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Technology for Roof Top Harvesting in Urban Centres Based on Geotechnical Aspects

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ABSTRACT

The climate change of last decade shows plenty of floods and vast areas having scarcity of water. Looking to international studies by WHO, Prime Minister gave priority to harvesting every drop of rainwater in urban & industrial sectors in his water resources day speeches (2006-07). The rooftop harvesting to succeed, he states, must make it public participation programme. This cannot be possible unless a simplified technology which can be adopted by public at large is provided by engineers. The paper presents State Of Art, Professional Practice, Codal guidance & their limitations. To overcome them Geotechnical aspect based, field tested technology evolved is illustrated for wide applications. It includes evolving required parameters in execution to confirm a design discharge for planning rooftop harvesting which is environmental friendly and tested on prototype. The economics is briefly outlined for cost benefit ratio.

1. INTRODUCTION

Critical state of water resources have been indicated by Desai M.D. (1991, 2008). This is based on WHO survey and PM's speeches on water resources day 22/07/2006 emphasising mobilization, inventiveness, knowledge, wishdom and energy of common man to augment massive nationwide campaign for rainwater harvesting in urban and industrial zones. On 11th Sept 2007 address he stated "It is widely recognised that portable water is finite and vulnerable source". He challenged engineers to evolve simple economical system of collecting every drop of rainwater and conserving it by ground water recharging. Incidentally on vast coastal areas it will retard intrusion of salinity. The present contribution is attempt to provide quick, economical, simple technology for roof top harvesting to recharge fast depleting ground water table in urban India.

2. PRESENT LITERATURE / CODES

The references available to professional & public can be a) IS code 15792 (2008), b) National building code (2005), c) Artificial ground water recharge (Huisman et. al., 1983). For use by Architect, Engineer and Town Planners enforcing compulsory recharge requirements of municipal acts they have inadequate details for use without elaborate explorations of soil profile, G.W.L., geological formation, test records of aquifer characteristics. Such geological geographical, soil maps & data are available for some countries for ready use. Unless R & D provides such maps for city for house top recharge, public participation is impossible from cost aspects. NGO's therefore have developed local practices at places but its performance evaluation is not widely published.

3. PRESENT PRACTICE

As it is compulsory to provide recharge system for housing, the glaring shortcomings were observed. Many recharge systems never performed. Study shows poor conceptual knowhow of process, non-availability of standard specifications and qualified devoted agencies. It has been unfruitful formality complied by builder. To illustrate the practice, three typical cases are illustrated in Table 1, Table 2 and Figure 1 respectively.

Table 1: Case A- Part Item 46 of Overall Building Complex Tender

Sr. No	Quantity	Item Descriptions
46.		WATER RECHARGING SYSTEM : (
46.a. ✓	12.00 Nos. 8 Nos	Digging 500 mm. mean outer dia. Bore-wells up to 24.40 mts. depth, cleaning the same by compressor machine, providing and placing gravel in the same, fixing 315 mm. dia. unplasticized selfit PVC-U pipes, of class - 3, (0.6 Mpa) 6.00 kg., having one end self socketed and the other end plain, fitted together without using couplers and using strong solvent cement as per IS : 4985 - 2000 by 'Finolex' or as approved by the Engineer-in-Charge, using the above pipe for half the depth and using the above with strainer for the balance half of the depth, fixed 300 mm. below the average ground level, including providing and fixing ready made water recharging system filtration units, having 03 nos. of pre-cast r.c.c. panels (M : 30) of 1.10 mts. height each, fixed together in an octagonal formation, topped with a pre-cast r.c.c. slab (M : 30), the top two units being filled with gravel, etc. and the bottom unit being filled with fine grade sand, having 200 mm. high stainless steel strainer at the bottom to let out the filtered water into the bore-well, providing and fixing Cantex wire mesh of 2,000 mm. dia.

Observations

Case A

The number of bores for roof runoff, special drilling for large 500 mm hole and size 315 mm casing, almost double length of strainer in expected aquifer of sand and wasting sweet water to dilute saline water beyond 15 m in area, problems of filling gravel & its performance for deep depths not only added to cost with no special benefit of increasing inflow rate added uncertainty in long term performance. A standard bore of 250 mm with 200 mm casing and 3 m V wire strainer to total depth of 14 m would have recharge potential of 30 m^3/hr.

Table 2: Case B- Typical NGO Tender Accepted for Recharging of Public Buildings

Recharge Job work includes supply of materials, labour, PVC Pipes of IS mark (6 kg/cm^2). Packing gravel, cleaning of bore & Providing chamber of 1:6 mortar masonry of 1.2 x 1.2 x 1 m deep with 4 – 6 inlets. Precast recover on top, all relevant materials	*Bore Size*	*Rate Approved*
	10" dia (254 mm)	Rs 513/- Per feet (30 cms)
	8" dia (200 mm)	Rs 394/- Per feet (30 cms)
(Exemption to agreement, security and surity deposit, free power & water at site.)		

Case B

The job has been lump-sum rate contract leaves important performance parameter of depth to layman drilling bore, length & type of strainer and efficiency of bore to drain rooftop area for building. Thus actual performance depends on expertise / art of driller. Execution of bore may or may not serve purpose as there is no evaluation parameter such as recharge potential prescribed.

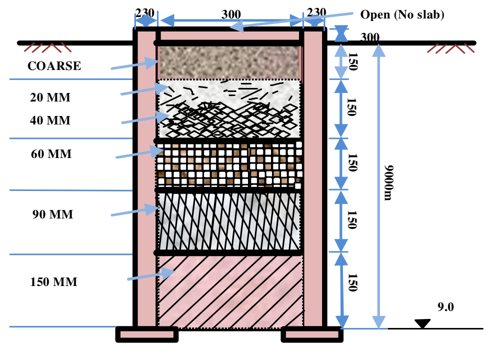

Fig. 1: Case C- Design of Well Offered for Large Industrial Complex

Case C

This costly well with filter planned for environmental governance did not perform as bottom & sites of well are in deep cohesive soils having very low permittivity.

Without casting aspirations four typical tender documents by Govt, Architect, Municipal Corporation and Project advised by Academicians have brought out following aspects:

(1) Tenders do not specify design depth and discharge capacity (approx) with respect to total roof yield in storm. This will provide success rate in project.

(2) In some examples depth specified is 25 m where the ground water level is at 10 m and water at 20 m onwards is saline.

(3) The system of transferring roof outlets to recharge wells requires a collection tank of adequate capacity. This is too small and occasionally delinked with bore. In most of cases bore capacity is fraction of roof yield and hence objective of conserving water is not really fulfilled.

(4) The large soak pits with filter at huge cost in industrial sector has been 10 m deep. The bottom and sides are impervious expansive plastic clay and hence intake was negligible. The same site 250 mm dia x 40 m deep bore in sand aquifer tested approximately shows intake of 35 m^3/hr.

(5) The slotted PVC casings without proper gravel pack & sealing at top were choked up in 2 years. The factory made strainers or V – wire mesh strainers, designed with annual maintenance, can increase life for 5 to 8 years. In public buildings investments will be dead unless maintained annually.

(6) The need to bypass first rain water by valve is rarely planned. The filter of water works design needs regular washing & replacement patented systems (e.g. Furaat) are excellent replacement but cannot be used successfully for surface water, oil & decayed plant leaves unless additional filters are planned. They require monthly maintenance.

(7) The yield of water and its rise with reference to year & withdrawal by users bores around needs critical assessment, as in clays it may influence foundation of structures and durability.

(8) Diameter of bore, PVC casing, length of strainer, type of strainer, filter, assessment of capacity to recharge, rise of water table (Probable), quality of water must be such that evaluation of system will be finally checked for economical feasibility. The agencies mostly are those who have mastered drilling for water supply bore for housing (pumping out, not pumping in).

4. RESEARCH WORK

Taking above background, the unique work was done by Prof. Pratima A. Patel, a Ph.D. scholar (2006-2010) to evolve design parameters. Table 4 gives recharge potential (Q_r) m^3/hr for a bore of radius (r) m, (h_w) depth of G.W.L. below G.L., (k) coefficient of permeability based on disturbed sample of aquifer (k = Avg. 3.6 m/hr for Surat) for pilot recharge bore. In Table 4, for different k values, Q_r effective = (0.28 x Q_r x k) m^3/hr. Here the value of k can be derived from Table 3.

Table 3: Estimating Coefficient of Permeability k (m/hr) from D_{10} of Sand in Aquifer

D_{10} (mm)	k (m/hr)	D_{10} (mm)	k (m/hr)
0.1	0.43	0.3	3.9
0.2	1.73	0.5	10.8

Table 4: Selection of Flow Capacity for Given r (Bore Radius), h_w (Depth to W.T.) and k Value (After Patel and Desai, 2010)

	h_w (m)						
Radius (m)	4	6	8	10	16	18	20
	$Q_r = m^3/hr.$ for $k = 3.6$ m/hr						
0.050	3.00	4.49	5.99	7.49	11.98	13.48	14.98
0.075	4.49	6.74	8.99	11.23	17.97	20.22	22.46
0.100	5.99	8.99	11.98	14.98	23.96	26.96	29.95
0.125	7.49	11.23	14.98	18.72	29.95	33.70	37.44
0.150	8.99	13.48	17.97	22.46	35.94	40.44	44.93
0.300	17.97	26.96	35.94	44.93	71.88	80.87	89.86
0.450	26.96	40.44	53.91	67.39	107.83	121.31	134.78

Fig. 2 shows the photographs of pilot case of rooftop harvesting system executed at Structural Engg Lab S.V.N.I.T. Surat. The typical prototype set up for it is shown in Fig. 3 with on line patented filter (Furaat) bore, strainer for unconfined aquifer. Design can, depending on local facilities plan diameter or detention tank.

The present state of art as seen from the tenders and projects for roof top harvesting suffers from ultimate assessment of intake capacity and probability of even partial success. The codes and stipulations by government for compulsory recharge would not serve objective defined by PM for needs of future.

The presented provisional technology provides design procedure for wide circulation, reassessment and finally incorporated in IS code.

5. DESIGN OF ROOF TOP RECHARGE SYSTEM

Design steps, charts and illustrated values for at typical case are indicated to arrive at design of bore diameter, number of bores, detention tank if possible, depth of bore & strainer. The pilot bore will provide required parameters such as depth to G.W.L. (h_w), D_{10} mm of aquifer sand from tube samples and control field constant head test to check Q_r estimated from charts. Data base will provide reduction or increase coefficient for sites at other sites. Additional bore will have revised design keeping infrastructure & local facilities.

(a) Network of Rainwater Collection Pipes with Furaat System

(b) Furaat System with Water Meter Chamber and Recharge Bore

Fig. 2: Photographs of Rooftop Harvesting System at Structural Engg Lab (A.M.D., S.V.N.I.T. Surat)

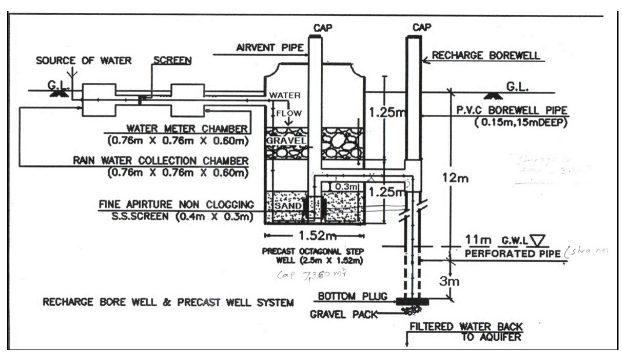

Fig. 3: Sectional View of Pilot Recharge System From the Terrace of Structural Lab (A.M.D., S.V.N.I.T., Surat)

6. VALIDATION AND PERFORMANCE OF SYSTEM

Pilot system for 300 m^2 area of the Structural Engg Lab at S.V.N.I.T. Surat was observed for runoff as per water meter and rainfall average for city reported by press daily. The Fig. 4 shows trend and reliability very good when practice does not have any indicator of rainwater recharging recorded.

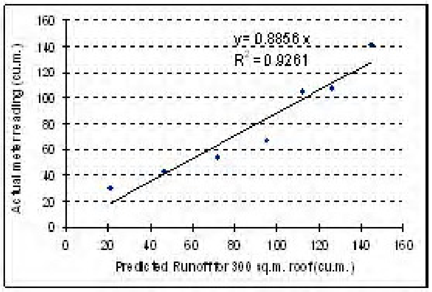

Fig. 4: Chart Showing Predicted and Observed Runoff Recharged for Struc. Engg Lab at SVNIT for July '10 Surat

To convince public to participate cost and benefits Item 13 above are essential. Variability of actual rain, k_h or k_v at depth, leakages and high storm than design can be accounted for by judgement and experience for a region.

Table 5: Design Steps for Roof Top Rainwater Harvesting

			Surat Case
Item 1	Estimate rooftop area to be drained (Surat Site: 4 m^3/100 m^2 of roof area per day for rechargeable rain storm 50 mm per hour	A (m^2)	2000 m^2
Item 2	Total daily design runoff	m^3/day	80
Item 3	Prepare site plan, outfalls of rain drains & collection chamber / chambers as per site. Estimate piping	r.mt	100
Item 4	Drill pilot 300 mm maximum size bore manually/wash boring without bentonite collecting data of soil profile, 2 tube samples from aquifer with/without casing. Depth will be 10 m below W.T. normally (Soil profile clayey up to 15m, sand up to 30m)	Depth of bore	h_w = 14 m Bore depth = (h_w+10)m = (14+10)m = 24 m
Item 5	Based on sieve analysis D_{10} of aquifer sand	D_{10} (mm)	Avg. 0.3 mm
Item 6	Data of site M.S.L. and R.L. of G.W.L. probability of salt water		MSL 18.0m GWL 4 m Salinity below RL(-)3m (guess)
Item 7	Provide PVC 250 mm (6 kg/cm2) casing as per IS code (Item 4) 2 m below W.T. Strainer PVC (Factory) or V-wire 1 mm, 3 m long Gravel pack at bottom and around casing with mortar plug for top 1 m (2- 4 mm size) Clean the bore by air jet till fresh water is ejected		16.0 m 16 to 19 m 0.5 m^3
Item 8	Using Table- 1 & 2 k = 3.9 m/hr, r = 0.125 m, h_w = 14 m, estimate recharge rate		20 m^3 (PVC strainer) 25 m^3 (V-wire strainer)
Item 9	Bores for total runoff		3 nos. (V-wire strainer)
Item 10	Design options: a) 2 bores + detention tank OR b) One pilot bore. Additional larger diameter to makeup requirement.		50 m^3/hr + detention tank 40 m^3 25 m^3/hr, r = 0.3 m h_w = 10 m, Q_r= 45m^3/hr
Item 11	Evaluate approx. Cost of system with filters (Furaat)	2 bores Tank Filter (Furaat)	Say Rs 3.0 lakhs
Item 12	Annual water conserved & its value at market rate.	30 days rain x 80m^3/hr	At Rs 70/- per m^3 water at source. Rs 1 lakh per year, life 5 years
Item 13	Prototype unit test by Pumping in test		28 m^3/hr average

7. CONCLUSION

1. The state of the art reviewed including IS codes, NBC and practice, a need to evolve a method to evolve design based on soil profile, D_{10} of aquifer sample, depth of G.W.L. observed during drilling of pilot bore. The failure rate and life of works executed do not meet PM's challenge to provide technology for harvesting every drop of rain water in urban & industrial India.
2. The work presented gives systematic design based on rate of flow in aquifer which is user friendly for practicing professionals and public participation at large.
3. The technology could supplement to IS Code: 15792 (2008) to make it user friendly.
4. The reliability and cost benefit analysis will convince every property owner to harvest his rainwater to the optimum.

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