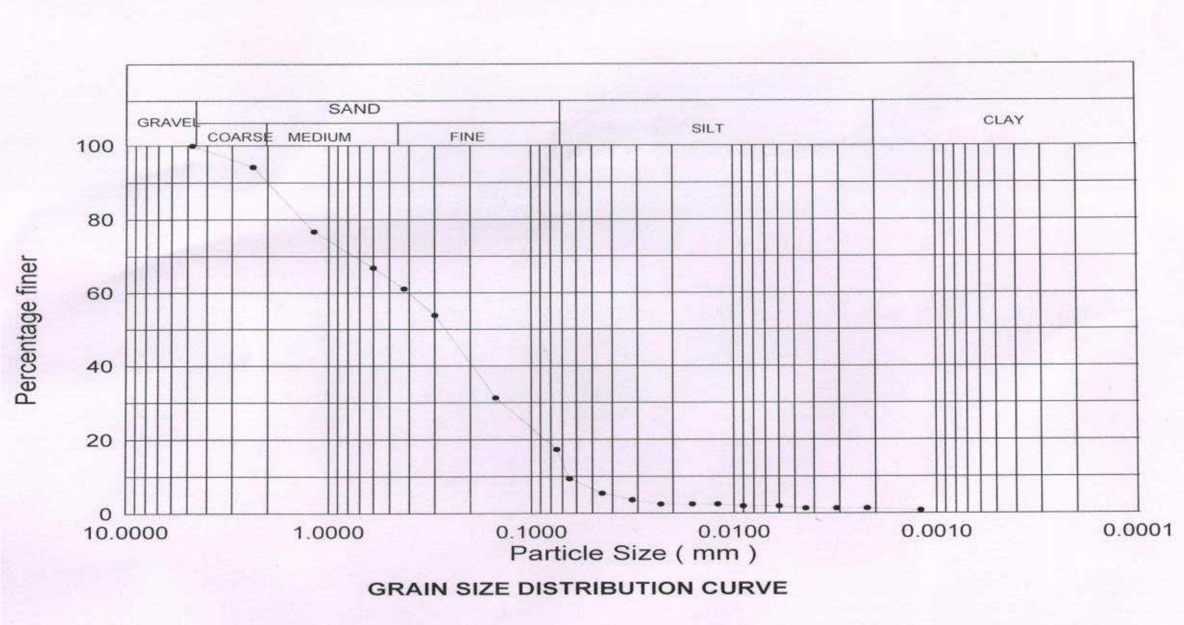


Fig. 3.4: Grain size analysis of bottom ash of Ghazipur MSW processing plant

Table 3.3: Chemical composition of Bottom ash

Sr. No.	Parameters	Values (%)	
		Okhla WTE Plant	Ghazipur WTE Plant
1.	SiO_2	35.20	41.18
2.	Al_2O_3	17.23	15.01
3.	Fe_2O_3	2.29	2.95
4.	CaO	23.74	24.50
5.	MgO	5.92	7.59
6.	P_2O_5	3.23	2.91
7.	Na_2O	5.66	----
8.	K_2O	4.33	3.66
9.	Cl	1.81	----
10.	MoO_3	0.04	0.05
11.	BaO	----	0.93

3.2 BUILDING PRODUCTS USING BOTTOM ASH OF WTE PLANT, OKHLA

The Okhla Waste to Energy (WTE) project is India's first largest integrated Waste-to-Energy facility that aims to disposes and process 1/3rd of the Delhi garbage and convert into the much-needed Clean Renewable Energy, enough to serving 6 lakh homes. The plant is set up aiming for a sustainable solution (Zero Waste Concept) taking Municipal Solid Waste

(MSW) through an environmentally friendly combustion process to generate energy. At present, plant is processing 1300 MT of MSW per day and generating 16 MW of electricity.

3.2.1 Development of Road Paving Blocks and Engineering Properties

The various mix compositions used and designations for control and fine aggregate replaced by bottom ash (30-70 %) mixes are given in Table 3.4.

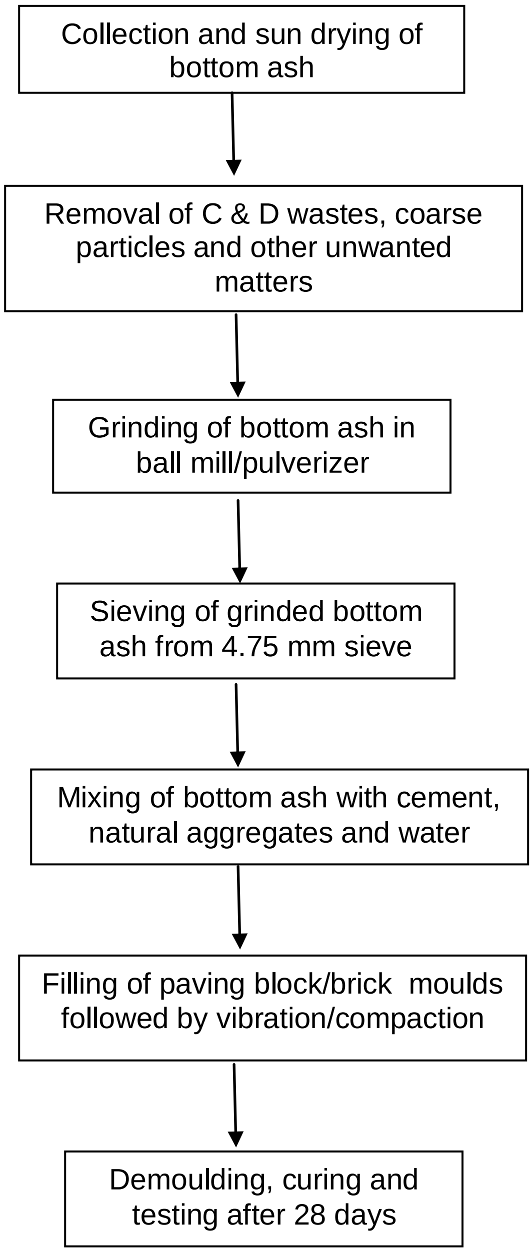


Fig. 3.5: Flow chart for fabrication of road paving blocks and bricks using bottom ash

Table 3.4: Mix proportion of paving blocks using bottom ash, WTE plant, Okhla

Mix designations	**Cement (%)**	**Stone dust (%)**	**Bottom ash (%)**	**Coarse aggregate (%)**	**Water (%)**
Top Layer	33.33	66.67	----	----	9.00
A0 (Control)	**25.00**	**37.50**	**----**	**37.50**	**8.00**
A1	25.00	26.25	11.25	37.50	9.25
A2	25.00	22.50	15.00	37.50	9.50
A3	25.00	18.75	18.75	37.50	10.25
A4	25.00	15.00	22.50	37.50	10.50
A5	25.00	11.25	26.25	37.50	10.75
B0 (Control)	**22.25**	**33.25**	**----**	**44.50**	**7.5**
B1	22.50	23.25	10.00	44.50	8.50
B2	22.50	20.00	13.25	44.50	8.75
B3	22.50	16.63	16.62	44.50	9.25
B4	22.50	13.30	19.95	44.50	9.50
B5	22.50	10.00	23.25	44.50	9.75
C0 (Control)	**20.00**	**30.00**	**----**	**50.00**	**7.0**
C1	20.00	15.00	15.00	50.00	7.0
C2	20.00	12.00	18.00	50.00	7.5
C3	20.00	9.00	21.00	50.00	8.0

After 28 days of curing period, visual inspection of blocks was carried out in natural day light prior to the tests for other properties. Visual inspection revealed that all paving blocks were sound and free of cracks. No other visual defects were observed which may interfere with proper paving of the unit or impair the strength or performance of pavement constructed with the paving blocks. The bottom layer was showing proper bonding with top layer in all the paving blocks. The physical and mechanical properties of paving blocks determined after 28 days of curing period are shown in Table 3.5. The results show that all the mixes are having the compressive strength more than 30 MPa and water absorption less than 6 % satisfying the requirements of IS: 15658.

Table 3.5: Physical and mechanical properties of paving blocks using bottom ash, WTE plant, Okhla

Mix designations	Water absorption (%) (28days)	Compressive strength (MPa) (28 days)	Remark
A0 (Control)	**2.0**	**62.50**	
A1	3.20	48.00	**Recommended**
A2	3.75	42.00	**Recommended**
A3	3.75	37.50	**Recommended**
A4	4.60	34.60	**Recommended**
A5	4.95	32.50	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.30	40.50	**Recommended**
B2	5.25	37.50	**Recommended**
B3	5.50	34.60	**Recommended**
B4	5.60	32.50	**Recommended**
B5	5.90	30.20	**Recommended**
C0 (Control)	**3.20**	**45.00**	
C1	5.30	39.50	**Recommended**
C2	5.75	36.00	**Recommended**
C3	5.75	32.50	**Recommended**

3.2.2 Development of Cement Bricks and Engineering Properties

The various mix compositions used for development of bricks from bottom ash and designations are given in Tables 3.6. The properties of bricks like water absorption and compressive strength were determined following the procedure laid down in IS: 3495 and are shown in Table 3.7 along with bulk density.

Table 3.6: Mix proportion of cement bricks using bottom ash, WTE plant, Okhla

Mix designations	Cement (%)	Stone dust (%)	Bottom ash (%)	Water (%)
E0 (Control)	**10.00**	**90**	**----**	**7.50**
E1	10.00	45.00	45.00	25.00
E2	15.00	42.50	42.50	26.00
E3	20.00	40.00	40.00	28.00

Table 3.7: Physical and mechanical properties of bricks using bottom ash, WTE plant, Okhla

Mix designations	**Water absorption (%)**	**Bulk density (kg/m^3)**	**Compressive strength (MPa)**	**Remarks**
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	22.00	1855	3.50	
E2	10.75	1876	7.20	**Recommended**
E3	8.50	1890	9.00	**Recommended**
IS:1077: 1992 requirement	<20% for class up to 12.5 <15% for class higher than 12.5		> 5 MPa	

3.2.3 RECOMMRENDATIONS

After receiving the results of blocks and bricks development utilizing bottom ash, following recommendations are given:

1. TCLP studies are not carried out as no hazardous heavy element is observed in the chemical composition of bottom ash.
2. Mixes A1-A5, B1-B5 and C1-C3 are recommended for development of blocks as strength is more than 20 MPa in each case and water absorption is less than 6.0 %. Maximum strength of 48 MPa was observed with A1 mix having 11.25 % of bottom ash of total mix.
3. Cement bricks may be developed using 40-42.50 % of bottom ash and mixes E2 and E3 are recommended, meeting the requirements of Indian Standard 1077.

3.3 BUILDING PRODUCTS USING BOTTOM ASH, WTE PLANT, GHAZIPUR

Ghazipur landfill site is spread over 5.728 acres and a 1300 TPD WTE plant has been installed. At present plant is processing 1000 Tonnes of MSW and producing 12 MW of electricity.

3.3.1 Development of Road Paving Blocks and Engineering Properties

The various mix compositions used for development of road paving blocks and their designations are given in Tables 3.8. After 28 days of curing period, properties like water absorption and compressive strength were determined and results are shown in Table 3.9.

Table 3.8: Mix proportion of paving blocks using bottom ash, WTE plant, Ghazipur

Mix designations	Cement (%)	Stone dust (%)	Bottom ash (%)	Coarse aggregate (%)	Water (%)
Top Layer	33.33	66.67	----	----	9.00
A0 (Control)	**25.00**	**37.50**	**----**	**37.50**	**8.00**
A1	25.00	18.75	18.75	37.50	10.60
A2	25.00	15.00	22.50	37.50	10.90
A3	25.00	11.25	26.25	37.50	11.20
A4	25.00	7.50	30.00	37.50	11.50
A5	25.00	3.75	33.75	37.50	11.80
A6	25.00	----	37.50	37.50	12.00
B0 (Control)	**22.25**	**33.25**	**----**	**44.50**	**7.5**
B1	22.50	16.63	16.62	44.50	9.60
B2	22.50	13.30	19.95	44.50	10.00
B3	22.50	10.00	23.25	44.50	10.50
C0 (Control)	**20.00**	**30.00**	**----**	**50.00**	**7.0**
C1	20.00	15.00	15.00	50.00	8.75
C2	20.00	12.00	18.00	50.00	9.25
C3	20.00	9.00	21.00	50.00	9.75
D1	15.00	17.50	17.50	50.00	8.75
D2	10.00	20.00	20.00	50.00	8.75

3.3.2 Development of Cement Brick and Engineering Properties

The mix compositions used for development of bricks using bottom ash and designations for control and bottom ash replaced mixes are given in Tables 3.10 along with water content. The properties of bricks like water absorption and compressive strength were determined following the procedure laid down in IS: 3495 and are shown in Table 3.11 along with bulk density.

Table 3.9: Physical and mechanical properties of paving blocks using bottom ash, WTE plant, Ghazipur

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.0**	**62.50**	
A1	2.80	46.60	**Recommended**
A2	3.75	42.50	**Recommended**
A3	3.75	42.00	**Recommended**
A4	3.75	41.60	**Recommended**
A5	3.80	41.10	**Recommended**
A6	4.00	40.00	**Recommended**
			Recommended
B0 (Control)	**2.80**	**50.50**	
B1	2.90	45.20	**Recommended**
B2	3.50	42.00	**Recommended**
B3	3.75	40.00	**Recommended**
C0 (Control)	**3.20**	**45.00**	
C1	3.50	42.00	**Recommended**
C2	3.80	40.20	**Recommended**
C3	4.30	38.50	**Recommended**
D1	4.20	36.80	**Recommended**
D2	4.80	27.00	**Recommended**

Table 3.10: Mix proportion of cement bricks using bottom ash, WTE plant, Ghazipur

Mix designations	Cement (%)	Stone dust (%)	Bottom ash (%)	Water (%)
E0 (Control)	**10.00**	**90**	**----**	**7.50**
E1	10.00	45.00	45.00	25.00
E2	15.00	42.50	42.50	26.00
E3	20.00	40.00	40.00	28.00

Table 3.11: Physical and mechanical properties of bricks using bottom ash, WTE plant, Ghazipur

Mix designations	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	24.00	1823	3.75	
E2	10.90	1887	6.30	**Recommended**
E3	8.20	1902	9.50	**Recommended**
IS:1077 : 1992 requirement	<20% for class up to 12.5 <15% for class higher than 12.5		> 5 MPa	

3.3.3 RECOMMENDATIONS

After receiving the results of blocks and bricks development utilizing bottom ash, following recommendations are given:

1. TCLP studies are not required as no hazardous heavy element is present in bottom ash chemical composition.
2. All the mixes (A1-A6, B1-B3, C1-C3 and D1-D2) are recommended for development of blocks utilizing bottom as in the range of 15-37.50 % having strength more than 20 MPa and water absorption less than 6.0 %. Maximum strength of 46.60 MPa was observed with A1 mix having 18.75 % of bottom ash and 25.0 % of cement.
3. Cement bricks may be developed using 40-42.50 % of bottom ash with 15-20 % of cement as per Indian standard. Mixes E2 and E3 are recommended meeting the requirements of Indian Standard 1077.

3.4 BUILDING PRODUCTS USING FLY ASH, WTE PLANT, GHAZIPUR

Although development of fly ash bricks has become common practice using fly ash from a coal based thermal power plants. In the present investigations fly ash has been used generated from MSW incinerators producing energy.

3.4.1 Characterization of Fly Ash

The sample of fly ash were sieved through 4.75 mm size sieve and characterized for physio-chemical parameters. The physical and chemical properties of fly ash are shown in Table 3.12 and 3.13 respectively. The fly ash have been used as replacement of natural fine aggregates in the development of building products like road paving blocks and cement bricks.

Table 3.12: Physical properties of fly ash, WTE plant, Ghazipur, Delhi

Sr. No.	**Properties**	**Values**
1.	pH	12.34
2.	colour	Light Grey
3.	Specific gravity	2.20
4.	Bulk Density	0.74 g/cc
5.	LOI	22.54
6.	**Particle size**	
	10 mm	100
	4.75 mm	100
	2.36 mm	99.75
	1.18 mm	92.50
	600 µm	20.25
	300 µm	94.75
	150 µm	89.63
7.	Fineness modulus	2.76

Table 3.13: Chemical composition of fly ash, WTE plant, Ghazipur, Delhi

Sr. No.	**Parameters**	**Values (%)**
1.	SiO_2	5.83
2.	Al_2O_3	5.55
3.	CaO	45.68
4.	MgO	4.11
5.	P_2O_5	1.29
6.	K_2O	11.11
7.	Cl	12.51
8.	SO_3	12.84

3.4.2 Development of Road Paving Blocks Using Fly Ash and Engineering Properties

The mix compositions used for development of road paving blocks using fly ash and designations are given in Table 3.14. The physical and mechanical properties of paving blocks like water absorption and compressive strength were determined after 28 days curing period and results are shown in Table 3.15. The results show that all the mixes are having the compressive strength more than 20 MPa, and water absorption less than 6 % satisfying the requirements of IS: 15658.

Table 3.14: Mix proportion of paving blocks using fly ash from WTE plant, Ghazipur

Mix designations	Cement (%)	Fly ash (%)	Stone dust (%)	Coarse aggregate (%)	Water (%)
Top Layer	33.33	-----	66.67	----	9.00
A0 (Control)	**25.00**	**-----**	**37.50**	**37.50**	**8.00**
A1	25.00	10.00	27.50	37.50	8.75
A2	25.00	15.00	22.50	37.50	9.35
B0 (Control)	**22.25**	**-----**	**33.25**	**44.50**	**7.50**
B1	22.50	10.00	23..25	44.50	8.75
B2	22.25	13.25	20.00	44.50	9.35

Table 3.15: Physical and mechanical properties of paving blocks developed using fly ash, WET plant, Ghazipur

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	4.10	36.37	**Recommended**
A2	5.85	23.50	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.10	36.25	**Recommended**
B2	4.60	28.20	**Recommended**

3.4.3 Development of Cement Bricks and Engineering Properties

The mix compositions used for development of bricks using fly ash are given in Tables 3.16. The properties of bricks like water absorption and compressive strength were determined following the procedure laid down in IS: 3495 and are shown in Table 3.17 along with bulk density. The results show that both the mixes are having the compressive strength more than 5.0 MPa, and water absorption less than 20.0 % satisfying the requirements of IS: 1077

Table 3.16: Mix proportion of cement bricks developed using fly ash WTE plant, Ghazipur

Mix designations	Cement (%)	Stone dust (%)	Fly ash (%)	Water (%)
E0 (Control)	**10.00**	**90**	**----**	**7.50**
E1	15.00	75.00	10.00	11.75
E2	20.00	65.00	15.00	12.75

Table 3.17: Physical and mechanical properties of bricks developed using fly ash WTE plant, Ghazipur

Mix designations	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	10.25	1730	9.95	**Recommended**
E2	9.25	1740	8.65	**Recommended**
IS:1077 : 1992 requirement	<20% for class up to 12.5 <15% for class higher than 12.5		> 5 MPa	

3.4.4 RECOMMRENDATIONS

After receiving the results of blocks and bricks development utilizing fly ash, following recommendations are given:

1. TCLP studies are not required as no hazardous heavy element is present in the chemical composition of fly ash.
2. It is observed that with increase in fly ash content in mix composition as a replacement of stone dust (30-70 %), compressive strength decreases.
3. Fly ash was used 10-15 % of the total mix with various cement compositions (22.5-25 %) in the development of blocks. All the trail mixes (A1-A2, B1-B2) are recommended for development of blocks as strength is more than 20 MPa in each case and water absorption is less than 6.0 % . Maximum strength of 36.37 MPa was observed with A1 mix having 10 % of fly ash and 25.0 % of cement.
4. Cement bricks may developed using 10-15 % of fly ash with 15-20 % of cement as per Indian standard. Mixes E1 and E2 are recommended as meeting the requirements of IS: 1077.

DEVELOPMENT OF BUILDING PRODUCTS USING SEWAGE TREATMENT PLANTS (STPs) SLUDGE

4.1 STATUS OF SEWAGE TREATMENT PLANT (STPs) IN DELHI

Delhi, the capital of India, has a population of about 17 million and is expected to increase 23 million by 2021. The population growth pattern of Delhi is the single most important factor that affects the level quantity of water supply and sewerage services available to its habitants. Delhi Jal Board (DJB) is the authority responsible for planning, designing and execution of water supply and wastewater management facilities within its jurisdiction in the National Capital Territory of Delhi. DJB is supplying about 900 MGD of drinking water to population of Delhi. Sewage treatment plant capacity in Delhi is about 700 MGD against an estimated waste water generation of 752 MGD. The information collected from DJB regarding status of Sewage Treatment Plants (STPs) in Delhi is given in Table 4.1. A perusal of Table 4.1 shows that there are total 36 plants in 22 locations and 31 plants are in working condition. At present total sewage treatment carried out is 460-470 MG per day against the installed capacity of 700 MGD and about 350 MT per day sludge is generated from these plants.

4.1.2 STPs Visit and Sludge Sample Collection

It has been observed that mostly STP plants are running on Activated sludge process (ASP) apart from extended aeration, membrane batch reactor etc. After discussion with competent authority, three locations were selected and visited (Fig. 4.1-4.3) for collection of sludge samples viz. Okhla (ASP), Mehrauli (Extended aeration) and Dr. Sen nursing home nalla (biochemical). These samples will represent all types of sludge generated from STP plants based on different technologies.

Okhla sewage treatment plant is fully automated, SCADA controlled and based on conventional activated sludge process with fine buffled diffused aeration system. Aeration tanks are provided with anoxic zones for removal of nitrogen in the waste water through the process of denitrification-nitrification". The capacity of the plant is 30 MGD and is a major component of the Yamuna Action Plan-II. Power generation is also done at the plant using biogas produced from the sludge through gas-based power engines. About 60% of the power

Table 4.1: Status of Sewage Treatment Plants in Delhi

S. No.	Name & location of STP	Year of Construction	Technology	Designed parameters BOD : SS (ppm)	Capacity (MGD)	Proposed for tertiary <10 BOD and SS
01.	Keshopur Phase-I Keshopur-phase-II Keshopur-phase-III	1958 Rehabilitated 1975 Rehabilitated 1990 Rehabilitated	Activated Sludge Process (ASP)	20 : 30 30 : 50 30 : 50	12 20 40	---- ---- ----
02.	Okhla Phase-I Okhla Phase-II Okhla Phase-III Okhla Phase-IV Okhla Phase-V Okhla Phase-VI	1937 1982 1993 1993 2001 2012	ASP ASP ASP ASP ASP ASP (with Power generation)	30 : 50 30 : 50 30 : 50 30 : 50 30 : 50 20 : 30	30 12 37 45 16 30	Yes Yes Yes Yes ---- ----
03.	Kondli Phase-I Kondli Phase-II Kondli Phase-III Kondli Phase-IV	1987 1989 2001 2013	ASP ASP ASP ASP (with power generation)	Under Rehab. 30 : 50 Under rehab. 20 : 30	**10 (non-functional due to no sewage)** 25 **10 (non-functional due to no sewage)** 45	Yes Yes Yes ----
04.	Rithala –I Rithala-II	1989 2002	ASP ASP (with power generation)	30 : 50 15 : 20	40 40	Yes
05.	Yamuna Vihar Phase-I Yamuna Vihar Phase-II Yamuna Vihar Phase-III	1999 2002 2015	ASP ASP ASP (with power generation)	30 : 50 30 : 50 20 : 30	10 10 25	---- ---- ----
06.	Vasant Kunj Phase-I Vasant Kunj Phase-II	1982 2001	Ext. Aeration Ext. Aeration	30 : 50 30 : 50	2 3	---- ----
07.	Coronation Pillar (old) Coronation Pillar-I&II Coronation Pillar-III	1957 1999 2000	ASP ASP ASP	UNDER REHAB. 30 : 50 30 : 50	**10 (Closed)** 20 10	---- ---- ----
08.	Narela	2001	ASP	30 : 50	10	----
09.	Nilothi Phase-I Nilothi Phase-II	2002 2015	ASP ASP with	30 : 50 10 : 10	40 20	---- ----

			power generation			
10.	Najafgarh	2002	Extended aeration	30 : 50	5	----
11.	PappanKalan –I PappanKalan – II	2000 2015	ASP ASP with power generation	30 : 50 10 : 10	20 20	---- ----
12.	Dr. Sen Nursing Home Nalla	1998	MBBR	10 : 10	2.2	----
13.	Delhi Gate Nalla-I Delhi Gate Nalla-II	1998 2015	MBBR MBBR (with power generation)	10 : 10 10 : 10	2.2 15	---- ----
14.	Mehrauli	2003	Extended Aeration	20 : 30	5	----
15.	Rohini	2002	ASP	30 : 50	15	----
16.	Ghitorni	1997	Extended aeration	Under rehab.	5	----
17.	Kapashera	2013	SBR (Sequential Batch Reactor)	10 : 10	5	----
18.	Commonwealth Games Village	2010	Membrane Bio Reactor (MBR)	2 : 1	1	----
19.	Bakkarwala	Taken over from MCD	Fluidized Bed Reactor (FBR)	30 : 50	**0.66 (Defunt.)**	----
20.	Molarbandh	Taken over from MCD	Fluidized Bed Reactor (FBR)	30 : 50	**0.66 (Defunct.)**	----
21.	Timarpur Oxidation Pond	----	Aeration Lagoon	30 : 50	6.00	----
22.	Chilla	2014	SBR	10 : 10	9.00	

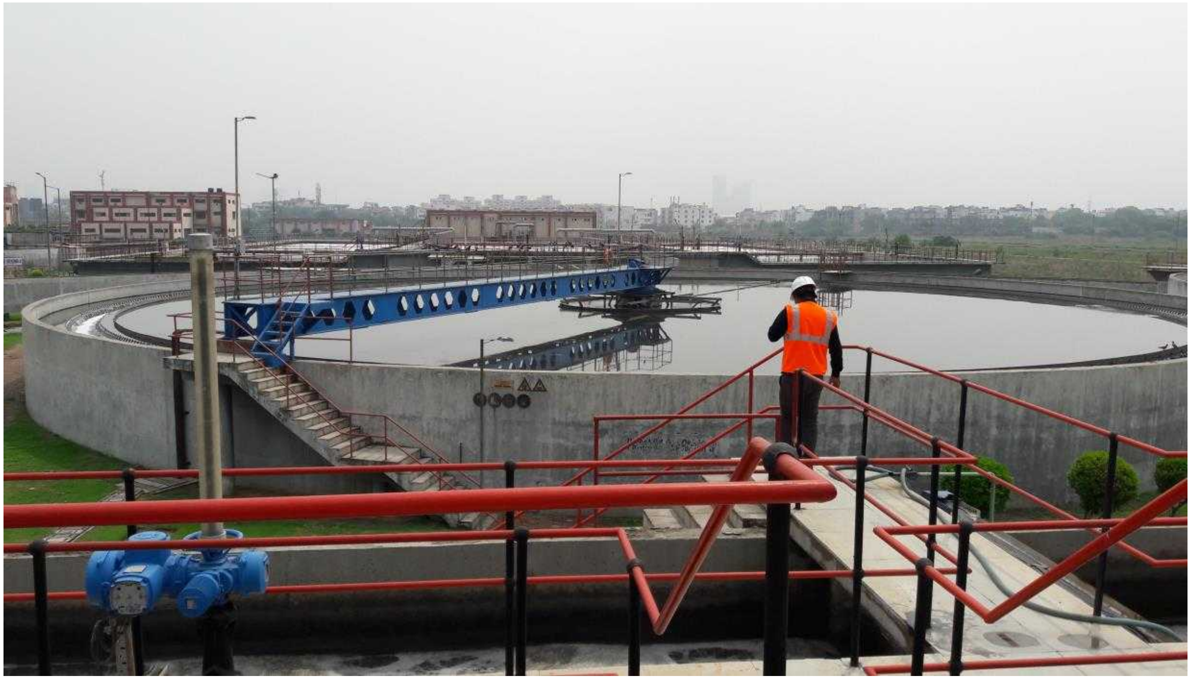


Fig. 4.1: A view of clarifier at Okhla sewage treatment plant based on ASP

required for running the plant is met from the power generated through the gas engines. The designed efficiency of the plant is to reduce BOD from 200 to 20 mg/l. About 15 MT of digested sludge is generated per day and is disposed on sludge drying beds for solar drying. This sludge is partially used as soil conditioner by nearby farmers and rest is disposed in landfill.

Mehrauli sewage treatment plant is based on activated sludge process using extended aeration system. The process maximizes the stability of the operating environment and provides high efficiency treatment. The design ensures the lowest cost construction and guarantees operational simplicity. The capacity of the plant is 5 MGD and the designed efficiency of the plant is to reduce BOD from 200 to 20 mg/l. After screening and girt removal, the sewage is pumped in to two aeration tanks where 8 stage aeration is carried using 16 aerators. About 2.5 MT of digested sludge is generated per day and is disposed on sludge drying beds for solar drying. This sludge is partially used for soil conditioning by nearby farmers and rest is disposed in landfill.

Fig. 4.2: A view of Mehrauli sewage treatment plant based on extended aeration

Fig. 4.3: A view of Dr. Sen Nursing Home Nalla sewage treatment plant

Dr. Sen nursing home nalla STP is a small plant having a capacity of 2.2 MGD and is based on biochemical process. After screening and girt removal, sewage is treated biologically with diffused air followed by chemical treatment with PAC and alum. The sludge generated is about 2 MT per day of digested sludge is generated which is collected in trucks and sent to SLF for disposal.

4.1.2 Characterization of STP Sludges

After survey, about 100 kg of sludge samples were collected from each location for development of building materials. The samples of STP sludge were dried at 50 ± 2^{o}C in trays, cooled to room temperature, ground in a ball mill and passed through 4.75 mm sieve. The physical and particle size analysis of the STP sludge has been shown in Table 4.2. The chemical characteristics of the sludge are shown in Table 4.3. The sludge has been used as a replacement of fine aggregate (stone dust) for the development of paving blocks/bricks.

Table 4.2: Physical properties of STPs sludge samples

Sr. No.	**Properties**	**Values**		
		Okhla STP	**Mehrauli STP**	**Dr. Sen Nursing Home Nalla STP**
1.	pH	6.80	8.0	6.50
2.	Colour	Light Brown	Light Brown	Light Brown
3.	Specific gravity	1.91	1.76	1.63
4.	Bulk Density	1.04 g/cm^3	1.17 g/cm^3	0.87 g/cm^3
5.	LOI	40.20	43.70	47.90
6.	**Particle size**	**Passing (%)**	**Passing (%)**	**Passing (%)**
	10 mm	100	100	100
	4.75mm	100	100	100
	2.36mm	99.5	100	93
	1.18mm	98.25	98.37	72.25
	600 µm	91.37	75.87	85.12
	300 µm	78.37	75.50	82.62
	150 µm	69.37	77.12	84.37
7.	Fineness modulus	1.09	1.25	2.41

Table 4.3: Chemical properties of STPs sludge samples

Sr. No.	Parameters	Values (%)		
		Okhla STP	Mehrauli STP	Dr. Sen Nursing Home Nalla STP
1.	SiO_2	39.55	34.24	11.12
2.	Al_2O_3	21.03	19.00	3.27
3.	Fe_2O_3	3.92	3.96	----
4.	CaO	14.12	16.79	52.92
5.	MgO	4.31	5.15	----
6.	P_2O_5	8.04	9.10	29.56
7.	SO_3	5.76	4.22	----
8.	K_2O	2.89	3.07	----
9.	TiO_2	----	2.89	----
10.	Total Carbon	19.97	26.62	26.46
11.	Total Organic matter	34.34	45.78	45.51

4.2 DEVELOPMENT OF ROAD PAVING BLOCKS AND TESTING

The various mix compositions used for development of road paving blocks and designations are given in Table 4.4. The physical and mechanical properties of paving blocks like water absorption and compressive strength were determined after 28 days of curing period and the results are shown in Table 4.5, 4.6 and 4.7 for Okhla, Mehrauli and Sen Nursing Home STPs respectively. The results show that the compressive strength varied from 2.50 to 7.0 MPa and was less than 20 MPa . Water absorption is also more than 6 % and does not satisfying the requirements of IS: 15658.

Table 4.4: Mix proportion of paving blocks

Mix designations	Cement (%)	STP sludge (%)	Stone dust (%)	Coarse aggregate (%)	Water (%)
Top Layer	33.33	----	66.67	----	9.00
A0 (Control)	**25.00**	**----**	**37.50**	**37.50**	**8.00**
A1	25.00	8.00	29.50	37.50	11.25
A2	25.00	10.00	27.10	37.50	11.50
A3	25.00	15.00	22.50	37.50	12.00
B1	30.00	8.00	24.50	37.50	11.50

Table 4.5: Physical and mechanical properties of paving blocks developed using STP sludge, Okhla

Mix designations	Water absorption (%)	Compressive strength (MPa)
A0 (Control)	2.00	62.50
A1	15.50	3.80
A2	20.75	3.00
A3	22.50	2.50
B1	12.50	4.20

Table 4.6: Physical and mechanical properties of paving blocks developed using STP sludge, Mehrauli

Mix designations	Water absorption (%)	Compressive strength (MPa)
A0 (Control)	2.0	62.50
A1	16.75	3.80
A2	18.50	3.25
A3	20.25	2.70
B1	14.25	4.25

Table 4.7: Physical and mechanical properties of paving blocks developed using STP sludge, Dr. Sen nursing home nalla

Mix designations	Water absorption (%)	Compressive strength (MPa)
A0 (Control)	2.0	62.50
A1	13.00	6.25
A2	15.50	4.50
A3	18.50	3.20
B1	12.25	7.00

4.3 RECOMMENDATIONS

The STP sludge can not be recommended for development of building products as the results do not meet the requirement of Indian Standards.

4.4 FUTURE SCOPE

*Few suggestions have been provided for utilization of STP sludge after proper processing or pretreatment:

1. The STPs sludge contain substantial quantities of organic and volatile matter which is generally non-conductive to produce reliable and suitable construction materials as the material developed is highly porous and has high water absorption properties.
2. There is a strong potential for use of sewage sludge as a fertilizer due to its pH, presence of nitrogen and phosphorous content.
3. The calorific value of sewage sludge, which is related to its organic content, also suggests that it could be potentially be utilized with some processing as a fuel, with a calorific value equivalent to around 50 % that of coal.
4. Incineration is a treatment process involving the combustion of pretreated sewage sludge followed by energy recovery from the heat produced. This process leads to large reduction (about 90 %) in its volume and sewage sludge converts in to sewage sludge ash (SSA). The SSA can be utilized as fine sand for development of building products especially the light weight components. The SSA can also be used as a good adsorbent for heavy metal ions as well dyes.

   Dehydration, devolatization and autogasification occur as the sludge is fed into the furnace, leading to the evaporating of residual moisture and vaporization of volatile organics and metals, followed by char combustion to gases. Residual inorganic fine particulates are carried out with the exhaust gases out of the combustion chamber and typically pass through a heat exchanger. As the temperature subsequently reduces, condensation of metal vapours to inorganic particulates also occurs and the residual ash fraction is then removed by cleaning system.
5. Sewage sludge and sewage sludge ash (SSA) are two such materials that contain substantial amount of phosphorus. The recovery of phosphorus from these materials is one method of preserving the available resources and indeed can also reduce the adverse

environmental impact and high energy consumption associated with mining of phosphate ore.

With sewage sludge, the high moisture and organic content are problematic for phosphorus recovery and leads to higher processing infrastructure. With sewage sludge ash (SSA), the focus is on managing the heavy metal ions and improving the phosphorous bioavailability. The processes developed can be grouped into two categories:

a) Wet Chemical Treatments

This process involves the removal of phosphorous along with other elements from the SSA by elution after which the dissolved elements are recovered by precipitation or ion exchange. The elution process predominantly involves the use of strong acidic solvents, through on occasion, alkaline substances have been used or a combination of the two.

b) Thermochemical Treatments

There has been significant interest in the thermochemical treatment of SSA. It is observed that the degree of heavy metal ions removal increases with the incineration temperature. About $1000^{o}C$ temperature is most appropriate for SSA phosphorous products. The retention time during heating is about 30 min.

*Source: Book on "Sustainable Construction Materials": Sewage Sludge Ash, Authored by Ravindra K. Dhir OBE, Gurnel S. Ghataora and Ciaran J. Lynn. Published by Elsevier, Woodhead Publishing, UK, 2017.

CHAPTER V

DEVELOPMENT OF BUILDING PRODUCTS USING COMBINED EFFLUENT TREATMENT PLANTS (CETPs) SLUDGE

5.1 STATUS OF COMBINED EFFLUENT TRATMENT PLANTS (CETPs), DELHI

It is difficult for each industrial unit to provide and operate individual wastewater treatment plant because of the scale of operations or lack of space or technical manpower. However, the quantum of pollutants emitted by SSIs clusters may be more than an equivalent large scale industry, since the specific rate of generation of pollutants is generally higher because of the inefficient production technologies adopted by SSIs. Keeping in view, the key role played by SSI units and the constraints in complying with pollution control norms individually by these units, The Ministry of Environment and Forests (MoEF) initiated an innovative technical and financial support scheme to ensure their growth in an environmentally compatible manner. The scheme promoted common facilities for treatment of effluents generated from SSI units located in clusters through liberal financial assistance.

The concept of CETP was adopted as a way to achieve end-of-pipe treatment of combined wastewater at lower unit cost than could be achieved by individual industries, and to facilitate discharge, monitoring and enforcement by environmental regulatory agencies and the investment of substantial government finances in the CETP scheme was justified on the basis of potential benefits in terms of pollution reduction and environmental improvements.

The information regarding combined Effluent Treatment Plants (CETPs) in Delhi was collected from Delhi Pollution Control Committee (DPCC) and is given in Table 5.1. A perusal of Table shows that there are total 13 CETPs in Delhi which are treating about 59.3 MLD of waste water.

Table 5.1: Details of CETP in Delhi

S.NO.	CETPs	Address of CETPs, Name of in-charges, contact Nos. and emails	Waste water treated	Sludge generated (data given by CETP)
1	OKHLA	The resident/Secretary, Okhla Industrial Area, CETP Society, C-141, Phase-I, New Delhi-110020. cetpokhla@gmail.com , cetpokhla07@rediffmail.com, 9212012166, 9810047716 (Shri. Harish Arora)	2 MLD	approx. 400-500 kg/day
2	NARAINA	The President/Secretary, Naraina Industrial Area CETP Society, NIA House, A-5 Community Centre, Naraina Industrial Area, Ph-II, New Delhi -110028, narainacetp@gmail.com, 9811046358. (Shri. Jatinder Singh)	4.5 MLD	approx. 600-700 kg/day
3	MAYAPURI	The President/Secretary, Mayapuri Industrial Area CETP Society, Opposite Govt. Of India Press, Phase-I, Mayapuri Indl. Area, New Delhi-110064. mypcetp@yahoo.co.in, 9811584117, (Shri, Somnath).	3.3 MLD	approx. 150 kg/day
4	BADLI	The President/Secretary, Badli Industrial Estate CETP Society, Behind Suraj Park, Rohini, Sector-18,Delhi- 110042. cetpbadli42@hotmail.com, 9868110187. (Shri. Ravi Sood)	1.5 MLD	approx. 500-600 kg/day
5	BAWANA	M/s Bawana Infa Devlopment Pvt. Ltd, Bawana Industrial Area CETP, Sector-5, Bawana Industrial Area, New Delhi-110039. support@dsiidc.org, pankaj.tekriwal@abhyudayainfra.com, 9711939267	11 MLD	approx. 1000 kg/day

6	GTK	The President/Secretary, GTK Road Industrial Estate CETP Society (Regd.), CETP Complex Society Building, B-Block, GTK Road Industrial Area, Delhi-110 033, gtksociety@gmail.com, 9811049385, 9013555151 (Shri. Tripathi, Operator Maintenance) (Shri. S.P. Gupta)	2.5 MLD	approx. 150 kg/day
7	**LAWRENCE ROAD**	The President/Secretary, Lawrence Road Indl. Area CETP, Near HP petrol pump , Ring Road, Delhi-35, support@dsiidc.org, kesplacetp@gmail.com, 9818250728 (Shri. Sharad Kumar, SE. DSIIDC)	12 MLD	approx. 100-150 kg/day
8	**MANGOL-PURI**	The President/Secretary, Mangolpuri Industrial Area Phase- I & II CETP Society (regd.), Mangolpuri Industrial Area, Phase-I, Delhi-110083, mpiacetp@gmail.com, 9811232270. (Shri, Ashok Alag, President).	2.4 MLD	approx. 50-60 kg/day
9	NARELA	M/s PNC Delhi Industrial Infra Pvt. Ltd. Narela CETP, Opposite H Block, DSIIDC Narela Industrial Area, Delhi – 110040, support@dsiidc.org, rjain@pncinfratech.com, 9212244588.	5.5 MLD	approx. 600-700 kg/day
10	SMA	The President/Secretary, North West Industrial Area CETP Society, 119, SMA Co-operative Industrial Area, GT Karnal Road, Delhi-110033. nwiacetp@gmail.com, nwiacetp@yahoo.com, 9811166065 (Shri. Grover)	1.6 MLD	approx. 500 kg/day
11	**WAZIRPUR**	The President/Secretary,Wazirpur Industrial Pollution Control CETP Society, Adarsh Complex (IInd Floor), Plot No.3, Community Centre, Wazirpur Industrial Area, Delhi- 110052, wipcon.cetp@yahoo.com, info@jaykayenterprises.org, 9811025308 (Shri.Jay Kumar Bansal, President).	3.5 MLD	approx. 2500-3000 kg/day

12	NANGLOI	The President/Secretary, DSIDC Nangloi & Udyog Nagar CETP Society, Behind DTC Nangloi Depot, Rohtak Road, Delhi- 110041. cetp2006@yahoo.com, cetp.nangloi@gmail.com, 9868229252 , 9810071435 (Shri. Sunil Monga)	2 MLD	approx. 200 kg/day
13	JHILMIL	The President/Secretary, Jhilmil & Friends Colony Industrial Area CETP Society, B-Block (Opp. B-43), Jhilmil Industrial Area, Delhi-110095. info@jfc-cetp.com, cetpjhilmil@ikspspl.com. 9810033673 (Shri. R.K. Bansal)	7.5 MLD	approx. 100-120 kg/day

5.1.1 CETPs Visit and Sewage Sample Collection

Three CETPs were finalized for collection of sludge viz. Lawrence Road, Mangolpuri and Wazirpur in Delhi. A team of scientists visited these plants and collected the sludge sample for development of building products. Fig. 5.1 to 5.3 shows the view of these plants during visit.

Laurence road CETP is based on anaerobic biological treatment having an installed capacity of 12 MLD. About 1.2 MLD effluent is reaching the CETP and approx. 100-150 kg sludge is generated per day. The sludge is collected into the bags at plant for disposal into low lying areas or into SLF. The influent reaching to the plant is mixed with sewage having large amount of organic matter.

Mangolpuri CETP having a capacity of 2.4 MLD is based on activated sludge process system. About 2.2 MLD effluent from both Phase I and Phase II is reaching the CETP. Effluent from both PST and SST contains a high concentration of suspended solids. Dual media filter (DMF) and activated carbon filter (ACF) units were included in the CETPs to improve the effluent quality. Removal of TSS by DMF reduces not only the TSS in the final effluent but also its BOD and COD concentration, which is associated with the organic fraction of TSS. The ACF is used to remove trace organics, such as pesticides, phenols, etc., and heavy metals, which escape the primary treatment.

Wazirpur CETP is based on chemical treatment having a capacity of 3.5 MLD. About 3.5 MLD effluent from industrial area is reaching the CETP and is highly acidic having a pH of

2-3 and has high concentration of suspended solids. Effluent is treated with lime followed by PAC treatment. Enormous amount of sludge (3000 to 3500 kg/Day) is generated as waste causing disposal problems. Dual media filter (DMF) and activated carbon filter (ACF) units are included in the CETPs to achieve the effluent standards.

Fig 5.1.: A view of Mangolpuri CETP

Fig. 5.2: A view of Laurence Road CETP

Fig. 5.3: A view of Wazirpur CETP

5.1.2. Characterization of CETPs Sludge

About 100 kg of CETPs sludge samples were collected from three plants each location for development of building materials. The samples of sludge were dried at 50 ± 2^{o}C in trays, cooled to room temperature, ground in a ball mill and sieved through 4.75 mm sieve. Physical and particle size analysis of all three samples was carried out and the results are shown in Table 5.2. These sludge samples were also characterized for chemical properties and the results are shown in Table 5.3. All the sludge samples were used as a replacement of fine aggregate (stone dust) for the development of paving blocks/bricks. The process flow chart of fabrication of paving blocks and bricks using CETPs sludge is shown in Fig. 5.4.

Table 5.2: Physical properties of CETPs sludge samples

Sr. No.	**Properties**	**Values**		
		Laurence Road CETP	**Mangolpuri CETP**	**Wazirpur CETP**
1.	pH	6.25	7.76	8.30
2.	Colour	Dark Grey	Light Gray	Brown
3.	Specific gravity	1.98	1.68	2.58
4.	Bulk Density	0.65 g/cm^3	0.64 g/cm^3	0.99 g/cm^3
5.	LOI	55.56	46.24	23.19
6.	**Particle size**	**Passing (%)**	**Passing (%)**	**Passing (%)**
	10 mm	100	100	100
	4.75mm	100	100	100
	2.36mm	97.87	100	100
	1.18mm	96.87	97.75	67.25
	600 µm	84.12	81.12	52.87
	300 µm	96.87	75.50	97.25
	150 µm	58.25	62.50	88.50
7.	Fineness modulus	1.18	1.52	2.89

Table 5.3: Chemical characterization of CETPs sludge

Sr. No.	Parameters	Values (%)		
		Laurence Road CETP	**Mangolpuri CETP**	**Wazirpur CETP**
1.	SiO_2	32.24	32.56	13.12
2.	Al_2O_3	29.56	17.03	3.94
3.	Fe_2O_3	7.03	7.75	17.76
4.	CaO	6.68	19.36	24.89
5..	MgO	3.40	7.21	----
6.	ZnO	----	1.59	----
7.	TiO_2	----	1.52	0.13
8.	CuO	----	0.53	----
9.	P_2O_5	6.22	5.44	----
10.	Cr_2O_3	----	----	4.15
11.	SO_3	9.93	4.82	23.84
12.	MnO	----	----	2.51
13.	K_2O	2.41	2.09	0.63
14.	Total Carbon	32.41	26.88	13.48
15.	Total Organic Matter	51.85	43.00	22.08

5.2 DEVELOPMENT OF ROAD PAVING BLOCKS AND TRESTING

The mix compositions used for development of road paving blocks and designations for control and fine aggregate replaced by CETP sludge are given in Table 5.4. The sludge was used (8-15 %) as fine aggregates in various mix composition (A1, A2, and B1). The physical and mechanical properties of paving blocks like water absorption and compressive strength were determined after 28 days of curing period and results are shown in Table 5.5, 5.6 and 5.7 for Laurence road, Mangolpuri and Wazirpur CETPs respectively.

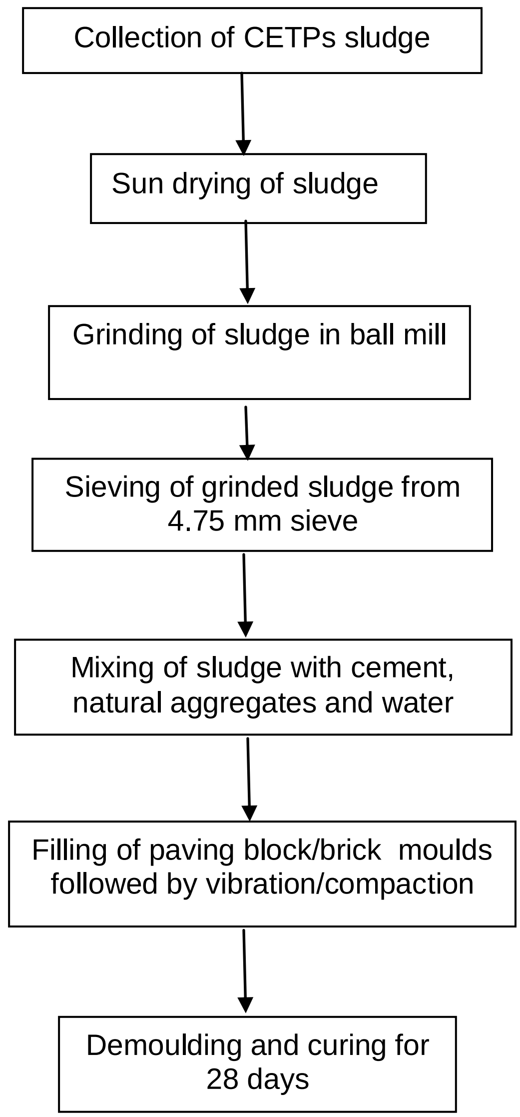


Fig. 5.4: Flow chart for fabrication of road paving blocks and bricks using CETPS sludge

Table 5.4: Mix proportion of paving blocks

Mix designations	Cement (%)	CETP sludge (%)	Stone dust (%)	Coarse aggregate (%)	Water (%)
Top Layer	33.33	-----	66.67	----	9.00
A0 (Control)	**25.00**	**-----**	**37.50**	**37.50**	**8.00**
A1	25.00	8.00	29.50	37.50	10.00
A2	25.00	15.00	22.50	37.50	11.25
B0 (Control)	**22.50**	**----**	**33.25**	**44.50**	**7.50**
B1	22.50	10.00	23.25	44.50	9.35

Table 5.5: Physical and mechanical properties of paving blocks developed from CETP sludge, Laurence Road

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.0**	**62.50**	
A1	4.60	24.00	**Recommended**
A2	8.85	10.10	
B0 (Control)	**2.80**	**50.50**	
B1	7.50	16.80	

Table 5.6: Physical and mechanical properties of paving blocks developed from CETP sludge, Mangolpuri,

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.0**	**62.50**	
A1	4.50	28.20	**Recommended**
A2	6.80	16.00	
B0 (Control)	**2.80**	**50.50**	
B1	5.50	21.30	**Recommended**

Table 5.7: Physical and mechanical properties of paving blocks developed from CETP Sludge, Wazirpur

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.0**	**62.50**	
A1	3.30	45.00	**Recommended**
A2	5.80	30.00	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	5.00	34.60	**Recommended**

5.3 DEVELOPMENT OF CEMENT BRICK AND TESTING

The mix compositions used for development of bricks using CETP sludge and designations are given in Tables 5.8 along with water content. The properties of bricks like water absorption and compressive strength were determined following the procedure laid down in IS: 3495 and are shown in Table 5.9, 5.10 and 5.11.

Table 5.8: Mix proportion of cement bricks

Mix designations	Cement (%)	Stone dust (%)	CETP sludge (%)	Water (%)
E0 (Control)	**10.00**	**90**	**----**	**7.50**
E1	15.00	75.00	10.00	10.00
E2	20.00	70.00	10.00	11.00

Table 5.9: Physical and mechanical properties of bricks developed from CETP sludge, Laurence Road

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	24.85	1731	3.75	
E2	21.90	1744	3.95	
IS:1077: 1992 requirement	<20% for class up to 12.5 <15% for class higher than 12.5		> 5 MPa	

Table 5.10: Physical and mechanical properties of bricks developed from CETP sludge, Mangolpuri

Mix designations	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	22.00	1794	5.50	
E2	16.50	1831	6.20	**Recommended**
IS:1077:1992 requirement	<20% for class up to 12.5 <15% for class higher than 12.5		> 5 MPa	

Table 5.11: Physical and mechanical properties of bricks developed from CETP sludge, Wazirpur

Mix designations	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	12.00	1698	6.50	**Recommended**
E2	12.80	1719	6.75	**Recommended**
IS:1077: 1992 requirement	<20% for class up to 12.5 <15% for class higher than 12.5		> 5 MPa	

5.4 TCLP STUDIES

TCLP studies were carried out of blocks developed using CETPs sludge for field application to know the concentration of metal ions which may leach in land. Blocks developed and recommended using sludge of Laurence road plant (mix A1), Mangolpuri plant (mixes A1 and B1) and Wazirpur plant (mixes A1, A2 and A3) were selected for TCLP studies. The results of these studies are shown in Table 5.12. A perusal of table shows that all the metal ions present in the sludge samples are immobilized in cement matric and leachable amount is complying to the limits of USEPA.

Table 5.12: Leaching characteristics of metals from paving blocks developed using sludge from CETPs

Name of CETP	Mixes	Metal Ions (mg/l)						U.S. EPA TCLP Standards
		Iron	Zinc	Copper	Nickel	Chromium	Lead	
Laurence Road	A1	0.00	0.11	0.88	0.85	0.11	0.16	Cr < 5.0 mg/l For rest of the metal ions it is not available
Mangolpuri	A1	0.00	0.12	0.91	1.02	BDL	0.17	
	B1	0.00	0.10	0.95	0.97	BDL	0.17	
Wazirpur	A1	0.13	0.17	0.21	0.17	0.23	0.17	
	A2	0.11	0.12	0.20	0.17	0.21	0.17	
	B1	2.55	0.11	0.16	0.15	0.21	0.16	

5.5 RECOMMENDATIONS

After receiving the results of blocks and bricks development utilizing CETPs sludge, following recommendations are given:

1. TCLP studies show that leaching of heavy metal ions present in CETP sludge blocks is negligible and complying to the limits of USEPA in all mixes.
2. It is observed that with increase in sludge composition as a replacement of stone dust (21-40 %), compressive strength decreases.
3. Sludge is used 8-15 % of the total mix with various cement compositions (22.5-25 %) for the development of blocks. Recommended mix are A1 for Laurence road CETP, A1 and B1 for Mangolpuri CETP and A1, A2 and B1 for Wazirpur CETP.
4. Laurence road CETP sludge is not found suitable for making bricks. Mix E2 for Mangolpuri CETP sludge (20 % cement) and mixes E1 (15 % cement) and E2 for Wazirpur CETP sludge are recommended for development of cement bricks as per Indian standard with 10 % of sludge.

CHAPTER VI

DEVELOPMENT OF ROAD PAVING BLOCKS USING DRAIN SILT

6.1 STATUS OF DRAIN SILT GENERATION IN DELHI

Desilting from drains is carried out by different department like North Delhi Municipal Corporation (NDMC), East Delhi Municipal Corporation (EDMC), South Delhi Municipal Corporation (SDMC), Delhi Development Authority (DDA), Irrigation and Flood Control Department Delhi (I&FC) and Delhi State Industrial and Infrastuctural Development Corporation Ltd. (DSIIDC) under respective Action Plan of Drains Desilting. Information regarding total No. of drains of four feet and above in depth and total silt generation in different zones/divisions/wards of Delhi was collected from the above departments through personal contact/Delhi Govt. Portal. As per the information received/collected, the status of desilting of drains in various zones of Delhi from 4 feet and above drains in depth is given in Tables 6.1-6.5.

Table 6.1: Status of drains silt generation in East Delhi Municipal Corporation (EDMC)

Sr. No.	Zones/Divisiones	Total No. of drains	Total Silt to be removed as per Actions Plan (MT)
	Shahdara (North)		
1	EE(M)-I	40	6834
2	EE(M)-II	32	11516
3	EE(M)-III	24	7002
4	EE(M)-IV	16	8435.1
	Total	**112**	33787.10
	Shahdara (South)		
5	EE(M)-I	34	3794
6	EE(M)-II	18	3075
7	EE(M)-III	23	3983.44
8	EE(M)-IV	39	4028
9	EE(Pr)-II	01	2923.20
	Total	**115**	**17803.64**
	Grand Total	**227**	**51590.74**

Table 6.2: Status of drains silt generation in North Delhi Municipal Corp. (NDMC)

Sr. No.	Zones/Divisions	Total No. of drains	Total Silt to be removed as per Actions Plan (MT)
	Rohini Zone		
1	EE(M)-I	25	859.88
2	EE(M)-III	17	906.63
3	EE(M)-IV	30	633.12
	Total	**72**	**2399.63**
	Civil Lines Zone		
4	EE(M)-CLZ-I	8	442.05
5	EE(M)-CLZ-II	7	136.95
6	EE(M)-CLZ-III	13	797.34
7	EE(M)-CLZ-IV	16	1890.92
	Total	**44**	**3267.26**
	Sadar Pahar Ganj		
8	EE(M)-I & II	**5**	**434.71**
	Karol Bagh Zone		
9	EE(M)-I	20	1028.52
10	EE(M)-II	14	901.81
	Total	**34**	**1930.33**
	City Zone		
11	EE(M)-I & II	**2**	**152.81**
	Narela Zone		
12	EE(M)-I	19	484.00
13	EE(M)-II	19	366.61
	Total	**38**	**850.61**
	Grand Total	**195**	**9035.35**

Table 6.3: Status of drains silt generation in South Delhi Municipal Corp. (SDMC)

Sr. No.	Zones/Divisions	Total No. of drains	Total Silt to be removed as per Actions Plan (MT)
	Central		
1	EE(M-I)	32	8639
2	EE(M-II)	11	2067
3	EE(M-III)	7	1946
4	EE(M-IV)	7	1578
	Total	**57**	**14230**
	South		
5	EE(M-I)	26	2729
6	EE(M-II)	14	1970
7	EE(M-III)	13	3121
8	EE(M-IV)	13	1946
	TOTAL	**66**	**9766**
	West		
9	EE(M-I)	25	1167
10	EE(M-II)	15	1370
11	EE(M-III)	13	291
12	EE(M-IV)	21	1334
	TOTAL	**74**	**4162**
	Najafgarh		
13	EE(M-I)	45	1368
14	EE(M-II)	07	189
15	EE(M-III)	19	994
	Total	**71**	**2551**
	Grand Total	**268**	**30709**

Table 6.4: Status of drains silt generation in Irrigation and Flood Control, Department, Delhi (IF&CD)

Sr. No.	Zones	Total No. of drains	Total Silt to be removed as per Actions Plan (Cum)
1	FC-I	15	177365
2	FC-II	29	60785
3	FC-III	03	42316
4	FC-IV	17	96503
	Grand Total	**64**	**376969**

Table 6.5: Status of drains silt generation in Delhi Development Authority (DDA)

Sr. No.	Zones	Total No. of drains	Total Silt to be removed as per Actions Plan (Cum)
	Dwarka Zone	03	91700
1	East Zone	08	10599
2	Project Zone	07	27700
3	North Zone	05	22055
4	Rohini Zone	03	995
	South Zone	01	Nil
	Grand Total	**28**	**153049**

About 8000 MT per annum of silt is generated from New Delhi Municipal Corporation including mechanical road sweeper, silt collection etc. The information about the status of silt generation from Delhi State Industrial and Infrastructural Development Corporation Ltd. (DSIIDC) and Public Works Department (PWD) has not been received. All the drain silt generated from different zones/sub area of Delhi is dumped in landfills at three locations viz. Ghazipur, Bhalsawa and Okhla.

6.2 SITE SELECTION FOR UTILIZTION OF DRAIN SILT

After discussion with competent authority, it has been decided that total 21 samples of drain silt will be collected from different departments/areas of Delhi which will represent different types of silt having different characteristics. The details of sites are as follows:

(A) Irrigation and Flood Control, Department (IF&C), Delhi : Total 12 samples

1. Najafgarh Drain : CD-I
2. Najafgarh Darin : CD-II
3. Ghazipur Darin : CD-III
4. Trunk Drain No. 1 : CD-IV
5. Ali Drain : CD-V
6. Drain No. 6 : CD-VI
7. Bawana Escape Darin : CD-VII
8. Kirari Suleman Drain : CD-VIII
9. Supplementary Drain : CD-II
10. Supplementary Drain : CD-IX
11. Supplementary Drain : CD-XI
12. Jahangirpuri Outfall Darin : CD-X

(B) Municipal Corporation of Delhi (MCD), Delhi : Total 6 samples

1. NDMC : Pool Training Centre
2. NDMC : Pitampura Village
3. EDMC : Luxmi Nagar
4. EDMC : West Vinod Nagar
5. SDMC : Central Zone
6. SDMC : R. K. Puram

(C) Public Works Department (PWD), Delhi : Total 3 samples

1. PWD (South) : Aurobindo Marg
2. PWD (North) : Mall Road Extension (Azadpur –Mukbara Chowk)
3. PWD (East) : Ring Road near Rajghat

6.3 DRAIN SILT SAMPLE COLLECTION AND CHARACTERIZATION

About 50 kg of drain silt samples were collected from each select location for development of building materials. After sun drying the silt samples, demolition waste, plastics, polythene, rubber, leather, glass etc. were removed manually, ground in a ball mill and passed through 4.75 mm sieve. The silt has been used as a replacement of fine aggregate (stone dust) for the development of paving blocks/bricks. The physical and particle size analysis of the silt has been shown in Table 6.6-6.12. The chemical analysis of silt samples is shown in Table 6.13-6.19.

Table 6.6: Physical properties of drain silt samples of IF&C, Delhi

Sr. No.	Properties	Values			
		Najafgarh Drain CD-I	**Najafgarh Drain CD-II**	**Ghazipur Drain CD-III**	**Trunk Darin No. 1 CD- I V**
1.	pH	6.75	7.38	6.88	7.90
2.	Colour	Dark Brown	Light Brown	Grey	Grey
3.	Specific gravity	2.36	2.57	2.62	2.58
4.	Bulk Density	1.20 g/cm^3	1.33 g/cm^3	1.52 g/cm^3	1.14 g/cm^3
5.	LOI (%)	18.95	9.65	23.98	7.50
6.	**Particle size**	**Passing (%)**	**Passing (%)**	**Passing (%)**	**Passing (%)**
	10 mm	100	100	100	100
	4.75 mm	100	100	100	100
	2.36 mm	99.87	96.62	99.88	92.13
	1.18 mm	97.50	87.25	99.38	79.00
	600 µm	92.00	93.25	96.38	85.38
	300 µm	85.00	91.62	84.75	85.38
	150 µm	70.75	65.62	34.63	71.50
7.	Fineness modulus	0.94	1.39	1.09	2.25
8.	Sand (%)	57.96	64.79	71.80	63.88
9.	Silt (%)	38.42	31.39	25.65	33.82
10.	Clay (%)	3.62	3.82	2.55	2.30

Table 6.7 : Physical properties of drain silt samples of IF&C, Delhi

Sr. No.	Properties	Values			
		Ali Drain CD-V	**Drain No. 6 CD-VI**	**Bawana Escape Drain CD-VII**	**Kirari Suleman Drain CD-VIII**
1.	pH	7.80	7.60	8.00	7.95
2.	Colour	Grey	Light Brown	Brown	Light Brown
3.	Specific gravity	2.35	2.69	2.30	2.55
4.	Bulk Density	1.28 g/cm^3	1. 28 g/cm^3	0.98 g/cm^3	1.18 g/cm^3
5.	LOI (%)	7.85	4.25	5.67	13.60
6.	**Particle size**	**Passing (%)**	**Passing (%)**	**Passing (%)**	**Passing (%)**
	10 mm	100	100	100	100
	4.75 mm	100	100	100	100
	2.36 mm	99.87	98.38	99.50	99.63
	1.18 mm	98.12	91.13	95.50	98.25
	600 µm	89.00	93.25	69.50	69.25
	300 µm	87.50	89.00	73.25	82.50
	150 µm	43.75	57.25	67.25	68.38
7.	Fineness modulus	1.22	1.28	1.98	1.67
8.	Sand (%)	57.74	54.12	44.57	47.38
9.	Silt (%)	38.46	43.25	47.99	47.77
10.	Clay (%)	3.80	2.63	7.44	4.85

Table 6.8: Physical properties of drain silt samples of IF&C, Delhi

Sr. No.	Properties	Values			
		Supplementary Drain CD-II	**Supplementary Drain CD-IX**	**Jahangirpuri Drain CD-X**	**Supplementary Drain CD-XI**
1.	pH	7.06	8.01	7.07	8.30
2.	Colour	Light Brown	Brown	Brown	Light Brown
3.	Specific gravity	2.04	2.31	2.23	2.52
4.	Bulk Density	0.86 g/cm^3	1.22 g/cm^3	1.05 g/cm^3	1.39 g/cm^3
5.	LOI	34.85	8.57	21.98	9.56
6.	**Particle size**	**Passing (%)**	**Passing (%)**	**Passing (%)**	**Passing (%)**
	10 mm	100	100	100	100
	4.75 mm	100	100	100	100
	2.36 mm	99.50	99.37	99.88	99.87
	1.18 mm	95.50	97.10	99.25	97.12
	600 µm	25.75	19.63	84.75	24.25
	300 µm	92.75	93.12	80.50	94.37
	150 µm	89.50	91.37	53.75	85.87
7.	Fineness modulus	2.69	2.79	1.34	2.64
8.	Sand (%)	33.35	55.36	53.30	50.30
9.	Silt (%)	62.99	41.81	41.96	46.73
10.	Clay (%)	3.66	2.83	4.74	2.97

Table 6.9: Physical properties of drain silt samples of NDMC

Sr. No.	**Properties**	**Values**	
		Pool Training Centre	**Pitampura Village**
1.	pH	4.50	6.73
2.	Colour	Dark brown	Light brown
3.	Specific gravity	3.45	2.42
4.	Bulk Density	1.44 g/cm^3	1.07 g/cm^3
5.	LOI (%)	19.34	29.09
6.	**Particle size**		
	10 mm	100	100
	4.75 mm	100	100
	2.36 mm	91.50	98.50
	1.18 mm	80.50	92.75
	600 µm	91.00	91.63
	300 µm	81.63	68.50
	150 µm	70.00	65.63
7.	Fineness modulus	2.14	1.59
8.	Sand (%)	38.01	71.15
9.	Silt (%)	61.35	22.85
10.	Clay (%)	0.64	6.00

Table 6.10: Physical properties of drain silt samples of EDMC

Sr. No.	Properties	Values	
		Luxmi Nagar	**West Vinod Nagar**
1.	pH	7.16	8.43
2.	Colour	Light brown	Grey
3.	Specific gravity	2.38	2.39
4.	Bulk Density	1.26 g/cm^3	0.86 g/cm^3
5.	LOI (%)	19.40	15.92
6.	**Particle size**		
	10 mm	100	100
	4.75 mm	100	100
	2.36 mm	98.75	99.38
	1.18 mm	95.50	94.63
	600 µm	93.63	90.13
	300 µm	98.88	76.13
	150 µm	51.50	59.00
7.	Fineness modulus	1.54	1.43
8.	Sand (%)	65.61	52.49
9.	Silt (%)	33.03	44.51
10.	Clay (%)	1.36	3.0 %

Table 6.11: Physical properties of drain silt samples of SDMC

Sr. No.	Properties	Values	
		Central Zone	R. K. Puram
1.	pH	5.38	3.59
2.	Colour	Light brown	Dark brown
3.	Specific gravity	2.39	2.44
4.	Bulk Density	1.56 g/cm^3	1.81 g/cm^3
5.	LOI (%)	17.68	23.39
6.	**Particle size**		
	10 mm	100	100
	4.75 mm	100	100
	2.36 mm	96.38	99.00
	1.18 mm	89.00	94.50
	600 µm	85.00	87.25
	300 µm	48.25	36.00
	150 µm	81.88	84.25
7.	Fineness modulus	2.28	2.09
8.	Sand (%)	74.88	79.20
9.	Silt (%)	23.79	19.40
10.	Clay (%)	1.33	1.40

Table 6.12: Physical properties of drain silt samples of PWD, Delhi

Sr. No.	Properties	Values		
		PWD, South Aurobindo Marg	**PWD, East Mall Road Exten.**	**PWD, North Ring Road**
1.	pH	8.54	9.23	4.85
2.	Colour	Brown	Brown	Dark Brown
3.	Specific gravity	2.38	2.44	1.96
4.	Bulk Density	1.49 g/cm^3	1.44 g/cm^3	0.81 g/cm^3
5.	LOI (%)	6.72	7.93	26.45
6.	**Particle size**			
	10 mm	100	100	100
	4.75 mm	100	100	100
	2.36 mm	98.25	98.62	99.13
	1.18 mm	90.25	96.00	94.75
	600 µm	93.00	95.88	24.00
	300 µm	84.88	87.38	89.25
	150 µm	73.25	51.00	93.50
7.	Fineness modulus	1.04	1.09	2.81
8.	Sand (%)	68.18	75.32	52.62
9.	Silt (%)	30.59	23.20	40.86
10.	Clay (%)	1.23	1.48	6.52

Table 6.13: Chemical characterization of drain silt samples of IF&C, Delhi

Sr. No.	Parameters	Values (%)			
		Najafgarh Drain CD-I	**Najafgarh Drain CD-II**	**Ghazipur Drain CD-III**	**Trunk Darin No. 1 CD- I V**
1.	SiO_2	49.02	54.75	53.83	49.14
2.	Al_2O_3	22.60	19.52	25.59	25.83
3.	Fe_2O_3	3.53	3.58	2.81	3.58
4.	CaO	14.70	11.57	5.00	6.19
5.	MgO	2.52	3.27	----	5.06
6.	P_2O_5	1.80	----	4.32	0.70
7.	MoO_3	0.04	0.04	0.02	----
8.	TiO_2	----	----	0.58	0.66
9.	K_2O	3.80	3.72	3.61	5.14
10.	Na_2O	----	----	----	3.63
11.	ZnO	----	----	----	0.04
12.	Total Carbon	2.10	1.41	3.29	1.62
13.	Total Organic Matter	3.80	2.56	6.08	2.91

Table 6.14: Chemical characterization of drain silt samples of IF&C, Delhi

Sr. No.	**Parameters**	**Values (%)**			
		Ali Drain CD-V	**Drain No. 6 CD-VI**	**Bawana Escape Drain CD-VII**	**Kirari Suleman Drain CD-VIII**
1.	SiO_2	50.59	56.22	49.72	48.99
2.	Al_2O_3	33.82	25.61	27.87	27.73
3.	Fe_2O_3	2.83	3.36	4.74	3.53
4.	CaO	5.17	----	4.72	7.47
5.	MgO	----	3.71	5.47	5.15
6.	P_2O_5	1.56	----	----	1.81
7.	TiO_2	1.04	0.54	0.78	0.55
8.	SO3	0.33	----	----	----
9.	MoO_3	0.04	0.04	----	----
10.	K_2O	2.58	4.71	3.77	3.65
11.	Total Carbon	1.22	1.33	1.83	1.72
12.	Total Organic Matter	2.08	2.28	3.34	2.90

Table 6.15: Chemical characterization of drain silt samples of IF&C, Delhi

Sr. No.	Parameters	Values (%)			
		Supplementary Drain CD-II	**Supplementary Drain CD-IX**	**Jahangirpuri Drain CD-X**	**Supplementary Drain CD-XI**
1.	SiO_2	34.72	46.93	41.90	50.53
2.	Al_2O_3	31.90	26.32	21.07	26.85
3.	Fe_2O_3	6.69	3.61	6.09	2.42
4.	CaO	7.85	13.29	10.02	8.65
5.	MgO	3.84	3.38	4.17	3.85
6.	P_2O_5	9.26	1.79	2.63	----
7.	SO_3	----	----	8.42	----
8.	K_2O	2.74	4.02	3.30	3.38
10.	Total Carbon	4.29	1.36	2.66	1.88
11.	Total Organic Matter	7.37	2.23	4.78	3.24

Table 6.16: Chemical characterization of drain silt samples of NDMC

Sr. No.	Properties	Values (%)	
		Pool Training Centre	**Pitampura Village**
1.	SiO_2	11.09	51.80
2.	Al_2O_3	----	20.95
3.	Fe_2O_3	50.05	----
4.	Cr_2O_3	16.21	----
5.	MnO	6.73	----
6.	CaO	1.01	10.14
7.	MgO	1.38	3.67
8.	P_2O_5	1.17	3.07
9.	SO_3	4.08	6.37
10.	K_2O	0.72	3.12
11.	Total Carbon	3.54	6.20
12.	Total Organic Matter	6.40	11.20

Table 6.17: Chemical characterization of drain silt of EDMC

Sr. No.	Properties	Values (%)	
		Luxmi Nagar	**West Vinod Nagar**
1.	SiO_2	48.32	37.08
2.	Al_2O_3	11.98	19.31
3.	BaO	3.41	----
4.	Cr_2O_3	----	7.60
5.	Na_2O	3.36	1.86
6.	CaO	15.14	9.94
7.	MgO	6.18	3.03
8.	P_2O_5	2.43	2.38
9.	SO_3	5.15	5.54
10.	K_2O	3.14	2.46
11.	Total Carbon	6.65	5.58
12.	Total Organic Matter	12.23	10.29

Table 6.18: Chemical characterization of drain silt of SDMC

Sr. No.	Properties	Values (%)	
		Pool Training Centre	**Pitampura Village**
1.	SiO_2	44.77	57.80
2.	Al_2O_3	9.66	13.49
3.	Na_2O	4.99	1.69
4.	CaO	24.46	12.37
5.	MgO	6.79	5.33
6.	P_2O_5	2.34	1.94
7.	SO_3	2.76	2.83
8.	K_2O	3.31	3.75
9.	Total Carbon	3.22	4.75
10.	Total Organic Matter	5.82	8.59

Table 6.19: Chemical characterization of drain silt of PWD, Delhi

Sr. No.	Properties	Values (%)		
		PWD, South Aurobindo Marg	**PWD, East Mall Road Exten.**	**PWD, North Ring Road**
1.	SiO_2	53.95	65.84	36.88
2.	Al_2O_3	12.00	18.67	21.18
3.	Na_2O	4.79	1.00	1.99
4.	CaO	15.29	7.09	7.10
5.	MgO	5.32	3.26	2.68
6.	P_2O_5	1.33	1.33	4.03
7.	Fe_2O_3	2.71	----	----
8.	K_2O	3.45	2.40	2.90
9.	SO_3	----	----	19.93
9.	Total Carbon	2.79	3.55	9.75
10.	Total Organic Matter	5.14	6.45	17.65

6.4 DEVELOPMENT OF ROAD PAVING BLOCKS AND TESTING

The mix compositions used for development of road paving blocks and designations are given in Table 6.20. The silt was utilized in the range of 10-15 % of total mix as replacement of fine aggregates (26.66-40.0 %). The process flow chart of fabrication of paving blocks and bricks has been shown in Fig. 6.1. The physical and mechanical properties of paving blocks like water absorption and compressive strength were determined after 28 days of curing period and results are shown in Table 6.21-6.41.

Table 6.20: Mix proportion of paving blocks developed using drain silt

Mix designations	Cement (%)	Drain silt (%)	Stone dust (%)	Coarse aggregate (%)	Water (%)
Top Layer	33.33	-----	66.67	----	9.00
A0 (Control)	**25.00**	**-----**	**37.50**	**37.50**	**8.00**
A1	25.00	10.00	27.50	37.50	8.75
A2	25.00	15.00	22.50	37.50	9.35
B0 (Control)	**22.25**	**-----**	**33.25**	**44.50**	**7.50**
B1	22.25	10.00	23..25	44.50	8.75
B2	22.25	13.25	20.00	44.50	9.35

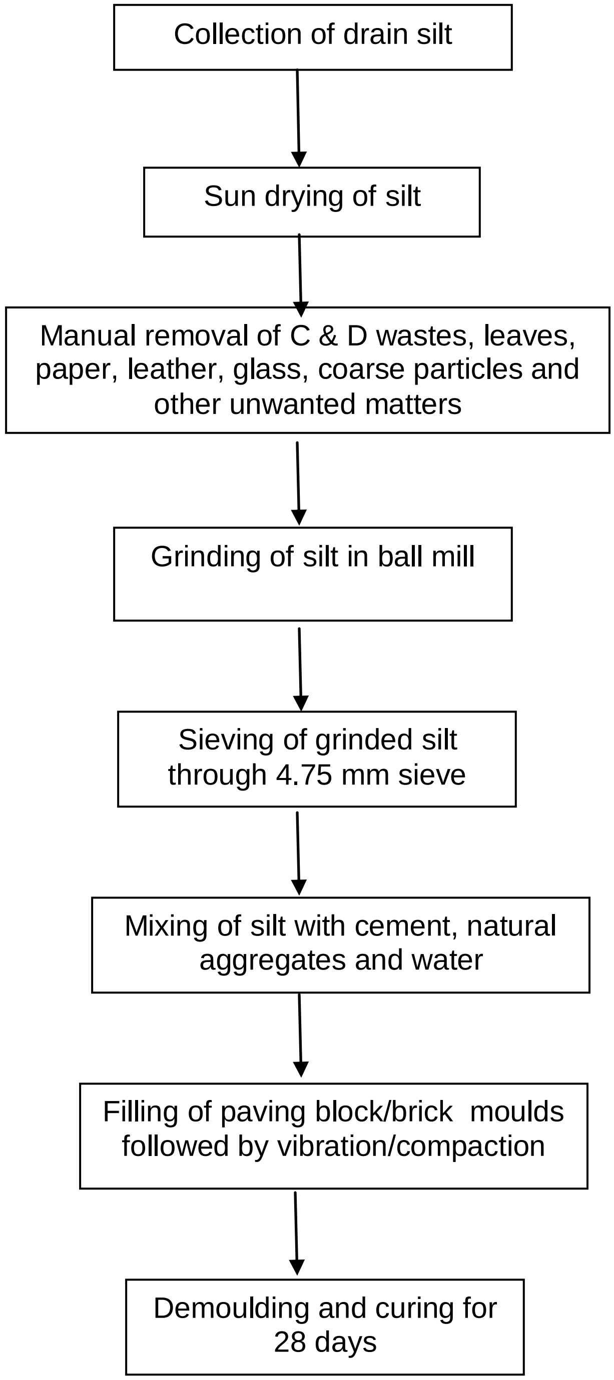


Fig. 6.1: Flow chart for fabrication of road paving blocks and bricks using drain silt

Table 6.21: Properties of paving blocks developed from Najafgarh drain silt (CD-I)

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	5.85	26.15	**Recommended**
A2	7.20	21.00	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	5.60	25.60	**Recommended**
B2	6.50	23.20	**Recommended**

Table 6.22: Properties of paving blocks developed from Najafgarh drain silt (CD-II)

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	4.40	40.20	**Recommended**
A2	5.60	38.40	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	6.20	39.50	**Recommended**
B2	6.40	37.60	**Recommended**

Table 6.23: Properties of paving blocks developed from Supplementary Drain silt (CD-II)

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	5.60	26.50	**Recommended**
A2	6.80	21.30	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	6.50	25.50	**Recommended**
B2	6.80	24.00	**Recommended**

Table 6.24: Properties of paving blocks developed from Ghazipur drain silt (CD-III)

Mix designations	**Water absorption (%)**	**Compressive strength (MPa)**	**Remark**
A0 (Control)	**2.00**	**62.50**	
A1	3.50	32.00	**Recommended**
A2	5.20	25.80	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	3.80	30.00	**Recommended**
B2	4.60	27.50	**Recommended**

Table 6.25: Properties of paving blocks developed from Trunk drain silt (CD-IV)

Mix designations	**Water absorption (%)**	**Compressive strength (MPa)**	**Remark**
A0 (Control)	**2.00**	**62.50**	
A1	5.60	37.25	**Recommended**
A2	6.75	29.75	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	5.50	37.00	**Recommended**
B2	6.00	30.25	**Recommended**

Table 6.26: Properties of paving blocks developed from Ali drain silt (CD-V)

Mix designations	**Water absorption (%)**	**Compressive strength (MPa)**	**Remark**
A0 (Control)	**2.00**	**62.50**	
A1	3.50	47.20	**Recommended**
A2	4.75	40.00	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	3.75	46.50	**Recommended**
B2	5.00	41.00	**Recommended**

Table 6.27: Properties of paving blocks developed from Drain No. 6 silt (CD-VI)

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	3.50	42.15	**Recommended**
A2	4.80	31.75	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	3.75	40.25	**Recommended**
B2	4.25	33.60	**Recommended**

Table 6.28: Properties of paving blocks developed from Bawana Escape drain silt (CD-VII)

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	4.50	29.35	**Recommended**
A2	5.25	21.90	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.50	28.80	**Recommended**
B2	5.50	22.15	**Recommended**

Table 6.29: Properties of paving blocks developed from Kirari Suleman drain silt (CD-VIII)

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	4.25	33.10	**Recommended**
A2	5.50	29.30	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.50	31.45	**Recommended**
B2	4.25	27.20	**Recommended**

Table 6.30: Properties of paving blocks developed from Supplementary drain silt (CD-IX)

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	4.25	42.40	**Recommended**
A2	6.50	34.60	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.75	40.00	**Recommended**
B2	5.50	38.50	**Recommended**

Table 6.31: Properties of paving blocks developed from Jahangirpuri Outfall drain silt (CD-X)

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	6.75	22.50	**Recommended**
A2	10.50	14.90	
B0 (Control)	**2.80**	**50.50**	
B1	6.75	20.80	**Recommended**
B2	9.50	17.60	

Table 6.32: Properties of paving blocks developed from Supplementary drain silt (CD-XI)

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	4.40	41.85	**Recommended**
A2	5.80	38.60	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.60	40.50	**Recommended**
B2	4.60	39.80	**Recommended**

Table 6.33: Properties of paving blocks developed using drain silt from Pool Training Centre, NDMC

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	4.00	35.20	**Recommended**
A2	4.40	31.46	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.40	32.00	**Recommended**
B2	5.25	30.20	**Recommended**

Table 6.34: Properties of paving blocks developed using silt from Pitampura Village, NDMC

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	5.80	22.25	**Recommended**
A2	7.20	17.60	
B0 (Control)	**2.80**	**50.50**	
B1	5.80	20.00	**Recommended**
B2	17.80	17.10	

Table 6.35: Test results of paving blocks developed using silt from Luxmi Nagar, EDMC Properties

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	5.65	21.70	**Recommended**
A2	8.20	14.77	
B0 (Control)	**2.80**	**50.50**	
B1	6.00	20.96	**Recommended**
B2	7.60	16.80	

Table 6.36: Properties of paving blocks developed using silt from West Vinod Nagar, EDMC

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	5.90	20.50	**Recommended**
A2	8.75	14.40	
B0 (Control)	**2.80**	**50.50**	
B1	7.60	18.80	
B2	7.75	16.40	

Table 6.37: Properties of paving blocks developed using silt from Central Zone, SDMC

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	3.90	41.15	**Recommended**
A2	4.85	36.00	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.60	39.15	**Recommended**
B2	4.60	35.50	**Recommended**

Table 6.38: Properties of paving blocks developed from using silt from R. K.Puram, SDMC

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	4.10	44.00	**Recommended**
A2	4.50	41.35	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.10	42.60	**Recommended**
B2	4.75	40.50	**Recommended**

Table 6.39: Properties of paving blocks developed using silt from Aurobindo Marg, PWD (South), Delhi

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	3.80	42.50	**Recommended**
A2	5.80	36.00	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.50	42.00	**Recommended**
B2	5.80	35.20	**Recommended**

Table 6.40: Properties of paving blocks developed using silt from Mall Road Extension, PWD (East), Delhi

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	4.65	27.75	**Recommended**
A2	5.25	25.50	**Recommended**
B0 (Control)	**2.80**	**50.50**	
B1	4.80	24.80	**Recommended**
B2	5.25	21.75	**Recommended**

Table 6.41: Properties of paving blocks developed using silt from Ring Road, PWD (North), Delhi

Mix designations	Water absorption (%)	Compressive strength (MPa)	Remark
A0 (Control)	**2.00**	**62.50**	
A1	5.50	21.50	**Recommended**
A2	8.00	13.25	
B0 (Control)	**2.80**	**50.50**	
B1	5.50	21.00	**Recommended**
B2	9.25	12.75	

6.5 TCLP STUDIES OF BUILDING PRODUCTS

TCLP studies were carried out of those recommended mixes in which heavy metal ions are present in silt chemical composition. Therefore, TCLP was carried out for A1 and B1 mixes of Pool Training Centre, NDMC and mix A1 for west vinod Nagar, EDMC. The results of these studies are shown in Table 6.42. A perusal of table shows that all the metal ions present in the sludge samples are immobilized in cement matric and leachable amount is very less complying to the limits of USEPA.

Table 4.42: Leaching characteristics of metals from paving blocks developed using drain silt

Name of Site	Mixes	Metal Ions (mg/l)						U.S. EPA TCLP Standards
		Iron	Zinc	Copper	Nickel	Chromium	Lead	
Pool Training Centre, NDMC	A1	1.22	0.12	0.82	0.38	0.77	0.17	Cr < 5.0 mg/l For rest of the metal ions it is not available
	B1	0.86	0.12	0.75	0.37	0.56	0.15	
West Vinod Nagar, EDMC	A1	0.00	0.13	0.73	0.36	1.26	0.17	

6.6 RECOMMENDATIONS

After receiving the results of road paving blocks development using drain silt as a replacement of fine aggregates, following recommendations are given:

1. TCLP studies show that leaching of heavy metal ions from blocks is negligible and complying to the limits of USEPA in all mixes.
2. Drain silt is used 10-15 % of the total mix with various cement compositions (22.5-25 %) in the development of blocks. Mixes giving strength of more than 20 MPa have been recommended as they meet the water absorption requirement (<6 %) of Indian standard.
3. The results of compressive strength of blocks using silt from IF&C shows that the strength was more than 20 MPa for all locations (CD I-CD XI) and mixes A1, A2 and B1, B2 have been recommended for development of paving blocks except in case of CD-X silt (Jahangirpuri drain) where strength is less than 20 MPa with A2 and B2 mixes.
4. The results of compressive strength of paving blocks developed using drain silt from NDMC, SDMC, EDMC and PWD show that the strength was more than 20 MPa for Mix A1 in all cases. The mixes A2 and B2 for Pitamura (NDMC), Luxmi Nagar (EDMC), A2, B1 and B2 for West Vinod Nagar (EDMC) and A2 and B2 for PWD (North) from were not recommended as the strength was less than 20 MPa in these cases.

DEVELOPMENT OF CEMENT BRICKS USING DRAIN SILT

7.1 DEVELOPMENT OF CEMENT BRICK AND ENGINEERING PROPERTIES

The mix compositions used for development of bricks using drains silt (IF&C, MCD and PWD) and designations for control and silt replaced mixes are given in Tables 7.1. The table shows that 10-15 % of the drain silt is used with 15-20 % of cement content for development of bricks. The properties of bricks like water absorption and compressive strength were determined following the procedure laid down in IS: 3495 and are shown in Table 7.2-7.22.

Table 7.1: Mix proportion of cement bricks using drain silt

Mix designations	**Cement (%)**	**Stone dust (%)**	**Darin silt (%)**	**Water (%)**
E0 (Control)	**10.00**	**90**	**----**	**7.50**
E1	15.00	75.00	10.00	11.65
E2	20.00	65.00	15.00	12.50
IS:1077: 1992 requirement : Water absorption: <20% for class up to 12.5; <15% for class higher than 12.5; Compressive strength : > 5 MPa				

Table 7.2: Properties of bricks developed from Najafgarh drain silt (CD-I)

Mix designation	**Water absorption (%)**	**Bulk density (kg/m^3)**	**Compressive strength (MPa)**	**Remarks**
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	18.50	1726	5.25	**Recommended**
E2	18.00	1715	5.50	**Recommended**

Table 7.3: Properties of bricks developed from Najafgarh drain silt (CD-II)

Mix designation	**Water absorption (%)**	**Bulk density (kg/m^3)**	**Compressive strength (MPa)**	**Remarks**
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	13.85	1718	9.00	**Recommended**
E2	12.90	1738	9.50	**Recommended**

Table 7.4: Properties of bricks developed from Ghazipur drain silt (CD-III)

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	12.50	1750	9.25	**Recommended**
E2	11.25	1731	9.50	**Recommended**

Table 7.5: Properties of bricks developed from Trunk drain silt (CD-IV)

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	13.85	1740	7.50	**Recommended**
E2	12.50	1725	8.30	**Recommended**

Table 7.6: Properties of bricks developed from Ali drain silt (CD-V)

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	10.50	1710	11.00	**Recommended**
E2	10.50	1722	11.50	**Recommended**

Table 7.7: Properties of bricks developed from drain No. 6 silt (CD-VI)

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	11.50	1705	9.00	**Recommended**
E2	11.00	1718	9.75	**Recommended**

Table 7.8: Properties of bricks developed from Bawana drain silt (CD-VII)

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	12.75	1690	5.90	**Recommended**
E2	12.75	1705	6.10	**Recommended**

Table 7.9: Properties of bricks developed from Kirari Suleman Drain silt (CD-VIII)

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	12.20	1710	9.75	**Recommended**
E2	12.20	1736	9.75	**Recommended**

Table 7.10: Properties of bricks developed from Supplementary drain silt (CD-II)

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	17.75	1732	5.25	**Recommended**
E2	18.50	1758	5.50	**Recommended**

Table 7.11: Properties of bricks developed from Supplementary drain silt (CD-IX)

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	13.20	1710	9.50	**Recommended**
E2	12.80	1722	9.50	**Recommended**

Table 7.12: Properties of bricks developed from Jahangirpuri drain silt (CD X)

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	15.50	1720	6.70	**Recommended**
E2	19.50	1715	3.90	

Table 7.13: Properties of bricks developed from Supplementary drain silt (CD-XI)

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	16.70	1732	7.90	**Recommended**
E2	16.80	1728	7.90	**Recommended**

Table 7.14: Properties of bricks developed from drain silt, Pool Training Centre, NDMC

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.00**	
E1	12.50	1828	10.00	**Recommended**
E2	13.80	1730	10.00	**Recommended**

Table 7.15: Properties Test results of bricks developed from drain silt, Pitamputa Village, NDMC

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	16.70	1705	8.10	**Recommended**
E2	16.80	1696	6.20	**Recommended**

Table 7.16: Properties of bricks developed from drain silt, Luxmi Nagar, EDMC

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	17.85	1695	7.95	**Recommended**
E2	18.00	1715	7.75	**Recommended**

Table 7.17: Properties of bricks developed from drain silt, West Vinod Nagar, EDMC

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	18.75	1740	6.10	**Recommended**
E2	22.00	1723	4.30	

Table 7.18: Properties of bricks developed from drain silt, Central Zone, SDMC

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	15.50	1795	9.10	**Recommended**
E2	15.75	1783	9.10	**Recommended**

Table 7.19: Properties of bricks developed from drain silt, R. K. Puran, SDMC

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	10.75	1710	10.75	**Recommended**
E2	11.80	1696	10.50	**Recommended**

Table 7.20: Properties of bricks developed from drain silt, PWD (South), Delhi

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	12.25	1750	10.25	**Recommended**
E2	12.65	1728	10.25	**Recommended**

Table 7.21: Properties of bricks developed from drain silt, PWD (East), Delhi

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	11.75	1780	8.50	**Recommended**
E2	12.25	1765	8.30	**Recommended**

Table 7.22: Properties of bricks developed from drain silt, PWD (North), Delhi

Mix designation	Water absorption (%)	Bulk density (kg/m^3)	Compressive strength (MPa)	Remarks
E0 (Control)	**3.50**	**1955**	**10.0**	
E1	22.50	1653	4.75	
E2	21.75	1645	4.75	

7.2 RECOMMENDATIONS

It is observed that with increase in drain silt (IF&C, MCD and PWD) content from 10-15 % and cement from 15-20 %, compressive strength of the brick remains almost same. Mixes E1 and E2 have been recommended for all the silt samples except in case of Jahangirpuri CD X (only Mix E1) and West Vinod Nagar, EDMC (only mix E1). Bricks could also not be developed using drain silt samples of PWD (North) as compressive strength of less than 5.0 MPa and water absorption more than 20 % have been observed and results are not complying Indian standards.

CHAPTER VIII

COST ESTIMSTION AND COMPARISON

8.1 GENERAL

The building components like paving blocks and bricks (Fig. 8.1) have been developed using ash from waste to energy plants, sludge from combined effluent treatment plants and drains silt from various locations of IF&C, MCD and PWD as fine aggregates and cement as binder material as per Indian Standards. The results of TCLP studies have shown that the products developed may be used for field applications without causing any harm to the land as well as underground water quality. For commercial production of these building components utilizing wastes, it is necessary to determine their cost and comparison with the similar product available in the market.

8.2 COST OF RAW MATERIALS

For development of paving blocks, main raw materials are OPC cement, natural fine aggregate, ash/sludge/silt as replacement of fine aggregates and coarse aggregates. The estimated cost of these raw materials are as under:

Cost of cement (1bag/ 50 kg of OPC)	= Rs. 350/-
Cost of fine aggregate/stone dust (100 kg)	= Rs. 100/-
Cost of coarse aggregate (100 kg)	= Rs. 100/-
Cost of drying/grinding/sieving of ash/sludge/silt used as replacement of natural fine aggregate (100 kg)	= Rs. 100/-

8.3 COST OF PAVING BLOCKS AVAILABLE IN THE MARKET

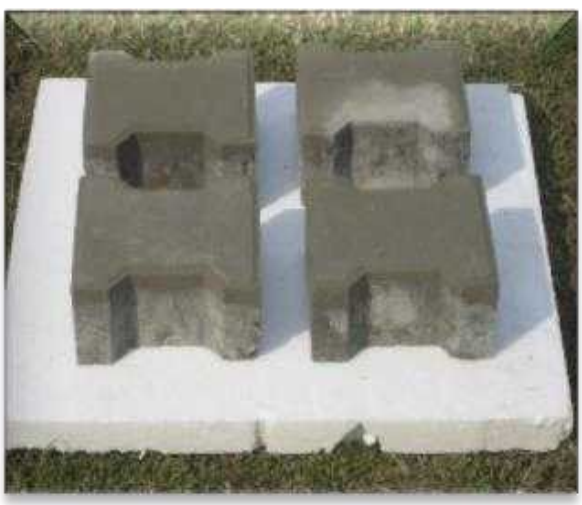
The normal weight and dimensions of the two layered interlocking paving blocks available in the market are 4.50 kg and 200 mm x 160 mm x 70 mm respectively. The percentage ratio of cement : fine aggregate : coarse aggregates used in bottom layer is generally 15 : 28 : 57. The compressive strength of the block is 12-15 MPa. Although size, composition and strength may vary as per consumer requirements and availability of raw materials. The composition and cost estimation of these two layers of paver block are as under:

(A) Cost Estimation of Top Layer

Weight of top layer (5-7 mm)	= 500 gm
Ratio of cement : Fine aggregate	= 1:2
Cement in Top layer	= 167 gm
Natural fine aggregate in top layer	= 333 gm
Cost of cement in top layer (b)	= Rs. 0.33
Total cost of top layer (a+b)	= **Rs. 1.50**

(B) Cost Estimation of bottom layer

Ratio of cement: Fine aggregate : coarse aggregate	= 1:2:4
Cement content	= 600 gm
Natural fine aggregate content	= 1120 gm
Natural Coarse aggregates	= 2280 gm
Cost of cement (a)	= Rs. 4.20
Cost of fine aggregate (b)	= Rs. 1.12
Cost of coarse aggregate (c)	= Rs. 2.28
Cost of Labour (fabrication and curing) and electricity (d)	= Rs. 2.00
Total cost of bottom layer layer (a+b+c+d)	= **Rs. 9.60**
Total cost of paving block (Top+ bottom layer)	= **Rs. 11.10**
Selling price (depending upon the availability of raw materials)	=**Rs.12.0-13.0**



Paving blocks

Cement bricks

Fig. 8.1: Paving blocks and bricks developed using waste

8.4 COST OF PAVING BLOCKS DEVELOPED USING WASTE MATERIALS

The cost of paving blocks developed using different wastes at different cement content (20.0 %, 22.25 % and 25.0 %,) have been determined and the cost of fine aggregate has been kept same as for natural fine aggregate. The cost estimation at different cement content is as under:

At cement content of 15.0 % (Strength less than 15.0 Mpa)

Cost of Top layer	= Rs. 1.50
Ratio of cement : Fine aggregate : coarse aggregate	= 15 : 28 : 57
Cost of bottom layer with 15.0 % cement content	= Rs. 9.60
Total cost of paving block	= **Rs. 11.10**

At cement content of 20 % (Strength more than 20.0 Mpa)

Cost of Top layer	= Rs. 1.50
Ratio of cement : Fine aggregate : coarse aggregate	= 25 : 37.5 : 37.5
Cost of bottom layer with 20.0 % cement content	= Rs. 10.80
Total cost of paving block	= **Rs. 12.30**

At cement content of 22.25 % (Strength 20-30 Mpa)

Cost of Top layer	= Rs. 1.50
Ratio of cement : Fine aggregate : coarse aggregate	=22.25:33.25:44.5
Cost of bottom layer with 22.25 % cement content	= Rs. 11.35
Total cost of paving block	= **Rs. 12.85**

At cement content of 25.0 % (Strength more than 30 Mpa)

Cost of Top layer	= Rs. 1.50
Ratio of cement : Fine aggregate : coarse aggregate	= 20 : 30 : 50
Cost of bottom layer with 25.0 % cement content	= Rs. 12.00
Total cost of paving block	= **Rs. 13.50**

8.5 COST OF CEMENT FLY ASH BRICKS AVAILABLE IN THE MARKET

The weigh and dimensions of the cement fly ash bricks available in the market are 4.50 kg and 225 mm x 110 mm x 70 mm respectively. The percentage ratio of cement : fine aggregate used is generally 10 : 90 or 15 : 85. The compressive strength of the brick 10-12 MPa. Although size, composition and strength may vary as per consumer requirements and availability of raw materials. The composition and cost estimation of market bricks are as under:

Weight of the raw materials	= 3500 gm
Cement (10.0-15.0 %)	= 350-525 gm
Fine aggregate including fly ash	= 2975-3150 gm
Cost of cement (a)	= Rs. 2.45-3.65
Cost of fine aggregate in top layer (b)	= Rs. 2.975-3.10
Cost of Labour , curing and electricity (c)	= Rs. 2.00
Total cost (a+b+c)	= **Rs. 7.425-8.75**
Selling price (depending upon the availability of raw materials)	=**Rs. 8.0-9.0**

8.6 COST OF BRICKS DEVELOPED USING WASTE MATERIALS

The cost of paving blocks developed using different wastes at different cement content (15 and 20 %) have been determined and the cost of fine aggregate has been kept same as for natural fine aggregate. The cost estimation at different cement content is as under:

At cement content of 15.0 %

Cement (15.0 %)	= 525 gm
Fine aggregate including fly ash	= 2975 gm
Cost of cement (a)	= Rs. 3.65
Cost of fine aggregate in top layer (b)	= Rs. 3.10
Cost of Labour and electricity (c)	= Rs. 2.00
Total cost of brick (a+b+c)	= **Rs. 8.75**

At cement content of 20 %

Cement (20.0 %)	= 700 gm
Fine aggregate including fly ash	= 2800 gm
Cost of cement (a)	= Rs. 4.90
Cost of fine aggregate in top layer (b)	= Rs. 2.80
Cost of Labour and electricity (c)	= Rs. 2.00
Total cost of brick (a+b+c)	= **Rs. 9.70**

8.7 COMPARISON WITH MARKET PRODUCTS

The developed paving blocks at different cement and aggregate content have been compared with the paving blocks available in the market. The cost estimation shows that the selling price of paving blocks in the market (cement content less than 15.0 %) is about Rs. 12.0-13.0 having a strength of less than 15.0 MPa. However, the paving blocks developed using different wastes at cement content 20.0-25.0 % shows a strength of 20-48 MPa and the cost ranges from Rs. 12.30 to 13.50. Similarly the cost of brick at 15.0 % and 20.0 % of cement content is Rs. 8.75 and 9.70 respectively as compared to the market selling price of Rs. 9.0 at 15.0 % of cement content. It shows that the difference in the cost of market product and the product developed utilizing waste is negligible and the quality of the product in terms of strength is better. Besides this, the product developed is ecofriendly utilizing waste as fine aggregate which will not only help to reduce the consumption of natural resources but also it will help in conservation of the environment. Further, utilizing waste as building materials will reduce the burden on landfills, helpful keeping the cities pollution free and clean.

CHAPTER IX

CONCLUSIONS AND RECOMMENDATIONS

9.1 GENERAL

Samples of bottom ash/fly ash from waste to energy plants (WTEPs), sludge from sewage treatment plants (STPs)/combined effluent treatment plants (CETPs) and drain silts were collected from Delhi. After required processing these samples were analysed for various physical and chemical parameters as per standard methods. The biological analysis of silt/sludge samples was not carried out due to the addition of cement in mix composition having a pH of 13.0. The highly alkaline medium does not support bacterial growth and also helps in stabilizing the biological content. Pozzolanic activity of the silt/sludge/bottom ash was also not determined as XRD results showed presence of crystalline matter which was inert in nature. The samples of bottom ash/silt/sludge were utilized for the development of building components like road paving blocks and bricks. Bottom ash is an inorganic materials and can also be used partially as replacement of natural fine aggregate in cement/concrete mortar as fine aggregate for plastering, sub base layer in road making and light weight building components. The percentage amount for utilization of bottom ash may be decided after detailed long term durability studies. However, sludge and silt both contain a high amount of organic matter along with hazardous elements which are responsible for land and water pollution. Further, their addition in the cement concrete/mortar will hinder in the hydration reaction of the cement and it will result in low strength responsible for cracking. Therefore, it is not advisable to use silt/sludge in concrete/mortar until or unless detailed studies are undertaken. However, this disadvantages of using silt/sludge can be avoided in mechanized molded concrete blocks. This is because in manufacturing concrete blocks using a mechanized molding machine, the mixed materials are molded under a combined vibrating and compacting action. This reduces the difficulties of controlling the w/c ratio and workability. Also, the low water content of the concrete mixtures for the molded blocks significantly reduces the creep and shrinkage of the hardened products.

The paving blocks are two layered building product in which top layer is made of cement and fine aggregates, while bottom layer is made of cement, fine aggregate and coarse aggregates. In present studies, the top layer is composed of cement and natural fine aggregate (stone dust) in the ratio of 1:2, while bottom layer is composed of utilization of ash/sludge/silt, as partial replacement of natural fine aggregate (stone dust). The paving blocks have been developed and tested as per IS: 15658: 2006. Mixes giving compressive strength of more than 20 MPa and water absorption of less than 6.0 % (as per IS) have been recommended for commercial production of paving blocks. Toxicity characteristics leaching procedure (TCLP) studies have also been carried out for field applications.

The cement bricks are made of cement as binder and fine aggregates. In present studies, the development of bricks have been carried out as per IS: 1077: 1992 using ash/sludge/silt as partial replacement of fine aggregate and the engineering properties have been determined as per IS: 3495: 1992. Mixes giving compressive strength of more than 5.0 MPa and water absorption of less than 20.00 % (as per IS) have been recommended for commercial production of bricks.

9.2 BOTTOM ASH FROM WASTE TO ENERY PLANTS (WTEPs)

Samples of bottom ash were collected from two plants viz. M/s Timarpur- Okhla Waste Management Company Private Ltd and M/s. East Delhi Waste Processing Company Ltd. Bottom ash was used as fine aggregate for development of paving blocks and bricks. Toxicity characteristics leaching procedure (TCLP) studies were not required for bottom ash mixed building components as no hazardous heavy element were observed in the chemical compositions of bottom ash.

(a) Recommendation for Paving Blocks

1. It is recommended that 11.25-37.50 % of bottom ash of total mix (30-100 % of natural fine aggregate replacement) may be utilized for the development of road paving blocks at various cement contents (10-25 %).
2. The results show that compressive strength is a function of bottom ash content in the mix. The compressive strength decreases with increase in percentage of bottom ash.
3. Based on experimental investigations, know-how process has been developed for commercial development of paving blocks and recommendations are given in Table 9.1.

Table 9.1: Recommended mix compositions and results for road paving blocks

Cement in Bottom Layer (%)	Fine aggregate (%)	Bottom ash (%)	Coarse aggregate (%)	Compressive strength (MPa)	Water absorption (%)
25.00	11.25-26.25	11.25-26.25	37.50	32.50-48.00	< 6.00
22.00	10.00-23.25	10.00-23.25	44.50	30.20-45.20	< 6.00
20.00	9.00-15.00	15.00-21.00	50.00	32.50-42.00	< 6.00
15.00	17.50	17.50	50.00	36.80	< 6.00
10.00	10.00	20.00	50.00	27.00	< 6.00

(b) Recommendation for Bricks

Cement bricks have been fabricated using 40-42.50 % of bottom ash as fine aggregates of total mix with 15-20 % of cement. Based on experimental investigations, know-how process has been developed for commercial development of bricks and recommended mix composition with results is given in Table 9.2.

Table 9.2: Recommended mix compositions and results for bricks

Cement in Bottom Layer (%)	Fine aggregate (%)	Fly ash (%)	Compressive strength (MPa)	Water absorption (%)
15.00	42.50	42.50	6.30-7.20	< 20.00
20.00	40.00	40.00	9.00-9.50	< 20.00

9.3 FLY ASH FROM WASTE TO ENERGY PLANTS (WTEPs)

Sample of fly ash was collected from M/s. East Delhi Waste Processing Company Ltd. and it was used as fine aggregate for development of paving blocks and bricks. Toxicity characteristics leaching procedure (TCLP) studies were not carried out for building components as no hazardous heavy elements were present observed in fly ash chemical composition.

(a) Recommendation for Paving Blocks

1. Fly ash (10-15 % of the total mix) in the range of 30-70 % have been recommended in mix composition as a replacement of stone dust for development of blocks.
2. It is observed that with increase in fly ash content in mix composition, compressive strength decreases.
3. Based on experimental investigations, know-how process has been developed for commercial development of paving blocks and recommendations are given in Table 9.3.

Table 9.3: Recommended mix compositions and results for road paving blocks

Cement in Bottom Layer (%)	Fine aggregate (%)	Fly ash (%)	Coarse aggregate (%)	Compressive strength (MPa)	Water absorption (%)
25.00	22.50-27.50	10.00	37.50	23.50-36.37	< 6.00
22.00	20.00-23.25	15.00	44.50	28.20-36.25	< 6.00

(b) Recommendation for Bricks

Cement bricks were developed using 10-15 % of fly ash as fine aggregates of total mix with 15-20 % of cement. Based on experimental investigations, know-how process has been developed for commercial development of bricks and recommended mix compositions with results are given in Table 9.4.

Table 9.4: Recommended mix compositions and results for bricks

Cement in Bottom Layer (%)	Fine aggregate (%)	Fly ash (%)	Compressive strength (MPa)	Water absorption (%)
15.00	75.00	10.00	8.65	< 20.00
20.00	65.00	15.00	9.95	< 20.00

9.4 SLUDGE FROM SEWAGE TREATMENT PLANTS

STPs sludge samples were collected from STPs viz. Okhla (ASP), Mehrauli (Extended aeration) and Dr. Sen nursing home nalla (biochemical). Various percentage of STP sludge have been utilized (8-15 %) as fine aggregate for development of paving blocks with cement content 25-30 %. However, development of building components meeting the requirements of Indian Standards was not possible due to the presence of high organic content in sludge. Although, few recommendations have been given for the utilization of STP sludge after proper processing or pretreatment:

1. The STPs sludge contain substantial quantities of organic and volatile matter which is generally non-conductive to produce reliable and suitable construction materials as the material developed is highly porous and has high water absorption properties.
2. There is a strong potential for use of sewage sludge as a fertilizer due to its pH, presence of nitrogen and phosphorous content.

3. The calorific value of sewage sludge, which is related to its organic content, also suggests that it could be potentially be utilized with some processing as a fuel, with a calorific value equivalent to around 50 % that of coal.
4. Incineration is a treatment process involving the combustion of pretreated sewage sludge followed by energy recovery from the heat produced. This process leads to large reduction (about 90 %) in its volume and sewage sludge converts in to sewage sludge ash (SSA). The SSA can be utilized as fine sand for development of building products especially the light weight components. The SSA can also be used as a good adsorbent for heavy metal ions as well dyes.

   Dehydration, devolatization and autogasification occur as the sludge is fed into the furnace, leading to the evaporating of residual moisture and vaporization of volatile organics and metals, followed by char combustion to gases. Residual inorganic fine particulates are carried out with the exhaust gases out of the combustion chamber and typically pass through a heat exchanger. As the temperature subsequently reduces, condensation of metal vapours to inorganic particulates also occurs and the residual ash fraction is then removed by cleaning system.
5. Sewage sludge and sewage sludge ash (SSA) are two such materials that contain substantial amount of phosphorus. The recovery of phosphorus from these materials is one method of preserving the available resources and indeed can also reduce the adverse environmental impact and high energy consumption associated with mining of phosphate ore.

   With sewage sludge, the high moisture and organic content are problematic for phosphorus recovery and leads to higher processing infrastructure. With sewage sludge ash (SSA), the focus is on managing the heavy metal ions and improving the phosphorous bioavailability. The processes developed can be grouped into two categories:

   Wet Chemical Treatments

   This process involves the removal of phosphorous along with other elements from the SSA by elution after which the dissolved elements are recovered by precipitation or ion exchange. The elution process predominantly involves the use of strong acidic solvents, through on occasion, alkaline substances have been used or a combination of the two.

Thermochemical Treatments

There has been significant interest in the thermochemical treatment of SSA. It is observed that the degree of heavy metal ions removal increases with the incineration temperature. About 1000^{o}C temperature is most appropriate for SSA phosphorous products. The retention time during heating is about 30 min.

*Source: Book on "Sustainable Construction Materials": Sewage Sludge Ash, Authored by Ravindra K. Dhir OBE, Gurnel S. Ghataora and Ciaran J. Lynn. Published by Elsevier, Woodhead Publishing, UK, 2017.

9.5 SLUDGE FROM COMBINED EFFLUENT TREATMENT PLANTS (CETPs)

Sludge from three CET plants viz. Lawrence Road, Mangolpuri and Wazirpur were collected and utilized as fine aggregate for the development of building components.

(a) Recommendations for Paving Blocks

1. CETPs sludge (8-15 % of the total mix) in the range of 21-40 % have been recommended in mix composition as a replacement of fine aggregate for development of blocks.
2. Compressive strength decreases with increase in sludge content.
3. The results of Toxicity characteristics leaching procedure (TCLP) studies show that leaching of heavy metal ions present in blocks developed using CETPs sludge is negligible and complying to the limits of USEPA in all mixes.
4. Based on experimental investigations, know-how process has been developed for commercial development of paving blocks and mix compositions recommended are given in Table 9.5.
5. Blocks could not be developed using sludge of Laurence road (10-15 %) and sludge of Mangolpuri (10 %) CETPs.

Table 9.5: Recommended mix compositions and results for paving blocks

Cement in Bottom Layer (%)	Fine aggregate (%)	CETPs sludge (%)	Coarse aggregate (%)	Compressive strength (MPa)	Water absorption (%)
25.00	22.50-29.50	8.0-15.0	37.50	24.00-45.00	< 6.00
22.00	23.25	10.00	44.50	21.30-34.60	< 6.00

(b) Recommendation for Bricks

1. Cement bricks may be developed using 10 % of CETPs sludge as fine aggregates of total mix with 15-20 % of cement.
2. Based on experimental investigations, know-how process has been developed for commercial development of bricks and recommended mix composition with results is given in Table 9.6.
3. Laurence road CETP sludge has not been recommended for bricks manufacturing.
4. Mangolpuri plant sludge can be utilized for development of bricks with minimum cement content of 20 %

Table 9.6: Recommended mix compositions and results for bricks

Cement in Bottom Layer (%)	Fine aggregate (%)	CETPs sludge (%)	Compressive strength (MPa)	Water absorption (%)
15.00	75.00	10.00	6.50	< 20.00
20.00	70.00	10.00	6.20-6.75	< 20.00

9.6 DRAIN SILT

Drain silt collected from 21 locations of Delhi (IF&CC, MCD and PWD) were used as replacement of fine aggregates for the development of building components.

(a) Recommendations for Paving Blocks

1. Drain silt (10-15 % of the total mix) in the range of 26.66-40 % have been recommended in mix composition as a replacement of stone dust for development of blocks.
2. It is observed that with increase in silt content in the mix, compressive strength decreases.
3. The results of Toxicity characteristics leaching procedure (TCLP) studies show that leaching of heavy metal ions present in blocks developed using silt is negligible and complying to the limits of USEPA.
4. Based on experimental investigations, know-how process has been developed for commercial development of paving blocks and mix composition recommended are given in Table 9.7.
5. Blocks could not be developed using 13.25 and 15 % of drain silt of IF&C (CD-X: Jahangirpuri drain), NDMC (Pitampura), EDMC (West Vinod Nagar and Luxmi Nagar)

and PWD (North) as compressive strength was less than 20 MPa. Further, blocks could not be developed using 10 % of drain silt of EDMC (West Vinod Nagar).

Table 9.7: Recommended mix compositions and results for paving blocks

Cement in Bottom Layer (%)	Fine aggregate (%)	Drain silt (%)	Coarse aggregate (%)	Compressive strength (MPa)	Water absorption (%)
25.00	22.50-27.50	10.0-15.00	37.50	21.00-47.20	< 6.00
22.00	20.00-23.25	10.00-13.25	44.50	23.20-46.50	< 6.00

(b) Recommendation for Bricks

1. Cement bricks may be developed using 10-15 % of drain silt as fine aggregates of total mix with 15-20 % of cement.
2. Based on experimental investigations, know-how process has been developed for commercial manufacturing of bricks and the recommended mix compositions with results are given in Table 9.8.
3. Bricks could not be developed using 15 % of drain silt of IF&C (CD-X: Jahangirpuri drain) and EDMC (West Vinod Nagar). Further, bricks could not be developed using drain silt of PWD (North).

Table 9.8: Recommended mix compositions and results for bricks

Cement in Bottom Layer (%)	Fine aggregate (%)	Darin silt (%)	Compressive strength (MPa)	Water absorption (%)
15.00	75.00	10.00	5.25-9.25	< 20.00
20.00	65.00	15.00	5.50-9.50	< 20.00

9.7 RECOMMENDATIONS FOR COSTING

1. The developed paving blocks at different cement and aggregate contents have been compared with the paving blocks available in the market. The cost estimation shows that the selling price of paving blocks in the market (cement content less than 15.0 %) is about Rs. 12.0-13.0 having a strength of less than 15.0 MPa. However, paving blocks developed in present studies using ash/sludge/silt at different cement content (20.0-25.0 %) show a compressive strength of 20-48 MPa with cost ranging from Rs. 12.30 to 13.50.

2. Similarly the cost of brick at 15.0 % and 20.0 % of cement content is Rs. 7.75 and 8.70 respectively as compared to the market selling price of Rs. 7.0 and 8.0 at 10 and 15.0 % of cement content respectively.
3. Cost comparison shows that the difference in the cost of market product and the product developed utilizing waste is almost negligible and the quality of the product in terms of strength is comparatively better.
4. Besides this, the product developed is ecofriendly utilizing waste as fine aggregate which will not only help to reduce the consumption of natural resources but also it will help in conservation of the environment. Further, utilizing waste as building materials will reduce the burden on landfills, helpful keeping the cities pollution free and clean.

9.8 REPLY TO ADDITION ISSUES

After perusing the draft report, few issues were raised by Secretary (Env.) and officers for the three MCDs regarding the project. The point wise reply to the above issues is given here under:

1. Proximate analysis of silt samples

The proximate analysis of silt depends on various factors like period of de-silting (age), season, moisture content, weather conditions, location of drain, depth of drain, population etc. Therefore, the proximate analysis of silt will show variability from sample to sample and it is very difficult to assess a true proximate analysis. However, an average proximate analysis of the dry silt is given in the following table 9.9:

Table 9.9: Proximate Analysis of Drain Silt, Delhi

Type of Material	Percentage (%)
Dry Material (Textile, light and hard plastic, leather, rubber, paper, glass, metal, wood, fruit peels & seeds, etc.)	5.0-15.0 %
Inert Material (Brick, stones, concrete, etc.)	5.0- 10.0 %
Soil Content Sand Silt Clay	 40-70 % 40-70 % 5.0-8.0 %

2. Seasonal effects on properties of silt

The change in seasons affect the physio-chemical properties of the silt due to the variation in eatables items, temperature and other climatic factors also affect the biodegradability of the organic fraction of silt. To reach to a conclusion, a detailed study is required and this task is not the part of scope of the project work.

3. Alternate uses of silt/sludge/bottom ash etc. apart from developing building materials viz. concrete/mortar mix etc.

CBRI proposed to develop building materials like road paving blocks and bricks in its proposal submitted to the Department of Environment, GNCTD and the same have been developed using silt/sludge/bottom ash. Bottom ash is an inorganic materials and can be used partially as replacement of natural fine aggregate in cement/concrete mortar as fine aggregate for plastering and sub base layer in road making. The percentage content for use of bottom ash may be decided after detailed durability studies. However, sludge and silt both contain a high amount of organic matter along with hazardous elements which are responsible for land and water pollution. Further, their addition in the cement concrete/mortar will hinder in the hydration reaction of the cement responsible for low strength and cracking. Therefore, it is not advisable to use silt/sludge in concrete/mortar until or unless detailed studies are undertaken and this activity is out of scope of project work awarded. However, this disadvantages of using silt/sludge can be avoided in mechanized molded concrete blocks. This is because in manufacturing concrete blocks using a mechanized molding machine, the mixed materials are molded under a combined vibrating and compacting action. This reduces the difficulties of controlling the w/c ratio and workability. Also, the low water content of the concrete mixtures for the molded blocks significantly reduces the creep and shrinkage of the hardened products.

4. Mixing of wastes like silt with ash/sludge with silt etc. for developing building materials/use in concrete/mortar mix etc.

Generally mixing of two wastes like silt with ash/sludge may not be recommended for developing building materials/use in concrete/mortar mix etc. Mixing of these wastes lead to magnification of toxicity because of mixing of inorganic and organic wastes. Further, their addition in the cement concrete/mortar will hinder in the hydration reaction of the cement results in low strength and cracking. Therefore, it is not advisable to use silt/sludge in concrete/mortar until or unless detailed studies are undertaken and this activity is out of scope of project awarded.

5. To provide a layout for a pilot plan for making building materials out of 100 tonnes of Waste

Considering the normal normal size of a paving block (250 mm x 160 mm x 70 mm), the weight of the block is 4500 gm. The weight of top layer is 500 gm and weight of bottom layer is 4000 gm. If blocks have to be prepared having 25: 18.75: 18.75: 37.5 ratio of cement: fine waste: stone dust: coarse aggregate in bottom layer, 750 gm of waste is consumed in each block. Therefore, utilization of 100 tonnes of waste per day, requires a plant capacity of 1,33000 blocks per day and this requires a big infrastructure. The maximum production capacity of a single automatic machine is 30,000 blocks per day in a single shift of 8-10 hours with a land requirement of one acre. Therefore, for production of about 1,00000 blocks per day, land requirement is minimum 04 acre. A sketch map is shown in Fig. 9.1 for production line of concrete blocks and the layout of a pilot plant for production of paving blocks utilizing wastes materials is shown Fig. 9.2.

6. Inclusion of capex and opex aspect ratio

To know the capex and opex aspect ratio, a detailed feasibility study report has to be prepared which should include location and capacity of plant, selection of technology, land, power, equipment, machinery and man power requirement, No. of shift and working days, cost of land, raw material availability, constructed area, shaded area, breakeven point, market demand, environmental considerations etc. Beside this, other factors like investments considerations, operational logistics, future development possibility, socio-economic factors including availability of services like transport and communication facilities etc. have to be taken into consideration for installing the plant.

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Fig. 9.1 Sketch map of production line of concrete blocks

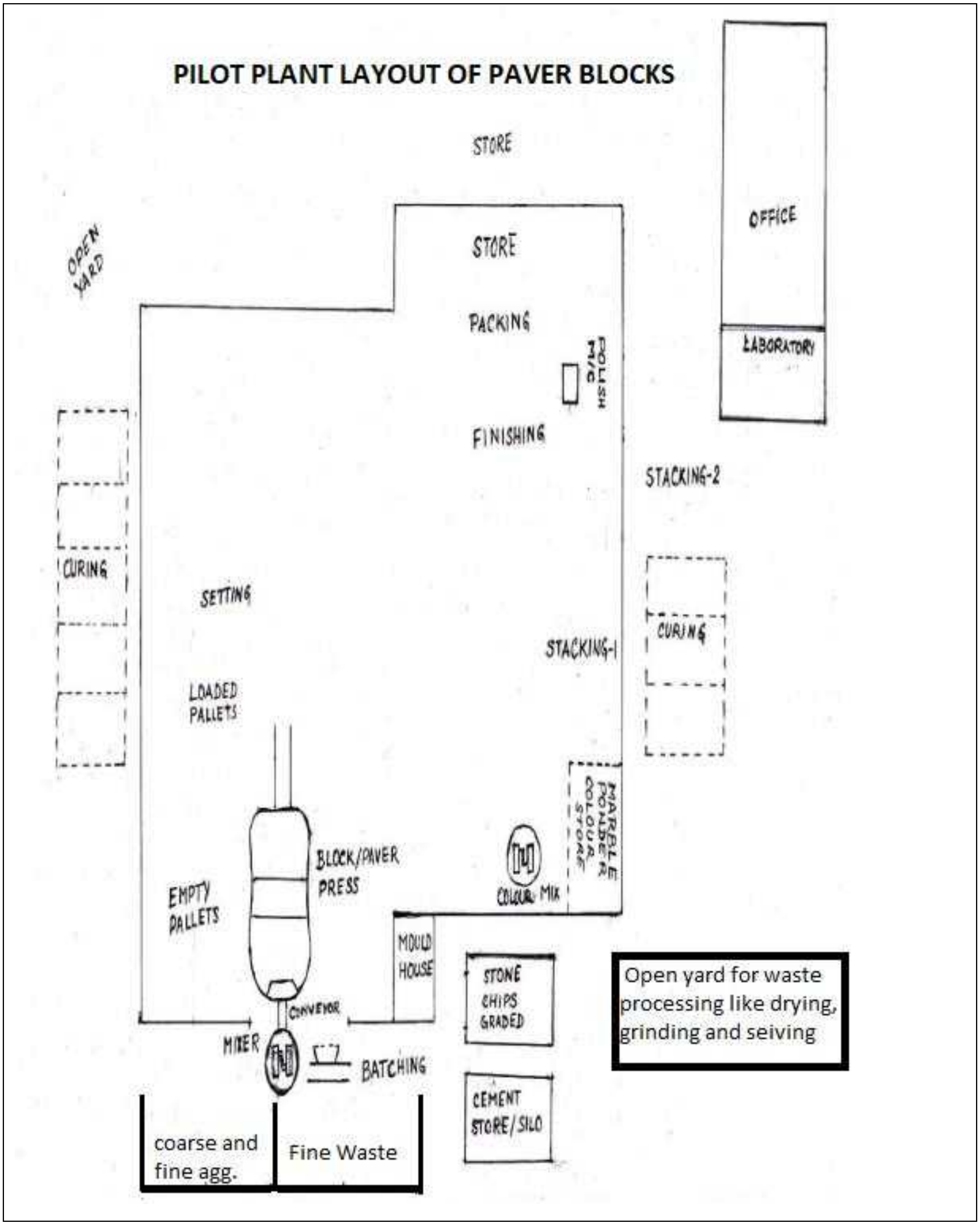

Fig. 9.2: Layout of a pilot plant for production of paving blocks