Chemical Stabilisation of Bauxite Tailings

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Red mud is the waste produce from the production of alumina from bauxite through the Bayer process. The chemical properties of red mud create an environmental hazard, subsequently causing a significant challenge for mining companies in red mud’s large scale transportation and storage. These challenges are currently the source of great expenditure and risk for mining companies and the focus of considerable attention by environmental protection agencies. The aim of this project is to continue the development of a solution to the transportation and storage issues red mud presents. The motivation for this investigation is to develop a mix design which is easily handled and requires less onerous storage methodologies. The intended mix design would also allow for investigation into further uses as a replacement material. Two red mud mixes were tested using mix designs that have previously been developed. The methodology for this investigation was to firstly verify the results achieved previously on an unsoaked sample of red mud, through the proctor compaction tests and permeability testing. The second part involved the testing of soaked red mud samples using the same methodology in order to verify differences between the red mud samples. The testing produced results that achieved lower than expected specific gravities for both mix designs. This was the source of further investigation into the moisture content properties of the mixed samples which also may account for expected variations in the permeability of each sample. This investigation has produced a mixing methodology for red mud samples to produce a consistent mix design for the reproducibility of these tests, and has established further paths of investigation into the performance of mixed red mud samples and their application to the solution of storage and transport challenges presented by red mud.

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1 Lieutenant, School of Engineering & Information Technology. ZEIT4500/4501
I. Introduction

Red mud is produced as a waste product through the refining process of alumina ore (bauxite) to alumina. The four stage Bayer process was developed in 1892 and has been refined continuously through the 20th century to increase efficiency and reduce costs. Red mud is so named due to its colour from its high iron oxide content and texture.

For 1 tonne of alumina to be produced, between 1.9 tonnes and 3.6 tonnes of bauxite is required; the amount of ore required is site dependant based on the quality of the bauxite [15]. As of January 2013, world bauxite production stood at 248 million tonnes of which Australia produced 28.2%. World production of alumina stood at 82.1 million tonnes of which Australia produced 22.8%. For every tonne of alumina produced, between 1 and 1.6 tonnes of red mud is disposed of. Current production of alumina therefore sees annual impoundment figures of 120 million tonnes. 2011 estimates determined approximately 2.7 billion tonnes of red mud exist in storage worldwide [21].

It can be seen from the above statistics that red mud presents a challenge, both for Australian and international mining companies. The properties of red mud that will be discussed in the literature review present a substantial challenge both for the storage and transport of red mud. Storage is achieved through several methods; firstly, the lagoon type disposal is a large lake of red mud and accounts for about 25% of global impoundment. The method of disposing red mud into the sea has been reduced to 15% of global impoundment over the last decade with significant environmental impacts occurring as a result of this. The final and increasingly popular method is the dry stacking storage of red mud which accounts for 60% of global storage.

The transport of red mud also presents a great challenge because of the sticky and caustic nature of raw red mud; special trucks are required to be able to move the red mud. Other methods include pumping high moisture content, low solids content red mud to the disposal site; however this method requires many pumps in series to produce the required head to displace the red mud to the storage site. The final method is using a conveyor belt to move the red mud however this requires the mud to be treated to low moisture content before it can be successfully achieved.

There is currently a growing body of groups and individuals studying and developing methods for the use, treatment or improvement of red mud and current industrial practices. Previous work along this theses line of investigation involved developing mix designs which improved the strength properties of red mud by Pacione 2012. It was found that the addition of fly ash in quantities of greater than 30% of the final mix design produced a grainy and sand like material that whilst it did not meet the strength goals of Pacione’s investigation, produced a material that displayed improved handling and storage properties. A subsequent investigation was conducted by Svenson 2013 into the storage and handling properties of stabilised red mud using mix designs of greater than 30% fly ash. This thesis will continue the investigation into the storage and handling properties of two red mud mix designs.

II. Project Outline

This section will outline the aims of this thesis and the significance of the investigation to the red mud problem and field of research.

A. Aim

The aim of this thesis is to continue the development of a solution to the transport and storage issues that red mud presents. The outputs will see a mix design and a procedure developed that will allow the production of a chemically stabilised red mud mix, and a quality assurance template including quantitative and qualitative checks to facilitate the reproducibility of the stabilised red mud.

B. Significance of Work

This thesis will contribute to the body of groups and individuals studying the red mud problem and developing solutions for it. The outputs from this thesis will allow for a methodology to produce stabilised red mud that is easily handled and stored. This will allow individuals conducting further investigation into the problem to reproduce the mix that has been created and deemed effective. Subsequent testing on this mix design can be conducted, as well as further investigation into the applications of this mix design as a replacement material for inclusion in products such as bricks and concretes.

III. Literature review

The literature review will address previous investigations into areas of the red mud problem. It will outline the chemical and physical properties of red mud which account for the issues of the various storage and handling techniques for red mud. The review will then discuss contemporary investigations into solutions to these issues and outline the properties of the additives for the mix designs to be used during this investigation.
A. Red Mud

The Bayer process is a four stage process which utilises the caustic concentrated sodium hydroxide to digest the bauxite at 270°C. The removal of the red mud from the process occurs during the second stage, called the ‘clarification’ stage in which the heated solution is flushed to atmospheric pressure. The undissolved solid impurities (red mud) then settle at the bottom of settling tanks and the finer impurities are captured through the addition of flocculating agents and removed by filtration. The entire red mud residue is washed prior to discarding as a waste product to the process [15, 2]. It is this washing and filtration step that is important in the determination of the disposed red mud’s moisture content. The objective of the process is to dispose of a red mud with as low moisture content as possible. Modern refineries typically use high rate (deep cone) washing systems which can develop a solids content to 50% - 55%, as well as vacuum filter or pressure filter producing solids contents of 50% - 65% and up to 70% respectively. An emerging technology that is being tested on large scale operations is the hyper baric filtration which can achieve a red mud product with a moisture content of 23% [9].

The red mud disposed from the process is highly alkaline with a pH of 10-14. The specific gravity of red mud is between 2.6 -3.5 tonnes/m³ and depending on the bauxite source, particles greater than 106µm are between 1% and 50% of the red mud composition, however a typical value is 5% and 80% of the particles in red mud are less than 10µm. Pacione identified the grading properties of the Red Mud samples used in this thesis. The sample 1 red mud had a moisture content of 80.5% and a composition of 50% clay, 48% silt and about 2 % fine pebbles. It had a liquid limit of 86% and plastic limit of 46% and a plasticity index of 40%. Sample 2 had a natural moisture content of 42% and contained 43% clay, 22% silt 23% sand and about 13% fine pebbles. This sample had a liquid limit of 49%. This accounts for the thixotropic behavior of red mud with a moisture content of greater than 28%. This is easily observed when the red mud is handled, as when a slight shear stress is applied, the mud displays decreasing levels of viscosity. It is this property that explains the poor ability of red mud to withstand stress and the difficulty of storage of the mud over a confined area.

An XRF machine analysis performed by Pacione produced the elemental breakdown of the two samples to be mixed during this thesis as seen in table 1. Sample 1 was ‘as disposed’ of red mud, obtained from the disposal site at Weipa, QLD. Sample 2 represents the red mud that has been soaked using seawater soaking at the disposal site, and it is this sample that was tested during part II of the thesis experimentation.

![Diagram of Bayer process](image_url)

**Figure 1. Removal stage of red mud from the Bayer process (left) and the governing equations (right)**

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<table>
<thead>
<tr>
<th>Red Mud Sample 1 (%) by weight</th>
<th>Red Mud Sample 2 (%) by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>63.678</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>12.340</td>
</tr>
<tr>
<td>SiO₂</td>
<td>10.360</td>
</tr>
<tr>
<td>TiO₂</td>
<td>6.750</td>
</tr>
<tr>
<td>CaO</td>
<td>3.295</td>
</tr>
<tr>
<td>BaO</td>
<td>2.194</td>
</tr>
<tr>
<td>SO₃</td>
<td>0.974</td>
</tr>
<tr>
<td>MoO₃</td>
<td>0.220</td>
</tr>
<tr>
<td>Cr₂O₃</td>
<td>0.189</td>
</tr>
</tbody>
</table>

**Table 1. Red mud sample element analysis results from XRF analysis. (Pacione 2012)
B. Storage and Handling Methods

The disposal of red mud requires the displacement of the mud from the alumina refinery, to the disposal site. Due to the sticky and caustic nature of red mud, there is a high maintenance liability on the machinery involved, and there is the requirement for unique machinery to deal with these properties. Special trucks are required to be able to move the red mud. Other methods include pumping high moisture content, low solids content red mud to the disposal site; however this method requires many pumps in series to produce the required head to displace the red mud to the storage site. The final method is using a conveyor belt to move the red mud however this requires the mud to be treated to low moisture content before it can be successfully achieved.

The storage of red mud at the disposal site takes several forms. The first type of storage method is the lagoon type disposal, essentially a large lake of red mud as seen in figure 2. The depth of these lagoons has been reported to be anywhere between 6-25m. In the 1970’s, this method accounted for 70-80% of red mud disposal, however by 2008, this figure was reduced to 25%. Prior to 1960, no sealing layer was provided beneath the mud, with the base layer of mud providing the seal. This led to seepage of caustic liquors into the water table which is an environmental hazard. The use of clay beds up to 400mm thick have been introduced, however it has been determined that the caustic liquors react with the clay over a long period of time, increasing the hydraulic conductivity of the clay bed and inevitably risks contamination of the water table [9]. A negative of this method of disposal requires strong retaining walls to hold the lagoon. On October 4, 2010 in Hungary, a catastrophic failure of one of these retaining walls released 1.9 million m³ of red mud which flowed through a small valley, killing 10 people and seriously injuring 120. The cleanup bill for this was €115 million however Hungarian Aluminium (MAL) were fined €451 million. This is one example of why there is a necessity for finding alternate storage, transport or use solutions for red mud [26].

Disposal of Red mud into the sea has been used in the past, with sea water successfully neutralising the caustic nature of red mud, however due to environmental impacts this method has been reduced significantly over the past decade. It was hypothesised that by pumping red mud to the bottom of the ocean as a large body, only the outer shell of the red mud would react with the seawater. As of 2008, disposal of red mud into the sea accounted for 15% of disposal methods. Whilst this practice has been reduced, the use of seawater in neutralising the caustic content of red mud has continued. The Queensland Alumina Limited (QAL) refinery, which this project is using for the red mud samples, uses seawater in small quantities to neutralise the caustic liquors reducing the pH of the red mud from pH 14 down to pH 8 [24]. Following this, the seawater is treated with concentrated sulphuric acid prior to being released back into the ocean. Approximately 0.05 L of sulphuric acid is required per 1000 L of red mud [23].

The other storage technique for red mud is that of dry mud stacking which accounts for 60% of world wide storage solutions. This process has been continuously developed since the 1940s and up-to-date systems achieve a solids content of approximately 72% and the highest reported mud stack is said to be 50m [9]. This process can be seen in figure 3. At the base, a compacted clay liner of 600mm thickness on which a plastic geomembrane made of HDPE is placed. This provides the sealant layer to prevent seepage into the water table. Like in a landfill system, this sealant layer can be replaced using a geosynthetic clay liner. Using the dry mud stacking system, the red mud is hardly permeable for any rainfall.

C. Contemporary Research

There is currently a growing body of groups and individuals studying and developing methods for the use, treatment or improvement of red mud and current industrial practices. A report conducted by ACC Limited, an Indian cement manufacturer, identifies several methods of red mud usage in several cement designs at a low scale additive. ACC Ltd also shows red mud’s ability for usage in ceramics, bricks and composites, and the
potential for the extraction of metals from red mud. The final usage identified was in catalysis in a range of chemical processes [23]. A study conducted by Tsakiridis et al. reiterates the findings by ACC in the use of red mud as a raw meal additive for Portland cement production in low quantities with no adverse effect on the quality of cement produced [29]. Other work conducted by E. Kalkan identified the potential for red mud to be used in the stabilisation of clay liners used for geotechnical purposes through increased compressive strength and reduced permittivity of tested mix designs [19]. These findings have all been accomplished in labs and small scale plant and not replicated on a macro level and as such do not provide a complete solution to the red mud problem.

Research conducted by G. Banvolgyi et al. cites several emerging technologies that are being used to deal with the red mud problem. One is the use of hyper-baric filtration in the clarification stage of the Bayer process, prior to release for disposal or use. This process obtains a red mud cake of moisture content between 23-25%, making it a crumbly and easy to handle material. This technology already exists in the handling of bauxite slurry prior to refining, and is being trialed in pilot stage at several sites around the world [9]. Partly neutralised red mud is another development that has increased in prevalence over the last 20 years, through the use of various neutralising agents like sea water or gypsum. The resulting red mud has a high acid neutralising capacity, high cyanide and toxic heavy metal trapping capacity and is no longer hazardous [9]. This has led for red mud to be successfully used in the treatment of various industrial pollutants and is in use at a commercial or trial scale. Finally, the Improved Low Temperature Digestion process, a developing method of the initial bauxite digestion provides a range of beneficial red mud chemical compositions that allow for more favourable usage opportunities and more environmentally sustainable disposal [9].

C. Klauber et al. identifies four important measures in determining the success of a solution for red mud. The first being a consideration of the volume of red mud currently in storage globally. A successful solution will consume a lot of red mud for minimal resource commitment. The economic and quality performance of the solution product must be such that it is competitive with existing resources available to customers and for equal or less cost and risk [21]. The third measure is that of cost, and the indication that due to limited progress on the red mud problem, there is not yet an economic case for a solution. Therefore any proven successful technique must provide economic benefits to implementation or its inception is unlikely. The final measure is that of risk, be it health, safety, environmental or corporate risk must be considered [21].

D. Mix Additives

1. Fly Ash

As a part of the mix designs, fly ash made up a significant proportion. Fly ash is the residue from coal combustion and is considered an industrial waste product and environment pollutant. Global estimates state that about 500 million tonnes of fly ash are produce annually. Global use of fly ash range from 100% in some countries to less than 50% in developing countries. There are currently several common uses for fly ash such as a soil additive improving the properties of soil, roadway construction, and the replacement for some Portland cement in concrete production [28].

The main chemical constituents in fly ash are; SiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$, and CaO. Fly Ash also consists of particles with diameters ranging from 2μm to 10μm and the average specific gravity for fly ash is approximately 2.3tonnes/m$^3$.

Investigation by Pacione found that greater than 30% by weight fly ash in a mix with red mud would produce a grainy and sand like material. When added with lime and water, fly ash forms a cementitious composition [27].

2. Additive H

This additive will be discussed further in the final thesis deliverable; however it is cheap and produced on a large scale for a range of niche and industrial uses. As a result of Pacione’s investigation it was determined that this compound produced a much better performing material than additives such as soda ash and gypsum.

IV. Experimental Method

This section will outline the processes used in this study in order to achieve the results. As an output for the project specific deliverable, a quality assurance template will be provided for the reproduction of the red mud material produced during this study. The testing conducted occurred in two parts. Part I was the verification of the results achieved by Svenson conducting the modified proctor compaction test and the falling head permeability test. These tests were conducted on the sample 1 red mud to allow for comparisons with results from part two. Part II was the replication of the testing however on sample 2 red mud. Also occurring during this part was the development of the quality assurance templates to ensure the mixed materials could be accurately reproduced. This would facilitate future investigation of the material is uses such as its use in bricks and concrete production.
A. Mix Designs

The mix designs used to produce the test samples were identified during the testing Pacione conducted. Mixes 13 and 15 were unable to be tested for strength because they produced grainy and sand like product. This was further investigated by Svenson using the same mix design. The two mix designs through percentage by weight are identified in table 2.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mix 13</th>
<th>Mix 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Mud</td>
<td>56.8</td>
<td>57.2</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>43.2</td>
<td>34.3</td>
</tr>
<tr>
<td>Additive H</td>
<td>8.5</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Mixes 13 and 15, percentages by weight

B. Testing Method

1. Mixing

The methodology that was used to produce mixes for testing and a quality assurance template that will determine whether the mix has met the required will be provided in the final deliverable of the thesis program.

2. Modified Proctor Compaction Test

Following the mixing, the mixed red mud was air-dried such that the moisture content would be below that at which it would be tested at. After this, water was added to the mix and left to sit for 48 hours in order to allow the moisture to be fully absorbed by the mix. A range of moisture contents were tested to determine the maximum dry density.

The Proctor Compaction tests were conducted in accordance with AS1289.5.2.1 – 2003: Soil compaction and density tests-Determination of the dry density/moisture content relation of a soil using modified compactive effort. Table 3 outlines the apparatus’ and dimensions used for this testing.

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mould A: 105 mm diameter</td>
<td>1000 ± 15</td>
</tr>
<tr>
<td>Nominal volume, cm³</td>
<td>4.9 ± 0.01</td>
</tr>
<tr>
<td>Rammer: mass, kg</td>
<td>5</td>
</tr>
<tr>
<td>Number of layers</td>
<td>25</td>
</tr>
<tr>
<td>Blows per layer</td>
<td>2703 ± 60</td>
</tr>
</tbody>
</table>

Table 3. Dimensions and tolerances for mould and rammer used during modified proctor compaction test. (AS1289.5.2.1-2003)

The total energy input of the compaction used during testing was 2703 kJ/m³ was achieved using a total of 125 blows over 5 layers. Literature about the broons impact roller states that one pass of the machine can achieved a bearing pressure of approximately 2200 kJ/m³ [8]. Typical construction methods utilize vibratory rollers that compact lifts of 300mm using several or more passes. Therefore the results achieved during this testing is below that of what could be achieved using the greater compactive effort available in the construction industry.

3. Permeability Testing

The permeability testing was conducted in accordance with AS1289.6.7.2: Soil strength and consolidation tests-Determination of the permeability of a soil-Falling head method for a remoulded specimen. The samples tested were in their as mixed condition for moisture and composition.

C. Further Investigation

During the conduct of the modified proctor compaction test, it was identified that the specific gravity of the compacted material being achieved was below that expected, based on the specific gravities of the red mud and the additives. It was subsequently decided to explore the moisture retention properties of the red mud. This required defining the two types of water that was being investigated. The first was the ‘mobile’ water that was retained by the soil however could be moved by static effort. The second type of water was that which most likely was adsorbed to the mix material and for the purposes of this investigation named ‘locked’ water. This locked moisture required greater thermal effort during the stage of determining the moisture content of the soil. It is hypothesised this moisture had been ‘locked’ to the material through chemical reactions or electrostatic interactions.
The importance of identifying this was that the mechanical properties of the material result from the mobile water. The locked water does not impact on the mechanical properties of the soil however, because it replaced the volume that could have otherwise been occupied by material of high specific gravity, would ultimately lower the specific gravity of the compacted material during the testing.

Figure 3 shows the method used to determine the degree of adsorption of the water added to the mixes.

Figure 3. Method of determining mobile and locked moisture content of soils.

V. Results

This section will outline the results that were achieved during part I and II of the investigation. At the time of writing, the results from the permeability and the moisture testing were outstanding; however the results achieved by Svenson will allow a discussion of the expected results, particularly surrounding the saturated structure of the two mix designs.

A. Part I

1. Modified Proctor Compaction Test

The results are displayed in table 4.

<table>
<thead>
<tr>
<th>Mix</th>
<th>Modified Maximum Dry Density ($\text{tonnes/m}^3$)</th>
<th>Modified Optimum Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>1.46</td>
<td>29-30</td>
</tr>
<tr>
<td>15</td>
<td>1.23</td>
<td>33-34</td>
</tr>
</tbody>
</table>

Table 4. Modified Proctor Compaction Test results for part I

2. Permeability Testing

The permeability testing is ongoing and the full results and discussion will be included in the final deliverable.

B. Part II

1. Modified Proctor Compaction Test

The results are displayed in table 5.

<table>
<thead>
<tr>
<th>Mix</th>
<th>Modified Maximum Dry Density ($\text{tonnes/m}^3$)</th>
<th>Modified Optimum Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>1.55</td>
<td>27-28</td>
</tr>
<tr>
<td>15</td>
<td>1.30</td>
<td>35-40</td>
</tr>
</tbody>
</table>

Table 5. Modified Proctor Compaction Test results for part II

2. Permeability Testing

As for part I the permeability testing is ongoing and the full results and discussion will be included in the final deliverable.

3. Moisture Content Investigation

The investigation into the moisture contents of the mixes is ongoing however the initial results indicate there is a significant degree of ‘locked’ water existing within the mixed materials. These results will be further discussed in the final deliverable

VI. Discussion

This section will discuss the results and observations made so far during the testing. It will outline the observations made about the performance of red mud, particularly through the mixing period, and the results
obtained from the modified proctor compaction tests. It will also discuss expected results for the permeability tests and the reasons for this.

It was identified early on that red mud was very sensitive to the mixing procedure that was used on it. Initially, mixing was conducted by adding the red mud and the additives to the mixing bowl all together from the start. However this produced a hard rocky mixture which was not homogenously mixed. The procedure was altered to place the red mud in the mixer and the additives were slowly added over a period of 30 minutes. This produced a fine grained sand-like mixture. This mixing procedure was continuously used and reliably produced the same mix for every batch of mix that was made. Figure 4 shows the difference the alteration in mix procedure created in the end mix.

Figure 4. Mix 13 using initial procedure (left) and slowly adding the additives to create a homogenous mix (right)

The use of the Hobart mixer also seemed to limit the degree of mixing that could be successfully achieved. A low RPM was required in order to contain all the products within the bowl of the mixer, and this limited the shear that could be applied to the red mud to break it apart. There was also the requirement to scrape red mud and additives from the bottom of the bowl that could not be reached by the mixing arm. A sieve analysis on the mixed product showed that about 30% of the mix by weight was retained on the 4.75mm sieve. Of these retained on the sieve, breaking them open revealed the core was unmixed red mud. Therefore further refining needs to be conducted on the processes in order to guarantee a complete mix. These samples need to be crushed open to expose the red mud core and allow it to mix.

It was found that by increasing the mix design from a 3kg batch to a 6kg batch improved the shear that was applied on the mix and improved the final homogeneity of the mix and also was more economic in terms of time and output as it half the required time allocation for mixing.

In comparing the results for part I with those results achieved by Svenson, it was identified that these results plotted the wet density against moisture content instead of dry density. Upon identifying this, the results that were achieved through the modified proctor compaction test for part I saw an improved wet density to that achieved by Svenson. However the dry density of the material appeared very low for both mixes when considering the specific gravity of the additives to the mixes.

The testing of the samples for part II saw further improved dry densities however they were still below that expected for the mixes. It was hypothesised that this was due to the degree of ‘locked’ water that existed in the soil following the water being added for testing. This theory was supported by the observation that the samples appeared very dry after the 48 hrs soaking period even after 30%-40% moisture was added. It took up to 50% moisture by weight to be added to the dry mix for mix 15 before the sample displayed its modified maximum dry density peak on the curve. This is because a great deal of the moisture is ‘locked’ through electrostatic interactions or reactions, or adsorbed into the mix before the moisture is absorbed and can affect the mechanical properties of the soil. This was observed to occur to a greater degree in mix 15 than it did for mix 13.

The results from the modified proctor compaction testing reflect a trend between the two mix designs. Mix 13 achieved a higher dry density than that achieved by mix 15. This difference was around 0.25 tonnes/m³ greater density in mix 13 which was a significant difference for a small change in the mix design. This result is believed to be due to the greater degree of adsorption that occurred in mix 15 than did in mix 13. This can be observed through the moisture content of the materials. The results reflect modified optimum moisture contents of between 33 and 40 for these results from the samples being put in the oven for 48 hrs instead of the normal 24 hrs in an attempt to remove the same amount of moisture that was added to the mixes. What was determined was that the mixes were actually consuming some of the moisture through chemical reaction and adsorption through electrostatic interactions. Therefore the 48 hrs in the oven meant that more than just the mobile water was being removed from the samples. As stated previously, the mechanical properties of soil, including compaction, are influenced by only the mobile water. Therefore if the moisture content had been determined
only based on the mobile water content, the moisture content of the samples would most likely have been in the low 20s. This will be further verified in the testing on the moisture contents of the samples that is currently ongoing.  

It is expected that mix 15 will perform better than mix 13 during the permeability testing because of the degree of electrostatic moisture retention. This has been proven in Svenson’s testing and is likely to be replicated during this round of testing. The reason for this is because it is thought that mix 15’s electrostatic interactions with the water will group together the soil particles that will generate larger voids for the mobile moisture to flow through. This is not expected to occur to the same degree in mix 13 and therefore it is expected that the permeability will be slightly reduced for this mix.

The handling properties of the mixes were improved significantly from the raw red mud at the start. Both mixes were easily scooped, handled, moulded. This was in direct contrast to the raw red mud material that when first handled, would leave red markings on anything it touched, was sticky and difficult to pick up and held no form when squeezed. The mixes did not leave any sticky residue or colour on any of the tools used to deal with them and any grains were easily washed away during cleaning. When the materials had moisture contents of 20% they appeared dry to touch and handle.

VII. Conclusion

This investigation has produced a material that is significantly easier to handle and store. The modified proctor compaction test returned results below that expected, however the source of this anomaly is likely to be resolved in the final deliverable. The use of this mix design in storage may need modification before successfully applied in the mining industry to improve the density following compaction. However this investigation has developed a procedure that will allow for the mix design to be made and used in further research, such as inclusion of the mixes in concrete and bricks.

VIII. Recommendations

Recommendations for further investigation includes the investigation of these mix designs applications in further research such as a raw material alternative in concrete and brick making. Recent studies have shown very good results for the use of red mud composites in the ceramic brick construction industry [14]. In order to increase the density of the compacted material, there may be scope to investigate methods to replace water through another additive in order to neutralise any electrostatic interactions occurring within the mixtures. This would remove the amount of 'locked' water and would allow for a denser material to be achieved.

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