Analysis of Sediment Samples and Erosion Potential: A Case Study of Upper Tamakoshi Hydroelectric Project

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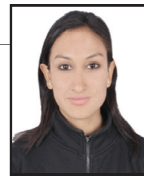
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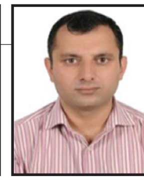
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Abstract: Hydropower can be an effective green solution for meeting the current energy demand in Nepal. However, despite having tremendous water resources, only 2% of Nepal's hydroelectricity potential has been tapped. Of the challenges that Nepali hydro faces, sediment erosion is a major one.

Sediment erosion refers to an erosive tendency of sediment particles flowing with water over the exposed turbine parts including the runner. This paper deals with a sample analysis of sediment particles from the Upper Tamakoshi Hydroelectric Project. In this paper, we test for particle size distribution, particle count, mineral composition, and erosion potential analysis. For the mineral and erosion potential analysis, the sand samples range from 75 μm to 200 μm because the Tamakoshi plant consists of sediment traping system for particles larger than 150 μm.

The sediment samples were collected from three different points in the headrace and the severity of the effect of erosion has been analyzed in terms of depending variables like particle size, concentration, and mineral composition.

Keywords: Sediment erosion, erosion tendency, Sieve, Particle Size Distribution, Mineral composition, Rotating Disc Apparatus, Nepal

Introduction

Sediment erosion is a major technical challenge to the smooth operation of hydropower plants. Previous research demonstrates that sediment erosion hampers project efficiency and productivity, but there is still much we do not know about the process and effects of sedimentation. The corrosive effects of sand particles in a hydropower system depend upon its shape, size, mineral content, and concentration. Laboratory estimates of the intensity of erosion on exposed turbine parts has been performed in accelerated test setups where the erosion phenomenon has been identified. Neupane et al. (2013) and Sujakhu et al. (2013) have worked on the particle size and mineral content analysis of Jhimruk and Sundarijal Hydropower plant and found out the variation in the sample properties with the size (Neopane, Sujakhu et al 2013 and Sujakhu, Neopane et al 2013). In this paper, analysis related to the sediment size distribution and the possibility of sediment passing to the hydro-mechanical and turbine components were identified. Additionally, the mineral composition on these particles and its erosion potential analysis were performed.

Methods

Sample collection

The samples were collected under the guidance of experienced personnel. They were collected from inside the water to represent the true nature and condition of the samples, where contaminations were prevented. The samples were from five different points maintaining collection distance (Transportation, A.n.d).

Sample Preparation

After a sample collection, they are prepared for the further analysis. The damp materials were dried, removing the foreign materials and stored for the analysis.

Particle Size Analysis

Particle size is considered a major factor for sediment erosion. According to Thapa, 2004, sediment erosion is directly proportional to particle size. For our study, we analyzed various sizes of sediment to estimate the severity of erosion that might be expected at the Upper Tamakoshi site which is presently under construction.

We employed a test sieve which is used to measure particle size. In its most common form, it consists of a woven wire screen, with square apertures, rigidly mounted on a shallow cylindrical metal frame.

Methods of Test Sieving

Sieve tests can be carried out by hand or on a machine designed to impart the necessary shaking, rotating, vibrating, or jolting motion to the material on the screens.

For our analysis, we employed hand test sieving.

Procedures for particle size analysis

To analyze particle size, we used seven sets of measurement: 1 mm, 0.6 mm, 0.3 mm, 0.2 mm, 0.150 mm, 0.125 mm and 0.075 mm. The sieves for these tests were arranged in descending order.

The standard procedure implemented in sieve analysis is shown in Figure 1.

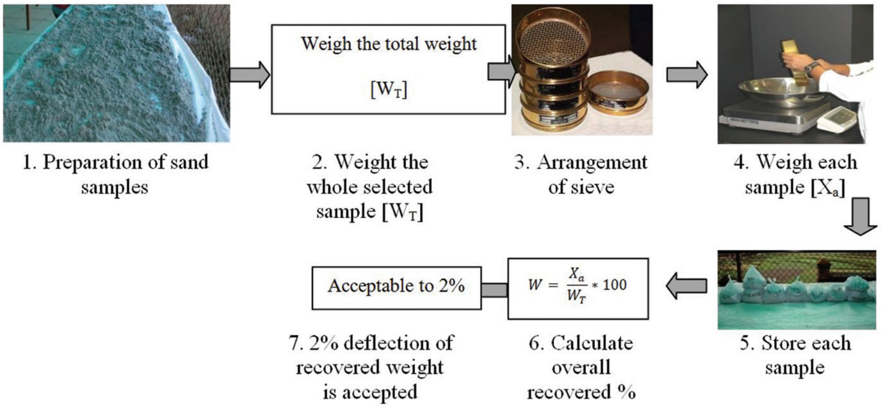

Figure 1: Procedure implemented in sieve analysis

Mineral Analysis

Sediment erosion in exposed turbine components also depends on mineral composition. Rivers in Nepal have a wide variation of minerals present in sand form. The erosion potential of these sand particles depends largely on their mineral compositions. Moreover, the hardness of these minerals is a major factor for erosion of machine parts (Neopane 2010).

In the course of this study, we analyzed particles through a microscope and projected those images to a computer screen with the aid of a USB camera. The obtained image was then identified and counted.

A radial Trinocular Stereo Zoom Microscope with binocular head of 0.7X to 4.5X and magnification of 7X to 45X was used. One part of the eyepiece was fitted with a 3 Megapixel USB camera at ISO 300.

We employed Neupane and Sujakhu's method (Neopane and Sujakhu et al 2013) for particle counts. This is illustrated in figure 2.

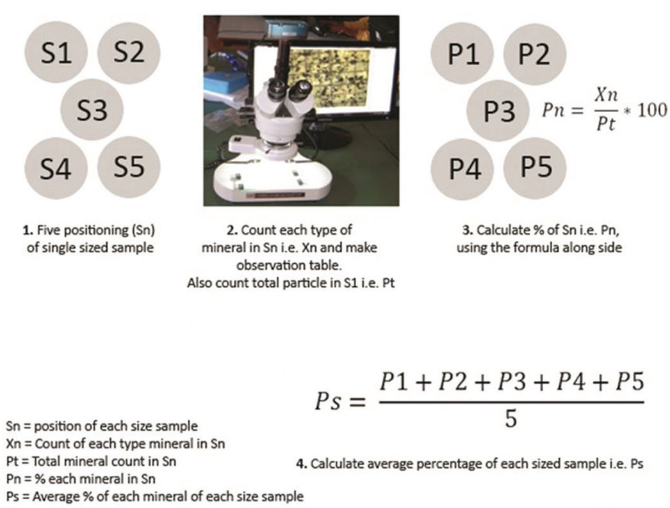

Figure 2: Procedure implemented for mineral analysis

Erosion potential analysis

We employed a rotating disc apparatus (RDA) to obtain the erosion potential. In the rig, a 280 mm diameter disc of mild steel rotates at a speed of 1440 rpm in an anti-clockwise direction against sediment slurry (Rajkarnikar, Neopane and Thapa et al 2013). A disc of mild steel was selected to follow the experimental analysis in accelerated test mode where the effect of sediment was seen in laboratory operating time (figure 3).

Result and Discussion

Sieve Analysis

The samples from the upstream of the Upper Tamakoshi Hydroelectric Project were drewed. The analysis results are plotted on a graph in Figure 4. In the analysis 44.12 kg of sample was taken of which 43.79 kg of sample was retained. The sediment less than 150 µm per particle is predicted to be responsible for the erosion of turbine materials in the site. From the graph, we observe 99.8% of the sample was 1000 µm or less in size per particle. Particles less than 150 µm were observed to be 32.6%. Hence, about 32.6 % of possibility for sediment escapes the trapping system.

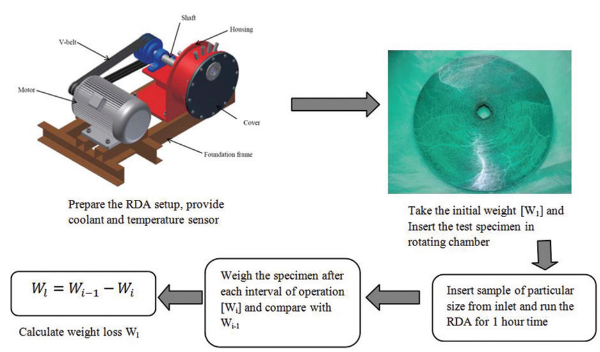

Figure 3: Procedure implemented for RDA experiment

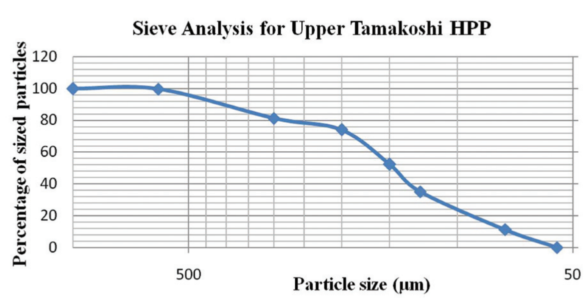

Figure 4: Result of Sieve analysis

Mineral Analysis

We analyzed for mineral content for size groups ranging up to 200 µm.

Figure 5 provides a pie chart illustration of the mineral content. We are most concerned with quartz as it is a more erosive mineral as measured with Mohr's number. Mohr numbers generally qualify erosive minerals as between 6 and 6.5. Quartz measures as 7. As we can see, the samples contain high quartz content. Thus, the erosion potentiality is high at Upper Tamakoshi. Besides, the samples showed high volumes of feldspar, which also is erosive. Other minerals, such as garnet, muscovite, biotite, and tourmaline, are also identified.

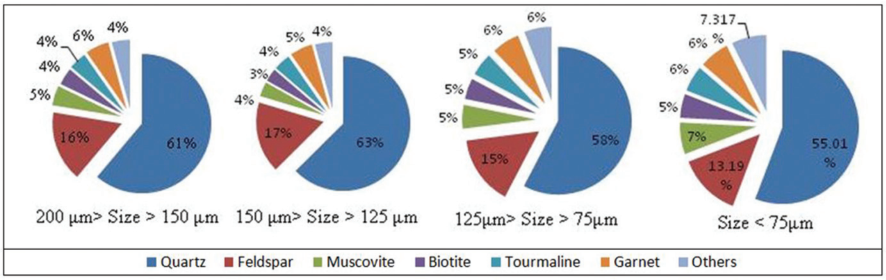

Figure 5: Percentage of mineral contents in the sediment of different size

A separate analysis notes that the amount of quartz in a sample declines as particle size decreases. The percentage of quartz is 62.18% in sediments between 0.15 mm and 0.2 mm but only 55.54% in sediments less than 0.075 mm. Thus, we can see that quartz's hardness prevents it from breaking into smaller particles below a certain level. On the other hand, softer minerals like muscovite and biotite increase in amounts as particle size deceases.

Erosion Potential Analysis

The erosion potential analysis of sediment samples from Upper Tamakoshi Hydroelectric Project were analyzed using a rotating disc apparatus, and based on three major criteria: particle size, concentration of sediment samples of different size, and time of operation for different particle size.

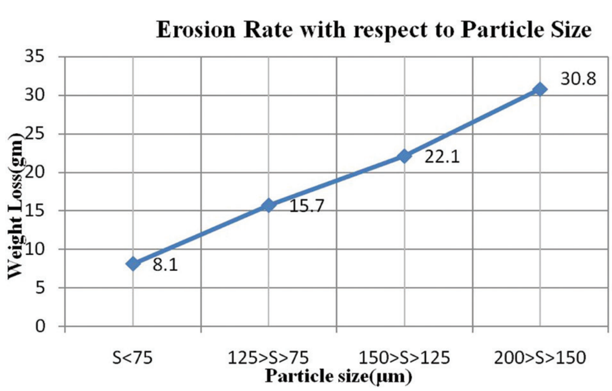

Figure 6: Erosion rate with respect to particle size

Erosion rate with respect to particle size

In the representative graph, the weight loss was plotted with respect to particle size. The time of operation for each was fixed to four hours. The graph shows that particle size is directly proportional to the erosion in the exposed turbine parts. Sediments of greater size are comparatively more responsible for the erosive effects.

Erosion rate with respect to concentration

In the graph below, erosion rates were plotted with respect to concentration of sample in different sets of particle size. The RDA has a capacity of 5 liter of water hence sediment sample was inserted to maintain the concentration and latter the concentration was converted to per liter. The results (figure 7) illustrate that erosion rate is directly proportional to the concentration of the particle. In other words, the higher the particle concentration, the larger the particle size, the greater the rate of erosion.

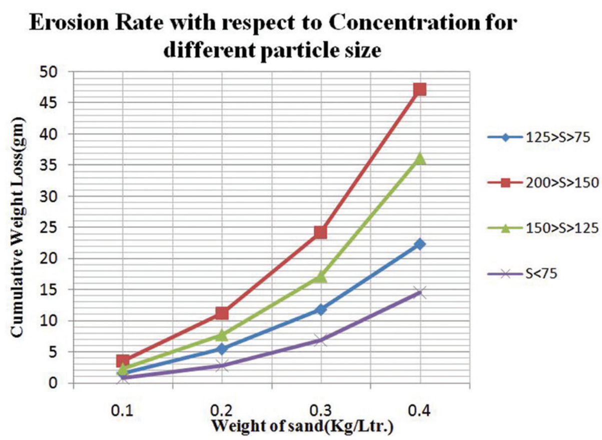

Figure 7: Erosion rate with respect to concentration for different particle size

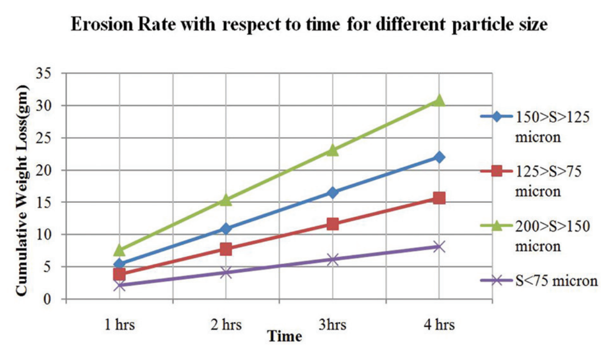

Figure 8: Erosion rate with respect to time for different particle size

Erosion rate with respect to time

This analysis was performed based on erosion rates with respect to time. A 1 kg sand sample mixed in 6.17

liters of water was tested for 4 hours; we took weight loss measure on the hour for the duration of the test. The results of analysis (figure 8) show that erosion is directly proportional to time of operation. As well, the larger the particle size, the larger is the amount of erosion over time.

Conclusion

We tested samples from the headrace of the Upper Tamakoshi Hydroelectric Project, conducting size analysis, mineral analysis and erosion potential analysis, using manual sieve method for particle size distribution, particle count method for mineral composition analysis, and rotating disc apparatus for erosion potential.

The Upper Tamakoshi plant has a trapping system for sediment larger than 150 µm, hence, we were concerned with particles ranging 75 µm to 200 µm. Our analysis found that particles with a greater likelihood (i.e., smaller size) of moving across the turbines are in higher quantity in the water. Mineral analysis determined a high concentration of quartz in the water, which signifies potential for erosion due to quartz's high hardness factor. However, the amount of quartz diminishes as particle size reduces. Erosion potential analysis found that the rate of erosion is directly proportional to particle size. Since the larger particles are trapped by the project screens, only long durations of operation can cause considerable erosion.

Earlier researches have supported the fact that adaptation of the turbine material harder than Quartz could reduce the sediment effect in long term. However, the comparative effect of changing the hardness of the turbine material on the overall performance of the turbine needs a thorough analysis, including the structural integrity.

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