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A Conceptual Design Model to Groundwater Recharge in Dense Urban Area Roads

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Abstract*: As increasing of Urbanization, the soil surface which is permeable through which groundwater recharge by infiltration can occur is reducing, this is resulting in much less groundwater recharge and greatly increased surface runoff. This Paper deals with the increasing of groundwater table utilizing of road runoff or stormwater through artificial recharge techniques. Infiltration devices that redirect surface runoff to the subsurface environment should be adopted, the infiltration system like infiltration trenches can be used to increase the groundwater table and the use of infiltration trenches has proven to be useful to reduce runoff in urban surface. By making continuous infiltration trenches in an area below the footpath and providing a filter media in it which consists of different layers of gravel and sand. Due to which filtered water goes inside the earth's surface and infiltration increases and the maximum portion of surface runoff go inside subsurface and stormwater management can be managed by using this technique. The methodology, applications, design & calculations are presented and discussed.

Keywords : Artificial Infiltration Techniques, Infiltration Trenches, Runoff, Stormwater Management.

I. INTRODUCTION

It is well known that Urban development strongly affects the hydrological condition of the natural environment. As by urbanization, removal of vegetation area occurs and the paved area which is impermeable increases, leads to an increase in the surface run-off peak, runoff volume and reduces the infiltration rate due to which groundwater table is lowering, also leads to stormwater management issues. Various approaches are made for reducing the amount the surface runoff and increasing groundwater recharge by the collection of rainwater which is effective for the recharging of groundwater through infiltration.

The infiltration of rainwater in urban areas decreased which is due to the development of concrete roads, parking lots, rooftops and compacted soil, which unable the rainwater to in filter inside the earth. The excess runoff is the portion of the rainfall that is not absorbed by interception, infiltration or depression storage.

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As per the report titled "Composite Water Management Index" published by NITI Aayog in June 2018 mentions that India is undergoing the worst water crisis in its history and nearly 600 million people are facing high to extreme water stress. The report further mentions that India is placed at 120th amongst 122 countries in the water quality index, with nearly 70% of water being contaminated.

As long as urbanization increases surface runoff and affects stormwater quality produces significant changes in hydrology that can result in an adverse impact on the streams and other receiving water bodies. Due to an increase of impervious surface percentage area which leads to reduce the groundwater recharge and can lower the groundwater table.

Stormwater management includes different methods such as detention ponds, retention ponds, onsite detention (OSD), constructed wet lands, infiltration trenches, grass filter strips, grassed swales, infiltration basins etc.

For disposal of stormwater infiltration trenches are considered most efficient in case of availability of less land area as in case of a dense urban area. They are shallow excavations with or without filter media to temporarily store stormwater and then infiltrate it into the subsurface.

Infiltration trenches are elements of green infrastructure that reduce runoff rates and volumes and can help replenish groundwater and preserve base flow in rivers. Infiltration trenches allow water to infiltrate into the surrounding soils from the bottom and sides of the trench, enhancing the natural ability of the soil to drain water. They treat runoff by filtration through the substrate in the trench and subsequently through soil. They are effective at removing pollutants and sediment through physical filtration, adsorption onto the material in the trench, or biochemical reactions in the fill or soil.

During the infiltration techniques clogging is the most important phenomenon that should be considered because it affects efficiency over time. The presence of sediments during the runoff entering the infiltration structure leads to clogging. Which accumulate and therefore reduces its mitigating capacity and its effective volume. Hydrological factors like catchment characteristics, structure geometry and soil property affects the clogging. when the Infiltration trench life cycle begins, infiltration takes place along through the bottom and the sides. As time goes due to the sediments accumulate both in the bottom and along the structure side causes progressive waterproofing of the structure bottom and side which reduces the effective infiltration area and clogging affects the whole area in which infiltration occurs.

II. OBJECTIVES TO STUDY

- The main objective of the present study is to discuss an efficient and effective way to apply the concept of infiltration trenches in a dense urban area with the least land area available.
- To design the different parameters infiltration trenches such as its dimensions, filter media, infiltration capacity etc.
- To discuss the worst scenario the designed infiltration trench can withstand.

III. CITY'S/ AREA'S KEY PARAMETERS

- Location: Indore, Madhya Pradesh, India
- Geographic area (Ha)=389800
- Admistrative Division Number of Tehsil/Blocks=4/4
- Number of Village =661
- Population(2011)=3272335
- Average Precipitation (last 10 years)=1107.5mm
- Major Soil Type =Medium Black Soil
- Principal Crops=Wheat, Soyabean

Table-I Rainfall data of Indore City (2010-2014)

	2010	2011	2012	2013	2014
Jan	5	0	0	0	19
Feb	2.2	0	0	17.94	43.4
Mar	0.1	0	0	5.25	0
Apr	0	0	0	7.9	1.4
May	1.1	8.4	83.7	0	2
Jun	56.4	105.6	34.4	336.4	8.6
Jul	192.8	497.2	490	755.7	325.7
Aug	376.1	772	269.1	367.7	165.8
Sep	228	202.7	174.7	136.7	202.8
Oct	18	16.2	0	42.8	23.7
Nov	79.1	0	0	0	0.1
Dec	0	0	0	0	18.7
Total	**958.8**	**1602**	**1051**	**1670.4**	**811.2**

Source – Indian Meteorological Department

Table-II Rainfall data of Indore City (2014-2019)

	2015	2016	2017	2018	2019
Jan	58.7	0.1	0	0	0
Feb	0.5	0	0	0	0
Mar	56.2	4.9	0	0.1	0
Apr	17.6	0	0	3.4	0
May	0.2	7.1	1.7	0.6	0.1
Jun	250.9	105.6	142.1	176.6	116.4
Jul	598.6	333.3	270.2	257.6	188.5
Aug	281.6	327.3	220.5	227.5	359.2
Sep	62.1	122	140.9	142.7	441.6
Oct	3	21.7	0.9	3.4	31.5
Nov	0	0	0	0	3
Dec	0	0	0.7	0	0
Total	**1329.4**	**922**	**777**	**811.9**	**1140.3**

Source – Indian Meteorological Department

Fig.1 A Street in Indore with no Stormwater management.

IV. METHODOLOGY

In the designing of ground water recharge in dense urban areas for artificial recharge of the ground water and capturing rainfall run off from the roads and making connectivity to the sub surface is the main key concept of the recharging ground water.

This concept helps for covering large areas and many benefits in terms of availability of more water, improvement in the water quality, reducing the cost on maintenance and repair of roads and improving the life of the road and also helps to maintain eco-balance.

For artificial groundwater recharge the continuous trenches with simple structures are made along both sides of the road which would not only control stormwater hazards in cities but also increase the availability of water. With the help of the normal rainfall and peak rainfall occurring, the structure is made such that the maximum amount of runoff of the road is sent back to the ground which will increase the groundwater recharge.

The structure will have natural infiltration media of coarse sand gravel and pebbles covered with a slab which will help the water to clean naturally. The filter media will consist of following layers – 250 mm & downsize boulders, 40 mm & downsize WBM, 20 mm & downsize WBM, 10 mm & downsize metal, Sand Bed, Nylon Mesh, 50 mm thick Sand Bed & 50 mm thick Pondicherry Pebbles.

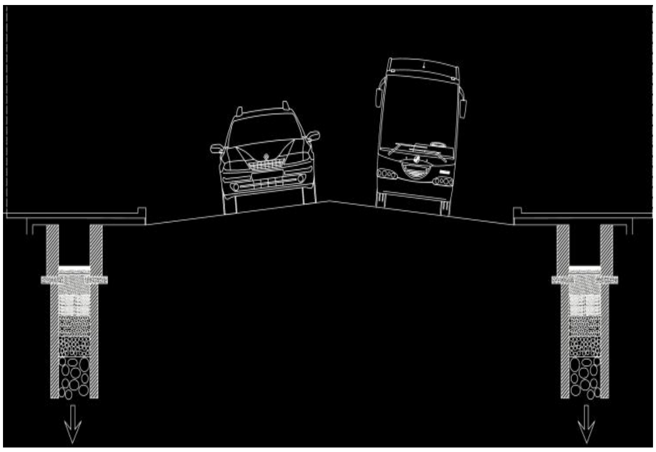

Fig.2 Cross Section of 2 lane road with Infiltration Trench on both sides.

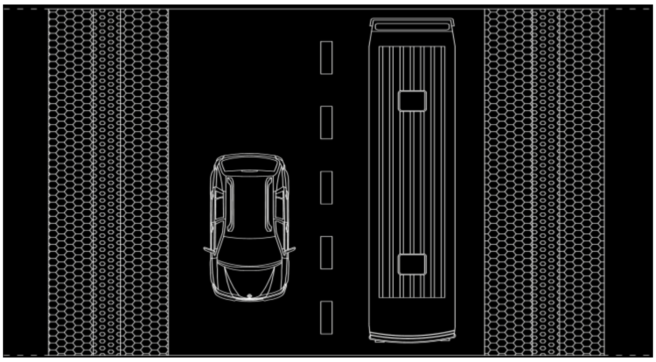

Fig.3 Top View of 2 lane road with Infiltration Trench on both sides.

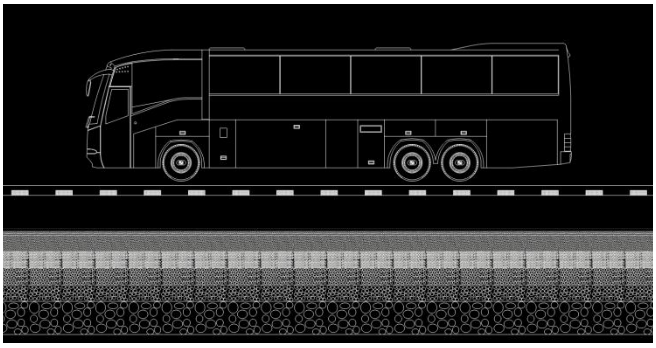

Fig.4 Side View of 2 lane road with Infiltration Trench on both sides.

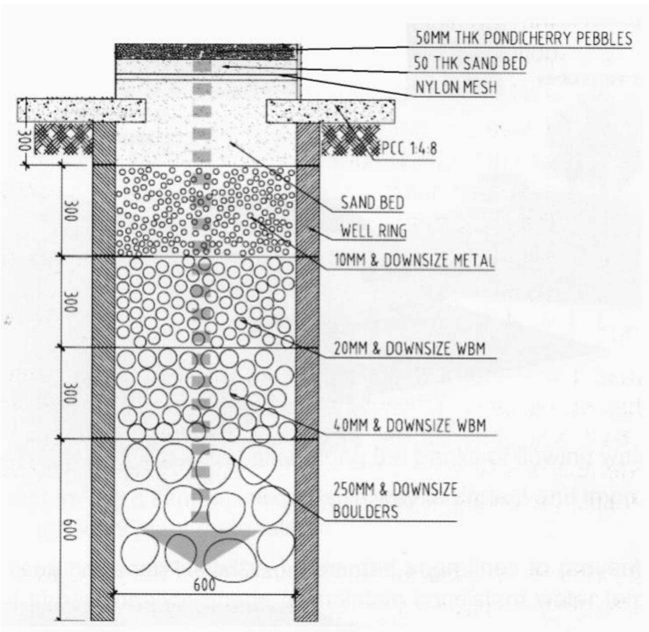

Fig.5 Different layers of Filter Media with width. (Source- IRC:SP:50-2013)

For successful implementation of artificial recharge schemes in urban areas following are major components: assessment of the source of water, proper planning of the recharge structures, finalizing of design and techniques, monitoring, economic and financial evaluation, operation and maintenance.

V. DESIGN OF INFILTRATION TRENCH

A. Quantity of Precipitation

Assuming the width of two-lane road with kerb be 7.5m & footpath with min. width as per IRC:103-2012, 6.1.5.2 for commercial areas be 2.5m each on both the sides.

The average annual precipitation in Indore is found to be 1107.5 mm

Therefore, Quantity of Runoff (Q_0) produced annually for a 2 lane road per km road length is

$$Q_0 = 1000m \times 12.5\, m \times \frac{1107.5}{1000} m$$

$$Q_0 = 13843.75\, m^3$$

$$Q_0 = 13.84375\, ML$$

B. Quantity of Runoff

As per Circular No. RW/NH-33044/14/2003-S&R(R)(Pt.II) dated 5 September 2013, Ministry of Road Transport & Highways, Government of India.

Take runoff efficiency as 80%.

Therefore, $Runoff\ Volume = 0.8 \times 13843.75\, m^3$

= 11075 m^3

C. Infiltration Rate

As per U.S. EPA, 1999. *Storm Water Technology Fact Sheet Infiltration Trench*, Office of Water Washington, D.C., Soils should have a low silt & clay content & have infiltration rates greater than 1.3 cm/hr or 0.5 in/hr.

As per experiments & research papers, the constant infiltration rate (f_c) is found to be near 1.3 cm/hr.

D. Average Runoff Volume

The average no. of rainfall/wet days in Indore= 60.5 days.

Therefore, Avg. Runoff = $11075/60.5 = 183.0578\, m^3$

E. Width of Infiltration Trench

Infiltration Trenches of Washington D.C. are designed to drain within 72 hours.

Let us assume detention time to be 24 hours considering the precipitation zone.

Therefore, Quantity of Water Infiltrated in 24 hours = Quantity of runoff.

Let the width of Infiltration Trench be $x\ m$.

$$\therefore 0.6 \times \frac{13}{1000} \times x \times 1000 \times 24 = 183.0578\, m^3$$

$$x = 0.977\, m$$

Since, the Infiltration Trenches are provided on both the sides, the width of each trench becomes 0.4885 m.

According to Storm Water Drainage Systems Manual 2019, it recommends a minimum width of Infiltration Trench to be 0.6 m.

Therefore, providing an infiltration trench with a width of 0.6 m on both the sides of road.

F. Design of Trench Volume

As per U.S. EPA, 1999. *Storm Water Technology Fact Sheet Infiltration Trench*, Office of Water Washington, D.C., the trench volume can be calculated using the first flush capture, which is defined as the first 1.3 cm (0.5 in) of runoff from the contributing area.

The State of Maryland & the Metropolitan Washington Council also recommends sizing the trench based on the first flush.

(i) Quantity of runoff capture in first flush is

$$= 1000\,m \times 12.5\,m \times \frac{1.3}{100}m$$

$$= 162.5\,m^3$$

(ii) Cross section area of the trench

$$= \frac{Volume}{Length} = \frac{162.5}{1000} = 0.1625$$

(iii) Depth of the Trench Volume

$$= \frac{C/s\ Area}{Width} = \frac{0.1625}{1.2} = 0.135\,m$$

Providing a depth of 0.25 m and freeboard of 0.15 m.

Total depth = 0.25 + 0.15 = 0.4 m.

VI. RESULT & DISCUSSION

- Infiltration trenches are found to be most suitable in case of dense urban area or a limited area.
- Instead of placing Infiltration trenches between road and footpath, placing it beneath the footpath pavement will reduce the width requirement.
- Different layers of Filter media consisting of 250 mm & downsize boulders, 40 mm & downsize WBM, 20 mm & downsize WBM, 10 mm & downsize metal, Sand Bed, Nylon Mesh, 50 mm thick Sand Bed & 50 mm thick Pondicherry Pebbles can be used for pollutants removal as suggested by Indian Road Congress.
- Infiltration trenches of 0.6 m width can be provided on both sides of the road.
- This system will able to infiltrate 11075 cubic meters of stormwater into the ground per km length annually.
- Detention time of 24 hours will be required to infiltrate stormwater
- Infiltration volume should be provided with 0.4 m depth to store water till the detention time and it should be connected to sewerage line in case of overflow so that stormwater will not be present on road in case of heavy rains.

VII. CONCLUSION

Due to urbanization activities the surfaces convert to impermeable ones. This leads to the growth of stormwater runoff and lessening both surface water quality and infiltration to groundwater. On roads, these effects can often be reduced by using the technique of infiltration trench. Some simple modifications to the placement of a stormwater management system can make it efficient in limited area locations and reduce maintenance intervals significantly.

Roads runoff gets to mix with sewage water which wastes all the run-off water and is of no use instantly, by adopting this method we can prevent it. In this method we have taken multiple layered systems to filter impure water and removal of sediments in the upper layer.

REFERENCES

1. Maryland Department of Natural Resources, 1986. *Minimum Water Quality Objectives and Planning Guidelines for Infiltration Practices.* Water Resources Administration, Sediment and Storm Water Division.
2. Schueler, T.R., 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices.* Metropolitan Washington Council of Governments.
3. Schueler, T.R., 1992. *A Current Assessment of Urban Best Management Practices*. Metropolitan Washington Council of Governments.
4. U. S. EPA, 1991. *Detention and Retention Effects on Groundwater,* Region V.
5. U.S. EPA, 1999. *Storm Water Technology Fact Sheet Infiltration Trench,* Office of Water Washington, D.C.
6. Katkar Namrata ,Korake Swapnali ,Thite Trupti ,Waghmode Tejasvi ,Satyawan Jagdale ,Shrikrishna Gosavi , (2019) " Infiltration Studies of Black Cotton Soils under Different Soil Conditions and Comparison of Infiltration Models with Field Data " , *International Journal of Advances in Mechanical and Civil Engineering (IJAMCE)* , pp. 4-8, Volume-6,Issue-4.
7. Jagdale Satyawan Dagadu, Nimbalkar P. T. Infiltration Studies of Different Soils under Different Soil Conditions and Comparison of Infiltration Models with Field Data, International Journal of Advanced Engineering Technology E- ISSN0976-3945.
8. IRC, 'Guidelines On Road Drainage', IRC: SP: 50-1999, Indian Roads Delhi.
9. Coffman, L. (2000). *Low-impact development design strategies: An integrated design approach*, Dept. of Environmental Resource, Programs and Planning Division, Prince George's County, MD.
10. Hwang, C. C. (2005). "Assessing the performance of a porous pavement on pollution control and runoff abatement." *J. Chin. Inst. Civ. Hydraul. Eng.*, 17(3), 529–535 (in Chinese).
11. Prince George's County. (1999). *Low impact development hydrologic analysis*, Dept. of Environmental Resources Programs and Planning Division, Prince George's County, MD.
12. S. Mohan and Kumari Sangeeta, (2005). Recharge estimation using infiltration models, ISH. Journal of Hydraulic Engineering, Vol. 11, pp 1-10.Journal.
13. K. Subramanya. Engineering Hydrology. Third reprint (2009). TataMCGraw-Hill, third edition. Pp: 80-91.
14. John Diamond and Thomas Stanley. (2003), Infiltration rate assessment of some major soils. Irish Geography, vol. 36(1): pp32-46.
15. Horton, R.E. 1940. "An approach towards a Physical Interpretation of Infiltration Capacity." Soil Sci. Soc. Am. Proceedings 5: 399- 417.
16. Balraj Singh, Parveen Sihag, Diwan Singh, Study of Infiltration Characteristics of Locally Soils, 2014, Journal of Civil Engineering and Environmental Technology Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 1, Number 5; August, 2014 pp. 9 – 13.
17. Amreeta Champatiray, Vinay Balmuri, K. C. Patra, Mrunmayee M Sahoo, Standard Test for Determination of Infiltration Rate of Soil Using Double Ring Infiltrometer, 2014, "Innovative Trends in Applied Physical, Chemical, Mathematical Sciences and Emerging Energy Technology for Sustainable Development" ISBN: 978-93-83083-71-8.
18. Amit H. Mulani, Dr. R. B. Khasiya, Dr. J. N. Patel, Determination of Infiltration Rate: Case Study of Bhimrad Area of Surat District, 2014, Volume : 4 | Issue : 9 | September 2014 | ISSN - 2249-555X.
19. Anjaneya Prasad M, Sundar Kumar P, Kaushik KHS, Bharath Kumar V, Sai Krishna PN and Vamshi Krishna G, "Determination of Infiltration Parameter Estimation Rates in a Small Region in Andhra Pradesh", International Journal of Earth Sciences and Engineering, ISSN 0974-5904, Vol. 08, No. 02, April,2015, pp. 212- 214.
20. Dr. Avinash S. Kadam, Determination of Infiltration Rate for Site Selection of Artificial Water Recharge: An Experimental Study, Volume 5 Issue 6, June 2016, http://dx.doi.org/10.21275/v5i6.NOV164327.
21. Gray, D. M., and Norum, D. I. (1968) The effect of soil moisture on infiltration as related to runoff and recharge In Proceedings of Hydrology Symposium.No. 6, p. 133 Queen's Printer.
22. Hazen, A. (1930). *Water supply: American civil engineers handbook*, Wiley, New York, 1444–1518.

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