Newmont Design Studio - Mechanical Dewatering of Tailings:

Design and Testing of Bench Scale Filter Pressing – Final Design Report

Reporting Period:

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Prepared By:
A Colorado School of Mines Capstone Design Course

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Introduction

When gold ore is processed, the rock is pulverized and exposed to various chemicals. This combination of waste rock and chemicals is known as tailings. Dams have been constructed with the intention to contain these tailings from polluting the surrounding environment. However, these tailing dams are failing at an unacceptably high rate. As a result, the mining industry is investing in the development of alternative tailing mitigation strategies. The goal of this project is to investigate mechanical dewatering technologies to safely dispose of tailings. Technologies which allow dry stacking of tailings were of main concern. As there are many mines with different tailings characteristics and site-specific throughputs, this project required the team to consider the wide range of expected throughputs at different Newmont sites.

First, through analysis of provided data on current tailings dewatering methods utilized by Newmont, a capability and economic comparison was conducted. The methods investigated for this study were tailing filter presses, vacuum/vibratory belt filters, and Geowaste/EcoTails. This comparison looked at three main key performance indicators. These were achievable moisture content, maximum throughput capacity, and capital and operational expenditures. By utilizing tailings characteristics data for four (4) Newmont sites around the world and numerous filtration case studies, a design solution was synthesized to meet the necessary design criteria for each site's unique situation. From the analysis of this data compiled during the first semester, the decision to further pursue development of filter presses was agreed upon between the CSM Team and Newmont.

Project Review

Reengagement with Newmont:

Re-engagement with Newmont

- Design a bench scale filter press machine capable of mechanically dewatering tailings samples that implements the use of both plate compaction and filter plate pressurization.
- Physically develop and fabricate the design outlined above through the use of the Colorado School of Mines Senior Design Laboratory and machine shop.
- Test the developed prototype and correct the necessary issues which prevent the machine from effectively dewatering tailings samples and creating a dried filter cake. Definition of “effective” based upon achieving a cake moisture content of ~20-25%.
- Utilize the design to run tests on multiple tailings samples and run moisture content tests on the produced cakes.
- Run Particle Size Distribution testing on dried filter cakes to better grasp how the prototype performs with varying tailings characteristics.
- Perform Atterberg Limits Testing on provided tailings samples.
- Perform Proctor Compaction Testing on provided tailings samples.
- Modify and improve the developed prototype with remaining amount of time left with the goal of achieving the lowest possible moisture content.

Dead ends

Often, design teams would find themselves facing a number of dead ends due to a difference in opinions and ideas between group members. Fortunately, our team did not have to worry about such issues, as all team members were on the same page throughout the project, willing to go investigate any unknowns when setting out to accomplish as much as possible. A lot of the dead ends for this project occurred due to a lack of receiving purchased equipment on time as well as a break in communications with laboratory technician staff. This waiting led to not fully being able to test all options and ideas that were planned during the intermediate design stage. One other dead end that the project did face was addressing the prototype’s tailings feeding mechanism. Trying to push the wet tailings through a handheld air pump was the first initial thought, utilizing the pressure inputs as the feeding inputs as well. The tailings themself were too thick and the only option to get past this hurdle was to further thin the slurry mixtures prior to loading, allowing the material to pass more easily into the machine prior to dewatering. Perhaps the only other dead end that the team attempted to proceed with was in regard to the fitting of rubber gasket material in conjunction with the filter media chosen. This turned out to be something that was less useful than anticipated due to the inability to precisely fit the gasket material to third party repurposed filter media. Future improvements in regards to this could include precision machine cutting and fitting of both gasket material and filter media to better mesh the two, resulting in an improved leak inhibiting performance.

Design Methodology

Problem Approach

The main avenue used for understanding what we would have to accomplish to create a bench scale filter press was research. Once we were certain that Newmont was open to the idea of proceeding with hands-on prototype development, rather than a further developed research-based project, we were able to begin with conceptualization. Ranging from rough hand-drawn drawings to 3DCAD models of a possible solution to a bench scale filter press.

Existing Technology

Like any good project, you have to be two steps ahead in any direction in order to ensure that if failure were to occur, we would have options in order to move forward. We have looked into the option of purchasing/ renting a miniature Filter press and fortunately, such technology exists already. A company called Micronics filtration specializes in renting miniature filter presses to potential clients. It was an initial thought of the team to get a hold of such a machine in order to better understand exactly how to go about creating a foundation for our own bench-scale prototype. In the end, the team opted to model certain visible characteristics of the Micronics-style press but with variations such as the number of plates used as well as the direction of pressurization.

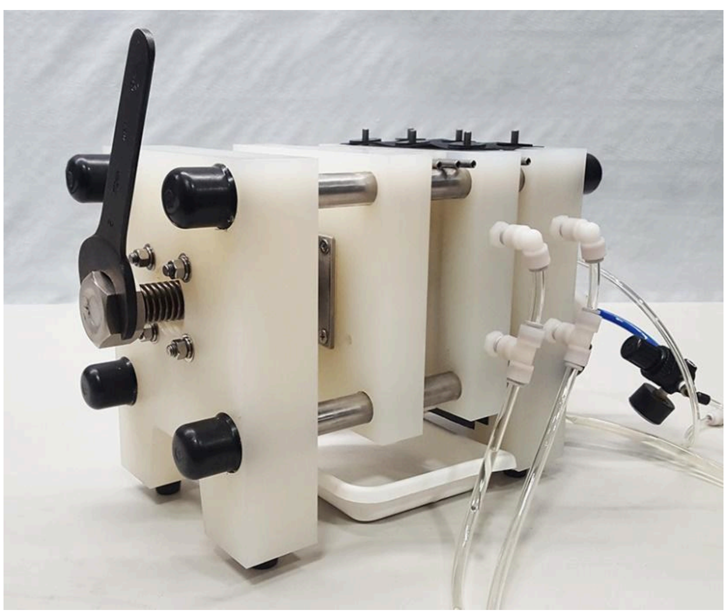

Figure 1: *Micronics Filter Press kit*

An example of what is included in purchasing the equipment from Micronics is as follows: Comes equipped with Membrane Squeeze and Cake Blow capabilities for demonstrating the ability to achieve very dry filter cakes. allows testing for cake thicknesses ranging from 15 mm up to 60 mm, and comes complete with press, feed pump, and a high-pressure manual air pump for the Membrane Squeeze. The only item that was needed for this to operate was an air compressor machine.

Black Box Model:

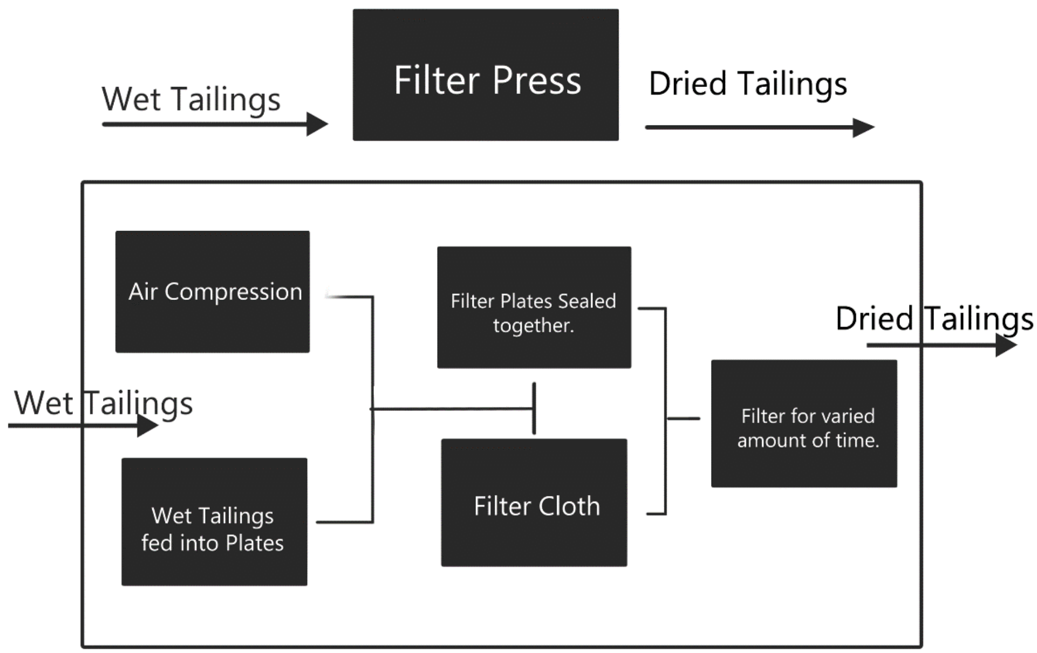

Figure 2: Black Box Model

Stakeholder Discussion:

During the first semester of this project, all time was spent on internal preliminary research of dewatering technology. This was primarily due to the fact that the project was brand new to both Newmont as well as CSM, and project scope and expectations were not clearly thought out. Most of the Team's options were limited at the beginning due to the unfolding of the COVID-19 pandemic, so an easy route was to opt for research until it became more feasible to start planning an idea that could have a physical prototype. The start of the second semester allowed us to first gain possible new team members and even a plan. Newmont, being the main stakeholder expressed their interest in progressing towards hands-on development and outlined their respective expectations and desired deliverables accordingly. The budget to be utilized was discussed and settled upon at the end of last semester, in late November of 2020.

Project Expenditures as of 2/27/2021				
Item	**Cost**			
Filter Cloth Pads	$14.67		TOTAL =	**340.49**
Travel Mileage - CSU Tailings Pickup	$71.68		AMOUNT REMAINING =	1159.51
All-Thread rod and fasteners	$17.04			
Amazon - Cheese Cloth + Rubber	$27.03			
Home Depot - Pressure Fittings and Rubber Seals	$89.51			
Home Depot - Missing Fitting	$3.93			
Additional Filter Media pads	$77.23			
ASTM 152-H Hydrometer	$39.40			

Figure 3: *Bill of Materials*

Prototype User Instructions Overview:

With respect to the operation of the team's composed prototype, the procedure for running a sample of tailings is as follows. The first step is to hook up the necessary hoses running from the quick coupler and ball valve. This is done via the ½" ID fiber reinforced hose being clamped to the brass barbed fittings that were tapped and threaded into the back of the two outer filter plates. Hose clamps are used to ensure a tight fit. Once the outer filter plates have the pressure hoses fitted to the quick coupler and ball valve, the desired source of regulated pressure is to be connected to the quick coupler and ball valve. Once this step is complete and the compressor/pressure source regulator is set to 15-20 psi, the operator then switches the ball valve on the quick coupler to the open position, allowing pressurization of the filter plates. The machine is then run for the desired cycle time and then switched off via the ball valve. The hose clamps holding the fiber reinforced hose to the barbed brass plate fittings can be removed and the fasteners holding the filter plates together loosened. This will allow the operator to separate the filter plates and remove the filter cake produced.

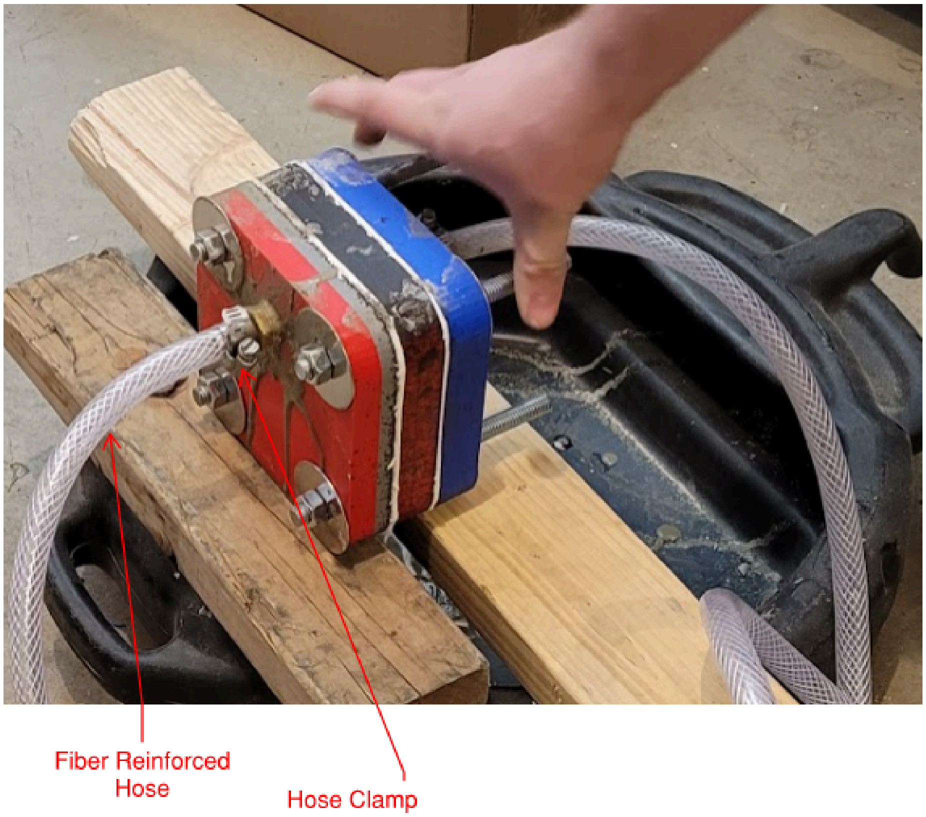

Figure 4: Apparatus Set-up

Figure 5: Apparatus Set-up

Figure 6: Example of Produced Filter Cake

Future physical revisions to the prototype should address efficiency of assembly set-up and teardown. The implementation of a system which allows the operator the more easily and quickly empty the machine of the filter cake produced each trial is one potential avenue of focus which the continuation of the project should consider come next semester.

Engineering Analysis

In order to ensure design workability and safety, a variety of tests were run to ensure part stability and prototype effectiveness. For ease of access, the engineering analysis work of the semester is highlighted below to paint a full picture of the work completed to manufacture and test the prototype.

SolidWorks Drawing, Model, & Analysis

To properly understand a bench scale model, initial models, calculations, and drawings were generated to ensure safe operation and proper documentation of the prototype. This section contains all relevant work completed from the intermediate design report in order to provide the complete design, testing, and analysis in one report. Drawing packages and additional figures have been moved to the appropriate appendix section.

A SolidWorks model was generated to aid in 3D visualization and additional studies. The three plates were drawn and modeled in SolidWorks for both its ability to properly complete engineering studies and the availability through the university. The drawings and models of the remaining components were imported from McMaster-Carr. The plates are modeled using acrylonitrile butadiene styrene, or ABS, plastic material and additional components are made using 1040 Steel-Cold Rolled. Postprocessing work will be required to add inlet and exit points for pressurization and to bore the holes for ease of operation. Current and previous drawing sheets for individual part and assembly drawings can be viewed in section A-1 of the appendix.

A SolidWorks study has been performed to ensure operational safety and assembly efficacy. The threaded rods, washers, and nuts were removed for the study in order to simplify the model for FEA, finite element analysis. These changes can be visualized in section A-2 of the appendix. A fixed-point fixture was applied to each hole exits and roller slider fixtures were applied to all flat sidewalls. A pressure of 15 psi was placed in each of the two internal chambers. A maximum Von Mises stress of 14.92 psi was found and a maximum displacement of 0.001528 inches was found in the middle of outer plates. Due to the prototype material selection of ABS, a factor of safety calculation could not be completed at this time. It is important to note the limitations of modeling nonmetals with FEA. FEA relies on multiple factors that are not readily available with plastic materials. Temperature and yield strength are not as concrete of properties with plastics, so inaccuracies are expected. With that in mind, testing was done at a safe, low psi in order to limit failure during operations.

Newmont Testing Deliverables

The main and initial goal for both this design team and Newmont was to verify the efficacy and functionality of this prototype. After prototype completion, additional steps were taken to increase product workability. A sprayable rubber sealant was applied to the cavity of each part in order to both act as a gasket sealant and provide an additional layer to the unaltered 3D print. Even with a full infill, 3D prints contain many small passageways and channels for which a pressurized test would not work, not allowing a completely air-tight environment. Adding a sealant helped close up any microscopic holes and flaws in the 3D print. Additional post processing work took the form of drilling holes for filtered moisture to exit the device and further increase the size of the holes responsible for the fasteners, resulting in quicker setup and tear down, ultimately an increase in testing efficiency. With the original design along with the noted above changes the device was able to successfully operate and produce a filtered tailings cake. Similar moisture content results can be viewable in Figure 8 which suggest successful dewatering.

With prototype effectiveness demonstrated to Newmont, further tests were chosen to allow for verifiability and versatility. Each individual test the team performed and/or still plans on performing is as outlined below. Testing not fully completed during this project cycle is noted with a single asterisk and testing not begun is noted with two asterisks. Any results of the tests performed can be found within their appropriate section in project deliverables.

Particle Size Distribution (PSD) Test *

During the Intermediate Design review, it was anticipated that a sieve analysis would be able to take place for each of the tailing's samples on hand. It was quickly apparent upon the delivery of the samples that the PSD of all samples were far too fine to perform a sieve analysis. Instead, a hydrometer analysis needed to be performed.

This test was performed in accordance with ATSM Standard D-422 [2]. The purpose of this test was to analyze the particle size distribution of the tailings being fed through the model press and compare them to the moisture content achieved. By testing several different wet tailings samples and then performing a PSD test on each of the filter cakes, a correlation between cake moisture content and the respective grain size distribution could be made. The basic principle behind a PSD test is to use several different sieves with openings varying greater in size to smaller in size. Via the hydrometer method as well as Stokes' Law of settling particle velocity, a PSD curve can be synthesized, illustrating the gradation of the individual tailing's samples tested. From previously performed research during last semester's portion of the project, it was noted that tailings with excessive amounts of fine particulate matter tend to be more difficult to achieve a lower moisture content. By performing a PSD on each of the tailings samples the team dewaters, the team can verify this general predicted trend throughout the project via confirmation within our own results. Due to the time constraints caused by a lack of correspondence from CSM department heads, the team was only able to complete PSD testing for the two extremes of the MC testing results, one trail for the Nevada Gold sample, the coarsest and most dewatered, and one trial for the soda ash sample, the finest and least dewatered.

Moisture Content (MC) Test

This test was performed in accordance with ASTM Standard D-2216 and utilized the same equipment as specified in the detailed procedures section within the Appendix [3]. In correlation with the Particle Size Distribution test outline above, the purpose of a moisture content test was to determine how far the team's designed and fabricated bench scale filter press is able to dewater various mining tailing samples. Moisture content testing also provided insight on the effectiveness of the initial prototype, as one of the primary goals will be to achieve a moisture content of around 20-25% (typical of operational filter presses utilized by Newmont and other mining operations). Results for all moisture content testing were utilized to analyze correlations between particle size distribution and achievable filter cake dewatering.

Wet Tailings Sample pH Test

In addition to the ASTM Standardized tests outlined within this section of the report, the team performed initial pH testing and recording of the tailings samples that were ran through the prototyped filter press. By recording the initial wet tailing sample's pH prior to dewatering, an analysis on the effects of pH on achievable moisture content can be made and then compared between tailings samples. This testing will be performed through the utilization of a standard pH meter appropriately calibrated prior to testing. A second purpose of performing this test was to establish a record of integrity management, proving beforehand that each of the tailings samples the team planed on testing did not possess dangerously high or low pH readings.

Proctor Compaction Test **

The purpose of this test would have been to quantify each different tailing sample's optimum moisture content (OMC), thus allowing the team to compare the developed prototype press' achievable moisture content to each sample's MC with the most shear strength, stiffness, and minimum void ratio. It would be to be performed in accordance with ASTM Standard D-698 [4]. Ideally, all mechanical dewatering equipment would be able to achieve the OMC unique to each tailings sample. This would ensure maximum stability and strength of each dewatering tailings when dry stacking.

The main concern with performing this test within the scope of this project is the potential shortage of tailings samples necessary to accurately perform the test. Because an Optimum Moisture Content test involves dewatering, compacting, and testing multiple batches of filter cake each with varying moisture content (more wet to less wet), the team is concerned that there may not be enough of each sample available to perform the test without re-compacting the sample over and over again, which violates the explicit procedure within ASTM D-698 and is considered to be extremely poor practice. After discussion with Newmont personnel, it was decided that this test would be performed to the best of our ability, reusing tailings samples within different trails in order to ensure that some sort of results can be produced despite a limited amount of each sample. This means that any results produced will not conform to the ASTM standard. This has been authorized by Mr. Brett Byler of Newmont. After failing to receive correspondence from the CSM department heads responsible for allocating lab and equipment access during COVID-19, the team was unable to perform any proctor compaction testing this semester. It is the intend that such testing would be able to occur at a later date during the continuation of the project.

Atterberg Plastic and Liquid Limit Testing *

The purpose of this test was to quantify the liquid and plastic limits of each of the tailing's samples testing during the course of the project. The Plastic Limit was tested in accordance with ASTM standard D-4318 [5]. This involved mixing dry sample with water by hand until the sample achieves a putty-like consistency. The sample was then hand rolled into a cylinder until a specific diameter was achieved and the sample broke and crumbled. The appropriate results were recorded. After failing to receive correspondence from the CSM department heads responsible for allocating lab and equipment access during COVID-19, the team was unable to perform any liquid limit testing this semester. It is the intent that such testing would be able to occur at a later date during the continuation of the project. The Liquid Limit testing will be performed in accordance with ASTM Standard D-4318 via the Casa Grande method. This involves the use of a specialized brass percussion cup, dropping a liquified sample a specific number of times, recording the time taken for a disturbed sample to become evenly distributed again. These results will produce a Flow Chart which will ultimately quantify the given sample’s Atterberg Limits.

Project Deliverables

For this past semester, it was the Mechanical Dewatering Team's goal to move forward from performing additional research on the topic of dewatering, taking a hands-on approach, allowing the team to gain further technical insight into the industry itself. The team proposed and carried out the design, development, and fabrication of a functioning bench-scale filter press machine. Methodology such as three-dimensional modelling software (SOLIDWORKS) was utilized to created models of the prototype filter plates. The team then proceeded to fabricate the parts modelled via the Colorado School of Mines Maker's Society 3D printers. Next, the team proceeded to design and assemble the plate pressurization system. This involved the procuring of the necessary plumbing and fittings which allowed our prototype's design to implement both plate compaction as well as plate pressurization, something that not all bench scale filter press models possess. After the prototype was assembled, the next step was to test the machine and evaluate the performance according to the Key Performance Indicators (KPI's) set at the beginning of the semester, outlined within the Project-client Re-engagement letter sent to Newmont January 28th, 2021. Below within Figure 7 is an outline which illustrated the goals set and the respective outcomes associated with goal completion. The team was able to fully complete six of the eight goal categories established during the re-engagement process, with the remaining two categories (sample-specific testing and further prototype research and development) being the two categories that fell under partial completion.

In regards to the partial completion in sample-specific testing, the team found that establishing the necessary lab equipment access to perform the proctor compaction and liquid limit testing much more difficult than first anticipated. The team made several efforts to establish contact with Colorado School of Mines officials responsible for laboratory and equipment access. After initial conversation on borrowing equipment and workspace, the team was unable to receive any sort of further correspondence with lab department officials for almost three weeks. This meant that the team was unable to perform the proctor compaction testing or the liquid limit Atterberg testing, both of which required specialized equipment. Due to the time constraint caused by a lack of department response, the team only had enough time to perform two particle size distribution (PSD) tests via the hydrometer method. The decision was made to run testing on either end of the achieved MC results. This meant that PSD testing took place for the Nevada Gold Tailings samples and the Soda Ash samples. It is the team's intent to complete these outstanding tests in the semester to come.

The team was however able to achieve test results for both the moisture content achieved by the prototype as well as the plastic limit of the gold tailings samples provided by CSM and Newmont. Due to the extremely fine and 'slimy' nature of the Copper and Soda Ash samples provided, plastic limit testing could not be completed, as the samples failed to be rollable to the 1/8" diameter rods necessary within the ASTM standardized test which took place.

The team first experimented with both a course and a fine filter pad obtained from a home brewery kit. The course filter pads had openings which ranged from 5-7 microns, while the fine possessed openings listed as 1-2 microns. By first comparing the course and fine filter media results via dewatering trials which used the same Penasquito gold tailings sample, the team was able to determine which size filter media should be used for subsequent testing. As seen below within Figure 8, the course filter media pads achieved a significantly lower moisture content (~7%), despite being used multiple times prior to the comparison test. The second series of Moisture Content (MC) testing took place with brand new course filter media pads for each and every trial. This was done in an effort to maximize the prototypes dewatering capability and yield the most successful results when contrasted against the project goals outlined in Figure 7. Two sets of testing with brand new media were performed. The first round of testing was performed such that the machine was ran until there was no more water that could been seen visibly excreting from the drainage holes. This time frame was labelled "Time to No Water". Next, a second run was performed in which the time the machine was ran for was two times the "Time to No Water". The two series of achieved MC's were then compared to one another, outlining how cycle time most definitely affects the MC the prototype is capable of achieving. By allowing the machine to run for "2X Time to No Water", the prototype designed and fabricated within this semester was able to achieve MC's within the ~20-25% range established within the project goals for both gold tailings samples. The teams prototype and selected filter media had a more difficult time filtering the Copper and Soda Ash tailings provided, as outlined in Figure 8. Besides the outlined MC results, Figure X also outlines the measured pH of each sample's slurry prior to dewatering. No correlation between achievable MC and pH could be determined. Each of the sample's tested did not possess an unsafe pH level, preventing the team from safely conducting testing.

MECHANICAL DEWATERING TEAM - SEMESTER 2 PROJECT GOALS			
Goal:	Completed?		
	Yes	No	Partial
Gain feedback from Newmont on proposed path forward.	☑	☐	☐
Compile and organize IDR based on re-engagement meeting and the preliminary proposed prototype design.	☑	☐	☐
Design Bench scale filter press utilizing Re-engagement meeting feedback on initial design ideas.	☑	☐	☐
Physically fabricate the designed prototype through the use of the Design laboratory, machine shop and any other available resources.	☑	☐	☐
Test the developed prototype and correct the necessary issues preventing the press from effectively dewatering tailings to a MC ~20-25%.	☑	☐	☐
Utilize the design to run tests on multiple tailings samples. Run MC, PSD, LL/PL, and Proctor Compaction tests on the produced cakes (Better understand tailings characteristics-specific performance).	☐	☐	☑
Compile and organize FDR based on test results from the designed prototype filter press	☑	☐	☐
(TIME PERMITTING) - Modify and improve prototype with the goal of achieving the lowest possible MC.	☐	☐	☑

Figure 7: Project Goal Outline and Attainment Matrix

	Colorado School of Mines - Capstone Design	Date: 3.20.2021
	Newmont Design Studio - Mechanical Dewatering Team - Moisture Content Test Results	

Course vs. Fine Filter Media Comparison

Tailings Sample	Time to No Water	M1 (g)	M2 (g)	M3 (g)	MC (%)
Penasquito - FINE MEDIA	1:04	184.66	239.13	225.16	34.49383
Penasquito - COURSE MEDIA	1:39	183.99	241.91	229.27	27.91519

Tailings Sample	Time to No Water	M1 (g)	M2 (g)	M3 (g)	MC (%)	Slurry pH
Penasquito	1:44	1.68	19.17	14.67	34.64203	6.97
Nevada Gold	1:41	1.46	28.88	22.7	29.09605	7.85
Copper	1:41	1.27	24.62	15.71	61.7036	8.5
Soda Ash	1:33	1.31	19.33	12.84	56.28794	8.2

Tailings Sample	2X Time to No Water	M1 (g)	M2 (g)	M3 (g)	MC (%)	Slurry pH
Penasquito	3:28	1.27	25.11	20.5	23.97296	6.97
Nevada Gold	3:22	1.58	40.94	34.6	19.20048	7.85
Copper	3:22	1.28	18.46	12.56	52.30496	8.5
Soda Ash	3:06	1.31	23.41	15.31	57.85714	8.2

Plastic Limit Test Results

Penasquito:

	Can 1	Can 2
M1 (g)	1.31	1.31
M2 (g)	5.98	7.18
M3 (g)	5.07	5.99
PL	24.20213	25.42735

Average = 24.81474

Nevada Gold:

	Can 1	Can 2
M1 (g)	1.29	1.34
M2 (g)	6.94	7.35
M3 (g)	5.38	5.63
PL	38.14181	40.09324

Average = 39.11752

Figure 8: Moisture Content and Plastic Limit Test Results

The team had the opportunity to compare one set of test results with another report performed by Mr. Christopher Bareither from Colorado State university. Mr. Bareither performed different soil mechanics testing than the team did, however results such as the Plastic Limit testing results could be compared, as both projects produced this specific set of results. Below within Figure 9 is a comparison of the Plastic Limit (PL) results obtained within the Team's testing as well as Mr. Bareither's testing. Differences between the two results can be attributed to the fact that our team synthesized data from a small sample size when compared to Mr. Bareither. The Team was provided one single pail of Penasquito tailings, whereas the study performed by Mr. Bareither utilized multiple pails, thus increasing the overall sample size.

Penasquito Gold Tailings - Sample Plastic Limit Test Results	
Borja and Bareither, 2020	CSM Mechanical Dewatering Team
20%	24.8%

Figure 9: Penasquito Sample Plastic Limit Result Comparison [1]

The next test that was performed was the PSD testing via the hydrometer method. Due to time constraints, the team performed this test on the sample that the prototype dewatered the best (Nevada Gold Sample) and the worst (Soda Ash Sample). This was done in an effort to confirm the suspicion that the Soda Ash had a much finer PSD, thus inhibiting the prototype from performing as effectively as it did on the gold tailings that were tested. INSERT HYDROMETER RESULTS AND DISCUSSION HERE

With respect to future areas of concern, the team foresees continued issues with the current prototype's dewatering capabilities when processing materials with similar characteristics as the copper and soda ash tailings tested this past semester. Specifics include a continued struggle to achieve moisture contents lower than the observed values within this past testing cycle (see Figure 8). These areas of concern could be addressed via further experimentation with varying filter media as well as different cycle times and pressurization limits.

Next Steps and Project Management

With the successful creation of a prototype and various tests completed to ensure operational effectiveness and workability with a multitude of tailings, the question of what comes next is inevitable. With Newmont's approval, the project can be taken in a variety of directions dependent on the team available next semester. An influx of civil engineering students would be beneficial in the continuation of previously outlined testing and further refinement through analysis of various tailings samples. Alternatively, an influx in mechanical or design engineering students would allow the project to take look into improving set up time or investigate changes to design to improve performance. Each case will provide Newmont with new and valuable information on this project. Below outlines potential sources to investigate in each scenario during the next semester. It is also important to note that overlap between the two scenarios is highly possible and even likely.

Continuation of Testing and Prototype Refinement

With the addition of new members from the civil engineering department, testing will be able to smoothly resume next fall. Completion of the tests outlined above will provide information to Newmont about the effectiveness of this dewatering system as a bench scale model for a variety of different tailings. Additionally, working with actual dewatering filters and potentially trying higher pressure tests, while keeping within a safe limit, will be able to provide further insight on the success of this prototype.

The results of these tests will also reveal how effective the prototype is with different tailings based off of particle size, acidity, and even maximum achievable moisture content. Complete results will also provide additional data to work off of for prototype refinement, allowing for further refinement to be made to the design.

Operational Improvement and Prototype Refinement

With the addition of new members from the mechanical or design engineering department, further work could be completed in either operational design or prototype plate design. With the initial round of testing completed, potential ways for the prototype to be refined have been noted during the development process. Due to the relatively long lead time required to fabricate a prototype, a few of these options could be investigated in the fall. Implantation of an alternate linking system between the plates would be valuable to decrease tailing loading and unloading time. Investigating prototype scalability or the implementation of the prototype in Newmont facilities could provide insight on the onsite application of this design. Changes to materials, either to the plate or gasket material could further improve the effectiveness and increase the ability to achieve the desired moisture content. Changes to the prototype design could be an effective way to increase the functionality of the design. Investigating working with a sloped inner cavity, locational change of pressure inlet and exit, or reducing the size of the inner cavity would be interesting topics to investigate. Similar to the above section, the prototype should be further refined with additional information and input from new team members.

Budgeting and Capital Considerations

Budgeting required for these objectives to be met should be limited. As the prototype is functional as it stands, with testing equipment available from school facilities at no charge, the bulk of money spent next semester will go towards resupplies of filter pads, which are inexpensive but specialized and limited in the number of trials they are useable for. Additional expenses could embody design alterations to the prototype; likely inexpensive, but necessary in furthering the design. With this semester's generous budget still largely unscathed, it is believed that the above goals could be undertaken in the fall with no further budgeting from Newmont. This semester's budget overestimated for the money required for the prototype by a sizable margin, allowing for a comfortable working environment with few functional limits on the design, and more room for improvements in the future.

These improvements will serve to 'round out' the final deliverable of this project, which has evolved since its inception; a handheld, 'field usable' dewatering press that can effectively predict results of full-scale dewatering for preliminary site investigations. Minor improvements to the existing design, such as tweaks to improve cycle time and batch reliability, shall represent the next steps to be taken in the project's development, and the final ultimate tasks to be undertaken to meet Newmont's current project scope.

Lessons Learned

In moving from a ‘paperwork’ oriented project to a ‘lab work' project this semester, the learning curve sharpened significantly. Perhaps the biggest group takeaway from this semester’s activities was the utmost importance of anticipating supply line delays; shared between ordering, stocking, and shipping losses. Time spent waiting for materials to be processed, shipped, and delivered to campus accounted for roughly 20% of project delays, second only to time allocation concerns.

When it came to organizing time slots for lab, tool, and skill usage, almost three full weeks were lost in March due to communication disruptions and lab capacity concerns. In the future, it is of the utmost importance that lab usage be organized upfront, weeks, if not months, ahead of schedule. Of course, COVID-19 contributed massively to these delays, as lab capacity and tool usage was limited inherently with the partial shutdown of campus. While these concerns will likely not be present in the future, the lessons and takeaways they presented shall not go unheeded for later project work.

Both of these trouble sources, accounting for most of the non-trivial issues encountered by the group this semester, can be mitigated in future by more thorough and more far-reaching planning up front. Group planning in January was somewhat hurried, due to the limited time and a looming schedule. Next semester, it is the group’s goal to dedicate at least a week up front to detailed, scope encompassing planning in enough depth to plan lab usage, material orders, and potential sources of delay up front. Luckily, this will also allow for more in-depth brainstorming, and better plan development in the long term. Armed with knowledge from this semester, and a possible influx of new insight with next semester's team recruits, supply and timing related issues with further testing and prototype development are expected to be limited.

Appendix

A-1: SolidWorks Drawing Package

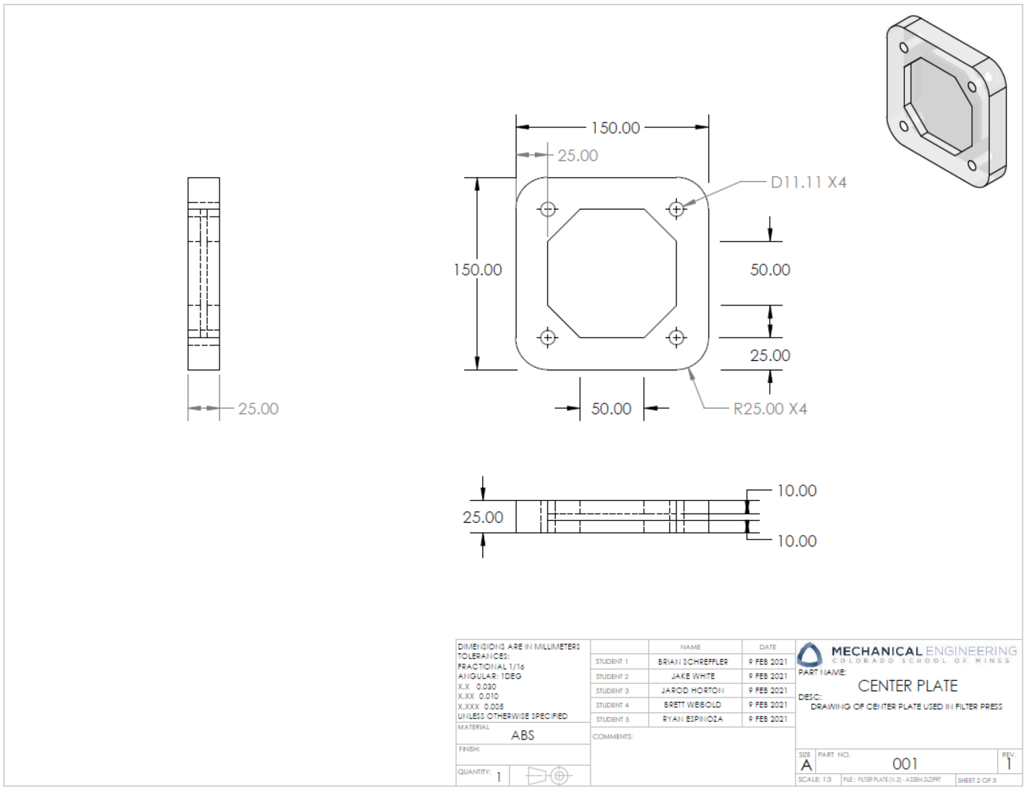

Figure 10: Center Plate Drawing

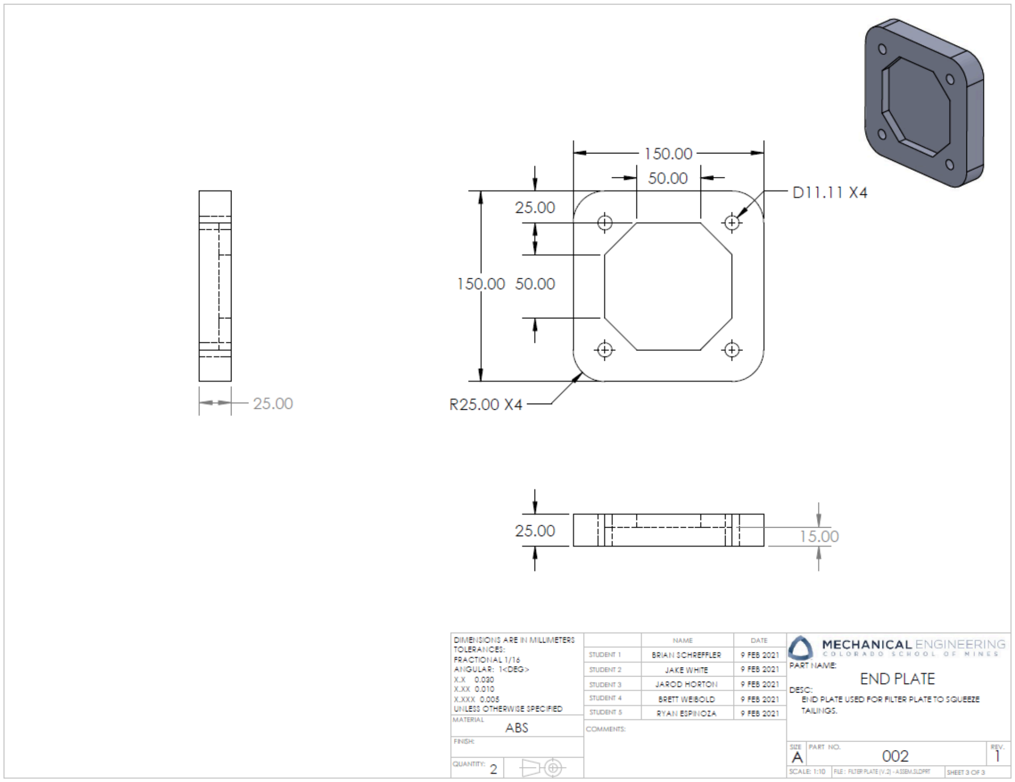

Figure 11: End Plate Drawing

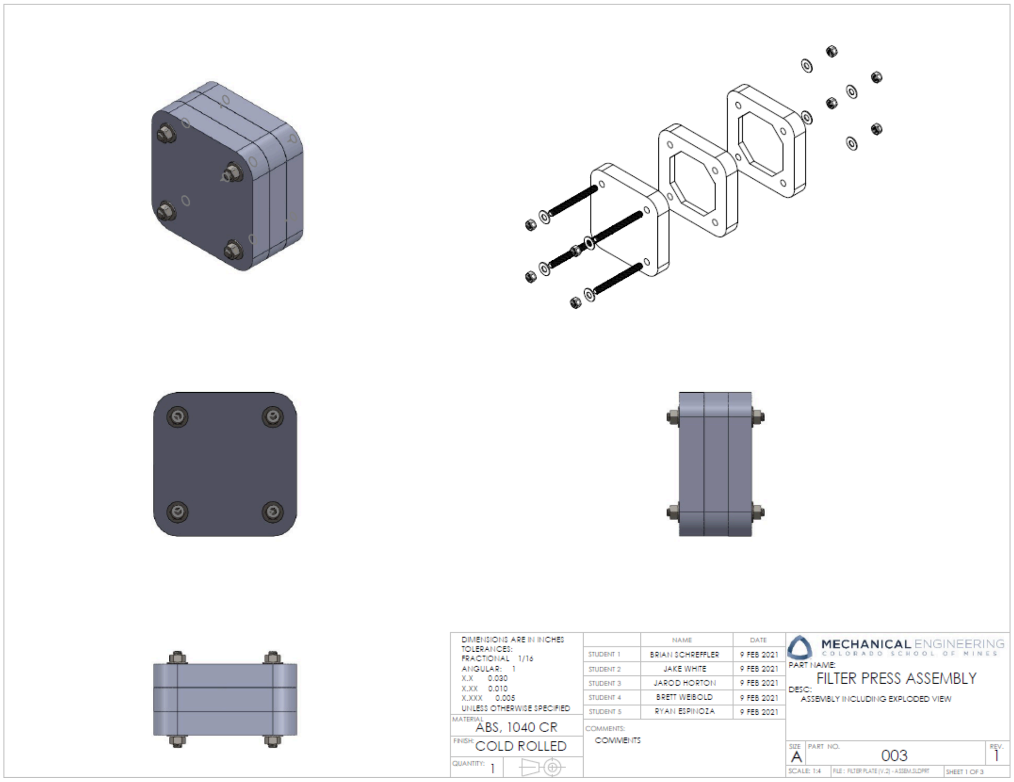

Figure 12: Assembly Drawing with Exploded View

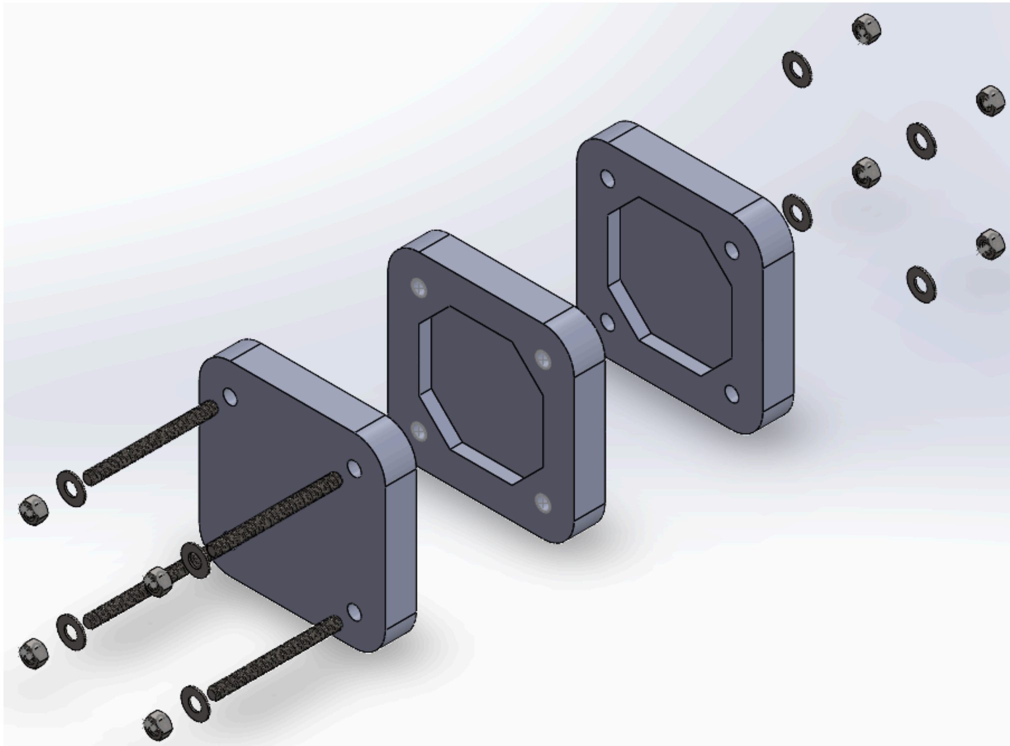

Figure 13: Prototype Exploded View

A-2: SolidWorks Finite Element Analysis Results Package

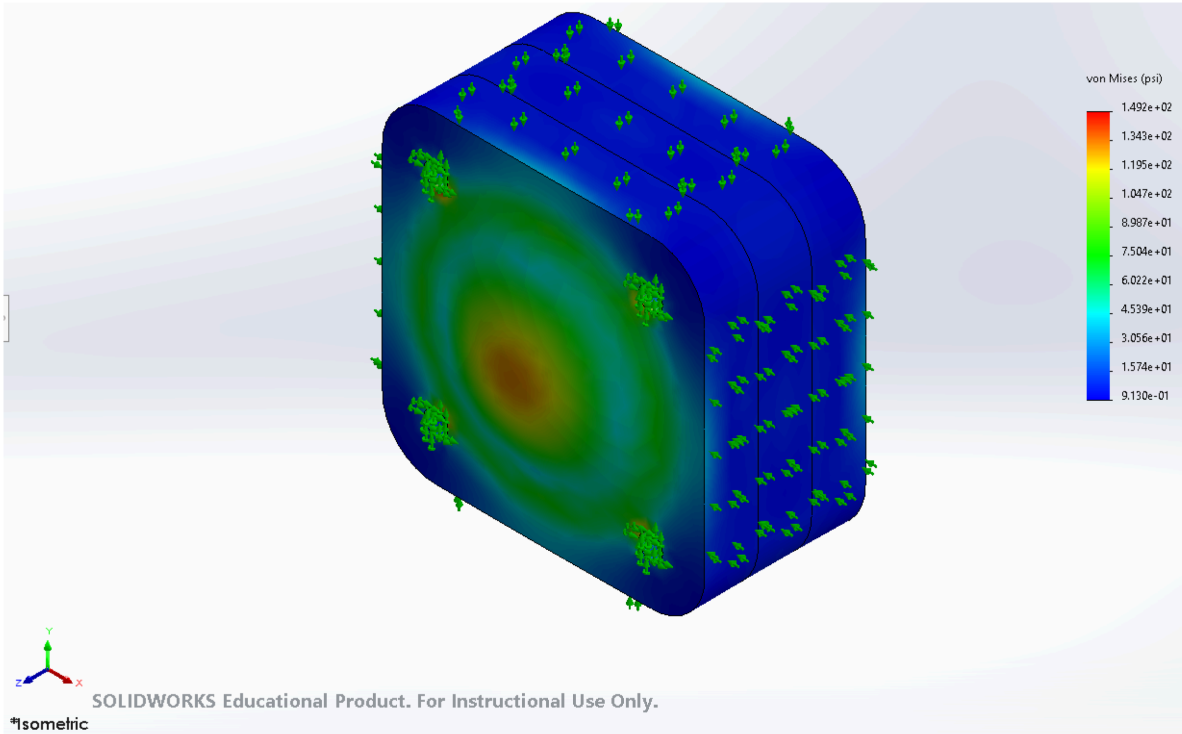

Figure 14: Prototype Von Mises Stress Distribution

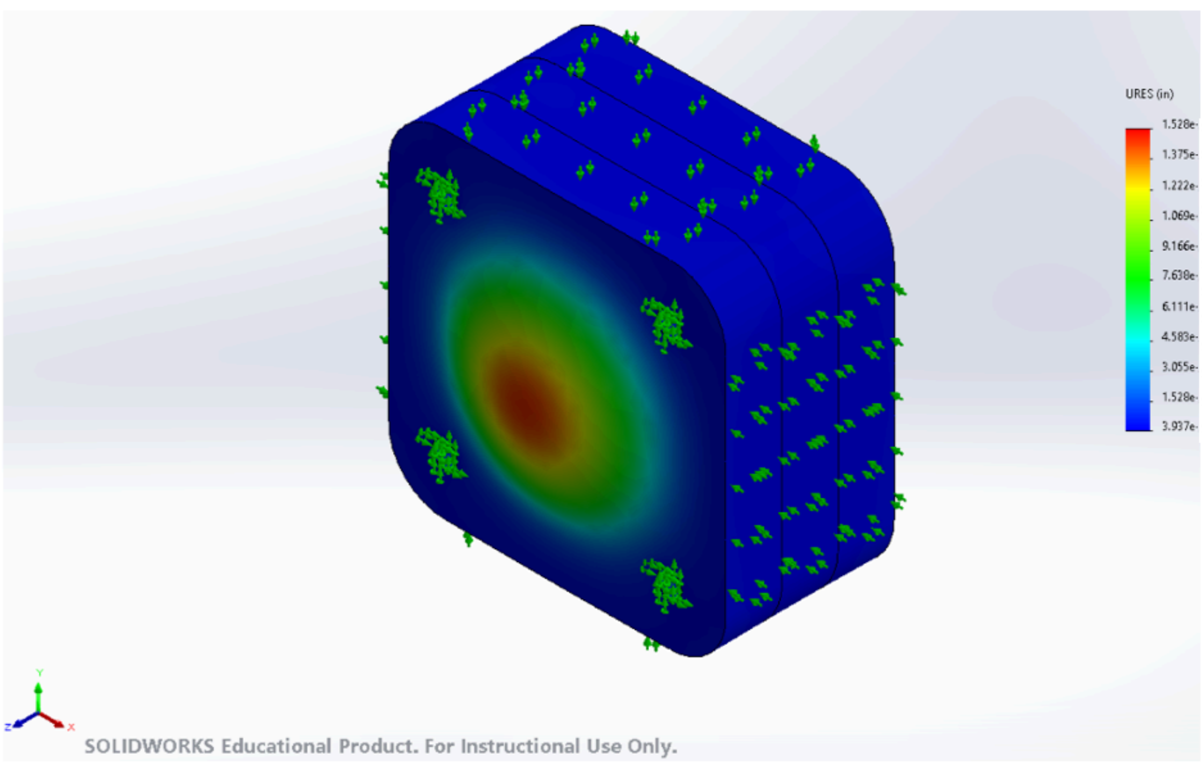

Figure 15: Prototype Displacement Results

A-3: Work Cited

[1] Bareither, C., & Borja, R. (2020). Shear Behavior of Waste Rock and Filtered Tailings Mixtures. *Geo-Congress 2020 GSP 318*.

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[4] ASTM D698-12e2, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3)), ASTM International, West Conshohocken, PA, 2012, www.astm.org

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