IC – 201P DESIGN PRACTICUM

GROUP - 34

Development of flume to study dynamics of the debris flow

Group Members:

Mayank goel	B22306
Aditya Kumar	B22029
R. Lohit vardhan	B22122
Om Litoriya	B22226
Ritik kumar	B22316
Sravya kumbha	B22112

Faculty Mentor:-

Dr. Mousumi Mukherjee
Dr. K.V. Uday

Student Mentor:-

Govind Kant Mishra

Introduction to Problem Statement and its need

We're embarking on a project to tackle real-world challenges, and one of our main focuses is creating a mini version of a flume in a lab. This setup will help us study how debris flows behave, which is crucial for understanding and managing these natural hazards.
Debris flow is a natural geomorphic process characterized by the rapid movement of a mixture of water, sediment, and organic material down steep slopes. This phenomenon typically occurs in mountainous regions, where steep gradients, loose soil.
The flow of debris can vary in velocity, ranging from slow-moving slurries to rapidly flowing torrents, depending on factors such as slope gradient, rainfall intensity, and sediment concentration. Debris flows are often triggered by intense rainfall events, snowmelt, or rapid thawing of glaciers, which saturate the soil and mobilize loose sediment. Despite its destructive potential, our understanding of debris flow dynamics remains limited, making it crucial to delve into this area to mitigate its impacts effectively. Here we can also see the destruction through this image:. Our project stems from the recognition of the urgent need to comprehend the underlying mechanisms of debris flow. With climate change increasing the frequency and severity of extreme weather events, including heavy rainfall and snowmelt, the risk of debris flow occurrences is escalating

As budding engineers, it is crucial for us to contribute to solutions that can help address these challenges. By designing and constructing a flume experimental setup, we aim to replicate key aspects of debris flow dynamics, allowing us to observe and analyze the behavior of water and sediment mixtures in controlled settings . By studying factors such as flow behavior, flow height, planar velocity. one can develop early warning systems, design effective mitigation measures, and inform land use planning decisions in debris flow-prone areas. Additionally, advancements in debris flow research contribute to improving hazard mapping, emergency preparedness, and infrastructure resilience against future events. Through our project, we aim to deepen our understanding of debris flow dynamics to contribute towards future research efforts in finding effective solutions to mitigate landslides.

Specifications for Developing a Lab-Scale Flume Experimental Setup for Studying Dynamics of Debris Flow:

1.**Description:** The experimental setup will consist of a lab-scale flume channel equipped with necessary components to simulate and study debris flow dynamics.

2.**Scope and Objectives:** The project aims to develop a controlled laboratory environment for studying the behavior and characteristics of debris flow, focusing on flow dynamics under varying conditions.

3.**Expected outcomes:**Through the analysis of experimental data, the project aims to generate new knowledge and understanding of the behavior, mechanics, and factors influencing debris flow.

4.**Key Components:** The experimental setup will include a flume channel, sediment delivery system, flow measurement devices, control mechanisms, and data acquisition systems.

5.**Scale and Accuracy:** The setup will be constructed to replicate lab-scale conditions accurately, ensuring precision and fidelity in studying debris flow dynamics.

6.**Materials and Construction:** Durable and suitable materials will be used for constructing the flume channel and components, capable of withstanding the forces and pressures associated with debris flow simulations.

7.**Flow Conditions:** Experiments will cover a range of flow conditions, including variations in flow velocity, sediment concentration and channel geometry.

8.**Data Collection and Analysis**: High-speed cameras and image analysis software will be utilized for capturing and analyzing relevant data, including flow velocity, sediment transport, flow depth, and flow patterns.

9.**Adaptability and Scalability**: The experimental setup will be designed with flexibility to accommodate future modifications and upgrades, allowing for scalability and adaptation to evolving research requirements and technological advancements.

BENCHMARKING: -

Flumes are experimental apparatus used to study the behavior of debris, in controlled laboratory or field settings. Benchmarking of flumes aims to assess the accuracy, reliability, and efficiency of different flumes and their associated measurement techniques by comparing their performance against established standards or reference data. Some of the research papers we referred to and comparisons were as follows.

1.Laboratory and fields tests and distinct element analysis of dry granular flows and segregation processes

Yung Ming Cheng, Wing Hong Ivan Fung, Liang LI

https://nhess.copernicus.org/articles/19/181/2019//#&gid=1&pid=1

Although the dimensions considered in this paper were almost the same as ours, it utilized polystyrene for the construction of flume

How Toughened Glass Rectifies the Disadvantages of Polystyrene:

•Strength and Durability: Toughened glass addresses the fragility and limited strength of polystyrene. It can withstand impact and mechanical stresses better, reducing the risk of damage during installation and operation.

•Longevity: Because toughened glass is more durable, it typically has a longer lifespan than polystyrene, reducing the need for frequent replacements and maintenance.

•Environmental Considerations: While neither material is biodegradable, toughened glass is more environmentally friendly in the long term due to its durability and potential for recycling.

Overall, toughened glass offers superior strength, durability, and visual clarity compared to polystyrene, making it a preferred choice for flumes in applications where these qualities are essential.

The flume which was built in this project is also cost efficient over the considered project as it uses two high-speed cameras and the mentioned processing of the images was more complex.

Indian Institute of Technology Mandi

2.Insight into Granular Flow Dynamics Relying on Basal Stress Measurements: From Experimental Flume Tests

Kun Li, Yufeng Wang, Qiangong Cheng, Qiwen Lin, Yue Wu, Yanmei Long

https://doi.org/10.1029/2021JB022905

The apparatus used in this experiment mainly consists of an inclined flume 2.5 m long and 0.2m wide, and a horizontal flume 2.0 m long and 0.22 m wide. The inclined flume could be adjusted to any angle between 20° and 60°.

•Cost Efficiency: Compared to larger and more expensive flumes, a smaller flume with dimensions of 1.5m length and 0.4m width can be more affordable to acquire and maintain. This makes it a cost-effective option, especially for research projects with limited budgets.

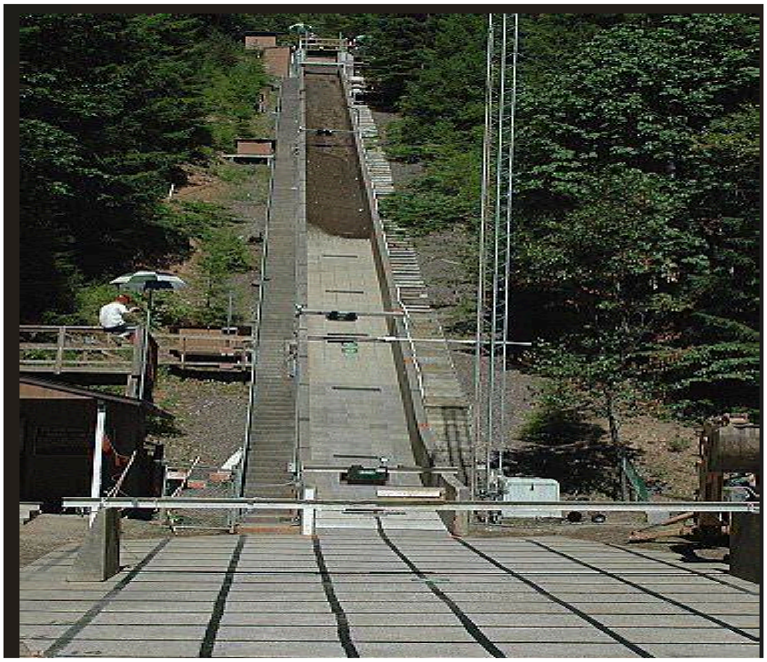
•Space Optimization: The compact size of the flume allows for easy installation in laboratory settings with limited space. Researchers can conduct experiments without the need for extensive facility modifications, reducing both space and infrastructure costs.

•Versatility in Angle Adjustment: Despite its smaller size, the flume still offers the advantage of adjusting to a wide range of angles, similar to the larger flume in the original apparatus. This versatility allows researchers to study various flow conditions and angles without compromising experimental flexibility.

•Focused Research Scope: While the flume's dimensions are smaller than the original apparatus, it can still accommodate a range of research objectives, particularly those focused on specific flow phenomena or scenarios. Researchers can design experiments tailored to their specific research questions within the constraints of the flume size.

3.Field and laboratory analysis of the runout characteristics of hillslope debris flows in Switzerland

Marcel Hürlimann, Brian W. McArdell, Christian Rickli



The flume which was built during this project duration is better than that of referred research paper as following:

•Improved Control and Precision: The pulley system enables precise control over the opening and closing of the gate, allowing researchers to initiate flow events at the desired time with accuracy. This enhances the repeatability and reliability of experimental results. The referred paper considered opening the gate by hand manually.

•Adaptability to Field Conditions: The compact and portable nature of the flume, combined with the pulley-operated gate, enhances its suitability for field experiments. Researchers can transport the equipment to different locations and conduct studies in diverse environmental settings, facilitating research on natural hydraulic processes.

•Accessibility to Researchers: The affordable cost and user-friendly design of the flume make it accessible to a wider community of researchers, including those with limited funding or expertise in hydraulic experimentation. This promotes inclusivity and collaboration in scientific research efforts.

4. Experiments on the flow behavior of granular materials at high velocity in an open channel

0. HUNGR* and N. R. MORGENSTERN

Morgenstern et al., 1984.pdf

- Accommodation of more volume: In the referred paper flume was built with the width of 0.2m which accommodates less volume and the flow velocity of particles has more dependency in that case which is a limitation of this as compared to the present project.
- Durability and Safety: Toughened glass provides enhanced durability and safety compared to traditional materials like Perspex. It is more resistant to impacts and scratches, reducing the risk of damage and ensuring the longevity of the flume. This durability contributes to cost savings by minimizing the need for frequent repairs or replacements.
- Ease of Cleaning and Maintenance: Toughened glass surfaces are smooth and easy to clean, reducing the time and effort required for maintenance. This improves the overall efficiency of the experimental setup, allowing researchers to focus more on data collection and analysis rather than routine upkeep tasks.

CONCLUSIONS OF BENCHMARKING:-

- In summary, each variation of the flume design offers unique advantages tailored to specific research needs, budget constraints, and experimental requirements. The selection of the most suitable flume configuration depends on factors such as space availability, desired experimental flexibility, safety considerations, visibility requirements, and material preferences.
- For instance, the flume with dimensions of 1.5m length, 0.4m width, and 0.5m height, equipped with toughened glass walls, provides enhanced durability, visibility, and aesthetic appeal. This option is ideal for researchers seeking precise control over slope angles, resistance to chemicals, and ease of maintenance, within a constrained budget.

- Alternatively, the flume constructed accommodates a wide range of angles and incorporates a pulley system for gate operation, offers cost-effective experimentation, improved safety measures, and adaptability to field conditions. This configuration prioritizes space efficiency, safety, and ease of operation, making it suitable for both laboratory and field studies.
- Ultimately, the choice of flume design should align with the specific objectives and constraints of the research project, balancing factors such as cost, space, functionality, durability, and experimental requirements. By carefully considering these factors, researchers can select the most appropriate flume configuration to effectively address their research questions and contribute to advancements in hydraulic science and engineering.

POSSIBLE SOLUTIONS OF PROBLEM STATEMENTS:

1. PROPOSED SOLUTION : We would construct a flume with toughen glass(10mm thickness) of dimensions 1.5x0.4x0.7. The flume would be using soil erosion and the concept of image processing to verify the velocity for sand of various densities and volume. The gate for the soil flow will be handled by a pulley system for quick and fast unloading so as to not disrupt the soil flow. We would be using a mobile phone through the transparent wall for image processing and get the required parameters of flow such as flow velocity, pressure.

2. CHANGE OF MATERIAL : we would use the material which is more readily available in the market and in the college. Manufacturing is also very easy compared to every other material with it being cheaper but the main drawback is that it will cause scratches on the wall which would result in inaccurate results.

3. CHANGE OF DIMENSIONS: We could change the flume dimensions to 1.5x0.2x0.4 which has a shallower channel for the flume. It would help us to create flume for special cases of fast falling debris. It would be a disadvantage to the increased amount of strain on the walls and it would be very disproportionate to its length.

4. PIV: using Particle Image Velocimetry instead of PTV, could lead to better average velocity but the requirements for the PIV to work properly are not economically viable due to the need of high laser and high-level cameras.

5. DSLR CAMERA FOR PTV: While a DSLR camera offers excellent image quality for PTV, its high cost makes it economically impractical for many applications and would not be economically viable.

6. POLYCARBONATE- we would be using polycarbonate material which is expensive but the hardness of polycarbonate is very high but on the offside it has low strength which could lead to breaking of flume if we use gravel or any other hard material in our sand consistency.

Indian Institute of Technology Mandi

7. CHANGE IN DIMENSIONS: We could change the flume dimensions to 1x0.5x0.7 with it having a shortened length. It would be less expensive but the short length would not allow us to have proper study and the falling debris due to the soil not getting enough runaway and it will be difficult for us to observe the phenomena of flow and segregation.

8. CHANGE IN DIMENSIONS: We could change the flume dimensions to 2x 0.6x0.7 with it having a long length, while it could lead to more ground to study the dynamics of debris slowly but it would be expensive and disproportionate to its width and height.

9. GATE MECHANISM: Employing a manual barrier to halt sand flow is a financially viable option, albeit prone to inconsistencies in particle tracking velocimetry (PTV) due to uneven sand movement, because all the sand will not flow all together. Exploring methods to promote uniform flow or considering alternative control mechanisms could mitigate errors in measurements.

10. STRUCTURE: The flume could be closed from both sides while it would be more user friendly. It can lead to the problem of causing the end that receives the high flowing sand to crack and not handle the pressure of the following sand and we have to consider other material for that side.

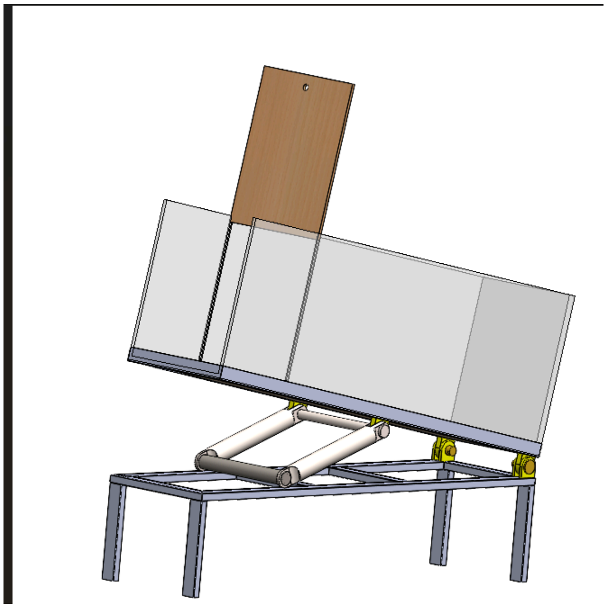
11. HYDRAULIC GATE: A hydraulic gate installation mechanism is complex and would have very high maintenance issues and it would be very expensive for its respective role.

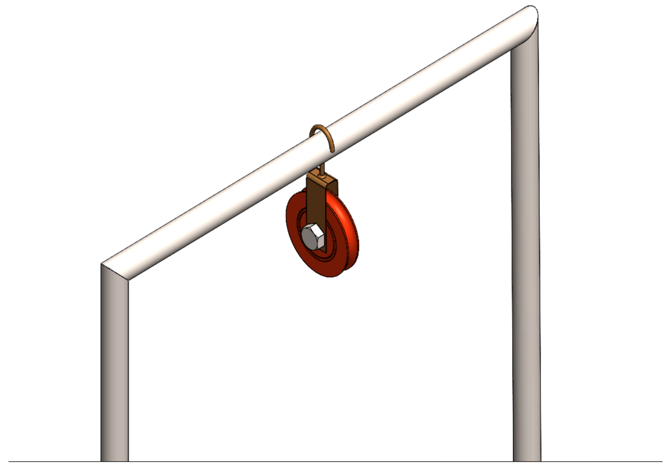
12. SURFACE OF FLUME: The flume floor could be smooth without any friction or friction while it would not emulate the soil erosion, it will limit the factors affecting the flume flow and could lead to more specialized experiments for flume.

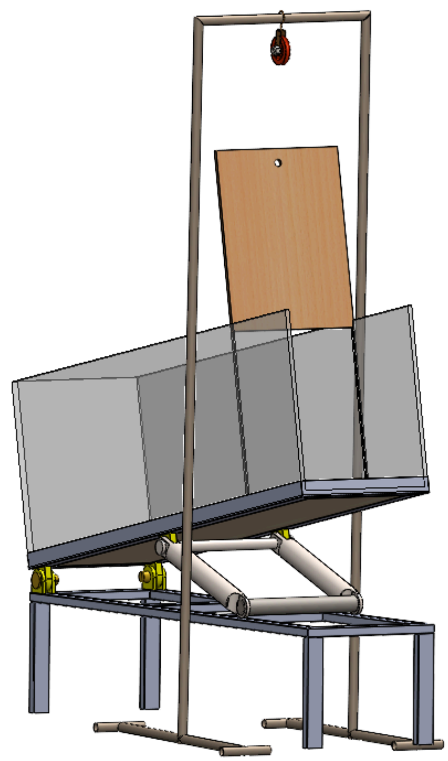
Solution Description	Cost of the Idea ((30000 /Amount)*10)	Availability of Parts	Ease of Manufacturing/Assembly	Fulfilment of Purpose	Ergonomics / Aesthetics	Integration of Power Source	Integration of Electronics	Timebound Manufacturing Feasability	Maintainance/ Servicing Cost	Overall Feel/Confidence in the Solution	Overall Score
1.PROPOSED SOLUTION	10	8	7	9	10	10	10	9	8	9	90
2.ACRYLIC SHEET	10	9	8	5	7	10	10	9	4	6	78
3.CHANGE IN DIMENSIONS	10	9	7	6	6	10	10	9	6	7	80
4.PIV	6	6	6	10	10	10	10	8	6	6	78
5.DSLR	7	6	7	10	9	10	10	9	6	8	82
6.polycarbonate	9	8	7	4	5	10	10	9	4	4	70
7 CHANGE IN WIDTH	10	9	7	5	5	10	10	9	6	7	78
8 CHANGE IN LENGTH	10	9	6	7	4	10	10	8	5	7	76
9. MANUAL BARRIER	10	9	7	9	8	10	10	9	8	7	87
10. CLOSED FROM BOTH SIDES	10	9	7	7	9	10	10	8	7	6	83
11. HYDRAULIC GATE	6	6	6	10	10	10	10	5	7	7	77
12. SMOOTH FLUME FLOOR	10	8	7	7	7	10	10	8	7	8	75

Indian Institute of Technology Mandi

CAD MODEL:







DETAILED DESCRIPTION:

Lab-Scale Flume Experimental Setup for Studying Dynamics of Debris Flow
-We would be constructing a flume with the material toughen glass of dimensions 1.5x0.4x0.7. The flume would be using soil erosion and the concept of image preprocessing to check the velocity of the sand for various densities and volume. The gate for the soil flow will be handled by a pulley system for quick and fast unloading so as to not disrupt the soil flow. We would be using a mobile phone through the transparent wall to use image processing and check the flow of soil, the lateral velocity and the height of sand flow.

Dimensions and capacity of flume: The flume has a capacity to accommodate debris for controlled and accurate experimentation based on the specified dimensions.

Dimensions:-

Length: 1.5m

Width: 0.4m

Side Wall Height: 0.7m

Material and Construction Specification:

Toughened Glass Thickness: 10mm

Joining Method: L Holders for joining the toughened glass wall with base.

Silicone sealing : on all the edges of the flume to create a airtight flume to stop any sand leakage

Support Structure: Flume stand designed to provide various inclination angles to the flume for controlled experimentation and simulation

Grooving: We have made 2 grooves in the flume for holding the gate at a distance of .15m and .3m from the closed side.

These specifications ensure the structural integrity of the flume using toughened glass, with silicon for sealing, and the flexibility to adjust inclination angles as needed for studying the dynamics of debris flow.

Pulley System and Debris Control:

- A pulley system supported by a dedicated stand is implemented to lift the gate, preventing debris from escaping before it is lifted.
- The pulley stand is strategically positioned to support the pulley system and ensure its stability and reliability during operations. It is constructed from robust materials to withstand the forces involved in lifting the gate and to maintain operational safety.
- This system offers precise control over the gate, ensuring no premature release of debris and contributing to the accuracy of experiments studying debris flow dynamics.

Data Analysis :

To take clear pictures of the particles in the flume, we'll use a good camera. We'll put the camera on a stand so it stays still and doesn't move around. This way, we can focus on a specific part of the flume without any shaking. It's important for the camera to stay in one place so we can carefully analyze the pictures and understand how the particles move in that area. This approach is crucial for accurate analysis and interpretation of sediment transport dynamics, providing valuable insights into erosion processes and flow behavior within the flume.

We're going to use a technique called backlighting to help us find out how fast the sand moves and how high it piles up in a certain spot. Here's how it works: first, we'll set up a ring light to shine behind the flume, which is like a long box where we'll put the sand. Then, we'll put a camera on the other side of the flume, opposite to the light. Before we start with the sand, we'll take a picture of the empty flume with a ruler next to it. This ruler is 30 centimeters long. This picture will help us figure out how far apart each dot, or pixel, in the picture is. by checking the number of pixels which have zero intensity due to the ruler blocking the light and by the number of pixels with zero intensity we can find out the pixels per meter.

With this method, we'll be able to study the soil as it moves through the flume. We'll record a video while the soil is flowing, capturing every moment. Then, we'll break down the video into individual pictures, looking at each frame one by one. By doing this, we can track how the soil height changes over time and how fast it's moving across the flume.

To measure these changes, we'll examine the brightness of the pixels in each frame. This will help us see how far the soil has traveled and how quickly it's moving. For example, if we're recording at 60 frames per second, there will be a tiny time difference between each frame—about 1/60th of a second. We'll use this time difference to calculate the soil's speed.

We won't just do this once. Instead, we'll repeat the experiment for different sections of the 1.5-meter-long flume. This way, we can cover the entire length and study how the soil flows from one end to the other.

We'll also use different types of soil to see how they behave differently. This includes looking at soil with various textures, particle sizes, and compositions. By doing all of this, we'll get a better understanding of how different factors affect the flow of soil in the flume

BILL OF MATERIALS: -

A Bill of Materials (BOM) in a project report is a comprehensive list of all the materials, components, parts, and assemblies required to manufacture, build, or complete a project.It helps in estimating the total cost of the project, planning procurement activities, managing inventory, and ensuring that all necessary materials are available when needed.BOM provides stakeholders with a clear understanding of the resources required for the project, facilitating budgeting, resource allocation, and decision-making processes.Bill of materials for our project is given below:

S.no	Item Name	Quantity
1	Toughened Glass(10mm)	36.6 sq. feet
2	Glass L holder	10
3	Plywood (0.4x0.7)	2 (0.28 sq. m)
4	Plywood(1.6x0.5)	1 (0.8 sq. m)
5	Flume stand	1
6	Ring light	1
7	Camera stand	1
8	T-50 extension cord	1
9	Pulley	1
10	Pulley stand material	1

Indian Institute of Technology Mandi