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"Economy Through New Walling Techniques and Plumbing Services"

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Economy through new Walling Techniques and Plumbing Services

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SYNOPSIS

Masonry is most commonly used for walling in India. Its structural potentiality was not fully explored resulting into massive and uneconomical construction. The paper describes a number of walling techniques which have either been developed or whose structural performances have been studied at Central Building Research Institute, Roorkee, for their rational design. Substantial economy can be achieved by adoption of these techniques besides saving in the building materials and speedier construction. The paper also describes some of the improved plumbing services, the adoption of which will lead to economy and conservation of water.

Introduction

India is a democratic country. The awareness towards the up-light in the standard of living and social welfare is increasing. This demands greater resources not only for the construction of houses but also for providing other basic requirements like educational buildings, health care centres etc. Due to the previous backlog, tremendous increase in the population, shortage of the construction materials and financial resources the country is facing huge shortage of houses and other buildings. For instance, the requirement only for the houses has been estimated to the tune of about 100 millions, which needs huge financial resources besides other requirements. Further, due to the present energy crisis the economic necessity of the country demands greater emphasis to other important sectors as power, industries and agriculture, which also needs huge construction activities. This will lead to the shortage of construction materials besides the financial difficulties to fund such a huge construction programme. On the other hand, due to the migration of large number of skilled workers to Middle-East and African Countries there is also a great shortage of such workers in the country. So the present situation demands greater and greater economy and optimum utilisation in the consumption of both, building materials and manpower available. The traditional construction systems are the outcome of the age-old experience which is more an art than science. This consumes more men and materials. Therefore, it is difficult to keep-up the pace by adopting these conventional systems. As such there is a need to examine them and to develop new construction systems and materials. With these objectives in view, the Central Building Research Institute, Roorkee has been carrying out research on various aspects of building leading to quick, efficient and economical methods of construction, reduction in the consumption of scarce materials like cement and steel by making their optimum use, partial or full replacement with locally available alternative materials, development of new materials, innovation of new construction techniques and better building services. Over the last few years studies have been carried out on the behaviour of both plain and reinforced brick masonry, masonry in mud mortar, precast stone block masonry and thin lintels. For efficient building services studies have also been conducted on Peak Hydraulic load on drainage system, single stack system and conservation of water in buildings. Some of these new techniques have been well tried and are being adopted on large scale by various construction organisations and also have been incorporated in the relevant I.S. Codes. These techniques are quite simple, save in the building material and labour, increase the valuable floor space and reduce the load on the foundations. The salient features of these techniques are described in this paper.

Wallings

In any building walling is an important and essential element. In India, masonry is most commonly used for walling which consumes about 20 percent of the total building cost. Studies carried out have led to its rationalised design and development of new techniques as given below :

1. Calculated Brick Masonry : Brick masonry is one of the oldest building materials which is in vogue for

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more than 5000 years. Because of its simplicity and availability of materials even today this is most commonly used for compression members as in building walls, retaining walls, piers and wells etc. Although, major part of the cost of any building goes in masonry work, the engineers and Builders are not well aware about it's structural potentiality. Therefore, the thickness of the walls was governed by Building-bye-laws or designed by emperical rules resulting in massive and uneconomical structures particularly in multi-storeyed buildings. The structural potentiality of the masonry, therefore remained unexploited. During the last few decades extensive studies carried out in India and abroad on the behaviour of masonry have highlighted the remarkable properties of masonry([1,2]) which apart from acting as a structural member in transferring the load to the foundation also acts as a barrier to weather, fire, sound, heat and is used to fulfil various architectural functions. Structurally, the strength of masonry is a function of bricks strength and their texture, mortar strength, workmanship, the slenderness ratio and eccentricity of load etc. Influence of various parameters on the strength characteristics under compression, tension and shear have been studied. It is now possible to evaluate the strength within certain limits. Based on these studies on masonry the I. S. Code of Practice 1905 ([3,4,5]) has under-gone successive revisions in the year 1961, 1969, and 1980, which provides adequate design data such as basic stresses of masonry with bricks of different strength and mortar composition, reduction factors for slenderness and eccentricity of load, additional permissible stresses under concentrated loads, tensile and shear stresses etc. The present trend for the design of masonry is based on the stress concept like any other structure which is more rational.

Fig. 1. Four Storeyed Residential Houses at Haily Lane, New Delhi.

It has been seen that a single brick thick (23 cm) load bearing wall can be used in all the floors for four storeyed residential buildings with bricks of about 100 kg/cm² compressive strengh and 1 : 1 : 6 (Cement : Lime : Sand) mortar. Also half brick thick wall (11 cm) is structurally adequate as load bearing wall in two storeyed residential buildings. Such walls have been adopted in several buildings (Fig. 1) and proved very satisfactory. This reduces the cost of construction by obout 20% besides savings in bricks, mortar and speedier construction. In other masonry structures like retaining walls, piers, and abuttments etc. economy can also be achieved by permitting tension to the extent allowed in the code which hitherto were designed on 'Middle Third Rule'.

2. Brick Masonry In Mud Mortar : Although mud has been extensively used as masonry mortar for the construction of houses in rural areas, low cost houses and in building of temporary nature, but no engineering data regarding it's strength characteristics is available. Based on the studies conducted at CBRI, Roorkee following recommendations have been made in Technical Note No. 76 of CBRI[6].

(i) Soils having clayey contents from 10-20% is suitable for mud mortar.

(ii) During rainy season 10-15% moisture is likely to penetrate in mud mortar even after pointing or plastering the exposed masonry surfaces, consequently the masonry strength is reduced. Therefore, two values of the basic stresses for masonry in mud mortar given in table No. 1 are recommended. The higher value may be allowed when masonry remains in dry condition. For other situation, lower value be considered.

(iii) Masonry at vulnerable points like sill, jambs, below roof/floor leval etc. should be laid in cement/lime mortar.

(iv) To avoid concentration of loads, bed blocks should be provided under beams etc.

(v) The walls should be plastered or pointed on external faces to avoid the erosion of mortar due to weathering.

(vi) The masonry below D.P.C. shall preferably be in cement/or lime pozzolanic mortar from durability considerations.

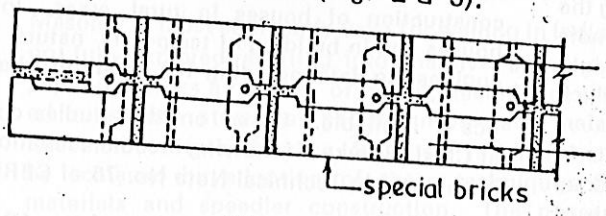
TABLE-1

Recommended Basic Stresses (Kg./cm²) in Mud-Mortar Masonry

Brick Strength in Kg/cm²	35	70	105	140
Dry condition	1.5	2.6	3.5	4.0
Moist. Condition	1.3	2.3	3.0	3.3

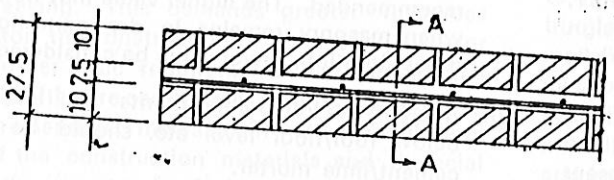
3. Grouted Reinforced Brick Masonry : With the production of good quality bricks and knowledge about structural behaviour of brick masonry, it can be economically used in load bearing walls in multi-storeyed repetitive type of constructions. However,

this being weak in tension crack may develop in it due to the horizontal forces, these walls need to be strengthened with reinforcement. Vertical reinforcement embedded in masonry strengthens it against tension. Among the various methods for providing the steel, the one with a continuous cavity, between two leaves of masonry wall is built for accommodating the steel, which is later on filled-up with cement concrete grout known as Reinforced Grouted Masonry was investigated at CBRI, Roorkee (Fig. 2 & 3).



PLAN

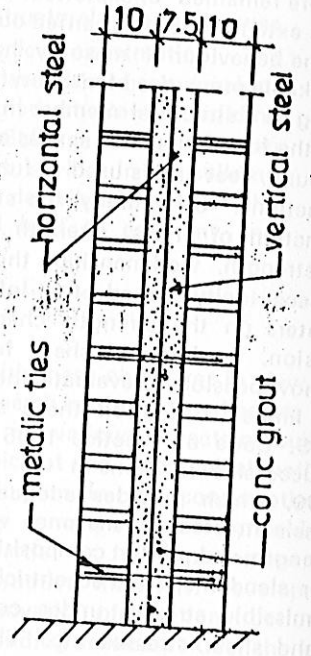
Fig 2 (a)



PLAN

(ordinary bricks with cavity wall type construction)

Fig. 2 (b)



SECTIONAL ELEVATION AT A-A

Fig. 2. Details of Reinforced Grouted Masonry Construction

For construction, the wall is built in two leaves with flat b icks laid in trangther course, leaving the required cavity in between them. The two leaves are connected by metal ties of U-shape made from 6mm dia M.S. Bars @ 80 to 90 cms horizontally and 35 to 40 cms vertically. These ties are staggered in alternate rows. The vertical steel specified in the design is placed in the centre of the cavity and supported temporarily. The horizontal steel should be tied with the vertical steel as the work proceeds further. Metal ties can also be made use for tieing and keeping in position the vertical steel.

Mortar for masonry should not be allowed to drop inside the cavity. The cavity should be free from any debris or mortar droppings etc. before filling it with the grout. Cement concrete grout having pourable consistency shall be used for filling the cavity. The slump of the grout may be of the order of 15 cms.

The wall shall be raised upto sill level of window or maximum upto 1.5 metres. It should be allowed to cure for atleast two days before pouring the grout. The grout shall be poured in a height of about 0.5 metre and lightly vibrated. The excessive water from the grout will be absorbed by the masonry bricks. After a period of about 15-30 minutes (depending upon the climate) before it losses its plasticity, it shall be revibrated. This shall improve the bond between grout and masonry. After revibrating the first layer, the grout shall be poured to a further height of 0.5 metre and likewise full storey height may be poured. It shall then be cured in usual manner.

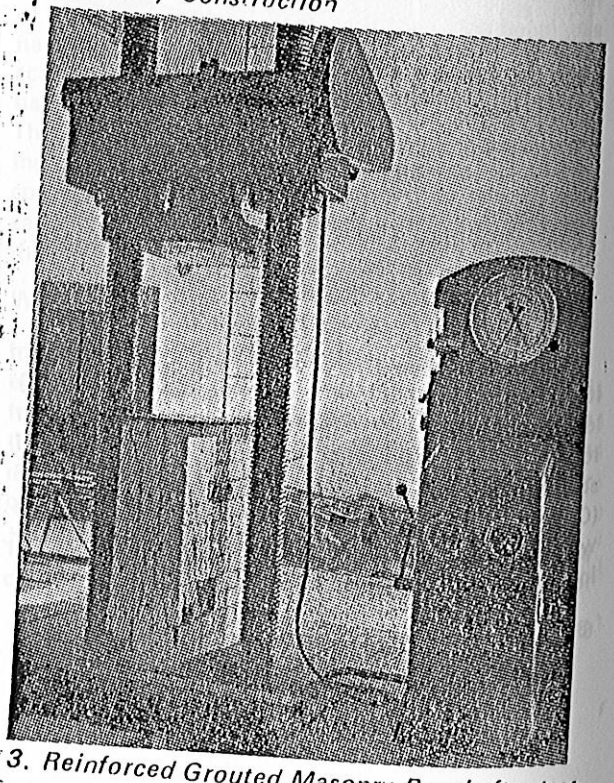


Fig. 3. Reinforced Grouted Masonry Panel after test.

Such type of construction has a promise for economical construction of multistoreyed residential buildings. This technique has also been used for reinforcing the masonry columns by providing in it pockets filled with cement concrete to accommodate steel (Fig. 4). Such columns can be used for carrying greater vertical loads and moments. The details of this study have already been published[7,8,9]. The conclusions drawn are given below :

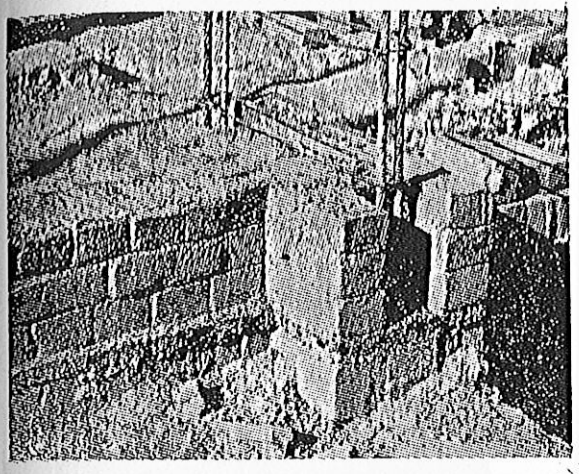


Fig. 4. Details of Reinforced Brick Masonry Column under construction.

(i) Masonry with weak mortar due to its low modulus of elasticity undergoes high initial strain when loaded. Therefore, weak mortar for masonry is not suitable for this technique. The mortar should not be leaner than (1 : 1/4 : 3) (cement : lime : sand) and also the bricks should not be of strength lower than about 150 kg/cm².

(ii) To improve the bond between concrete grout and masonry, the grout should be compacted by revibration.

(iii) It is reasonable to assume composite behaviour in this system of construction when the grout is revibrated.

(iv) The deformations are found to be very nominal at the working stage confirming that the design of this system to working load is adequate.

(v) The system provides considerably higher strength than ordinary masonry. The ultimate strength of about 800 to 1000 tonnes per sq. metre is available with bricks of 150 to 200 kg./cm² crushing strength and with about 25% concrete area and about 0.8% steel area.

(vi) The following column load formula is applicable for determining its load carrying capacity :

$$P = (B \times A) + (0.8\,G \times E) + (T \times S)$$

Where :

P = Ultimate axial load
B = Strength of brick masonry
A = Area of brick masonry
G = Strength of Grout
E = Area of Grout
T = Yield stress of steel
S = Area of Vertical Steel

4. Precast Stone Masonry Block Walling : Stone is a potential alternative building material in places where it is available in abundance. Presently, it is being used in the form of random rubble masonry for constructing the walls, which not only consume excessive materials but are undesirably massive. Besides, it is time consuming and calls for more skilled labour. The use of stones in the form of precast blocks ensures consistent quality, uniform strength, increase in speed of construction, reduction in materials requirements, lower foundation loads, better aesthetic look and performance and finally save in the floor space in a building. Considering these advantages, a new system contemplating the use of these stone blocks as masonry units for walling in the buildings was developed. In this system the blocks of 30 cm × 20 cm × 15 cm and 30 cm × 10 cm × 15 cm nominal size are cast in battery steel moulds using stone spalls of size ranging from 25 to 50 cm obtaining either from quarry or breaking the river boulders to provide rough surface for better bond and lean cement concrete of mix 1 : 4 : 9 as binding material. Blocks having strength from 50 to 100 kg/-cm² can be produced at construction sites employing local and unskilled labour. Thin walls having thicknesses of only 10, 15 and 20 cms can be constructed with these blocks like the traditional brick masonry. These walls can be both load bearing and non load bearing. The detailed information regarding production of blocks, materials, strength, masonry construction and cost economics etc. have been furnished in CBRI Data Sheet No. 8[10]. However, the brief information regarding the production of the blocks and precautions to be taken are given below :

The battery moulds are arranged in row on a level platform after oiling the inside surfaces. Stone spalls of as large sizes as possible are placed in the moulds at bottom. The number of stone pieces may be one or two depending upon their size. Cement concrete of medium consistency is poured to fill-up the gaps between the stone pieces and moulds at its lower portion to cover these stone pieces (Fig. 5). The remaining portion is again filled-up with stone pieces of smaller size of 5 to 10 cms. Maximum quantity of stone pieces are to be used taking care that adequate concrete cover is available around every stone piece. The remaining portion of the mould is again filled up with concrete, compaction is done by plate-vibrator placed at the top of the battery mould. After

compaction, the top surface is levelled and evenly finished. Soon after, the partitions in the mould are pulled up and the external sides are removed (Fig. 6). The process is repeated for further casting. The blocks are removed from platform after a period of about 36-48 hours depending upon climate for curing.

Fig. 5. Casting of Stone Masonry Blocks (Stone Spalls with Concrete at bottom)

To achieve good workability and bond of concrete with stone pieces the sand to be used in it should be well graded. It should have fine particles 15-20% passing I S. Sieve No. 300 micron and 5-10% passing I S. Sieve No. 150 micron. With very coarse sand flyash or stone dust should be added to improve the workability of concrete. The volume of stone pieces used should be about 30-35%. A minimum cushion of about 2 cms. of concrete should be provided around every stone piece. The blocks should be well compacted during casting and cured for about 14 days. These should be well dried before using in masonry. Smaller size blocks should be cast for breaking the joints in masonry.

The scheme results in substantial economy when compared with traditional methods. The main advantages of the system are:

i) Casting of blocks can be done by semi-skilled worker.

ii) The wall thickness is reduced, thereby saving in material and cost, and leading to larger usable floor area.

iii) Blocks being of proper shape and size, the productivity in laying is increased, and wall can be built by ordinary masons.

iv) One face of the block having stone texture exposed gives the natural stone appearance.

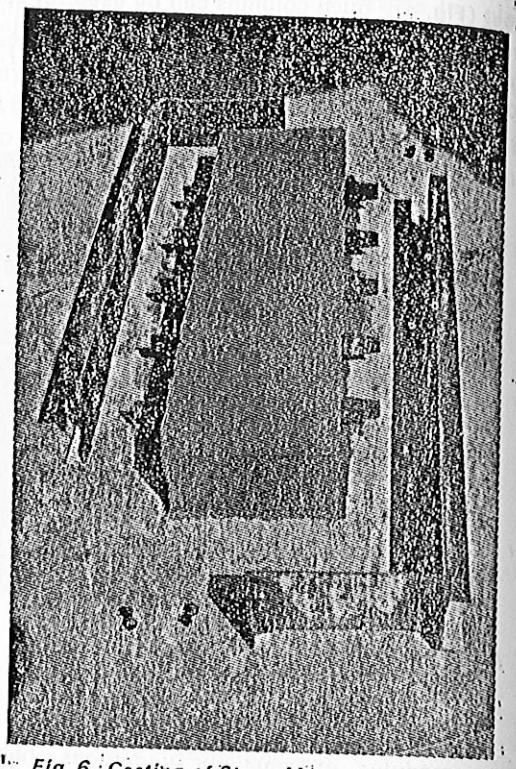


Fig. 6. Casting of Stone Masonry Blocks (Finishing and Demoulding)

This new system has been widely accepted by major construction agencies all over the country, namely housing boards and P.W.D. of various states as U.P., Himachal Pradesh, Madhya Pradesh, Andhra Pradesh, Rajasthan and Delhi Development Authority, C.P.W.D. and M.E.S. etc.

5. Thin Precast RCC Lintels in Brick Walls : Lintels are provided over door and window openings to support the load of masonry above and load from slab. Traditionally, these are designed on the basis of bending moment equal to WL/6 considering triangular portion of the wall. Such lintels are quite thick and uneconomical. The composite action between the lintel and masonry above has been well established and this Institute had earlier recommended the use of 7.5 cms. thick precast RCC lintel with 3 Nos. 10 mm dia m.s bars as reinforcement for opening upto 1.8 metres, provided the bricks used are of minimum strength of 100 kg/cm² and masonry mortar is not leaner than 1:6 (cement : sand) mortar. The height of the masonry above lintel is atleast 45

cms. Since bricks of 100 kg/cm² are not available in many parts of the country the feasibility of adopting thin lintel with low strength bricks was studied at the Institute (Fig. 7). Detailed information about this study are given in CBRI Data Sheet No. 1[11] (Revised). The conclusion and recommendations made therein, are as under :

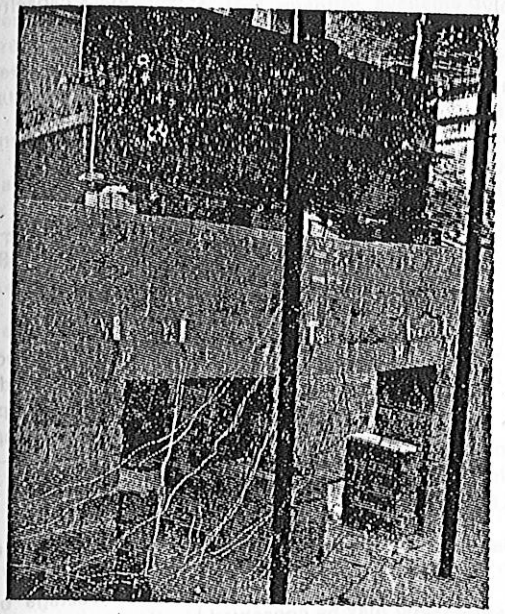


Fig. 7. Thin precast R.C.C. Lintel with Brick Masonry Under Test.

There is composite action of lintel and brickwork above, even when the brick masonry is of low strength and the height of brickwork is 45 or 30 cms. only. The load carrying capacity increases with increase in height of brickwork and also increases with strength of masonry. Further, when the height of brickwork above lintel is less than 0.37 of span and masonry of low strength, failure occurs by shearing of masonry over supports. As the design of the composite lintel is some what complicated and not easily amenable to calculations. For the ready use of the site engineers, design chart for thin precast lintels of normal residential buildings is given in Table No. 2. It is applicable only when the load on the lintel is uniformly distributed. Also the height of the brickwork over lintel shall not be less than 45 cms. and mortar not leaner than 1:6 (cement : sand). Thin lintels shall not be used in masonry in mud mortar. It shall be noted that there is no composite action in continuous lintel at intermediate supports. Thickness of the lintel shall be equal to the thickness of brick i.e. 7.0 cms and 9.0 cms. for traditional and modular bricks respectively. The lintel should have a bearing of 23/20 cms. on either support.

Use of the precast lintels speed-up the construction besides eliminating centering and shuttering. Also this results in about 50% saving in materials and overall cost; compared to lintels based on conventional design.

Table 2

Design Chart for Thin Precast RCC Lintels

Maximum clear Span of opening (cm)	Width of lintel (cm.)	Minimum Crushing Strength of bricks in wall (kg/cm^2)	Main reinforcement
120	20/23	40	2 Nos. 10mm dia M.S. bars
120	10/11.5	40	2 Nos. 10mm dia. M.S. bars
120	30/35	40	3 Nos. 10mm dia. M.S. bars
150	20/23	70	2 Nos. 10mm dia. M.S. bars
150	10/11.5	70	2 Nos. 10mm dia. M.S. bars
150	30/35	70	3 Nos. 10mm dia. M.S. bars
180	20/23	100	2 Nos. 12mm dia. M.S. bars
180	10/11.5	100	2 Nos. 12mm dia. M.S. bars
180	30/35	100	3 Nos. 12mm dia. M S. bars

Plumbing Services

Rapid growth of population in big cities has necessitated the vertical expansion of buildings. Plumbing services in such buildings become not only complicated but also costlier with the increase in the height of building. There is a need to improve upon the existing drainage systems, to determine the realistic design parameters and to conserve in the water requirements. The Institute has determined the peak hydraulic load on drainage system in multistoreyed residential buildings; studied the performance of single stack system and has developed sanitary appliances to conserve the water requirements. The same are described below :

1. Peak Hydraulic Load on Drainage System in Multistoreyed Residential Buildings for Intermittent System of Water Supply

The design of water supply and drainage system in India is accomplished on the basis of simultaneous peak flow and discharge unit, relationships. Design data is generally taken from U.S. National Plumbing Code (NPC) and British Standard Code of Practice (BSCP). Since the use pattern of sanitary appliances in our country is markedly different from that of USA or U.K., the design values do not hold good for our conditions. To determine the realistic design data,

CBRI conducted a survey in multistoreyed residential buildings to assess the use frequency, duration of use of each appliance separately and the use of the system as a whole. The number of appliances which may discharge simultaneously out of total number of particular type of appliance was determined by applying theory of probability. Based on this work, loading weights in terms of discharge unit values has been recommended as 1:3:6:9 for wash basin, kitchen sink, bath and W.C. respectively. Relationship established between discharge units and simultaneous peak flow in multistoreyed residential buildings for intermittant system of water supply is given in Fig. 8(12)

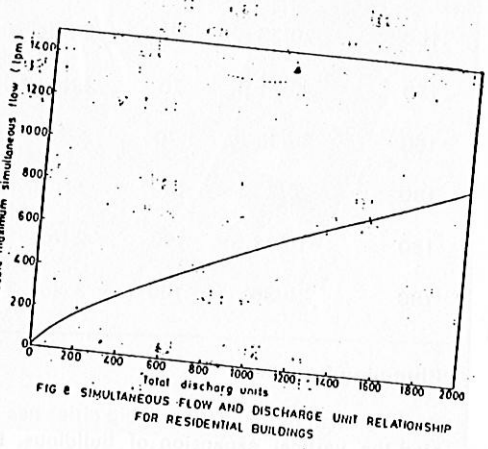


FIG 8 SIMULTANEOUS FLOW AND DISCHARGE UNIT RELATIONSHIP FOR RESIDENTIAL BUILDINGS

2. Single Stack System of Plumbing Drainage

In single stack system of plumbing, all the sanitary appliances in group discharge into a single 'soil and waste' stack and the traps are unventilated. This stack itself serves the purpose of venting also. This system has established its utility because of its simplicity, economy in the material and labour, and lesser duct space. The present design procedure based on analytical determination of pressure differentials within the stack is iterative and time consuming. Hydropneumatic studies carried out in eight storeyed test rig (each floor representing two service group) have led to the development of simple design procedure which relates hydraulic discharge in the stack to the pipe diameter for permissible suction created inside. Permissible capacity of 100mm diameter stack of A.C., C.I. and C.I. with special fittings, for an average allowable suction of 40mm water gauge which causes 25mm loss of water seal from the traps of sanitary appliances, have been recommended by this Institute. The values are given in Table No. 3(13).

Table 3. Recommendations on permissible capacity of 100mm stack.

S. No.	Single Stack System.	Permissible stack capacity lit/m	No. of storeys having twin units
1.	A.C. Stack	274	10
2.	C.I. Stack	284	12
3.	C.I. Stack with Aerators & Deaerators	373	21

Note :—Each group consists of a W.C., Bath, Sink and Wash Basin.

3. Water Conservation

Acute shortage of water in big cities has necessitated the need for its conservation. CBRI has developed some improved sanitary appliance/design procedure through which reduction in water consumption can be achieved. These are described below :—

i) Dual Flushing Cistern

In residential buildings W.C. is usd for both urination and defecation. Discharge of full capacity of flushing cistern after urination is mere a wastage of water. Water may be conserved by the use of Dual Flushing Cistern, by which fractional or full capacity of the cistern can be discharged as per requirement. The conventional cisterns can also be converted to Dual Flushing Cistern with nominal additional expenses.

To operate fractional discharge from siphonic type dual flushing cistern chain is just pulled and left. For full discharge, the chain is pulled and held in position untill the cistern is emptied. In bell type dual flushing cistern knob control is attached with a circular disc which is in turn connected by means of rubber/metalic pipe to the bell of the cistern at predetermined level. The cistern gives full discharge with stop cock closed and fractional discharge with stop cock open to atmosphere. The Dual Flushing Cistern have been patented, licensed and commercially available.

ii) Modified Water Closet Bowls/Pans

Studies carried out at CBRI revealed that even with 15 litre high level cistern the flushing efficiency of E.W.C. bowls having 150 cm² water seal area is hardly more than 60%. It has been experimentally found and later on analytically supported that bowls with 75cm² maximum water seal area give the best performance(14). Flushing efficiency of modified E.W.C., bowls is satisfactory even with 6 litre cisterns, resulting in a considerable amount of water conservation.

In case of Indian type W.C. pan it has been experimentally found that holes at a maximum spacing of 40mm in the box rim give best performance.

Installation of these improved appliances may result in considerable water conservation.

iii) Minimum Terminal Pressure

A minimum terminal pressure of 0.18 kg/cm² is subservient in making the desired quantity available on different floors of a multistorey building. The reduction in terminal pressure would also help conservation of water.

Acknowledgement

The authors are grateful to their colleagues whose work is reported here. The techniques described in this paper form part of regular research carried out at Central Building Research Institute, Roorkee, and is presented with the permission of the Director.

References

1. Bradshaw R.E. and Thomas K., 'Modern Developments in Structural Brickwork'. C.P.T.B., Technical Note Vol. 2 No. 3, Jan. 1968.
2. Chetty S.M.K. and Bedi S.S. 'Developments in Calculated Load Bearing Brickwork ; 'Seminar of Celebration of Centenary of U.P., PWD ; Jan. 71.
3. I. S. 1905-61, Code of Practice for Structural Safety of Buildings ; Masonry Walls.
4. I. S. 1905-69 ; Code of Practice for Structural Safety of Buildings ; Masonry Walls.
5. I. S. 1905 80 ; Code of Practice for Structural Safety of Buildings ; Masonry Walls.
6. Brick Masonry in Mud Mortar CBRI Technical Note No. 76.
7. Bedi S.S., Salek Chandra and Dhanesh Chandra; 'Grouted Reinforced Brick Masonry' ; Bulletin of the Builders Association of India, May 1976.
8. Sharma J.S. ; Bedi S. S., Salek Chandra and Dhanesh Chandra, 'Reinforced Grouted Brick Masonry'; CIB Symposium on Bearing Walls held at Warshaw (Poland), Sept. 1975.
9. 'Grouted Reinforced Brickwork' CBRI Technical Note No. 67.
10. Sharma J. S., Bedi, S.S., Sofat, G.C. ; 'Precast Stone Masonry Block Walling'. Data Sheet No. 8, Central Building Research Institute, Roorkee.
11. Jai Singh, M.P., Jaisingh, Lathika and Jain S.K. ; 'Thin Precast RCC Lintels in Brick Walls', Data Sheet No. 1 ; Central Building Research Institute, Roorkee.
12. Chakrabarti, S.P., Sudesh Kumar Sharma ; Suresh Kumar Sharma ; 'Simultaneous Peak Load on Drainage System in Multistorey Residential Buildings for Intermittent System of Water Supply Building and Environment (UK) ; Vol. 15, pp 95-100, 1980.
13. Chakrabarti ; S.P. ; N.K. Verma ; Sudesh Kumar Sharma and Suresh Kumar Sharma ; 'Capacities of Stacks in Unvented Drainage Systems for Building' ; Indian Journal of Environmental Health, Vol. 21, No. 4 pp. 308-320, 1979.
14. Rao, P.B., Ishwar Singh and S. K. Sharma ; 'A Rational Approach to the Design of Water Closet Bowls', Environmental Health, Vol. 12. pp. 39-47, 1970.
15. Ram Avtar, S. P. Chakrabarti ; N.K. Verma, and P. Khanna, 'Evaluation of Design Practice for Water Supply System in Multistorey Buildings' ; Journal of the Indian Water Works Association ; Vol.VIII, No. 2, pp. 167-171;1976.