METHOD OF SIMULATION OF DAM MODEL

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Abstract: *Dam failure is a risky phenomenon beyond human subjective will. The damage and impact caused by dam failure is huge. However, calculating and predicting the characteristics of dam failure is very difficult and complicated. The problem of dam failure has been studied hundreds of years ago using many methods such as physical models, mathematical models, actual statistics...., However, the research method using physical models still proves to be effective, has advantages and is increasingly being improved. This article presents simulation methods of two types of dams: local material dams and concrete dams (roller compacted concrete and gravity concrete).*

Keywords: *Dam failure, simulation*

1. PREAMBLE

There are many ways to classify dams according to different criteria. When classified by construction materials, dams are divided into two types: local material dams (loose materials) and concrete dams (monolithic materials). When a dam failure occurs, dams are built with different types of materials, the process of formation and development of the breach will be different.

For local material dams, in the case of overtopping, the process of forming and developing cracks occurs in 4 stages: Stage 1 - Water flows over the top of the dam, stage 2 - flow erosion of the downstream dam surface at surrounding locations; Stage 3 - The crack developing in depth and stage 4 - The crack developing in width and reaching a stable state [2]. Figure 1, shows four stages of formation and development of local material dam breaks. Dam failure time depends on dam type, backfill type, reservoir volume (V_w), dam height (H), water level height (Ho) and many other conditions [7] According to Dam safety Program [7] Columbia (2015), dam breaking time is usually 10 minutes for loose material dams and 15 minutes for sticky materials, sometimes lasting 50-60 minutes.

For concrete dams, cracks appear and develop at the joints of poured concrete blocks. The process of forming and developing holes takes place quickly. With inter-arch concrete dams, the case that the dam is completely destroyedshould be considered. The duration of dam break is from 0.1 ÷to 0.5 hours (6-30 minutes), inter-arch dam is 0.1 hour (6 minutes).

Methods for studying and calculating dam failure include theory, experimental research and digital modeling. In all experimental studies, in order to accurately simulate the characteristics of the dam failure, it is necessary to understand the mechanism, cause and way of formation of the rupture to be able to relatively simulate the nature of the phenomena in an accurate way. This article presents simulation methods and data collection on physical models

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for dam failure incidents.

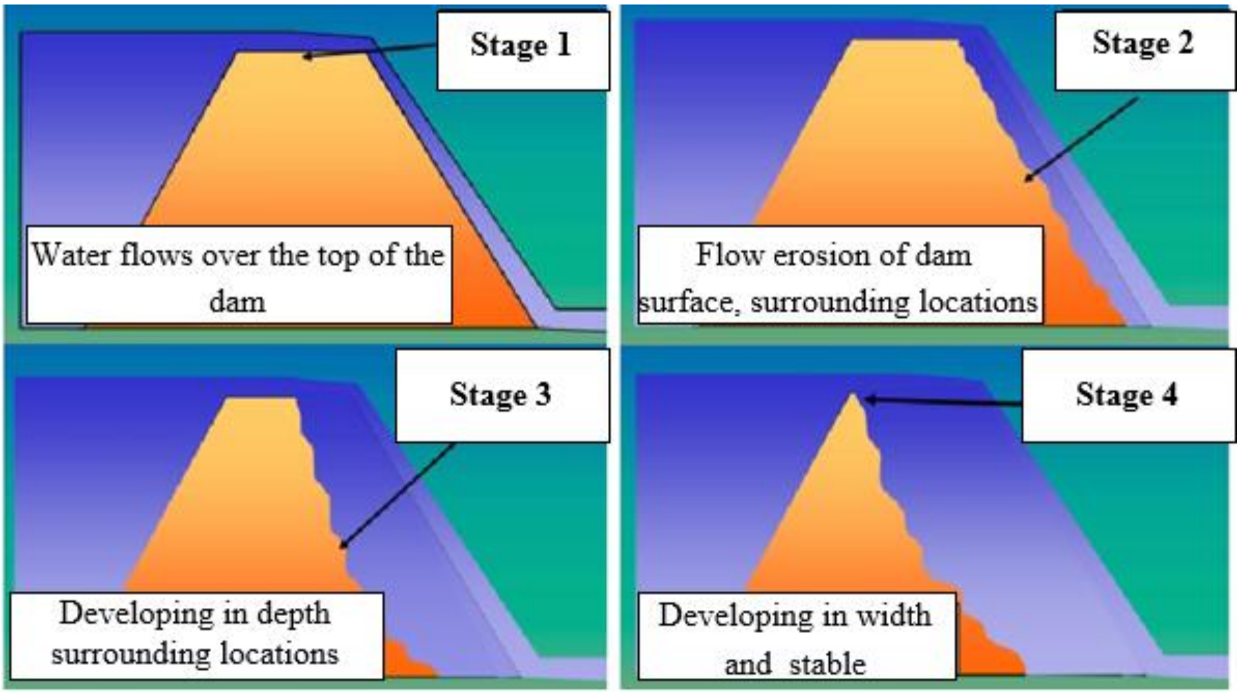


Figure 1: Development stages of local material dam breaks in case of overtopping

Figure 2: Dam Ha auxiliary dam break (Quang Ninh - 2014), field images

2. SIMULATION METHOD

2.1. Local material dams

For local material dams, holes often appear in critical locations, so to properly simulate the nature of the dam failure, we must properly simulate the characteristics of the materials constituting the dam, and the process of implementation as follows:

2.1.1. Documents to be prepared

During the material simulation process, the following documents are indispensable;

- Documents on project design (Construction plan, dam embankment section....)

- Grading curves of dam embankment layers;

- Physical and mechanical criteria of dam embankment materials;

- Dam construction documents;

- Other relevant documents.

2.2.2. Key principles of materials simulation

When simulating materials in model experiments, the first principles that must be considered are:

- Guaranteed particle size and composition;

- Ensure the allowable erosion speed of the material;

- These principles are suitable for bulk material simulation. However, in the process of simulating materials for filling rockfill dams, other factors must be paid attention to such as:

- Strip layer thickness;

- Number of compaction times and compaction force;

2.2.3. Checking material chemical modeling

a. Check particle size (d) and particle density (γ).

According to the Froude similarity law, it is necessary to ensure similarity with the original shape in terms of size and weight:

+ About size : Material size is checked according to the formula: $d_m = \frac{d_n}{\lambda_L}$

+ About weight: Weight is determined according to: G = W x γ_{vl} then $G_m = \frac{G_n}{\lambda_L^3}$

After determining similar calculations in terms of particle size and calculating the equivalent weight of each type of particle, proceed to sieve the material, randomly take N particles of the calculated size, and use a balance to determine the mass. Quantity and mass calculation for each particle are compared with the calculated results. If the two results are the same, the material chosen for simulation is guaranteed to be similar in density and particle size;

b. Determine the number of compaction times and check the aggregate porosity (n)

Use a cube with sides of a (cm) and a capacity of a^3(cm^3), with a drainage pipe attached to the bottom. Fill the tank with material, use a specialized compactor (record the number of compaction times and compaction force), then fill with water to just cover the material, then drain the water, use equipment (capable of determining capacity) calculates the capacity of water displaced in the material as b (cm^3). Then the porosity of the material is determined according to the formula:

$$n = \frac{a^3}{b} x100\% \, (\%)$$

If n of the simulated material coincides with n of the dam embankment material, that is the number of compaction times and compaction force of the simulated material. Otherwise, it is necessary to repeat the above experiment until it meets the requirements.

2.2. Concrete dam

With concrete dams, actual breaks often appear and develop at the joints of the concrete blocks used to build the dam. Therefore, to basically and accurately simulate the phenomenon, simulate the correct shape and size of the break:

2.2.1. Select the break type

Statistics of 58 concrete dam failures in the world such as Shih-Kang Dam, Taiwan-1999; Austin Dam, Texas - United States 1915; Gleno Dam - Italia 1923... shows that when a concrete dam breaks, the dam break usually occurs in the middle (30%), the break is rectangular in shape and breaks into many blocks [1]. Figure 3, shows images of some concrete dams remaining after dam breaks and Figure 4-Show diagram broken into many blocks.

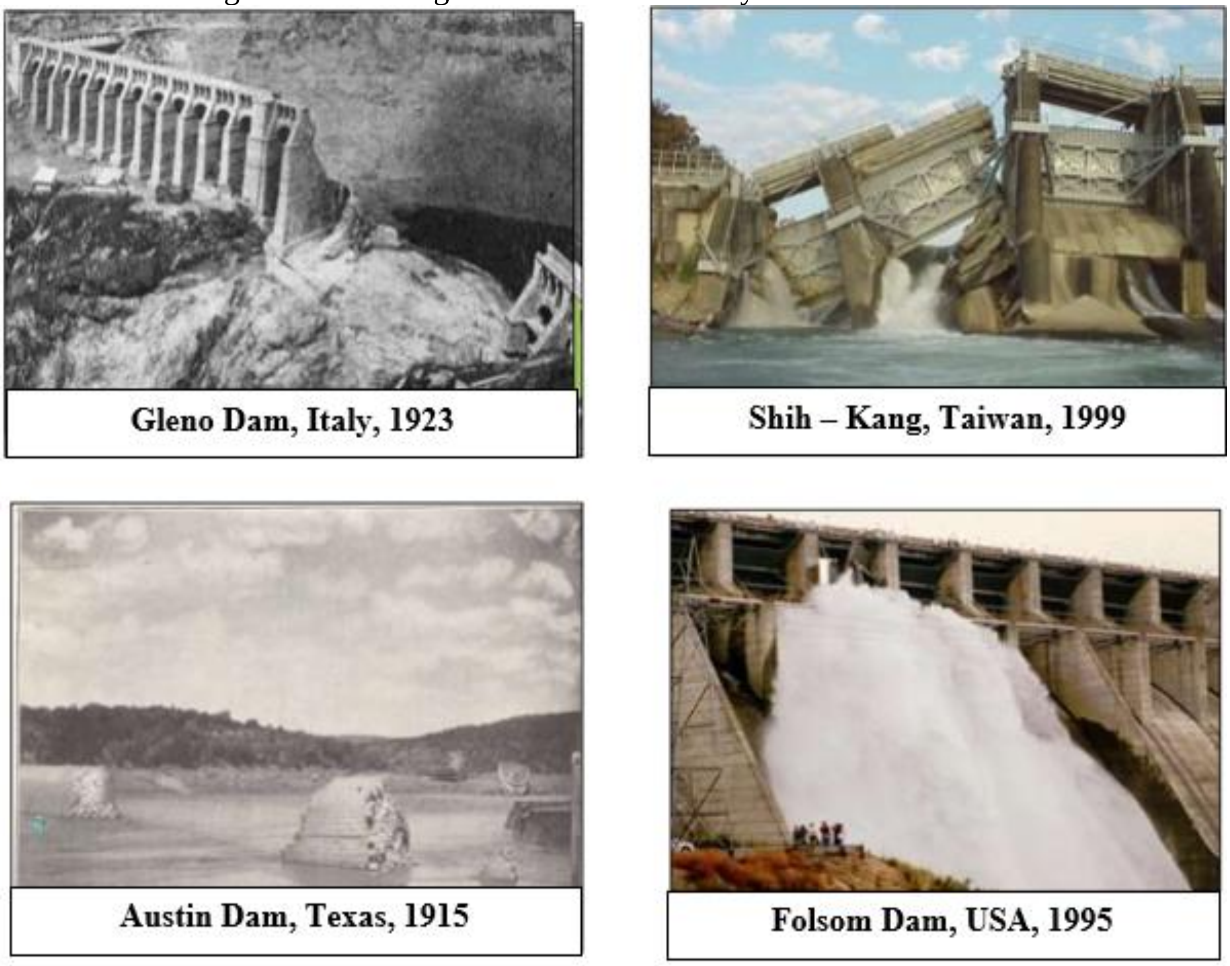


Figure 3: Concrete dam break incidents [1]

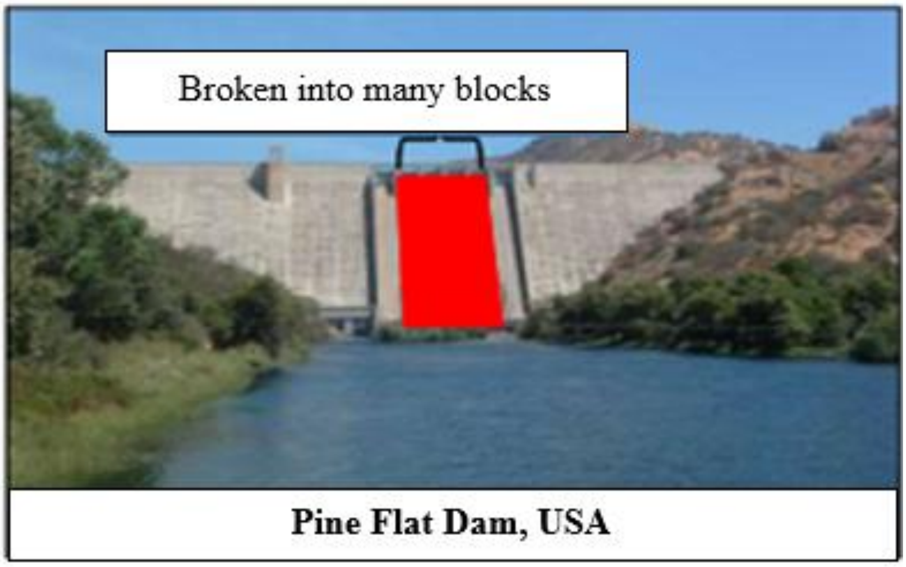


Figure 4: Broken into many blocks

These conclusions are completely consistent with the rupture parameters given by the USACE dam safety program (USA) in Table 1.

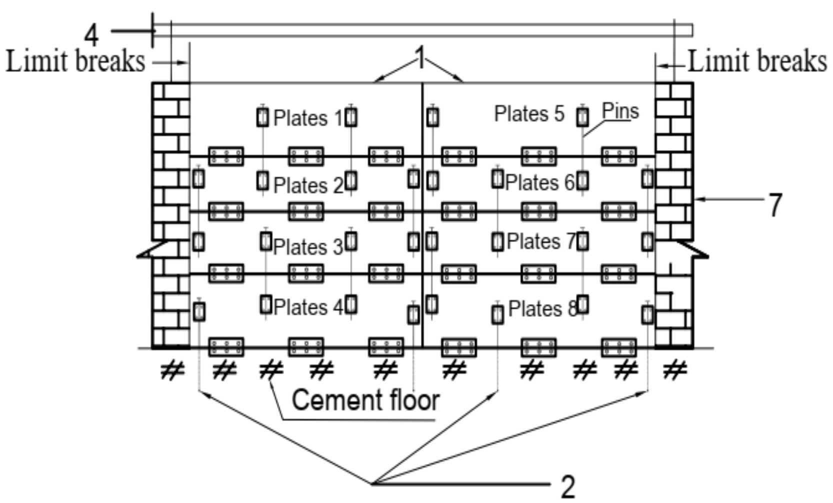
Table 1: Parameters of the rupture in case of a dam break

Dam type	Average width of the break	Break roof slope(H)	Breaking time (hour)	Standard
Gravity concrete dam	Blocks Usually ≤ 0.5L	Vertical, straight Vertical, straight Vertical, straight	0.1-0.5 0.1-0.3 0.1-0.2	U S ACE(2 0 07) FERC N W S
Rolled concrete	The entire dam (0.8 x L) to L The entire dam (0.8 x L) to L	Natural sloping roof 0 - Natural sloping roof 0 - Natural sloping roof 0 - Natural sloping roof	≤ 0.1 ≤ 0.1 ≤ 0.1 ≤ 0.1	U S ACE(1 9 80) U S ACE(2 0 07) FERC N W S

Therefore, it can be seen that when concrete dam breaks the rectangular blockyfracture shape and multi-block.

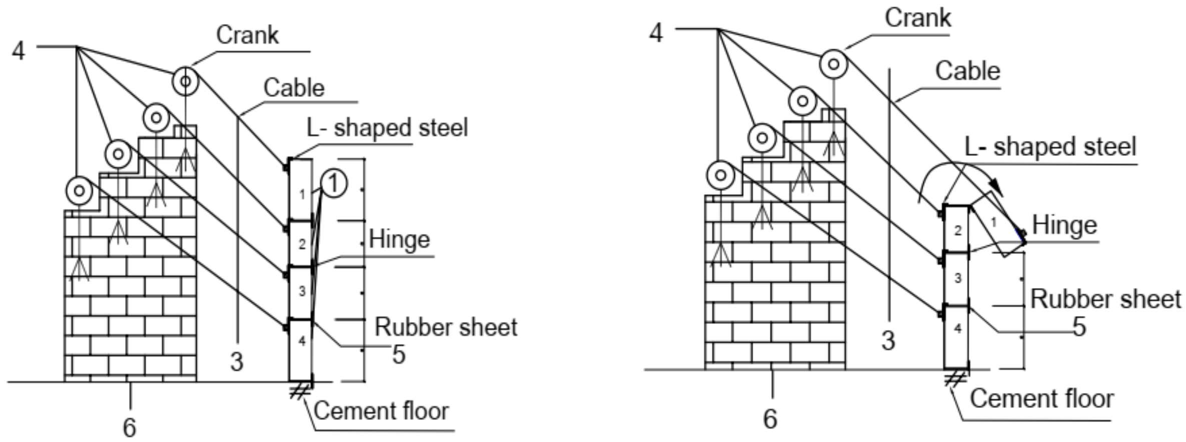
2.2.2. Fracture simulation [6]

For concrete dam failures, the rupture can be partial or complete. In this study, to simulate different sizes of ruptures, the author created ruptures using flip doors, fixed with locking pins and allowed to open immediately. This method of creating instant rupture holes has been granted useful solution certificate No. 2043 by the Intellectual Property Office - Ministry of Science and Technology: Equipment to simulate the process of concrete dam rupture according to Decision No. 35545/QD-SHTT May 9, 2019. Figure 5– Show the structure creates a hole when simulating a concrete dam breaking.



1 - Flip plates;
2 - Locking pins;
3 - Cable;
4 - Crank;
5 - Rubber sheet;
6 - Crank arm support;
7 - Door system

a. Structural facade



b. When a rupture has not yet formed c. When a rupture forms

Figure 5: The structure creates a hole when simulating a concrete dam breaking

3. MEASUREMENT METHODS

The dam breaking process occurs in a short time, so during the experiment, to determine the parameters we need appropriate measurement methods and diagrams.

3.1. Local material dams

For local material dams, the main factors that need to be determined are the process of formation and development of the break, the geometric size of the break (break width, break depth), formation time. rupture formation and development.

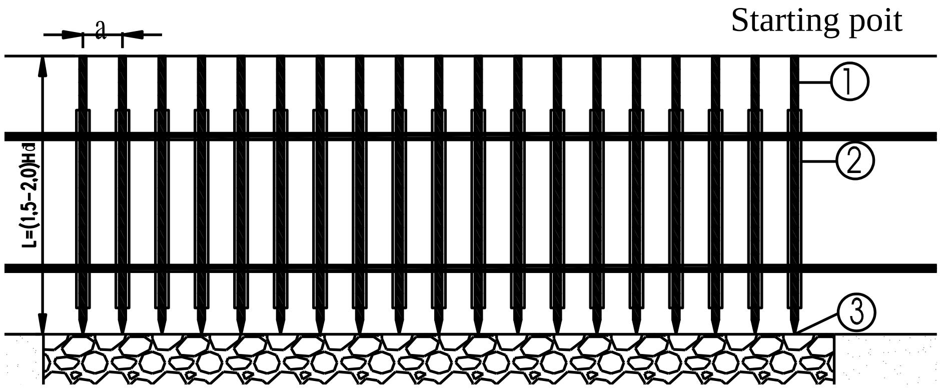
3.1.1. For segmented model (2D): determined by gridding method [3], [5]

This is a method of using colored indicators to draw a grid (usually a square grid) with a certain size and numbering for easy identification. During the incident, wherever the hole develops, the grid cells are lost. Through the number of grid cells lost, the size of the hole will be determined such as hole depth, hole width, etc. To apply this method on the cross-sectional model, draw a grid on the wall of the glass trough, thereby determining the depth of the break quite effectively.

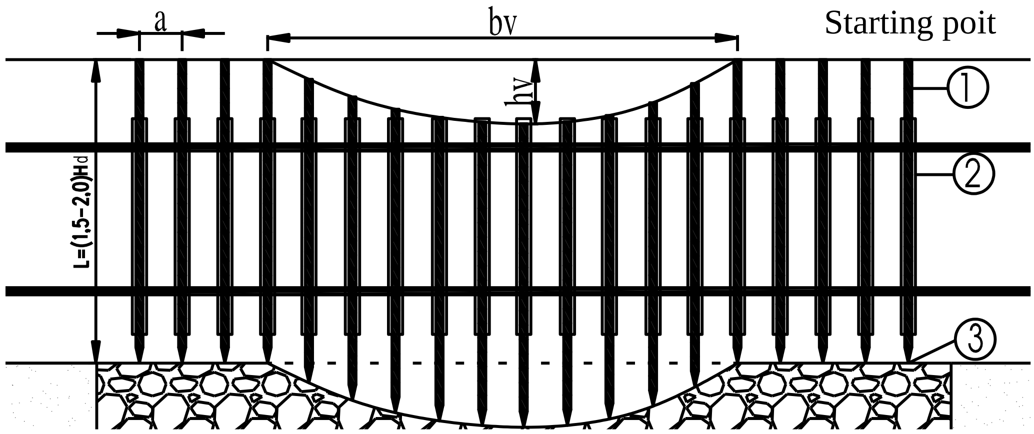
3.1.2. For the overall model

Using the semi-automatic measuring pole system: The measuring pole system consists of 4 main parts: - Needle system (1) - Made of steel at one end with a pointed tip (needle tip 3), with a diameter of d, length l (l = (1.5-2.0) $H_{đ}$; $H_{đ}$: Dam height); Automatic sliding rail (2): Made of steel or suitable material with pore diameter D=(1.2-1.5)d. Truss frame system (4): Made of steel and permanently mounted on the model; Time clock attached to truss system 4.

The depth of the rupture at each location is determined by the lowering of the needle at that location compared to the initial time, mark "0". The width of the rupture is determined by the number of needles moved. **Figure 6** – Show bar equipment system to measure the dam failure process.



The bar system at the initial time - when there is no breakage



Bar system at time t - When the hole has formed

Figure 6: Bar equipment system to measure the dam failure process

3.2. Concrete dam

For concrete dams, dam failure occurs immediately and often causes intermittent waves downstream of the structure. Intermittent waves are the main cause of damage downstream of structures, so determining the characteristics of intermittent waves is the main task in the dam failure process.

To collect data, use the British-made Duck pressure transducer system. Depending on the number of signals to be collected, arrange the number of measuring heads appropriately. Probes are mounted along the downstream flow length after the rupture. The probes measure simultaneously with a series of 10-15 signals/s. Collection time is 3-5 minutes. The water level process along the downstream channel is recorded with a video camera and a digital camera, combined with a signal measuring head to process the results. Figure 7- Show Experimental layout diagram.

The flood drainage process through the breach is determined by using a triangular measuring trough at the end of the model, and is automatically recorded by video combined with manual data reading and recording.

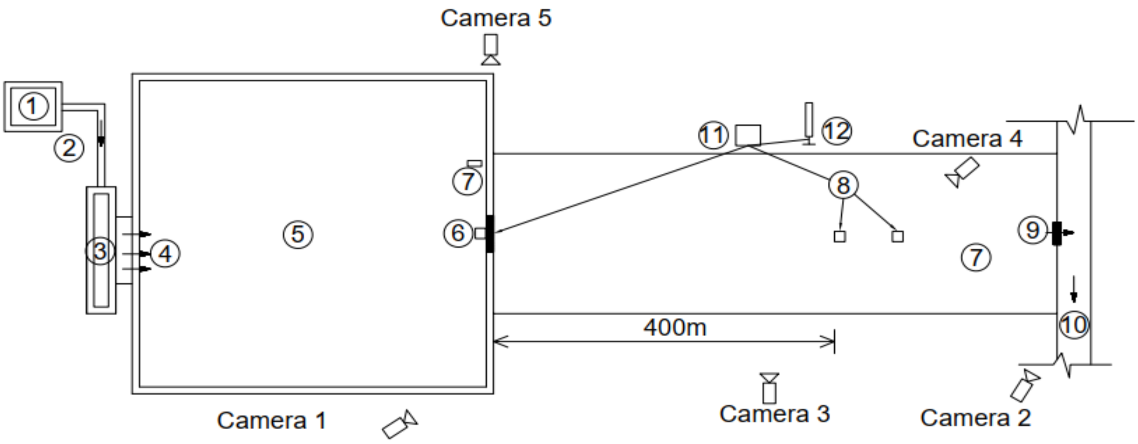


Figure 7: Experimental layout diagram

The experimental measurement system includes: Dynamic station (1), pipeline (2), measuring trough (3) and water pipe into the model (4); The upstream water reservoir (5) is built with solid brick walls covered with cement mortar, the tank floor is concrete to prevent water loss;

Breakage generation system (6), at (6) place the measuring head to receive the velocity signal when the dam breaks;

Water level gauge (7) is installed in the upstream reservoir to determine the evolution of upstream water level and recorded by Camera 5 (located upstream).

The signal measuring system (8) is arranged behind the rupture along the downstream channel;

The flow meter (9) mounted at the model outlet is a device used to check the flow leaving the model. The thin-walled trapezoidal measuring trough is made of 10mm thick mica glass, with a steel ruler attached to record the water level using Camera No. 2.

The flow return trough (10) is an available system used to collect water after passing through the model back to the tank.

The signal transducer system (11) and computer (12) are used to collect and determine wave signals caused by dam breaks in the downstream channel. Disrupted wave images were recorded by Camera systems 3 and 4 (located on both sides of the downstream channel).

4. CONCLUSION

There are many methods to study dam failures including collection methods, analytical methods, mathematical modeling methods and physical modeling methods. Each method has its own advantages and disadvantages. The physical modeling method has the advantage of giving us intuitive and observable results. However, due to the rapid failure of the dam, the collection work will face many difficulties. Therefore, it is necessary to have a method to simulate the phenomenon accurately.

Different types of dams are built with different types of materials. When an incident occurs, different phenomena will occur. For local material dams, holes often appear in any critical location, so to properly simulate the nature of the dam failure phenomenon, we must properly simulate the properties of the materials that make up the dam. For concrete dams, dam failure occurs immediately and often causes intermittent waves downstream of the structure. Intermittent waves are the main cause of damage downstream of structures. Therefore, determining the characteristics of intermittent waves is the main task during the dam failure process.

Data collection methods for each type of dam will be different. With dams made of local materials, attention should be paid to the process of formation and development of breaks, size, shape of breaks, and time. For concrete dams, attention should be paid to the characteristics of intermittent waves, because intermittent waves are the cause of harmful effects to downstream areas.

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