Journal of Science and Technology
ISSN: 2456-5660 Volume 06, Issue 04, July-August 2021
www.jst.org.in *DOI: https://doi.org/10.46243/jst.2021.v6.i04.pp160-171*

ROAD RAINWATER HARVESTING - EFFICIENT TOOL FOR ROAD DRAINAGE AND GROUND-WATER RECHARGE

Salim G. Shaikh[1], Rahul P. Agrawal[2], Shalini T. Dengle[3] and Abhijeet P. Wadekar[4]

[1] Research Scholar, P.E.S. College of Engineering, Aurangabad, Maharashtra, India
[2] Research Scholar, Government College of Engineering, Aurangabad, Maharashtra, India
[3]Assistant Professor, Vivekanand Arts, S.D Commerce and Science College, Aurangabad, Maharashtra, India
[4] Principal, P.E.S. College of Engineering, Aurangabad, Maharashtra, India
Corresponding Author: Email - salimcreator@gmail.com

To Cite this Article
Salim G. Shaikh, Rahul P. Agrawal, Shalini T Dengle and Abhijeet P. Wadekar, "Road Rainwater Harvesting - Efficient Tool for Road Drainage and Ground-Water Recharge", Journal of Science and Technology, Vol., Issue, August 2021, pp.: 160-171.

Article Info
Received: 22-08-2021 Revised: 25-08-2021 Accepted: 29-08-2021 Published: 31-08-2021

Abstract: *In the last 4 to 5 decades, roads were constructed/ improved at a large scale; hence road length has rapidly increased to a larger extent in India. This paper will provide a systematic way of finding the drainage status of existing roads, the need for proper drainage of the road water, and groundwater recharge to raise the existing water table by the way of road rainwater harvesting. For an investigation, the field data of camber of pavements, shoulders side-slope, embankment slope, and status of open/built-up gutters on both sides of the road was collected. This quantitative data is collected for the 10 km road length of Mumbai-Goa NH-66. This study site is a typical representation of the condition of road drainage in India and most of the parts of the world. However, their nature and magnitude will change depending upon local meteorological conditions, geographical and geological parameters, the standard of road, traffic volume, etc. Results/findings worked out under this study are effective and highlighted the concentration towards the need for road water harvesting. It will also resolve the problem of drinking and agricultural water to a certain extent. Building/terrace rainwater harvesting is popular all over the world. However, the road rainwater harvesting concept is yet not common in India and all over the world also. Hence, a decision policy of government road organizations in each nation is essential for the implementation of this scheme. It will not only increase the life of road but also play important role in the sustainable development in that area/region. Figure-1shows the graphical abstract of the current study.*

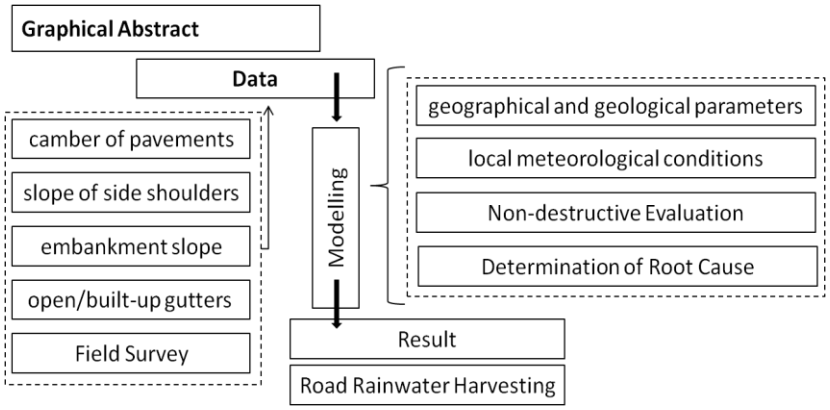


Figure 1: *Graphical Abstract of Current Study*

Keywords: *Road Drainage; Rainwater Harvesting; Pavement Failure; Ground-Water Recharge; Sustainable Development; Forensic Investigation*

I. Introduction

Water is a fundamental natural resource for a vast range of uses beside ecosystem, and biodiversity including domestic, agricultural, industrial, and recreational uses. Road infrastructures have a major impact on the landscapes immediately surrounding them. It determines the movement of water, sediment, and dust, among other things. Rainwater Harvesting (RWH) is a process of collecting water from raindrops, giving treatment and its storage. It has been the basic source of water origin for different uses for many years, before using systems of water conveyance. Many cities, towns and villages are trying to adopt developed, updated water infrastructure concepts like waterway city, water cycle city, and water sensitive city, to solve the water crisis.

Improper surface and subsurface drainage results in the formation of different types of distresses on road pavement surface and subsurface. Water stagnation on the road surface and along the road has always been a major problem. The stagnant water degrades the surface/subsurface of the road resulting in the formation of potholes and wears off the road surface. The major source of stagnant water is an improper camber/slope provided to the road. Moreover, due to heavy rains, the water is left on the surface of the road which damages the pavement. Most of the road water runoff goes to waste and is of no use. The value of water is important especially in the area where the average annual rainfall is below 1000 mm.

Drinking water is scarce, especially in the summer season. Hence recharge of groundwater by proper road drainage and harvesting this water by developing some technique/ model will help to some extent to resolve this issue. Such practice is yet not common and developed in India and other nations as well. If road water drains properly it will help for smooth traffic flow, minimize the road structure failure, avoid delay in travel time, decrease the expenditure on maintenance cost of road, decrease in vehicle maintenance cost, increased life of the road, and reduce the possibility of accidents.

II. Material and Methods

Related Work: It is necessary to maintain a road free of any surface damages /potholes. Good customer service is an important key objective of road maintenance. Therefore, quick drainage of the road surface and subsurface water is essential. When the term road drainage links to rainwater harvesting it will become a wider concept, on this topic. Under this topic, books mentioned in references are studied, Codes, Guidance Notes, Specifications, National and International Technical Journals, Special Publications (SP) of Indian Roads Congress (IRC), findings of National and International Seminars/Conferences, Technical Circulars issued by Highway/Road Authorities, Research works carried out by research Institutes, Scientists and Engineers. On this vast topic- 'road drainage, rainwater harvesting, groundwater recharge, and water conservation, following available work play the role of base for new research work:

Prithvi Singh Kandhal and Sapan Mishra (2014) extended their study on porous asphalt pavements. It can be used for a parking lot or low-trafficked roads/streets. Water percolates slowly into the underlying soil. It is collected through side gutters for rainwater harvesting. The study of Abhay Dixit (2015) concentrates on providing an effective way to collect this stagnant water on the road and to modernize the conventional system of drainage. Erna Ismiyani et al (2018) concentrated their study on drainage & maintenance of the road. Well-drained roads are always subjected to lower maintenance. As the stagnated and undrained water weaken the pavement, one should provide a proper drainage system to increase the life of the roadway at the stage of construction itself. This result was later elaborated by D. Iskandar et al (2019) by stating that weakening of road may be due to the standing huge amount of water in unstable areas, settling pavement layers, widening the cracks, or deepening potholes. It is further concluded that roads with bad drainage facilities require more maintenance comparatively. It’s better to invest onetime initial cost for drainage work than paying repairing charges multiple times.

IRC: SP: 50- 2013 specifically guide for designing the urban drainage work. This special code will consider many parameters while talking about urbanized areas i.e., urban infrastructure, available reduced area for rainwater infiltration due to concreting, a load of the multiplied population on the available drainage system, new transportation infrastructures, etc. IRC: SP: 42- 2014 provides the guidelines for providing drainage systems in the construction of roadways. These codes were prepared by expert engineers and researchers to facilitate proper drainage in highway construction.

George Kollaros and Antonia Athanasopoulou (2017) highlighted the importance of the Influence of drainage on flexible road pavement design in their research paper. It explains the yield of collected rainwater depends on the drainage characteristics of the pavement structure. As layer thickness plays a major role in pavement draining

process analysis and computation carried out around the same. Different drainage coefficients assign to different pavement thicknesses empirically. These coefficients indirectly symbolize the drainage nature of a particular pavement case. The study also considered the climatic factor, nature of traffic in addition to characteristics of pavement material and its thickness. The more will be the layer thickness less will be the water drainage. Nowadays empirically based designs are used for whole the nation. It may require modifications based on regional experience and a better assessment of the drainage conditions prevailing in each area crossed by a roadway project. Because design considerations are changes, the necessity for a shift towards more sophisticated design methods is considered obligatory.

The effect of poor drainage causes the failure of the road in different ways. The correct road drainage system increases road life. However, an improper drainage system leads to the failure of the road at an early age. Therefore, appropriate design, construction, and maintenance practices must be adopted to maintain road drainage. It is studied that as the rainfall intensity increases, the water depth increases, and this explains the height water level or water depth during floods in Jordanian roads, and this will increase if the street has a bad drainage system as found by inspection of roads widely studied by Mohammad Awwad (2021). Alireza Fathollahi and Stephen J. (2021) concentrated their research on the first comprehensive life cycle assessment of the most common drainage systems. Life cycle costing and uncertainty analysis was carried out for these selected drainage systems. The results of this study highlighted the important factors influencing the environmental impacts and life cycle cost of the drainage systems.

Nasyiin Faqih and Wiji Lestarini (2020) have contributed to a redesign of the road drainage system in Indonesia. It consists of cost factors and durability of drainage work depends on the building material, its transportation, the method adopted to construct civil works, and their maintenance. Work is done on multiple drainage systems which covers almost all types of such systems. The result of work helps one to provide guidelines for designing economical and durable drainage work. Also, it provides a checklist of various influencing factors and eases to select the most suitable practices according to the demanding situation. Further research carried out by M. Damayanti et al 2020 in Indonesia contributed to flooding control by the way of road drainage. The study by Mythili et al 2020 has contributed to an Experimental Approach for the Kerbside Rainwater Collection. Road geometry i.e., kerb, longitudinal slope, gutter depth, formation width, etc., and surface features affect the draining of rainwater. These geometrical parameters depend on the available rainfall and flood data of a particular locality. Well-designed pavement structures facilitate good drainage and ultimately lower the maintenance cost and longer the durability span. Rainfall, drainage system, and flood are interconnected parameters. If one will consider data on rainfall characteristics and design proper drainage work in the future, it will take care of the flood situation.

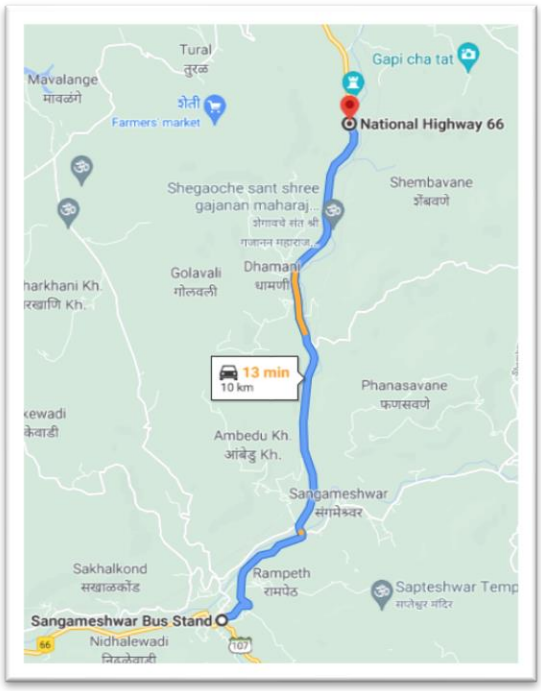
Andung Yunianta et al 2020 developed an experimental model for the sustainable road drainage system. Further research carried out by Andung Yunianta et al 2021 has succeeded in the development of the application of the Sustainable Road Drainage System by Simulation program. Saurabh Khode et al 2020 and Johannes Wolfgang Neupert et al 2021 worked on a sustainable road drainage system. It will conserve the environment by harvesting rainwater, reducing soil erosion, and protecting road structures. Treatment of stormwater and its testing will help to improve the serviceability of collected discharge from roadside drainage. The use of such water for commercial purposes, flushing toilets, gardening will reduce the water demand load of local bodies.

In the concept of rainwater harvesting from roads, water is conveyed away from the roadway, and this collected water is used to recharge the groundwater table in various ways. Such water conservation will gift productive land and increase the agricultural yield of people in the vicinity. A good drainage facility checks the ponding of rainwater on the road surface and drains off the discharge quickly. Accumulated runoff may lead to erosion of road surface. Poor design of drainage system may result in waterlogging and flooding action which will further turn into the functional and structural failures of the roadway. This study conducted by Jonathan Demenge et al 2015 has its importance and major role in the potential effects of combined roads and water harvesting infrastructure on livelihoods and poverty in Ethiopia.

The study carried out in the semi-arid region of Tigrai, Ethiopia by Kebede Manjur Gebru et al 2020 concentrated on both household and plot-level data to investigate the factors influencing roadside farmers' decisions to adopt Rainwater Harvesting (RWH) practices and their impacts on input use, yield, and farm income. Binary probit regression and Propensity Score Matching were used to analyze the data. Public policy can affect the promotion of RWH in drylands. The study suggests that RWH has positive and significant impacts on input uses (farmyard manure and fertilizer), crop yield, and farm income among the sample households. In the study by Abdullah A. Al-Maswari et al 2020, it is found that generally, the available drainage facility on roads is designed to drain out runoff from the roadway and to safeguard the pavement structure. One can think a step ahead and utilize such collected rainwater to nearby farms. This diverted water can use to recharge roadside wells or can allow percolating in the

ground. It will be better to take into consideration this design objective at a stage of the design itself. Some extra investment in addition to drainage work will fruits effectively in water harvesting and soil conservation.
It is learned that as per the present literature survey, some of the research papers and studies concluded about the causes of improper road drainage and some solutions for them. Very few researchers concentrated on the need for road water harvesting and worked for the betterment of roads and people. However, there is a need for further remarkable and effective work in harvesting the road water for better road drainage and groundwater recharge. We observe many road surfaces distresses within one to three years of their construction or improvement only because of improper road drainage systems.
Therefore, research in the evaluation and analysis of road drainage and proper harvesting of road water for increasing the groundwater table by the way of groundwater recharge is essential. This will lead to the perfect solution for road surface damages as well as resolve the drinking or agriculture water problem to some extent. With this gap of study, the following objective is set for present research work: Analysis of road drainage data and prepare a model to harvest the road water to raise the water table nearby.

Study Area: To know the exact type & magnitude of the road drainage problem, the road stretch of Mumbai- Goa National Highway No.66 is selected. Figure-2 shows the location of the selected road stretch. Approximate Year of Construction - 1960(1 Lane), 1985 (2 Lane), Rehabilitation to 2 Lane (1995), Rehabilitation to 4 lane - work in progress (2020-21) Kms 251/000 to 261/000 in Sangmeshvar Taluqa of Ratnagiri District in Konkan Region of Maharashtra State.



Key Features of Study Area:

- Geographical location:

Latitude - 17.2468 N to 17.1699N,
Longitude-73.5534 E to 73.5339 E

- Type of soil - Mostly murram and mix with small boulders
- Annual Average Rainfall - 3210 mm.
- Period of Data Collection - 15.05.2020 to 28.05.2020
- Type of Pavement – Flexible (Bituminous)
- Formation width -12m
- Carriageway width - 7m
- Type of treatment - WBM-30 cm, BM-50mm, BC/OGC- 25mm
- Traffic intensity - 12500 PCU

Figure 2: Location Map of Road under Study

Methodology: The various phases of the research methodology and techniques to be used are enumerated as follows. Figure-3 shows the flow diagram of the methodology.
Phase I: There would be an extensive literature survey.
Phase II: Survey / Investigation of selected road stretch and Collection of data on road drainage
Phase III: Interpretation and analysis of data, cause, and effect analysis, etc.
Phase IV: Developing Road rainwater harvesting model
Phase V: Results/Findings/Discussion/Conclusion

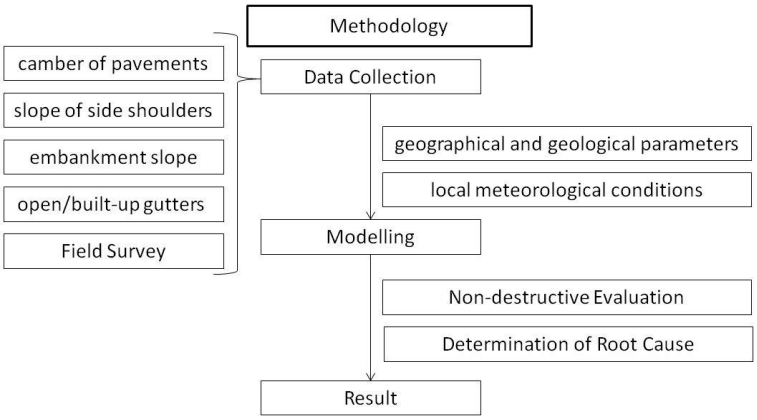


Figure-3: Flow Diagram of the Methodology

Forensic Investigation of selected road stretch: Rajib B. Mallick and Tahar El-Korchi (2017) highlighted the approach of forensic investigation to properly study the selected road stretch. It is decided to do the forensic investigation of the selected road stretch in the following ways.

- ✓ Data Collection – To know the type & magnitude of road drainage
- ✓ Interview – Interview with people familiar with the road, interview of related workers
- ✓ Nondestructive Evaluation – Visual Inspection, Detailed Condition Survey, site visit, etc.
- ✓ Determination of root cause(s) – Data analysis to know likely failure cause.

Data Collection: Realistic and accurate collection of data aims for systematic and proper research. A team of experienced and trained engineers & field staff working on-site were selected for this work. Special technical training sessions were conducted for this staff before starting the data collection. A data collection sheet (Table-1) was prepared to gather the data. Data had been collected on the proposed site in May-2020. The data collection team worked in three groups to work with coordination. This collected data is the quantitative type and recorded by working furlong wise. (i.e., taking observation for each 200-meter interval). After surveying, the team also interacted with local people to get some more qualitative information about the performance of the road drainage system. As per the above data collection sheet, measurements are taken on-site for pavement camber (slope), shoulder slope, embankment slope & functioning of roadside open gutters. Table-1 shows the abstract of the collected data. However, the results of any kind of study always depend upon accuracy and correctness in data.

Table 1: Data Sheet for Pavement/Shoulder Camber, Embankment Slope & Roadside Gutters

Sr. No.	Km		BT camber %		Side Shoulder Camber %		Embankment Slope		Gutters	
	LHS	RHS	LHS	RHS	LHS	RHS	LHS	RHS	LHS	RHS
1	2	3	4	5	6	7	8	9	10	11
1	251.000	251.200	0.97	2.00	1.60	2.40	1 in 2.50	1 in 2.20	-	Yes
2	251.200	251.400	3.10	3.20	3.20	3.00	1 in 2.25	1 in 1.50	-	Yes
3	251.400	251.600	3.42	1.71	2.40	1.50	1 in 1.50	1 in 2.50	Yes	Yes
4	251.600	251.800	3.00	3.20	3.10	1.50	1 in 2.20	1 in 1.75	-	Yes
5	251.800	252.000	3.20	2.85	1.60	2.10	1 in 2.50	1 in 1.50	-	Yes
6	252.000	252.200	3.10	3.10	2.40	1.50	1 in 2.50	1 in 2.50	Yes	-
7	252.200	252.400	2.00	4.29	3.20	2.20	1 in 2.50	1 in 1.50	Yes	Yes

8	252.400	252.600	2.57	3.14	2.10	1.50	1 in 2.20	1 in 2.50	-	-
9	252.600	252.800	2.85	2.00	2.40	1.50	1 in 2.00	1 in 2.50	-	Yes
10	252.800	253.000	1.71	2.90	2.15	2.20	1 in 2.50	1 in 1.70	Yes -	Yes
11	253.000	253.200	3.20	3.00	1.60	1.50	1 in 1.50	1 in 2.50	Yes	-
12	253.200	253.400	1.71	2.57	3.10	2.70	1 in 2.50	1 in 2.20	Yes	-
13	253.400	253.600	3.14	2.00	1.75	3.10	1 in 2.50	1 in 1.50	-	-
14	253.600	253.800	2.29	3.71	2.20	2.40	1 in 1.50	1 in 1.75	Yes	Yes
15	253.800	254.000	3.14	3.20	1.50	1.60	1 in 2.50	1 in 2.00	-	-
16	254.000	254.200	3.00	3.10	3.10	1.50	1 in 1.50	1 in 1.50	Yes	-
17	254.200	254.400	2.57	1.14	3.20	3.00	1 in 1.50	1 in 1.75	Yes	Yes
18	254.400	254.600	1.85	3.14	1.60	1.70	1 in 2.50	1 in 1.50	-	-
19	254.600	254.800	3.86	1.71	2.25	2.50	1 in 2.20	1 in 2.50	Yes	-
20	254.800	255.000	2.00	3.14	1.75	3.20	1 in 2.50	1 in 1.50	-	-
21	255.000	255.200	2.57	2.00	3.20	1.60	1 in 1.50	1 in 2.50	Yes	Yes
22	255.200	255.400	3.00	2.57	4.40	2.40	1 in 2.00	1 in 1.50	-	Yes
23	255.400	255.600	3.05	2.14	3.00	3.60	1 in 2.50	1 in 1.50	Yes	Yes
24	255.600	255.800	2.00	3.14	3.20	1.70	1 in 2.20	1 in 2.50	-	Yes
25	255.800	256.000	1.71	0.97	2.25	1.60	1 in 1.50	1 in 1.50	-	Yes
26	256.000	256.200	3.42	2.29	4.00	3.70	1 in 2.50	1 in 2.50	-	-
27	256.200	256.400	1.14	2.29	3.20	2.25	1 in 1.50	1 in 2.50	Yes	Yes
28	256.400	256.600	1.71	2.57	2.50	3.10	1 in 1.70	1 in 2.5	-	Yes
29	256.600	256.800	3.14	1.57	3.15	2.70	1 in 1.70	1 in 2.20	-	-
30	256.800	257.000	1.55	2.57	2.75	3.10	1 in 2.00	1 in 2.50	Yes	Yes
31	257.000	257.200	3.00	3.00	1.75	1.80	1 in 1.50	1 in 2.00	-	-
32	257.200	257.400	2.57	3.10	1.70	2.25	1 in 2.50	1 in 2.50	Yes	Yes
33	257.400	257.600	3.10	1.71	1.60	3.20	1 in 2.50	1 in 2.50	Yes	-
34	257.600	257.800	2.57	3.14	4.40	2.40	1 in 1.70	1 in 1.50	-	-
35	257.800	258.000	2.14	1.14	3.00	3.60	1 in 2.00	1 in 2.50	-	Yes
36	258.000	258.200	2.90	3.10	2.10	1.60	1 in 2.40	1 in 2.50	-	Yes
37	258.200	258.400	1.71	2.14	2.40	1.50	1 in 2.50	1 in 2.50	Yes	Yes
38	258.400	258.600	2.29	3.14	1.60	2.10	1 in 2.50	1 in 2.40	-	Yes
39	258.600	258.800	2.00	3.71	3.20	1.60	1 in 1.50	1 in 1.70	Yes	-
40	258.800	259.000	1.51	2.00	4.40	2.40	1 in 2.50	1 in 1.70	-	Yes
41	259.000	259.200	4.00	3.42	3.00	3.60	1 in 2.20	1 in 2.50	-	Yes
42	259.200	259.400	2.57	3.14	3.10	1.50	1 in 2.00	1 in 2.50	Yes	-
43	259.400	259.600	3.42	2.12	2.40	3.00	1 in 2.50	1 in 2.00	-	Yes
44	259.600	259.800	2.29	3.14	2.10	1.70	1 in 2.50	1 in 2.50	Yes	Yes

45	259.800	260.000	2.00	3.42	1.50	3.20	1 in 2.20	1 in 2.40	-	-
46	260.000	260.200	3.10	3.20	1.60	4.40	1 in 2.00	1 in 2.50	Yes	Yes
47	260.200	260.400	1.51	2.00	2.40	1.50	1 in 1.50	1 in 2.50	Yes	-
48	260.400	260.600	2.29	3.14	1.20	1.10	1 in 2.50	1 in 2.50	Yes	Yes
49	260.600	260.800	0.97	2.00	1.50	1.20	1 in 1.50	1 in 2.50	Yes	-
50	260.800	261.000	1.14	1.55	1.00	1.50	1 in 1.50	1 in 2.00	Yes	-

Data Analysis: The data collection system and data sheets were prepared. Site inspection and interaction with residents gave us an idea about the magnitude, their nature, and the overall performance of the road drainage under study. This kind of qualitative information also supported this research. Many researchers worked on asphalt pavement failure due to improper road drainage and their solutions. This paper emphasizes realistic observation and data collection at the grass-root level in the form of a forensic investigation by conducting non-destructive tests. A conventional method is adopted for analysing the collected data.

There are mainly four parameters for the analysis of road drainage data. IRC: SP:73-2018 specified these parameters and their acceptable values/standards.

a) Camber to bituminous road pavement - 1 in 40 - 2.5 percent
b) Slope to side shoulders - 3 percent
c) Embankment Slope - Varies with type of embankment material
d) Open/Built-up gutters - In the full length of road with specified sizes

Data was collected for these four parameters of road drainage. This data is analysed, and Table -2 shows the parameter-wise details and their acceptance as per the standard.

Table - 2: Road Drainage Parameters

Parameter	Total Length in meters	Length as per IRC Requirement	Length not as per IRC Requirement	% Length not as per IRC Requirement
2	**3**	**4**	**5**	**6**
Camber to BT Surface (2.5 percent)	10000	6200	3800	38
Camber to Side Shoulders (3 percent)	10000	3500	6500	65
Roadside Open Gutters	20000	10800	9200	46

Figure-4 shows parameter-wise Clustered Bar charts showing total road length understudy, length meets the IRC requirement and length does not meet the IRC requirements.

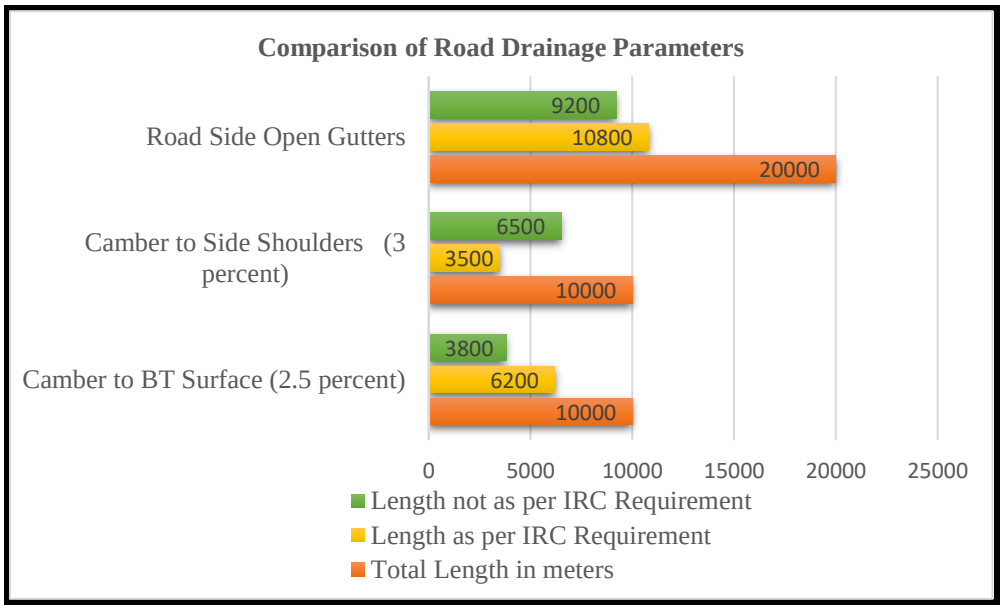


Figure-4: Clustered Bar Chart showing the Parameter wise Comparison of Road Drainage

Pre preparation for Effective Road Rainwater Harvesting: First important objective of road water harvesting is proper and perfect drainage of road water to avoid all kinds of damages and failure to road pavement, side shoulders, embankment slope, and roadside gutters. Then the second objective is road water harvesting for groundwater recharge. To make this objective effective and perfect, some pre preparations are needed. Road pavement/side shoulder camber for concrete/bituminous pavement shall be as per IRC or international standards. The pavement should be watertight, and water should not percolate into the subsurface through it. As far as possible side shoulder should be hard or if made from available soil/murum, it must have been compacted to achieve the standard proctor density. No or minimum water shall percolate through it. Then drained off water comes on embankment slope. Most of the roads in India till village approaches are already constructed. Hence to make proper draining off the road water, these slopes of the embankment to be repaired/turfed for minimum infiltration of rainwater. Depending upon the topography/vertical gradient of the road, roadside gutters should have perfect dimensions as per the standards to accommodate the drained-off water. A gradient of roadside gutter shall be perfect for easy and free flow of water. Water should not be accumulated anywhere in the roadside gutter, and it shall easily reach pre decided pits of rainwater harvesting. Maximum water up to 90 percent must be collected for proper groundwater recharge for raising the water level of existing water bodies. Initially study the terrain, its geographical & geological parameters. If terrain soil and rock are permeable, then conditions are favorable for groundwater recharge. We can implement different methods & techniques of groundwater recharge

Road Rainwater Harvesting Model: Depending upon the rainfall, water draining off from surface, subsurface, and embankment of road shall be properly collected through roadside open gutters. Topography and catchment area plays important role in deciding the road water collection pits. The study of vertical gradient of road and location of existing nalla/river is essential to develop the road water harvesting model/methodology. Depending upon rainfall and quantity of drained water, locations for collection of this water are to be decided. Following two methodologies /models / techniques can be used for the collection of road water from the pavement, side shoulders, embankment slope, and roadside gutters. Figure-5 shows these proposed techniques of road rainwater harvesting model.

a) Road water harvesting pits on both the side of a road in staggered pattern i.e., at 1 to 2 km center to center to be located depending upon the above-mentioned factors as per site condition. Regular rainwater collection circular pit of 3 to 4m diameter or 3mx4m in rectangular pattern and 4 to 7 m depth shall be prepared. While preparing

this pit, all specifications of rainwater harvesting shall be applied. These pits will help in groundwater recharge & raising water levels of nearby wells, boreholes and other water bodies may increase or maintain it for longer periods.

b) Another method that can be used is collecting this drained-off water from roadside gutters directly into the well or nearby water bodies by digging open/closed drains to these locations. Coordination with local people/farmers is needed in this methodology. By the way of awareness among the people regarding scarcity of water during the summer season is to be highlighted.

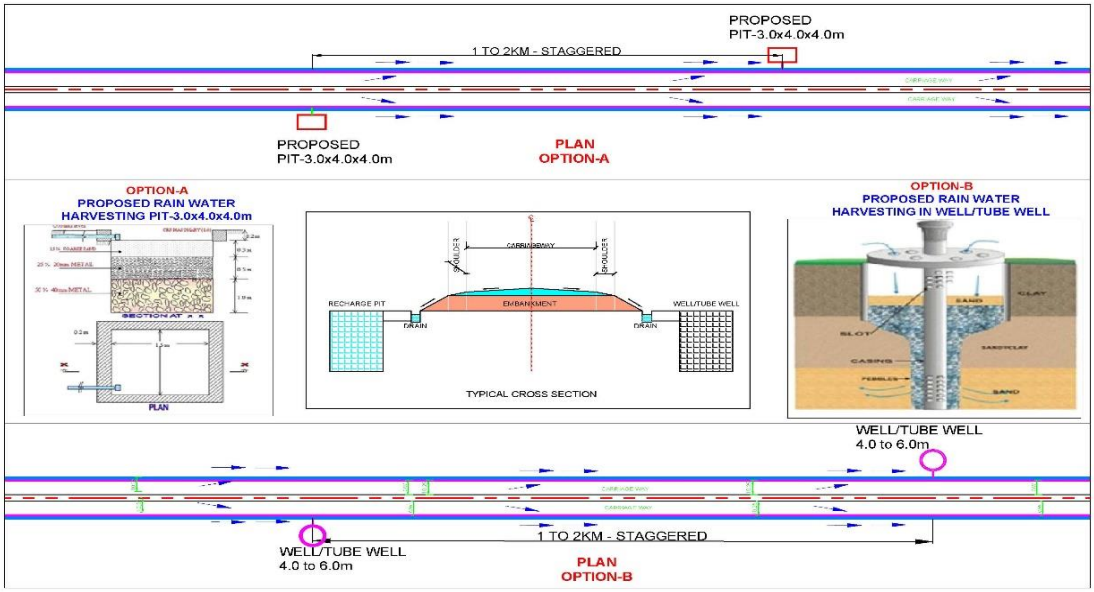


Figure-5: Proposed Techniques of Road Rainwater Harvesting Model

These kinds of small efforts and starting this mission from Maharashtra to solve the problem of drinking water in the summer season especially in Marathwada, Western & Northern Maharashtra. The many States in India and African countries/similar parts in the rest of the world are facing a similar problem of scarcity of drinking water in the summer season.

III. Results/Findings

This research broadly has the following results/findings:

a) Among the four main parameters of road drainage, all the parameters have shown their presence below the specified international standards/ Indian Road Congress standards (Refer Table- 1).

b) Improper bituminous pavement camber in 3.8 km length (38 %) out of 10 km length mainly leads to pavement failure by the way of different distresses (Refer Table- 2 & Figure-4).

c) Improper side shoulder camber/slope in 6.5 km length (65 %) out of 10 km length mainly lead to pavement failure at the edge, accumulation of water at the edge also resulted in subgrade & formation failure at these locations (Refer Table- 2 & Figure-4).

d) Improper embankment slope & absence of open gutter in 4.6 Kms length (46 %) out of 10 Kms length understudy mainly lead to hurdle in drainage of surface & subsurface water (Refer Table- 2 & Figure-4).

e) Less or more than 60% of total pavement failures are due to not being drained off the road water. It resulted in higher maintenance & road rehabilitation/improvement costs.

f) Considering sample results of all the above drainage parameters, it concentrates on the need for road water harvesting with proper model/simulation implementation on the site.

g) Road rainwater harvesting model is developed and two techniques are suggested for collection of road water for efficient drainage and ground-water recharge.

IV. Discussion

Nowadays water harvesting is a very important topic in sustainable development. It conserves water, soil, and ultimately the environment. Available research work and practicing methods are mainly concentrated on building terrace rainwater harvestings. Different government schemes rule regulations, public awareness programs played a very important role in the success of this eco-friendly program all over the world. To utilize this concept more effectively we can extend the idea from building terrace rainwater collection to the collection from road pavements. As the surface area of roadways is readily available and far more than building terrace area, comparatively it will be a good investment to promote rainwater harvesting practice for roadways along with conventional building terrace rainwater collection.

After summarising the results and findings as above, it is learned that effective road drainage is essential for the long life of the road, and it can be achieved by harvesting the road water during the monsoon. A pavement failure study of this stretch was also undertaking to know the type and magnitude of pavement distresses. Out of known 17 distresses, 13 distresses are observed on this road. It is found that fatigue; patches, rutting, longitudinal cracks, and shoving contribute about 90% of total distresses. These distresses have close relation with road drainage. The road under study falls under a heavy rainfall area (Average annual rainfall- 3210 mm). The findings of this research are applicable for the roads in India and for the location in the world where the conditions are similar. In this topic also to improve the quality of road pavements and to minimize the defects/surface damages at an early age, it is important to focus on the root causes of improper road drainage.

Detailed study, analysis, experiments, models, simulation, etc. needed to find the suitable method of road water harvesting depending upon the local site and meteorological/geographical/geological conditions. There is a vast scope to research aspirants to work on this sustainable development topic. Government organizations should take positive steps for the implementation of this new concept of road water harvesting. While framing the estimates of rehabilitation/improvement of roads, the policy decision of considering the cost of road water harvesting must be taken. It will not cost more than 5 percent of the total project cost. It is also widely accepted in the world that conditions of roads in any nation replicate their development status. The study, investigation, and analysis of the surface and subsurface drainage of the road are also important. Comparative study of drainage parameters and their relationship with pavement failure will be an interesting topic for researchers for further study.

V. Conclusion

Transportation is one of the prime needs of people. Most of the communication is by a roadway that handles the highest contribution as compared to railway, airway, and waterway. Therefore, it is important to construct, improve, and systematically maintain a highway with optimum cost.

a) Research in the investigation and analysis of road drainage of bituminous/concrete road pavement is of utmost importance as it contributes about 50 to 60 percent of pavement failures in which will lead to the perfect solution for road surface damages was the main aim of this research. This study will help towards making the bituminous/concrete pavement roads permanently free of surface damages.
b) As per the planned research methodology, the complete work is performed smoothly, accurately by studying the field observations very carefully. Road drainage of the case under study gave a clear idea about the existing drainage pattern. Drainage parameters are not functioning/or provided as per the international standards. It has shown lacuna in either original construction or maintenance. A detailed study is conducted under pavement distresses separately. Pavement failure & road drainage have specific relations between them. If road drainage is perfect, there are fewer chances or no pavement distresses.

c) Results from the above research are eye-opening for highway engineers. It indicated the concentration of the researcher to emphasize proper road drainage & harvest that water for ground-water recharge. It will help to resolve the drinking water problem in low rainfall areas to some extent. There is wide scope for researchers/government authorities to work further in preparing rainwater harvesting schemes/modules and their simulations.

d) It is concluded that rainwater harvesting is a tool for efficient road drainage and ground-water recharge to raise the water table. If the road surface became dry within five minutes after stopping the rain is called effectively draining roads. Such roads not only harvest rainwater but also will lead to better riding quality, saving in travel time, saving in vehicle maintenance cost to road users, reduced maintenance cost, increased life of the road, etc. This study directs the researcher to further concentrate on finding the exact relationship between road drainage and pavement failure.

References

[1]. Abdullah A. Al-Maswari, Sharafadeen A. Saleh, Fadhl A. Al-Nozaily, Mohammed A. Al-Abyadh, "Potential of Road Rainwater Harvesting in Yemen- its Social, Environmental, and Economic benefits- A Case Study of Sana'a, Hodeida road, Yemen", Journal of Science and Technology, pages 23 to 64, Volume 25 -(NO.1) 2020, https://doi.org/10.20428/JST.25.1.2

[2]. Abhay Dixit, "Efficient Use of Rainwater by Altering Channel System", The International Journal of Engineering And Science (IJES), Volume- 4, Issue- 3, Pages -1to 5,2015

[3]. Alireza Fathollahi and Stephen J. Coupe, " Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) of Road Drainage Systems for Sustainability Evaluation: Quantifying the contribution of different life cycle phases", Elsevier- Science of the Total Environment, Volume 776, 1 July 2021, 145937 www.elsevier.com/locate/scitotenv

[4]. Andung Yunianta, Suripin and Bagus Hario Setiadji, "Application of Sustainable Road Drainage System: Simulation by Using SWMM Program," Civil Engineering and Architecture 8(2): 55-65, 2020, http://www.hrpub.org

[5]. Andung Yunianta1, Suripin and Bagus Hario Setiadji,"Sustainable Road Drainage System: Experimental Model", MATEC Web of Conferences 181, 11005 (2018), ISTSDC 2017

[6]. Brad Lancaster, "Rainwater Harvesting for Drylands and Beyond, Volume 1", Second edition 2017, Rainsource Press Publication, Tucson USA.

[7]. D. Iskandar, S. P. Hadiwardoyo, R. J. Sumabrata and M. Fricilia,"Investigation of the Correlation between Drainage Condition and Pavement Performance", IOP Conf. Series: Materials Science and Engineering 673 (2019) 012115, Broad Exposure to Science and Technology 2019 (BEST2019)

[8]. M. Damayanti, M Sutrisno and I Karnisah,"The Road Drainage Planning for Flood Control in Dr. Djunjunan Road, Pasteur – Bandung, Indonesia", The 1st Annual Technology, Applied Science and Engineering Conference, IOP Conf. Series: Materials Science and Engineering 732 (2020), 012032

[9]. Erna Ismiyani, Dewi Handayani and RR. Rintis Hadiani, "The Impact of Drainage towards Roads in Maintenance Costs", MATEC Web of Conferences 195, 05012 (2018), ICRMCE 2018

[10]. George Kollaros and Antonia Athanasopoulou, "Influence of Drainage on Flexible Road Pavement Design", (Department of Civil Engineering, Democritus University of Thrace, Greece), Research on Engineering Structures and Materials, Pages 1 to 9, January 2017

[11]. IRC: SP: 42- 2014, "Guidelines of Road Drainage (First Revision)", Indian Roads Congress 2014

[12]. IRC: SP: 50- 2013, "Guidelines On Urban Drainage (First Revision)", Indian Roads Congress 2013

[13]. IRC: SP:73 2018, "Manual of Standards and Specifications for Two Laning of Highways with Paved Shoulders."

[14]. IRF Examiner, Volume 12, Winter 2017, ISSN: 2411-3867

[15]. Johannes Wolfgang Neupert, Philipp Lau, Daniel Venghaus, and Matthias Barjenbruch, "Development of a New Testing Approach for Decentralised Technical Sustainable Drainage Systems", Water 2021, 13, 722. https://doi.org/10.3390/w13050722, https://www.mdpi.com/journal/water

[16]. Jonathan Demenge, Rossella Alba, Katharina Welle, Kebede Manjur, Alemu Addisu, Lyla Mehta, Kifle Woldearegay, "Multifunctional Roads: The Potential Effects of Combined Roads and Water Harvesting Infrastructure on Livelihoods and Poverty in Ethiopia", Journal of Infrastructure Development 7(2) 165–180, 2015 India Development Foundation SAGE Publications

[17]. Kebede Manjur Gebru, Kifle Woldearegay, Frank van Steenbergen, Aregawi Beyene, Letty Fajardo Vera, Kidane Tesfay Gebreegziabher and Taye Alemayhu, "Adoption of Road Water Harvesting Practices and Their Impacts: Evidence from a Semi-Arid Region of Ethiopia", Sustainability 2020, 12, 8914, www.mdpi.com/journal/sustainability

[18]. Mohammad Awwad, "Studying the Effects of Roads Geometry and Design Parameters on the Pavement Drainage System", Civil Engineering Journal, (E-ISSN: 2476-3055; ISSN: 2676-6957), Vol. 7, No. 01, January 2021

[19]. Mythili, Kalamani, Krishnaraj, Soundarya, "Certain Investigations and an Experimental Approach for the Kerbside Rainwater Collection", IOP Conference Series: Materials Science and Engineering, ICCSSS 2020

[20]. Nasyiin Faqih and Wiji Lestarini, "Redesign of Road Drainage System in Jalan Banyumas Km 7 Selomerto, Wonosobo (Indonesia), with Normal Discharge Method", Journal of Physics: Conference Series 1511 (2020) 012063, International Conference on Science Education and Technology

[21]. Prithvi Singh Kandhal and Sapan Mishra, "Design, Construction, and Performance of Porous Asphalt Pavement for Rainwater Harvesting", Indian Roads Congress Journal 'Indian Highways", Vol. 42, No. 3, March-2014

[22]. Rajib B. Mallick and Tahar El-Korchi, "Pavement Engineering - Principles & Practice (Third Edition-2017)", CRC Press Taylor & Francis Group, New York

[23]. Saeid Eslamian and Faezeh Eslamian, "Handbook of Water Harvesting and Conservation, Basic Concepts and Fundamentals", Wiley Publication, First Edition January 2021

[24]. Salim G Shaikh and Abhijeet P Wadekar, "Systematic Evaluation and Analysis of Bituminous Road Pavement Failure", Journal of Physics Conference Series, ICACSE 2020, IOP Publishing, 1964 (2021) 072016, doi:10.1088/1742-6596/1964/7/072016

[25]. Saurabh Khode, Tanay Nallawar, Devesh Patel, Pratik Wasalwar, Rohit Gawali, Yash Hivase, Devendra Padole, "Development of Rainwater Harvesting System for Road Side Rainwater", International Journal of Research in Engineering, Science and Management Volume-3, Issue-2, February-2020, www.ijresm.com ISSN (Online): 2581-5792

[26]. Varinder S. Kanwar and Sanjay Kumar Shukla, "Sustainable Civil Engineering Practices", Springer Publication ISSN 2366-2557 ISSN 2366-2565 (electronic), Lecture Notes in Civil Engineering, ISBN 978-981-15-3676-2, ISBN 978-981-15-3677-9 (eBook) (https://doi.org/10.1007/978-981-15-3677-9