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An Implementation of Japanese Drainage System using Saint-Venant equation

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***Abstract*—The Saint-Venant Equations are widely used in hydraulic engineering and are particularly important for Japan's drainage system, which is designed to manage heavy rainfall and flood events.**
The Japanese drainage system utilizes Saint-Venant equations to model and analyze water flow, pressure, and velocity. This equation helps engineers and researchers in Japan's drainage system to model water flow, velocity and pressure, analyze pipe friction and resistance, predict flood wave propagation and water surface elevation, optimize drainage network design and operations, ensure efficient water management and urban sustainability.

Underground drainages will be connected to the five tunnels in the Drainage system and the recycled purified water will be used in the Agro-bio environment and remaining waste products will be separated and water will reach the Ocean through the River.
This project is designed to manage water resources, reduce flood risk, and protect the environment, while also supporting urban development and sustainability.

I. INTRODUCTION

Japanese Drainage System
Japanese drainage system known as the Metropolitan Area Outer Underground Discharge Channel, popularly referred as G-Cans, is a massive underground system located in Kasukabe, Saitama, Japan, is designed to mitigate flooding in Tokyo's metropolitan area. G-Cans is an impressive feat of engineering, featuring five concrete containment silos, 6.4 kilometers of tunnels, and a massive water tank supported by 59 pillars, each weighing 500 tons. This system can discharge up to 200 cubic meters of water per second, making it an essential component of Japan's flood control measures.

Implementation with success
Singapore:
The Singaporean government established the Institute of Technical Education (ITE) in 1992, which provides vocational training and apprenticeships based on the Japanese model.

South Korea:
The South Korean government established the Korea Vocational Training Institute in 1967, which provides vocational training and apprenticeships based on the Japanese model.

Germany (Wolfsburg):
The Volkswagen Group's training center in Wolfsburg, Germany, has adopted a dual education system similar to the Japanese training system.

Implementation with failure

China (Shanghai):
The Shanghai government established the Shanghai Vocational Training Institute in 2003, which attempted to adopt the Japanese training system. However, the program faced challenges due to limited resources and inadequate industry support.

India (Mumbai):
The Indian government established the National Skill Development Corporation (NSDC) in 2010, which attempted to adopt the Japanese training system. However, the program faced challenges due to limited

resources, inadequate industry support, and cultural differences.

Indonesia (Jakarta):
The Indonesian government established the Jakarta Vocational Training Institute in 2012, which attempted to adopt the Japanese training system. However, the program faced challenges due to limited resources, inadequate industry support, and cultural differences.
Reason for failure in implementation:

Insufficient maintenance of pipelines can lead to clogging, flooding and failure in drainage system. Japanese drainage systems may not be suitable for areas with high rainfall, poor soil quality or existing infrastructure limitations. Failure to educate and involve local communities in the maintenance and upkeep of the drainage system can lead to neglect.

II. NEED FOR THE STUDY

The Japanese drainage system is distinct from others due to its unique combination of traditional and modern approaches, reflecting the country's cultural, historical, and environmental context. It often employs a decentralized approach, using smaller, distributed facilities rather than large, centralized ones. This approach helps to reduce the burden on urban infrastructure and promotes more efficient water management. Its natural system helps to filter and slow down storm water runoff, reducing the load on traditional drainage infrastructure. Their high maintenance standards, with regular inspections, cleaning, and repairs ensuring optimal performance. This attention helps to prevent clogging, flooding, and other issues. It often prioritizes source control, focusing on managing rainwater at its source through techniques like permeable pavements, rainwater harvesting, and infiltration facilities.

III. OBJECTIVES OF THE STUDY

- Reducing the risk of flooding by slowing down storm water runoff and managing water flows.
- Improving water quality by filtering out sediments, pollutants, and other contaminants from storm water runoff.
- Recharging groundwater aquifers by allowing storm water to infiltrate the ground, reducing the burden on urban infrastructure.
- Importance of proper water management and encouraging public participation in maintenance.
- Designing drainage systems that can withstand extreme weather events, such as typhoons and floods.

IV. LITERATURE REVIEW

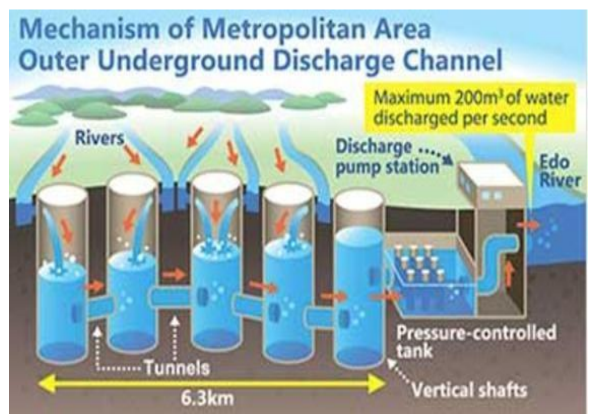
Ref [1] explores the importance of drainage systems in agriculture, surface drainage and subsurface drainage, drainage system design, and their applications. This book helps us to know the importance of drainage systems in preventing waterlogging, soil erosion, and improving crop yields, ultimately contributing to sustainable agricultural practices.

Ref [2] examines the impact of economic depression on agriculture in Britain and other developed countries. The book analyzes the causes, consequences, and responses to agricultural depression, including declining prices, increased competition, technological changes, and government policies. The book contributes to our understanding of agricultural history and the complexities of economic depression on rural communities.

Ref [3] explains on water resources management, technological innovations, and policy reforms. Helps us to understand the difficulties of water scarcity, irrigation, urban water supply, water governance, climate change, and water technology. This book serves as a valuable resource for researchers, policymakers, and water sector professionals, providing a comprehensive understanding of India's water policy challenges and potential solutions.

Ref [4] Japan's Metropolitan Area Outer Underground Discharge Channel is a cutting-edge flood control system that showcases the country's expertise in civil engineering and flood-control technologies. This system is completed in 2006, and it is an underground discharge channel is designed to mitigate flooding in Tokyo's metropolitan area. It features are.

- A 6.3 km long underground tunnel, 50 meters below ground, with a diameter of 10 meters
- Five gigantic vertical shafts, 70 meters tall and 30 meters in diameter, to store floodwater
- A huge pressure-controlled tank, 177 meters long and 78 meters wide, to regulate water pressure and discharge floodwater into rivers
- Advanced construction methods, including improved segment technology and a wedge method for joining concrete plates



Japanese drainage system has proven effective in managing floodwater

V. METHODOLOGY

The Saint-Venant equations are a set of nonlinear partial differential equations that describes the behaviour of unsteady, one-dimensional flow in open channels. Unsteady flow implies that the flow characteristics, such as velocity and depth, changes over time.

Formula:

Saint-Venant equation for unsteady flow of water:

$$\frac{\partial h}{\partial t}+\frac{\partial q}{\partial x} = 0 \longrightarrow 1$$

Where:

h = water depth
q = flow rate

t = time

x = distance along the channel

g = acceleration due to gravity

$\frac{\partial q}{\partial x}$ is rate of change of flow rate with respect to distance.

$\frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y}$ is water depth (h) changes over time (t) and dimension (x and y).

Therefore, $\frac{\partial q}{\partial x} = \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y}$ ——〉2

Substitute equation 2 in equation 1

Then, Equation 1 becomes,

$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0$ ——〉3

By rearranging equation 3

$\frac{\partial h}{\partial t} = - \frac{\partial (hu)}{\partial x} - \frac{\partial (hv)}{\partial y}$

Let us consider,

h = 10 m (water depth)
u = 5 m/s (horizontal velocity in x - direction or x - axis)
v = 3 m/s (horizontal velocity in y - direction or y - axis)

While the flow change in x - axis and y - axis dimension. Consider, $\frac{\partial h}{\partial t}$

$\frac{\partial u}{\partial x} = \frac{0.1}{s}$ (partial derivative of u with respect to x)

$\frac{\partial v}{\partial y} = \frac{0.2}{s}$ (partial derivative of v with respect to y)

$\frac{\partial h}{\partial t} = - \frac{\partial (10 \times 5)}{\partial x} - \frac{\partial (10 \times 3)}{\partial y}$

$\frac{\partial h}{\partial t} = -50 \times (\frac{\partial u}{\partial x}) - 30 \times (\frac{\partial v}{\partial y})$

$\frac{\partial h}{\partial t} = -50 \times 0.1 - 30 \times 0.2$

$\frac{\partial h}{\partial t} = -5 - 6$

$\frac{\partial h}{\partial t} = -11$

From the saint-venant equation, the negative sign indicates that the water depth is decreasing over time at a rate of 11meters per second. This affects the flow rate and hence
by analyzing the flow rate, we determine the optimal chemicals
quantity for the treatment of the tunnel.

Applications of Saint-Venant Equations

- Flood modeling and prediction
- River flow modeling
- Coastal engineering
- Dam break analysis
- Water supply system modeling
- Environmental modeling
- Hydroelectric power plant modeling

Sampling methodology

Roadside Water Utilization

i. Collection:
Roadside water is collected from drainage systems.

ii. Treatment:
Roadside water is treated.

iii. Utilization:
Treated roadside water is used for:
1. Industrial processes (e.g., cooling, washing)
2. Toilet flushing and other non-potable purposes

iv. Drainage Water Management

v. Collection:
Drainage water is collected from urban and industrial areas.

vi. Treatment:
Drainage water is treated.

vii. Disposal:
Treated drainage water is discharged into the ocean or other water bodies.

VI. RESULTS

Step 1: Material Preparation

- White cement was directly obtained and prepared for use.

- Sodium hydroxide was procured for reaction with the white cement.

Step 2: Reaction and Modeling

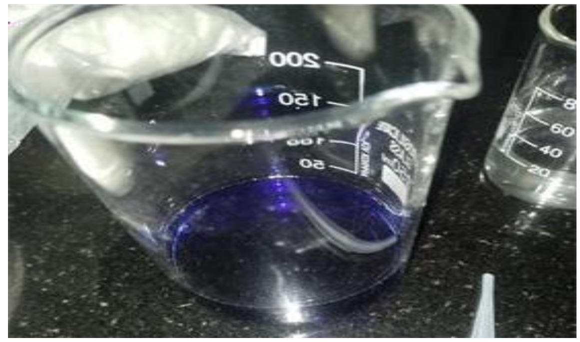
- The white cement was reacted with sodium hydroxide in workable mixture.
- A plastic model of the project was created for reference.
- By plastic model, we created by white cement. Then, White cement was covered with aluminum foil to prevent reaction with the white cement.

Step 3: Model Development:

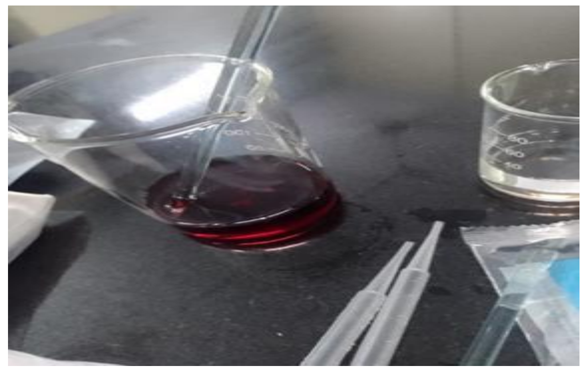
We divided our project into three parts:
1. A map board illustrating the implementation of the Japanese system in Tamil Nadu, including pipeline layouts
2. A non-working model of the project, providing an overview of the city after implantation.
3. A working model of the project, incorporating chemical reactions and demonstrating the application of the Japanese drainage system using Saint-Venant equation

Step 4: Assembly and Testing

- The two models were assembled and tested to ensure their functionality and accuracy.
- The working model was tested to demonstrate the chemical reactions and the effectiveness of the Japanese drainage system using Saint-Venant equation.
- From the following chemical reaction, we observe that the waste water sample is converted into pure water.

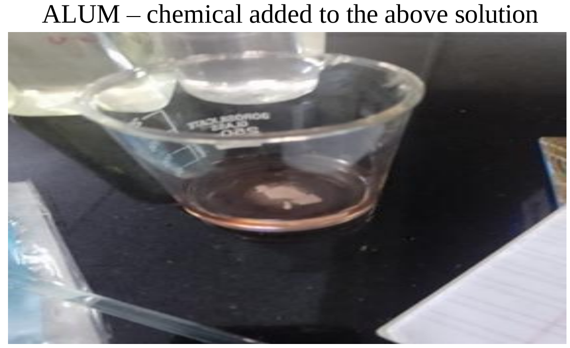


Waste water sample

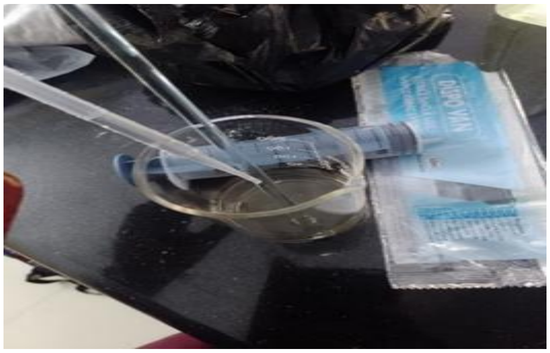


SODIUM HYDROXIDE (NaOH) added to the water sample

ALUM – chemical added to the above solution



After adding POLYETHYLENE GLYCOL (PEG 400) solution



Chlorine added solution results as a pure water

Step 5: Data Analysis and Interpretation

- Observation from the working model helps to understand the implementation of the Japanese drainage system.
- The results were interpreted to draw conclusions about the effectiveness of the system and its potential applications.

Step 6: Presentation

- The entire procedure of the working model was presented to demonstrate the application of the Japanese drainage system using the Saint-Venant equation.

VII. INFERENCE

The non-working model provided a visual representation of the implemented Japanese drainage system structure, while the working model demonstrated the chemical reactions and effectiveness of the system. The development of a working model, we demonstrated the effectiveness of the system in cleaning drainage water and allowed to sea. Then, road side water utilizing it for agriculture and industrial purposes. The Saint-Venant equation helped optimize water flow, reducing the risk of flooding and ensuring efficient drainage. The implemented Japanese drainage system also showed potential environmental benefits, including reduced pollution and conservation of water resources.

VIII. CONCLUSION

The Japanese Drainage System is a comprehensive and effective approach to urban flood risk management, water quality improvement, and environmental sustainability. While challenges remain, the system's design and functionality offer valuable lessons for other urban contexts.

IX. SUGGESTIONS

- Proper Design and Installation: Ensuring the drainage system is designed and installed correctly, taking into account local conditions and regulations, is crucial for success.
- Regular Maintenance: Regular inspections, cleaning, and repairs are essential to prevent clogging and ensure the drainage system functions optimally.
- Community Engagement and Education: Educating local communities about the importance of proper maintenance and upkeep can help prevent drainage system failure and promote sustainability.
- Adaptation to Local Conditions: Japanese drainage systems should be adapted to suit local conditions, including climate, soil type, and existing infrastructure.

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