BUILDING DIGEST
CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

ECONOMY IN THE USE OF CEMENT

Introduction

The present production of cement is unable to meet the requirements of fast growing building construction activity throughout the country. The proposed target of mass building construction in the next Fifth Five Year Plan, requires a serious thought about some alternative materials or means by which economy can be achieved in the consumption of cement. This digest describes some of the ways and means of effecting saving in cement consumption. Most of these processes have been developed at this Institute.

Saving in Cement by Use of Fly-ash

Flyash is a finely powdered residue resulting from the combustion of pulverised coal in boilers and is available as an industrial waste from thermal power stations. The flyash produced at various thermal power stations in India passes the specified requirements of chemical and physical properties as per IS: 3812 (Part I)-1966 "Specifications for flyash Part I, for use as Pozzolana."

Fly-ash Concrete Mixes

Tests carried out at C B.R I. have shown that structural concrete mixes, in which upto 20 per cent of cement by weight is replaced by flyash, can be designed to compressive strength, flexural strength and modulus of elasticity equal to those of plain cement concrete at 28 days. The mix proportions of different flyash concrete mixes are shown in Table 1.

The flyash mixes well with other ingredients during the preparation of mortar and concrete in the usual way. However to avoid dust nuisance and for better strength, following procedure is recommended for the preparation of flyash concrete.

Take 3/4 quantity of mixing water in the concrete mixer. Add to it weighed amount of the required quantity of flyash and mix for half a minute. To the slurry of flyash so obtained add weighed quantities of coarse aggregate, sand, cement and the remaining quantity of water and mix for another 1½ minutes. This method improves the mixing of flyash with other ingredients. For full details refer to C.B.R.I Building Digest No. 79 on 'Proportioning of flyash concrete mix'.

Masonry Mortars using Flyash

A good masonry mortar should have sufficient workability and water retention to provide easy spreading and filling of joints and good bond with bricks. It should develop adequate strength to carry the imposed load. It should also be durable and be able to withstand the action of weathering and efflorescence. In order to have these properties in mortars using flyash, it is necessary to exercise proper control over the quality of materials, preparation of mortar and curing of brick masonry.

The cement, flyash and sand used for making masonry mortars should conform to IS:269-1967 "Specification for ordinary, rapid handening and low heat Portland cement (Second Revision)", IS.3812 (Part I) -1966 "Specifications for flyash for use as Pozzolana" and IS:2116-1959 "Specifications for sand for masonry mortars" respectively. The mix proportions of masonry mortars are shown in Table 1. For full details refer to C.B.R I. Building Digest No. 87 on "Flyash Mortar for Brick Masonry."

Pozzolana Cement

It can be produced in the factory either by grinding together portland cement clinker and flyash, and adding the requisite quantity of gypsum, or by mixing of the two in powder form. The latter requires special type of blenders to effect intimate mixing. The specifications of such cement do not differ much from the portland cement.

The loss on ignition of such cements should not be more than 5 per cent and sulphuric anhydride should not be more than 2.75 per cent. The MgO and sulphuric anhydride content in Indian flyashes is much below the permissible limits hence these can be easily used in manufacture of portland cement. The soundness, setting time and shrinkage tests conducted with flyash content upto 20 per cent show that they satisfy the conditions laid down in IS:1727-1960.

Saving in Cement by use of Lime

There are varities of building limes possessing different properties, utilized for different purposes and manufactured from raw materials of varying compositions. The various types of building limes as classified according to IS:712-1956 and their uses are given in Table 2.

The various methods of slaking, storage and handling of lime are described in detail in C.B.R.I. Building Digest No. 8 on "Building Lime".

Lime Mortars

For residential buildings not more than three storeys high, the use of cement in foundation concrete can be eliminated except in areas with excessive soluble salts or in areas with high sub-soil water level. In areas with low average rainfall, foundations and plinth masonry of single storeyed building can be laid in well-burnt bricks in lime mortar and pointed in cement mortar (1:6). The recommendations for foundation concrete, masonry mortars and plaster on walls and ceilings are given in Table 3.For full details refer to C.B.R.I. Building Digest No. 16 on "Economy in the Use of Cement in Residential Buildings."

Table 1

Mix Proportions of Different Concrete and Mortars with Fly Ash

1. **Structural Concrete Mixes**

Grade of plain cement concrete

M 150 (1:2:4)
M 200 (1:1½:3)
M 250 (1:1:2)

(Proportions by weight*)

Cement	Flyash	Sand	C. Aggregate	Water
1	0.35	2.75	4.85	0.68
1	0.35	1.65	3.85	0.62
1	0.35	0.73	2.77	0.50

2. **Lean Concrete Mixes**

(Proportions by volume)

Cement	Sand	C. Aggregate
1	3	6
1	4	8
1	5	10

Equivalent Flyash Mixes

(Proportions by volume)

Cement	Flyash	Sand	C. Aggregate
1	1.5	3.0	7
1	2.0	3.5	9
1	2.5	4.0	11

3. **Masonry Mortars**

(Proportions by volume)

Cement	Sand
1	3
1	4
1	5
1	6
1	8

Equivalent Flyash Mixes

(Proportions by volume)

Cement	Flyash	Sand
1	1.5	3
1	2.0	4
1	2.5	5
1	3.0	6.5
1	4.0	8.0

*Proportion by weight, can be converted to proportions by volume, by deviding with the bulk density of the materials available for use at site.

Lime-Sludge Based Masonry Cement

About 2.5 million tonnes of waste lime sludge are available every year from sugar, paper, acetylene and tanning industries.

Masonry cement can be made by intergrinding waste lime sludge with portland cement and gypsum. A small amount of an air-entraining agent may also be added, if required for any special use.

A mixture of 1 part of this masonry cement to 3 parts (by volume) of graded sand (IS specifications 3466-1967 for masonry cement) shows good workability, water retention value of 72-82 per cent, initial setting time 125-138 minutes and compressive strength on 5 cm cubes, 26-28 Kg/cm^2 at 7 days and 51-60 Kg/cm^2 at 28 days. This process offers a direct utilization and useful means of disposal of waste lime sludges. For details refer to C.B.R.I. Project Proposal No. 20 on "Use of Waste Lime Sludge in Making Masonry Cement."

Prefabricated Roofing/Flooring Units

The roof/floor in a building consumes about 25 per cent of building cost. The cement consumption is about 42 Kg/M^2 of plinth area, which is roughly 26 per cent of the total requirement of cement in a building. The traditional method of cast-in-situ slab takes considerable time as work of different gangs are involved in providing shuttering, laying reinforcement and concreting

A few types of prefabricated roof/floor components of medium size which can be cast on-site or in a factory, handled and placed in a position with normal labour, have been worked out. The shapes of the units ensure optimum utilisation of the materials thereby giving savings in material and overall cost apart from substantial saving in construction time.

Doubly Curved Tiles

These are 70 cm square and 2 cm thick concrete units having curvature in all four sides and all the four edges in one plane and level. These are cast in timber moulds to which a hessian cloth is fixed with headless nails. The unit itself can also be used to cast more units. These units are placed on partially precast reinforced concrete beams at 75 cm centres and haunches filled with in-situ concrete to act as tee beams. It results in a saving of 28 per cent cement as compared to in-situ R. C. slab construction. The cost of roofing by this system is Rs. 15.60/m^2 against conventional R.B. & R. C. C. slab Rs. 32.15/m^2 and Rs. 35.50/m^2 respectively. These are recommended for use only in roofing as these are week in impact loads. For details refer C.B.R.I. Building Digest No. 43 on 'Doubly Curved Tile Roofs.' These units have been adopted in low cost housing system for rural areas.

Cellular Units

These are unreinforced hollow precast concrete units of nominal size 120 cm × 60 cm and 7.5 cm thick. These are cast in timber moulds and the cores are created by wooden form work with wedges wrapped with rubber sheeting. These are used alongwith partially or fully precast beams for normal residential roof/floor loads. The scheme results in saving of 22 per cent cement as compared to in-situ R.C. slab. The cost of roofing by this system is Rs. 24.70/m^2 against conventional R. C. slab Rs. 35.50/m^2. For full details refer to C.B.R.I. Data Sheet No. 4 on "Cellular Unit Floor/Roof."

Structural Clay Units

These units are used both as an element of joist and filler and can be used in floor/roof construction as structural element. The floors constructed by these units are lighter by about 20 per cent as compared to R.C. slab and save cement by 40 per cent. The cost of roofing by this system is Rs. 25.80/m^2 against conventional R. C. slab Rs. 35.50/m^2. For details refer to C.B.R.I. Building Digest No. 105 on "Prefabricated floor/roof using structural clay units."

Waffle Units

These units can be used for two-way spanning slabs having spans more than 6 metres. The waffle units are open box type units of nominal size 60 cm to 120 cm squares. The depth will vary according to span. These are cast in timber mould upside down and the same mould can be used to cast two to three units per day. These units are placed on shuttering which is provided with 15 cm wide planks at spacing equal to the size of the units. Reinforcement is provided in the joint between adjacent units at right angle to each other. The scheme results in a saving of 15 per cent cement against R.C. slab. The cost of roofing by this system is Rs. 29.40/m^2 against conventional R.C. slab Rs. 35.50/m^2. For details refer to C.B.R.I. Data Sheet No. 6 on "Waffle Units for floor/roof."

Channel Units

These are reinforced concrete through type units 30 to 60 cm wide and 13 cm deep. These are suitable for spans 2.5 metres to 4.5 metres. These are cast manually upside down on a concrete platform and removed for curing after 24 hours of casting. The joints between the units are filled with in-situ concrete after keeping the reinforcement to take the negative moments at continuous to supports. The scheme

Table 2

Classification and Use of Lime

No.	Classification	Class	Uses
(i)	Eminently Hydraulic	A	Used for structural purposes and for under water works.
(ii)	Semi-hydraulic	B	Normally used in mortars for masonry works.
(iii)	Non-hydraulic	C	Mainly used for finishing coat in plastering and white washing.
(iv)	Magnesian & Dolomitic	Depends upon the amount of silicious and argilacious impurities present in the raw materials.	Recommended for use only in completely slaked form in mortar mixes.

Table 3

Lime Mortars for Foundation Concrete, Masonry and Plastering

Type of work	Situation/sub-grade condition	Type of * loading	Proportion of Mix (by volume)				Remarks
			Lime with grading	Cement	Pozzolana**	Sand	
1. Foundation concrete.	(a) Dry sub-grade with sub-soil water level never within 8 Ft. of the foundation level.	—	1 A	—	—	2	Normally suitable for buildings not more than 3 storeyed high.
			1 B, C or A	—	1 Surkhi	1	
			1 B, C or A	—	2 Surkhi	—	
			3 B or C	1	—	12	
	(b) Moist sub-grade with high sub-soil water. Usually 8 Ft. or less below foundation level.	—	—	1	—	4	The corresponding concrete mix will be 1:4:8 and 1:3:6 respectively.
			—	1	—	3	
2. Masonry Mortars							
(i) In Foundation and plinth.	(a) Dry	Light	1 C	—	1	2	
			1 B or A	—	—	3	
			3 C	1	3	9	
		Medium or heavy	1 C	1	2	4	
	(b) Moist, but no soluble sulphates present	Light,	1 B	1	—	6	
		medium or heavy	1 B	1	—	6	

Type of work	Situation/sub-grade condition	Type of * loading	Proportion of Mix (by volume)				Remarks
			Lime with grading	Cement	Pozzolana**	Sand	
	(c) Moist, soluble sulphates present	Light, medium or heavy	1 B	1	—	6	
(ii) Walls in super-structure	(a) Solid wall	Light or medium	1 C	—	1	1 to 2	
			1 B	—	—	2 to 3	
			***8 to 9 B	4 to 3	—	36	
		Heavy, very heavy	2 B	1	—	9	
			1 B	1	—	6	
	(b) Cavity walls.	—	1 B	1	—	6	
(iii) In tall chimneys	—	Generally	1 A	—	—	2 to 3	
		Heavy or very heavy	2 B	1	—	9	
(iv) Pointing	—	In all cases.	1 A	—	—	1	
			6 B	1	—	7	
3. Lime Plasters	(a) External plaster below d.p.c. (10 to 15 mm thick)	—	1 B or C	1	—	6	
	(b) External plaster above d.p.c. (10 to 15 mm thick)	—	2 B or C	1	—	9	
			1 A	—	—	2 to 3	
			1 B or C	—	1	1 to 2	
	(c) Internal plaster in all low or medium cost house	—	3 B or C	1	—	12	
			2 B or C	1	—	9	
			1 A	—	—	2 to 3	
			1 B or C	—	1	1 to 2	

* Light loading — 4 kg/cm²; Medium loading — 4–6 kg/cm²; Heavy loading — 6-8 kg/cm².

** Pozzolana is essentially a silicious material which while itself possessing no cementitious properties will in finally divided form and in the presence of water react with calcium hydroxide at ordinary temperature to form compound possessing cementitious properties, e. g. surkhi (IS : 1344–1959), cinder, coal ash, flyash etc.

*** The proportion shall be such that the sum of lime and cement is equal to 12.

results in saving of 40 per cent cement against R. C. slab. The cost of roofing by this system is Rs.28.00/m² against conventional R.C. slab Rs. 35.50/m². These units have been successfully adopted in thousands of primary schools constructed in U.P. For details refer to C.B.R.I. Date Sheet No. 5 on "Channel Units for Floor/Roof."

Cored Units

These are reinforced concrete hollow box type units which are suitable for spans 3.0 metres to 4.5 metres. The units are 13 cm thick and 30 cm wide.The units are self supporting and do not require any propping. These are placed one adjacent to the other and the joints between the units are filled with concrete, after placing the reinforcement for negative moments at continuous supports. The scheme results in a saving of 25 per cent concrete against R.C. slab. The cost of roofing by this system is Rs. 29.60/m² against conventional R.C. slab Rs. 35.50/m². The scheme is being carried out successfully by Delhi Development Authority, L.I.C. at Shahadra and M.P. P.W.D. at Bhopal. For details refer C.B R.I. Data Sheet No. 3 on "Cored Unit for Roof/Floor."

Reinforced Brick (R.B.) and Reinforced Brick Concrete Slabs (R.B.C.) for Floor/Roofs.

R.B. and R.B.C. slabs can be used economically for floor/roof, saving an amount 5 to 15% cement as compared to R.C. slab. These are recommended specially where good bricks are locally available and the cost of stone aggregate is high. These are however not recommended in coastal areas. These slabs are suitable for spans 2.5m. to 4.5m. A survey carried out showed that life of R.B. slab is about 45 years. The cost of roofing by this system is Rs. 32.15/m² against conventional R.C. slab Rs. 35.50/m². A rational design method with ready reference table giving reinforcement for common typical spans is given in C.B.R.I. Building Digest No. 97 on "Reinforced Brick and Reinforced Brick Concrete slab for floors/roofs.

Prefab Brick Panel System

Bricks being the most versatile and easily available material and most commonly used, a housing system named as "Prefab Brick Panel System" has been evolved. The principle of prefabrication is applied to bricks in which precast brick panels are casted by arranging bricks in timber mould and filling mortar in joints. For wall panels no reinforcement is provided but for floor/roof panels reinforcement is laid during casting. The cost of roofing by this system is Rs. 20.93/m² against conventional R.B. & R.C. slab Rs. 32.15/m² and Rs. 35.50/m² respectively. The scheme results in a saving of cement 40% against R.B. slab.

Concluding Remarks

C.B.R.I. has also developed the processes of underreamed pile for foundation and light weight clay bricks and blocks for multistoreyed construction. By adopting these techniques considerable saving in the cost of building can be achieved, which also indirectly economises the consumption of cement. Further details of all the processes described in this digest can be made available to manufacturers, builders and others interested in making use of them.

There is a demand for short notes summarising available information on selected building topics for the use of Engineers and Architects in India. To meet the need this Institute is bringing out a series of Building Digests from time to time and the present one is the 112th in the series. Readers are requested to send to the Institute their experience of adopting the suggestions given in this Digest.

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