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Performance Studies on European Water-closets

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Water used in flushing toilets can be conserved to a considerable extent using available efficient designs of water-closet bowls/pans which can be flushed well even with a smaller volume of water. Since no information based on experimental study is available on the performance of European water-closet designs in use in India, engineers/users suspect that solids may not reach the municipal sewer through building drain if low flush volumes are used. This paper describes the effects of reduced flush volume on the flushing efficiency of European water closet-bowls when not connected to a drainage stack and also when connected at different floors of a drainage stack under various flow conditions from upper floors.

INTRODUCTION

Water is becoming scarce because of increased demand consequent to population growth besides improved living standard and the existing constraints of limited water resources. Need for water conservation has drawn the attention of research workers to its quantity being used to flush water-closet bowls/pans which account for 30 to 40% of the total quantity required for domestic purposes in a water supply system. This problem has been solved considerably using available efficient designs of water-closet bowls/pans which have good flushing even with a smaller quantity of water. No experimental data is available on performance of European water-closet designs used in India with low flush volumes. This paper describes in brief the following experimental investigations carried out at the Central Building Research Institute, Roorkee.

1. Effect of volume of flush water on the flushing efficiency of European water-closet (EWC) bowl patterns 1 and 2 (conforming to IS : 2556, Part II-1981).
2. Effect of floor levels on the flushing efficiency of EWC bowl (pattern 2) flushed with 6.5 l water.
3. Effect of flow from upper floors in drainage stack on the flushing efficiency of EWC bowl (pattern 2) connected at ground floor.

LITERATURE REVIEW

Flushing efficiency of EWC pattern 1 bowls conforming to Indian Standards[1] when coupled with high level cistern of 10 and 15 l capacity (bell type) and 15 l capacity (siphonic type) has been reported by Rao, *et al*,[2] without its connection with drainage stack. They reported the flushing efficiency of EWC pattern 2 bowl conforming to Indian Standards[1] coupled with high level cistern of 15/6 l capacity also. No information is, however, available about the effect of flush volume on the flushing efficiency of EWC bowl (patterns 1 and 2) coupled with low-level cistern.

Test procedure recommended in IS : 2556 (Part II)—1981 do not consider the water-closet to be connected with stack while testing and hence actual field conditions are not simulated. In case of multistoreyed buildings, pressure fluctuations present throughout the length of stack affect their efficiency significantly. Gupta, *et al*[3], reported a test procedure in which field conditions were simulated in an experimental mock-up. The effect of stack flow at different floors on the flushing efficiency of EWC pattern 1 bowl coupled with high-level cistern was studied. Studies regarding the flushing efficiency of EWC pattern 1 and 2 bowls coupled with high-level cistern of 10/6.5 l at ground floor were also pursued. No information is however available to predict the floor level effect on the flushing efficiency of pattern 2 bowl coupled with low-level cistern of 6.5 l capacity when there is no flow in the drainage stack. Effect of flow from upper floors in the stack on the efficiency of said combination of bowl and cistern, when installed at ground floor of multistoreyed building, is also not known.

EXPERIMENTAL SET-UP AND SCHEDULE OF EXPERIMENTS

EWC pattern 1 and 2 bowls conforming to IS : 2556 (Part II)-1981 connected with low-level cistern (conforming to IS : 774-1971) were used to study the effect of flush volume on flushing efficiency of respective bowls. Height between the top of the bowl and the bottom of the cistern was kept 205 mm in each case. Flush test for water-closet, described in IS : 2556 (Part II)-1981, does not include the procedure for working out its flushing efficiency. It gives only the requirements which are to be satisfied by EWC bowl for its acceptance by the user. However, for knowing the relative perfor-

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mance of different types of bowls, it is necessary to work out their flushing efficiency. It was, therefore, undertaken to work out the flushing efficiency of each bowl as suggested by Rao, *et al*[4]. Test objects used were polythene balls of 19 mm diameter and specific gravity adjusted to 0.84 to match that of faecal matter with the help of cork.

The water-closet (wc) bowls (pattern 1 and 2) were filled with water to its normal water seal and charged with 50 and 25 polythene balls, respectively (covering its water surface area) before operating the flushing cistern. After the flush was over, the number of balls flushed out of the bowl were calculated. Arithmetic mean of 10 such readings was taken in each case. The flushing efficiency of the bowl has been expressed as the percentage of balls flushed out. Experiments were conducted with the flush volumes of 12.5, 10.0, 6.5 and 5.0 l. The quantity of flush was adjusted by putting rubber blocks inside the cistern.

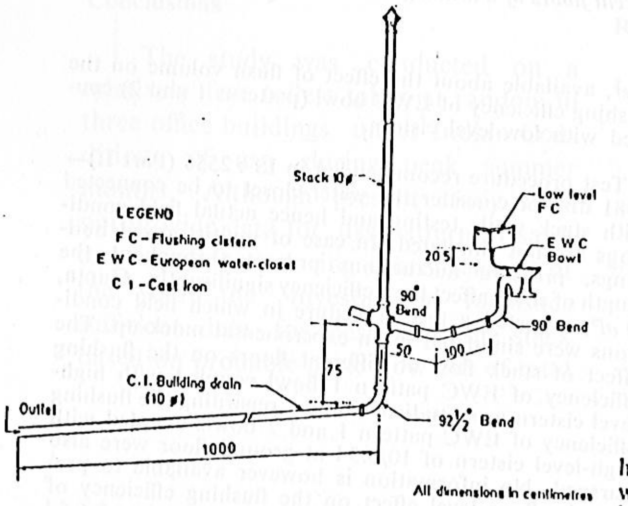

Fig 1 Diagrammatic view of test set up

An eight-storey test rig with provisions to instal sanitary appliances at each floor around a 100 mm diameter cast iron drainage stack was used to study the effect of floor levels on the flushing efficiency of EWC bowl (pattern 2) with 6.5 l flush volume (Fig 1). Observations were taken using single stack system of drainage in which all the sanitary appliances discharge into a single soil and waste stack which itself serves the purpose of vent also. At the foot of the stack a 92.5° large bend (radius : 0 cm) was provided to convey the discharge at a distance of 10 m through the 100 mm diameter cast iron pipe laid at slope 1/60. Bowl was connected with stack at each floor to study its performance against flushing efficiency. Test object and procedure to work out the flushing efficiency were the same as in the first experiment except that the objects were collected at the end of building drain pipe (10 m from the centre of the drainage stack).

The same experimental set-up, test objects and procedure were used to study the effect of flow from upper floors in drainage stack on the flushing efficiency of EWC bowl (pattern 2) with 6.5 l flush volume connected at ground floor. Arrangements were made to provide the steady water flow varying from 15 l/m to 170 l/m which simulates the flow to the extent of permissible capacity of stack, *ie*, 278 l/m. Permissible capacity of stack is reached by discharging a single bowl (having peak discharge rate : 108 l/m) alongwith a steady flow of 170 l/m.

Initially flushing efficiency of bowl was determined at each floor under a steady flow of 108 l/m from roof of top floor which is equivalent to a peak discharge of a wc. Since maximum reduction in flushing efficiency was observed at ground floor, combination of EWC bowl and cistern was connected with main drainage stack at this floor.

TEST RESULTS AND DISCUSSIONS

Effect of Flush Volume on Flushing Efficiency

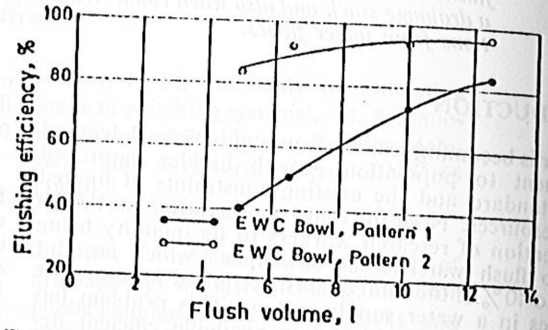

Fig 2 Effect of flush volume on flushing efficiency of EWC bowl

Flushing efficiency of patterns 1 and 2 of EWC bowl has been presented in Fig 2 for different flush volumes which indicates that flushing efficiency of both patterns increases with the increase in flush volume. The data suggests that decremental decrease in flushing efficiency with an decremental decrease in flush volume is more in pattern 1 bowl than pattern 2. If the flush volume is reduced from 10 l to 6.5 l, the decrease in flushing efficiency of pattern 1 and 2 is about 1 and 1.7%, respectively.

Although flushing efficiency of pattern 2 bowl appears good even with 5.0 l flush volume this quantity has not been found sufficient to transport the solids in building drain efficiently. The flush volume cannot be reduced below 10 l in case of pattern 1 bowl because acceptable minimum flushing efficiency is 70% as suggested by Sobolev[5].

Thus 5% water can be conserved in each flushing operation when pattern 2 bowl is flushed with 6.5 l instead of 10 l.

Effect of Different Floor Levels on the Flushing Efficiency of EWC Bowl (Pattern 2) Flushed with 6.5 litres Water

Flushing efficiency fraction, $\left(\frac{E}{E_o}\right)$ of EWC bowl pattern 2 with 6.5 l flush volume, at different floors of eight-storeyed test rig, were determined and have been presented graphically in Fi g . The observed data was fitted by least square method. The equation for the curve obtained is :

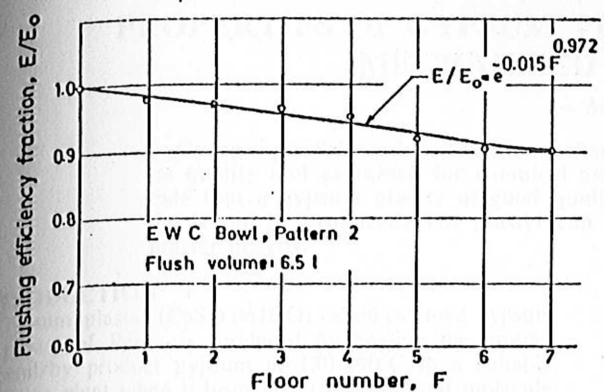

Fig 3 Relationship between flushing efficiency fraction and floor level

$$\frac{E}{E_o} = \exp\left(-0.015\ F^{0.972}\right) \qquad (1)$$

where, E is flushing efficiency of EWC bowl at the floor under consideration ; E_o, flushing efficiency of EWC bowl at ground floor ; and F, serial number of floor (ground floor has been taken as zero).

There is reduction in flushing efficiency of bowl with the increase in floor level. The reason for this reduction seems to be that in single stack system of drainage when low flush volume is used there are chances that solids flushed from upper floors enter the cross-junctions of lower floors resulting in efficiency loss of the system. On an average reduction in flushing efficiency is approximately 1.4% per floor.

Effect of Flow From Upper Floors in Drainage Stack on The Flushing Efficiency of EWC Bowl (Pattern 2) Connected at Ground Floor

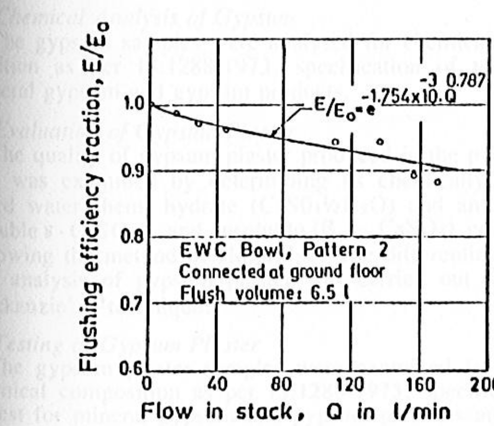

Fig 4 Relationship between flushing efficiency fraction and flow in stack

Flushing efficiency fraction (E/E_o) of EWC bowl pattern 2 with 6.5 l flush volume, connected to the main drainage stack, at ground floor of eight-storeyed test rig were determined under different rate of flow in stack (Fig 4). The observed data was fitted by least square method. The equation for the curve obtained was :

$$\frac{E}{E_o} = \exp\left(-1.754\times10^{-3}\right) Q^{0.787} \qquad (2)$$

where, E is flushing efficiency of EWC bowl under steady flow conditions in the stack; E_o, flushing efficiency of EWC bowl under no flow condition in stack from top floors ; and Q, steady flow in stack, l/m.

There is reduction in flushing efficiency of wc bowl with the increase of flow in stack. This might be due to increase of positive pressure, devèloped at the foot of the stack, with the increase of flow. An examination of the plot indicates that decrease in flushing efficiency of EWC bowl is of the order of 9.5% under the flow in stack to the extent of its permissible capacity in single stack system (permissible capacity of stack is reached by discharging a single wc having peak discharge rate 108 l/m alongwith a steady flow of 170 l/m).

CONCLUSIONS

1. Flushing efficiency of pattern 2 bowl is better than that of pattern 1 for any selected flush volume.

2. Capacity of flushing cistern can be reduced to 6.5 l using pattern 2 bowl without significant reduction in its flushing efficiency.

3. Reduction in flushing efficiency of bowl when connected with drainage stack varies with the floor level at which it is connected.

4. Deterioration in the flushing efficiency of bowl, connected at ground floor with drainage stack of multi-storey building carrying discharge from upper floors, changes with the flow inside the stack.

ACKNOWLEDGEMENT

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