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Provision of Staged Onsite Wastewater Treatment Units at Environmental Floors of Multi-storeyed Building with Hydraulic and Structural Feasibility

Snehal V. Dewalkar, Sameer S. Shastri

Abstract*: *In the present day context of urban areas in Indian climate, looking at the statistics of the operating efficiency of existing mechanically operated water treatment plants run by local governing bodies and even when huge costs are incurred in their maintenance, it is necessitated that an efficient wastewater treatment system suitable in Indian climatic conditions and that too efficient, self-operating with minimum interference and at a low-cost construction, operating and maintenance cost. Decentralized onsite and naturally operating treatment methods are much efficient, cost-effective and feasible for Indian context. In current research, Effective positioning and modeling of the non-mechanised, gravity-based wastewater treatment system is carried out at refuge floor which is coined to be proposed as "environmental floor" for G+32 storeyed residential building. Comparative analytical study for structural and seismic response of both the structures (with and without environmental floors) is performed to check feasibility of the treatment system and quantify the benefits arising from it. It is observed form obtained results that the system can be adopted as an ultimate sustainable solution for wastewater treatment in cities where otherwise a lot of unhygienic conditions prevail if centralized treatment plants are not efficiently working.

***Keywords* : : DOSIWAM, Environmental floor, Structural feasibility.**

I. INTRODUCTION

Sewage treatment and disposal is the largest contributor to the pollution of water resources. The CPCB (Central Pollution Control Board), India, in an assessment of the treatment plants for sewage generated across the country, revealed the enormous gap between the generated sewage and the installed treatment plants for sewage. In urban areas, a massive amount of sewage is generated proximate 62,000 million litre per day (MLD), whereas the capability of the treatment plant is about only 23,277 MLD. This statistical data indicates generation of 70% untreated sewage in urban India is haphazardly dumped in various water bodies of the country. Operation and maintenance of existing treatment limits are worse than average, with 39% plants not adjusting to environmental guidelines for release into streams.

In urban areas, the sewage generation problem will not be alleviated by an increase in the number of treatment plants. However, to tackle this problem; a sustainable, economical and efficient onsite treatment system is an essential need. One such system is DOSIWAM (Decentralized On-Site Integrated Waste Management) System developed by Dr. S.V. Mapuskar [2]. The fundamental concept of the DOSIWAM system is the profitable treatment, reuse and recycling of the wastewater at the source of generation itself.

The term 'environmental floor' is coined to be proposed here for the installation of the DOSIWAM system at intermittent levels of multi-storeyed building. The environmental floor is a new concept designated for refuge floor, where the treatment units are installed and worked on gravity basis to fulfill the requirement of treated water used for various non-consumptive purposes like flushing, gardening, firefighting, floor washing, etc. The treatment units consist of Malaprabha digester and Stabilization tank with storage tank. The hydraulically and environmentally better solutions will be achieved by the effective allocation of on-site wastewater treatment system at the proposed refuge floor, in a multi-storeyed building. The basis of this research is to investigate the feasibility of these systems in the context of an urban environment and to quantify the water-saving and the environmental benefits.

II. LITERATURE REVIEW

Review of the various literatures gives an elaborate awareness on potential of wastewater reuse. Based on available statistics from published literature, the insufficiency and inefficiency of mechanical treatment systems are highlighted with the necessity of implementation of natural (non-mechanised) systems. In consideration of increasing water scarcity and continuously growing urban population worldwide, a shift occurs towards the decentralization of domestic wastewater [9, 10].

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* Correspondence Author
Snehal V. Dewalkar*, Research scholar at Savitribai Phule Pune University, Pune, India. Email: svdewalkar.sae@sinhgad.edu.
Sameer S. Shastri, Head of Department, Civil engineering, Sinhgad College of Engineering, Pune, India. Ph. D. from Savitribai Phule Pune University, Pune, India. Email: ssshastri.scoe@sinhgad.edu.

Decentralized wastewater treatment system is more cost-effective than centralized treatment system for small countries [1]. In centralized WWT system, 60-90% of cost is associated with transportation of waste from the source to the treatment plant, whereas 10-20% of the cost is attributed on the treatment of an effluent [4].

Inappropriate and lack of cost utilization data considering local environmental conditions, can lead to inappropriate WWT system selection in developing countries [11, 12]. When traditional water supply systems are accompanied by onsite greywater reuse, the comparative reliability analysis in the research yielded improvement in the reliability of about 5.83% [8]. However, by evaluating techno-economic comparison between mechanized and non-mechanised treatment system, a significantly lower amount of CO_2 emitted from non-mechanised treatment system.

III. DECENTRALISED ON-SITE INTEGRATED WASTE MANAGEMENT SYSTEM

In Decentralized Onsite Waste Management System (DOSIWAM), every grain of solid and every drop of liquid is treated hygienically. The system consists of two different types of treatment units, Malaprabha digester, and Stabilization tank with a storage tank. The system is allocated on refuge floors which are termed as environmental floors in current research. This gravity-based system is non-mechanized, which collects the waste from floors above the refuge floor and passes the treated water below the refuge floor. Here, as system has a non-mechanized arrangement for treatment and collection on the environmental floor, thus, mechanical equipments are not required which could cause additional weight and complications on floor.

A. Stabilization Tank

Stabilization tank is multi-sections series where grey water can be stabilized. The tank can be divided into total of ten compartments with 5 main and 5 sub-compartments maintaining L: B ratio as 1:3 for each compartment, wherein horizontal and vertical zigzag flow of grey water is maintained. Thus, due to the horizontal and vertical flow of greywater at bottom suspended solids settle down or float at the top and get digested gradually. During the flow of greywater through various compartments, oxidation takes place progressively. Stabilized water is then collected at a storage tank which can be used for various purposes.

- Inlet diameter and outlet diameter – 10 cm.
- Internal compartment openings – 15 cm.

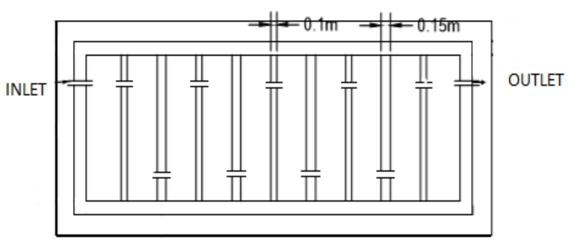

Fig. 1. Stabilization tank

B. Malaprabha Digester

DOSIWAM system includes Malaprabha Digester which turns out to be economically sustainable and treat all the waste by means of integrated and complementary approach. Biogas generated from night soil serves a dual purpose of providing energy and helping manage human waste. It can help to reduce dependency on LPG. Human night soil is a good substrate for generating biogas. The process of organic matter conversion to methane gas which is utilized as source of energy is fully trapped in Malaprabha digester while, in case of improperly maintained STP's if it is not appropriately trapped, it gets escaped to atmosphere and is turn out to be almost 22 times detrimental as Green House Gases as compared to CO_2. Odour is not an issue with the fully airtight digesters. However, if any leakage occurs, it would be of inconvenience to the users of the buildings. Hence two sustainable methods have been employed for odour control.

a. Orientation of the major openings of the building by 0 degrees to 45 degrees angle with the most prevalent direction.

b. Development of garden around the space at environmental floor, and also landscaping around the building periphery, using indigenous odour removing plants.

The first method is suitable for new buildings where the aspect of orientation can be considered at the planning phase itself. The second method is suitable for both, new as well as existing buildings, and is considered as a sustainable retrofitting measure.

Malaprabha digester (fig. 2) consists of total 3 main compartments: Digestion chamber, displacement chamber and outer chamber.

- Inlet pipe diameter = 10 cm
- Outlet diameter = 10 cm
- Gas outlet = 7.5 cm
- Vent pipe diameter = 5 cm (At the level of outlet)
- Opening 1 = 30X30 cm at the distance of 22.5 cm from bottom.
- Opening 2 = 10 cm diameter at the distance of 70 cm from bottom.

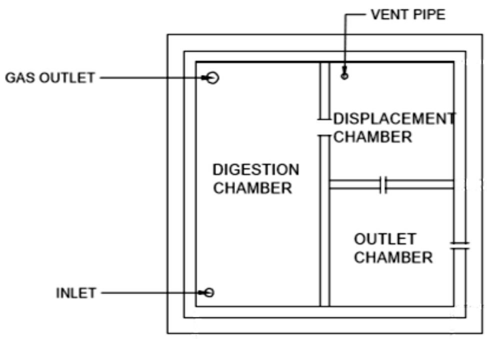

Fig. 2. Malaprabha digester tank.

Table-I: Rate of biogas generation

Biogas generated per person	35 to 40 litres/day/person
Total amount of biogas generated	1215000 litres/month

It is estimated that household burners used for cooking biogas use: 200-450 L/h. Assuming the burners operate for 40 min a day, one household will need 6435 litres/month of biogas, which can easily be provided by the digester. Thus, for 32 storeyed residential building with 216 families can be made completely self-reliant in terms of fuel for cooking.

C. Hydraulic Design of DOSIWAM system

Basic hydraulic and drainage requirements are considered while placing the underground Malaprabha digesters and the treatment units which treat the wastewater collected from first 7 floors.

Whereas, the greywater treatment is carried out by stabilization tanks are staged on environmental floors.

Table-II: Hydraulic design of treatment units positioned underground.

Parameters	Black water	Grey water
Population (first 7 floors with 8 no. of flats at each floor and assuming 5 persons per flat)	280	280
Per capita sewage generation	45 lpcd (liters per capita per day)	110 lpcd (liters per capita per day)
Total sewage generation	12600 lit/day	30800 lit/day
Detention time	45 days	5 days
Depth	1.83 m (considering free board of 0.30 m)	1.53 m (considering free board of 0.30 m)
Area	309 sq. m.	100.6 sq. m.
Hydraulic Dimensions	Malprabha digester	Stabilization tank
	No. of units=04	No of units=02
	L= 8.8 m	L= 12 m
	B= 8.8 m	B= 4 m

Table-III: Hydraulic design of treatment units installed at environmental floor.

Parameters	Black water	Grey water
Population	160	160
Per capita sewage generation	45 lpcd (liters per capita per day)	110 lpcd (liters per capita per day)
Total sewage generation	7200 lit/day	17600 lit/day
Detention time	45 days	5 days
Depth	1.83 m (considering free board of 0.30 m)	1.53 m (considering free board of 0.30 m)
Area	177.04 sq. m.	57.51 sq. m.
Hydraulic Dimensions	Malprabha digester (positioned underground)	Stabilization tank (positioned at environmental floors)
	No. of units=03	No of units=04
	L= 7.68 m	L= 5 m
	B= 7.68 m	B= 2.9 m

IV. WATER REQUIREMENTS FOR VARIOUS NON-CONSUMPTIVE USES.

As per BIS 1172: 1993, reaffirmed in 1998, 45 litres per head per day is consumed for flushing requirements, thus, for G+32 storeyed residential building, flushing water requirement is 48,600 litres/day. Requirement of water for gardening actually depends on the crop water requirements of respective plants species used for gardening, climatology and accordingly the frequency of watering. Duty and delta of the plants is a guide to what quantity of water exactly required. However, from experience it is fairly assumed that water required for gardening is about 7 litres per square meter per day. The rate of watering may be decided based on actual availability of the treated water from time to time. In current research, area under gardening is 10% to 15% of plot area Thus, 8400 liters/ day water required for gardening. As per the provision of water tank prescribed in Part-4 of NBC, the arrangement shall be made at the rate of 1000 litres per minute to the underground static water tank for replenishment by means of an alternate source of supply. Hence, in case of fire emergencies, treated water can be diverted accordingly for firefighting purposes.

Table-IV: Quantity of sewage generation, wastage, treatment and uses.

Activity	Water Requirement (Litres/Day)
Total sewage generated	101200
Total wastage in sludge (10% wastage of total sewage generated)	10120
Total sewage treated	91080
Toilet flushing	48600
Car washing	4320
Gardening	8400
Fire fighting	3310
Other purposes like recharge of ground water	26450

V. EFFECTIVE ALLOCATION OF DOSIWAM SYSTEM AT ENVIRONMENTAL FLOOR

As per the guidelines given by Gov. of Maharashtra India, to hold the occupants at refuge floor, 15 sq. m or 0.3 sq. m. per person area should be provided as refuge area, where building's height is more than 24 m. whereas if, height of building is more than 39 m, first refuge floor should be after 39 m and so on subsequently every 15 m [14]. Thus, Refuge floor distributions for G+ 32 storeyed building are at 8th, 13th, 18th, 23rd, 28th. At every floor total 8 flats are present, assuming total 5 person per flat, the refuge area required for 1st refuge floor is 84 m^2, similarly 48 m^2 refuge area required for 2nd, 3rd, 4th, 5th refuge floor. Thus, the remaining area can be utilized for effective allocation of DOSIWAM system. Total 4 numbers of stabilization tanks with storage tanks are positioned keeping standard refuge area vacant. (fig.3)

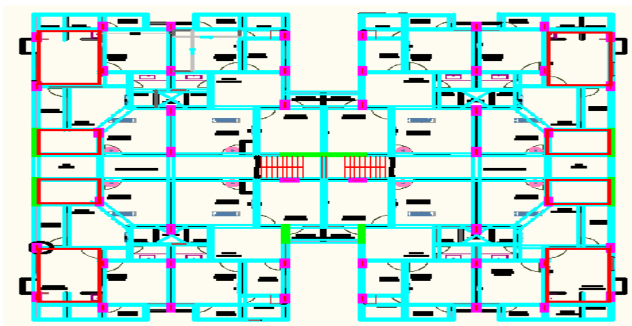

Fig. 3. Plan of effective allocationof decentalised on-site wastewater treatment system at an environmnetal floor.

VI. METHODOLOGY

The current study deals with comparative analysis between residential building with environmental floors where, DOSIWAM system is installed and building with same physical properties without treatment system (Seismic Zone: II, Importance Factor:1, Response Reduction Factor:5).

To analyze seismic performance of multi-storeyed building the important factor which affects the building frame is time period of structure. The mass on the environmental floor is generally more than the mass of successive floors, owing to the load of the tanks to be carried. This is a case of vertical mass irregularity that is detrimental to seismic performance of a high-rise structure. Hence the effect caused by mass distribution on the seismic performance has been calculated to ensure anticipated performance. The base shear is estimated which gives the maximum expected lateral force which arises at the structure's base due to seismic ground acceleration. Furthermore, story drift and displacement caused by action of later forces along with overturning moments throughout the heights of building structures are estimated. (Table V)

VII. RESULT AND DISCUSSION

Following results are derived from comparative analysis of both the structures.

1. There is an increase in base shear of about 70-80kN due to increase in seismic weight of the building with environmental floors, where treatment units are installed. So, need to increase some columns of building but it is not significant.

2. Time period of building is nearly the same in both cases. (1.29% increase for building with environmental floors.)

3. Increase in maximum Story drift in the case of building with environmental floors is 3.44% in X direction and 3.5 % in Y direction. Here, for both the buildings (with and without environmental floors) maximum story drift is in the permissible range (0.004h).

4. Increase in maximum Story displacement in X direction is 2.8 % and in Y direction is 3% for building with environmental floors, which is in controllable range.

5. There is a little increase in overturning moment which not so detrimental in case of treatment units installed at environmental floors.

Table-V: Results of comparative analysis.

Assessment Parameters	Structure 1 (With Environmental Floors)	Structure 2 (Without Environmental Floors)
Base Shear	1905kN	1835kN
Time Period	4.63 sec	4.571 sec
Maximum Drift I	0.0008901	0.0008627
Maximum Story Displacement	68.67mm	66.4mm
Overturning Moments	107944 kN-m	104208kN-m

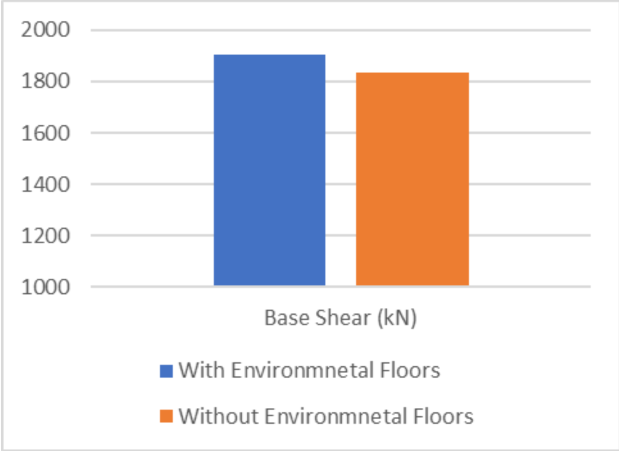

Fig. 4. Base shear comparison for multi-storeyed building with and without environmental floors.

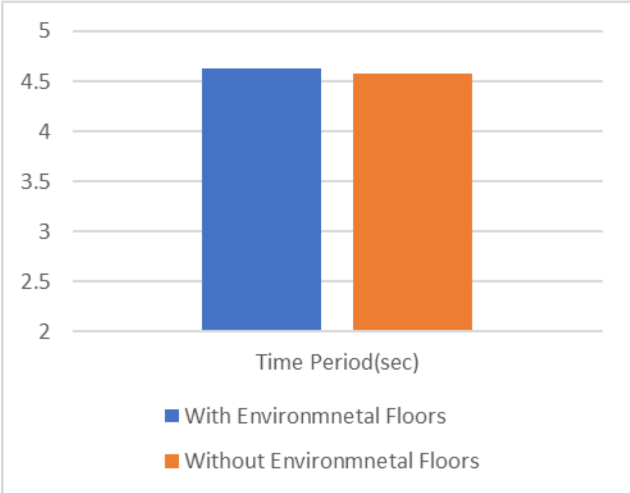

Fig. 5. Time period comparison for multi-storeyed building with and without environmental floors.

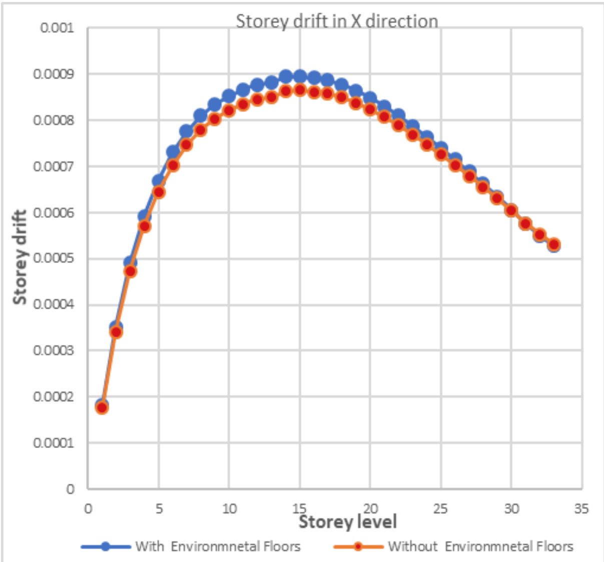

Fig. 6. Storey drift comparison in X-direction for multi-storeyed building with and without environmental floors.

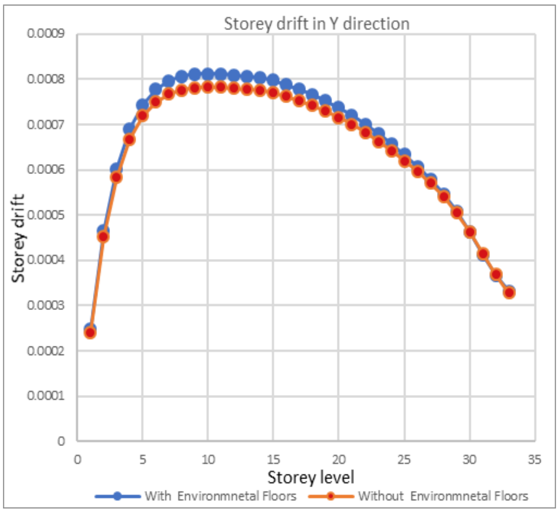

Fig. 7. Storey drift comparison in Y-direction for multi-storeyed building with and without environmental floors.

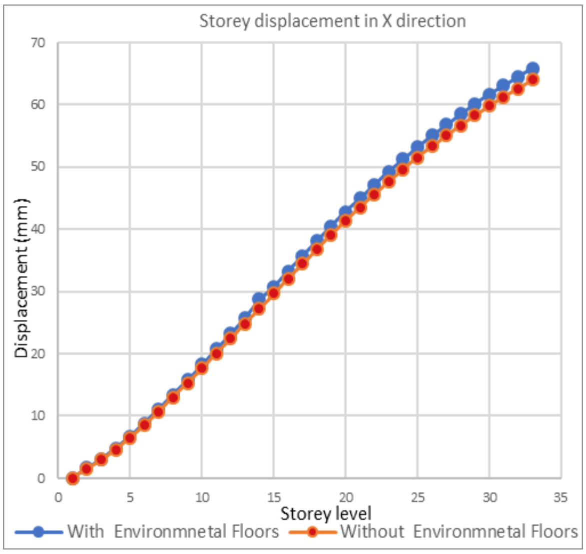

Fig. 8. Storey displacement comparison in X-direction for multi-storeyed building with and without environmental floors.

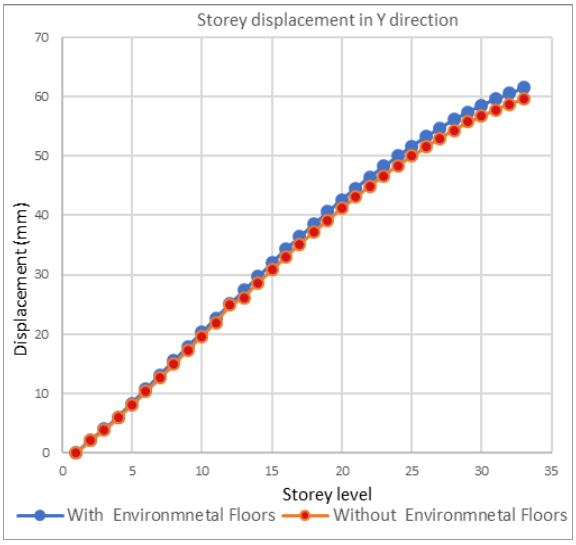

Fig. 9. Storey displacement comparison in Y-direction for multi-storeyed building with and without environmental floors.

VIII. CONCLUSION

The wastewater generated in residential buildings needs to be treated at its source in order to reduce its load on municipal sewage treatment plants. On-site treatment is the best solution for efficient minimization of these impacts. The treatment system used in research is on-site, non-mechanized and has various tangible as well as intangible benefits. Feasibility of Malaprabha digester and stabilization tank in multi-storeyed building on intermittent environmental floors is studied and the same are designed accordingly for the requirements of the building. Reuse of treated water for various non-consumptive uses achieve maximum water efficiency. Also, biogas generated from Malaprabha digesters can be utilized as an alternative source of fuel to reduce the dependency on LPG. Furthermore, DOSIWAM system is proved to be more sustainable as compared with other conventional wastewater treatment system which required regular maintenance skilled manpower and chemicals whereas, DOSIWAM is maintenance and chemical free treatment system. Moreover, construction cost for DOSIWAM system is 30 to 35 rs per lit while, STP or conventional sewerage system involve 60 rs per lit. construction cost along with huge operation and maintenance cost. Structural changes owing to the excess loads due to treatment units and corresponding changes in seismic performance of the building are analyzed. Behavioral response of the structures studied from the obtained results, clearly states that the locations of DOSIWAM (decentralized on-site wastewater treatment system) are safe. With minor changes in design and construction, system would be effective in urban areas, especially for high rise buildings. In view of current research, a proposal can be made to the respective local planning authority to incentivize the effort undertaken in the benefit of residents as well as the Government.

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AUTHORS PROFILE

Snehal V. Dewalkar, has completed M.Tech. form Visvesvaraya National Institute of Technology, Nagpur, India. She is research scholar at Savitribai Phule Pune University, Pune, India. She is life member of ISTE. She served as Assistant Professor, Sinhgad Academy of Engineering, Pune, India.

Dr. Sameer S. Shastri, has completed Ph.D. from College of Engineering, Pune, Savitribai Phule Pune University, India. He has 26 years of experience and currently working as Head of Department, Sinhgad College of Engineering, Pune. He is life member of IWWA, ISTE, IEA and Institute of engineers, India. He has total 20 research publications.