University of Ottawa

GNG 1103: Engineering Design



Deliverable C- Design Criteria

February 4th, 2023

Group F-12

Avery Taylor (300366472)

Emily Facette (300109170)

Rashad Nesar (300372555)

Annabelle Osazuwa (300361617)

# Introduction

Ailsa Eyvindson from Canadian Nuclear Laboratories has requested a design for a highly accelerated erosion testing system for different materials. Following the first client meeting, the client’s needs were identified, summarized, and prioritized. The following document identifies design criteria based on client needs, explores similar solutions, examines design specifications, and reflects on the findings.

# Design Criteria

Following the first client meeting, the client's needs were recorded, refined, and categorized. The resulting needs were broken down into design, function, and theory & testing, which can be seen in Project Deliverable C. The following table summarizes the identified needs and their corresponding design criteria.

Table 1: Design Criteria Based on Client Needs

|  |  |  |
| --- | --- | --- |
| **Number** | **Need** | **Design Criteria** |
| 1 | The prototype should be safe to use | The prototype will have a limiter on how high the temperature can get |
| 2 | The prototype should be flexible enough to test a variety of materials, temperatures, diameter of components, fluid viscosities, abrasion, and rotational speeds | A limiting sensor for water temperature will be used. A spout will be installed on the barrel for ease of draining liquids |
| 3 | The prototype set up should be used to accelerate erosion testing by rotating components. | The prototype will have a motor to spin the tested material |
| 4 | Demonstrate your system and describe the features that accelerate the erosion with empirical proof  | Arduino will record results which will be stored on excel. |
| 5 | The process should be repeatable | The apparatus will be easy to empty and restart with different parameters. |
| 6 | Erosion should be visible in a week or two after testing started | A variety of abrasive materials and high temperatures will be tested |
| 7 | The prototype should be stable and able to accommodate the high rotational speed | The prototype will be designed with a wide and heavy base |
| 8 | Affordability and Durability | The prototype will be constructed using free and inexpensive materials of good quality |
| 9 | Minimal Maintenance | The apparatus needs to be simple |

The needs in the table above will be grouped based on design criteria and explained further.

**DESIGN**

**1. Safety and Stability**

Ensuring the safety of the apparatus is extremely important. To guarantee the safety of the design and configuration, we will construct it with a wide, heavy base and a cylindrical-shaped barrel. Stability is particularly crucial as the materials will undergo testing at high rotational velocities. Another design criterion to ensure apparatus safety involves limiting the rotational velocity. The average rotational velocity must be kept below 1800 rpm to minimize the risk of damage. Additionally, the liquid in the barrel will neither be corrosive nor exceed 40°C. This precautionary measure aims to prevent burns resulting from the liquid's nature or temperature. The maximum temperature the liquid can attain will be strictly controlled to enforce this safety standard.

 **2. Affordability and Durability**

The allocated budget for constructing the prototype is $100. To ensure that we remain within this budget, we will utilize resources available to us through the university, as well as materials we already possess, or thrift/free materials from the Facebook Marketplace, or other discount stores. It is imperative to use quality materials when constructing the apparatus to guarantee its safety and durability.

**FUNCTION**

**1. The prototype should accelerate erosion testing by rotating components**

The primary function of the apparatus is that it will accelerate erosion by using rotating components. This will be accomplished by fastening the material that will be tested onto a rod or a dowel. The rod or dowel will be attached to a rotating motor at the desired RPM.

**2. The prototype should be flexible enough to test a variety of materials, temperatures, diameter of components, fluid viscosities, abrasion, and rotational speeds.**

There will be other parameters which will be changed to determine optimized erosion conditions, such as liquid temperature, liquid composition, abrasives, etc. The liquid type/viscosity and abrasive materials will be added manually and do not affect the composition of the prototype. The temperature of the liquid will be limited using a sensor, as mentioned in *Safety* above. A drain will be installed in the barrel of the apparatus for ease of removal of liquids.

 **THEORY AND TESTING**

**1. Features which accelerate erosion quickly must be described, demonstratable, and repeatable**

As mentioned in the *Flexibility* of the apparatus, there will be different parameters tested to analyze the rate of erosion. For this reason, the experiment needs to be repeatable. The results from different parameters will be recorded by Arduino and summarized in Excel. The spreadsheet will track the different conditions, the material used, the time taken, the total erosion, and other parameters.

**2. Minimal Maintenance**

In real-world testing, the apparatus will be left alone to erode, with minimal maintenance. For this reason, it is important that once the erosion testing period has started, minimal to no maintenance will be required. The apparatus will be designed simply to ensure that minimal maintenance will be required.

# Benchmark

1. Rotating Erosion Testing Apparatus - RETA (Briaud et al., 2019)

Kerr (2001) and Sheppard et al. (2006) modified the previous versions of the Rotating Cylinder Test by Moore and Masch (1962) at University of Texas. The modified version, called the rotating erosion testing apparatus (RETA), was built at the University of Florida. The test makes use of a self-supporting sample, such as erodible rocks and stiff clays. The test apparatus is equipped with a real-time control unit to monitor the shear stress imported by the torque, a load cell to record the weight of the sample and a water-cooling system to reduce the temperature for long tests (more than 72 h for rocks). The following figures show a technical sketch of the apparatus, as well as the test system configuration.



***Figure 1:*** Labelled Diagram of the RETA parts (Briaud et al. 2019)



***Figure 2:*** Technical sketch of RETA apparatus (Briaud et al, 2019)

1. An improved Rotating Cylinder Test – RCT (Lim & Khalili, 2009)

This device is designed and manufactured for laboratory measurement of erosion in clay soils. The improved device provides for a rapid and practical procedure for sample assembly and allows testing cylindrical samples 100 mm (about 3.94 in) in height and 100 mm (about 3.94 in) in diameter. The improved RCT apparatus has been calibrated using dummy samples to isolate the torque applied to the soil surface. A control program has been developed to operate the RCT and record test data for analysis. Typical erosion test results are presented for clay soil.

1. The Sediment Erosion Rate Flume (SERF): A New Testing Device for Measuring Soil Erosion Rate and Shear Stress (Crowley et al., 2012)

The Sediment Erosion Rate Flume (SERF) is an advanced apparatus designed to measure soil erosion in a flume. The SERF uses a computer-controlled system with lasers, ultrasonic depth sensors, and a Servo-stepper motor to precisely monitor and control instantaneous changes throughout erosion tests, as opposed to other technologies which take an average rate over a period. The apparatus includes a device to measure shear stress for samples with uniform roughness directly.

# Target Specifications

The RETA mentioned no specific RPM, instead the RPM of the device adjusts according to the amount of torque set when starting the device. The RCT states that the speed can be set anywhere from 2 – 1500 RPM. The chamber holding the sample being eroded is a cylinder with a diameter of 100 mm and a height of 40 – 100 mm. The sample itself is a cylinder with a diameter of 40 mm and a height of 4 mm. No weight of either device is mentioned but both manufacturers seem worried about the device tipping over as they both have metal casing and are clamped to the surface they are on. None of the devices adjusted the temperature of the water to try and speed up the erosion, instead trying to maintain a room temperature (22 – 25 Celsius).

# Reflection

The client meeting provided much clarification on certain aspects of the design and certain requirements we should focus on. A frequent question we had throughout our meetings and process was regarding the configuration of the prototype itself, such as:

* How the prototype/materials will be rotated;
* How we will keep the prototype stable and safe
* How we will keep the motor dry;
* If there were any limitations or restrictions on the design.

The client was able to give us a deeper understanding and clarification on all those questions through this meeting, a form of communication much more efficient than several emails could have done. We were informed about the limitations/restrictions on temperature and corrosive liquids for testing, the time frame by which we should be aiming to see signs of corrosion, as well as general information maintenance-wise and which aspects we should be keeping a record of through the process. We noted any questions the client was not able to answer and began to narrow down through communicating as a team discussing possible solutions and benchmarking.

# References

1. Briaud, J., Shāfiʻī, Ī., Chen, H., & Medina-Cetina, Z. (2019). Relationship between erodibility and properties of soils.
2. Lim, S. S., & Khalili, N. (2009). An improved rotating cylinder test design for laboratory measurement of erosion in clayey soils. Geotechnical Testing Journal, 32(3), 101448. <https://doi.org/10.1520/gtj101448>
3. Bloomquist, D., Sheppard, D. M., Schofield, S., & Crowley, R. W. (2012). The rotating erosion testing apparatus (reta): A laboratory device for measuring erosion rates versus shear stresses of rock and cohesive materials. Geotechnical Testing Journal, 35(4), 104221. https://doi.org/10.1520/gtj104221
4. Crowley, R., Bloomquist, D., Shah, F. D., & Holst, C. M. (2012). The Sediment Erosion Rate Flume (SERF): a new testing device for measuring soil erosion rate and shear stress. Geotechnical Testing Journal, 35(4), 103814. <https://doi.org/10.1520/gtj103814>