STANDARD OPERATING PROCEDURE

SOP NUMBER	SOP TITLE
CAR-017-01	**OPERATING PROCEDURE FOR THE MANUFACTURING CLAY BRIQUETTES**

PART 1

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PART 2

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PART 3

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PART 4 (To be filled in by OOS, QSU or RSSD)

☐ This procedure has been revised and is no longer valid as from: (Write date)	☐ Date of NEXT REVISION is extended until: (Max. 4 years)	☐ SOP rendered obsolete on: (Write date)

1. Reason for revision

1.1. New SOP

2. Purpose and scope

2.1. Manufacturing clay briquettes produced for laboratory-based controlled experimental firing, with the scope of supporting archaeological research including fabric characterisation studies and experimental archaeology.

3. Definitions

3.1. **SOP** – Standard Operating Procedure

3.2. **Clay** – The term clay is here used to describe clay-rich sediments. This SOP adopts an archaeological perspective of clay defined as the raw material for pottery.

3.3. **Slab and briquettes** – A slab is formed in the mould (see below) with clay that has been blended with water and worked into a paste. One slab will then be divided into a number of briquettes (here 4 briquettes of 3cm) when it is fully dry. The slab length shall be greater than the gauge measurement of 10 cm used to measure shrinkage.

3.4. **Hydro plasticity** – 'property of a material that enables it to be shaped when wet and to hold this shape when the shaping force is removed' (Rice 2015, 460); 'Plasticity' is similarly used in this SOP.

3.5. **Water of plasticity** – 'amount (by weight) of water required to develop optimum plasticity in a dry clay' (Rice 2015, 67).

4. Responsibilities

4.1. It is the responsibility of staff and students carrying out manufacturing of briquettes with the Department of Classics and Archaeology of the University of Malta to read and follow this SOP.

4.2. It is the responsibility of the staff and students using the equipment to wash and store it properly after use according to the specific regulations established by the Department of Classics and Archaeology scientific officer.

4.3. If equipment is borrowed from other departments, it is the responsibility of the staff and students carrying research to maintain and return the equipment as well as follow the Departments procedure for washing and storing.

4.4. As stipulate in ACT 27/2000, reg 7, it is the duty of every worker to safeguard his or her own health and safety and that of other people who may be affected by the work being carried out.

5. Health and Safety Requirements

5.1. When using a mortar for crushing clay powder, one has to be careful not to hurt oneself particularly by placing fingers in the way.

5.1.1. It is recommended to put the mortar on a stable surface.

5.2. Working the clay when wet is a long process which requires strain on the hands and arms soft tissues (e.g. tendons).

5.2.1. As the procedure can be tiring (crushing and working the clay), breaks should be planned between the different steps.

5.3. If a sharp instrument is used (e.g. a knife) to cut the clay projecting out of the slab after moulding, care is to be taken.

5.4. When drying and using the drying oven:
  5.4.1. Care is to be taken when placing/removing the samples in/out the oven to avoid burns.
  5.4.2. The sample should be left cooling in the open oven or heat resistant gloves should be worn if handling the sample containers when hot.
  5.4.3. If using silica gel, instructions of the manufacturer and safety data sheet are to be followed.

5.5. A first Aid box made of suitable material and designed to protect its contents, identified as such by means of a white cross on a green background must be available and equipped as per requirements stipulated in article 2.(4). Of L.N. 11/2002.

6. Procedure

6.1. Equipment (see Figure 1):
  6.1.1. Dividing a large sample for manufacture: a large flat container / tray and plastic scraper.
  6.1.2. Measuring: An electronic balance (0.01 g precision); a glass beaker (100ml) and pipette; calipers and a ruler, a knife/blade.
  6.1.3. Crushing and homogenising: Mortar and pestle, a container, a toothbrush, rubber/protection gloves, tap water (or, ideally, deionized water).
  6.1.4. Forming: a mould (see section 6.2 for the mould used in this SOP), cling film.
  6.1.5. Recording: Letter or number punches for naming (or equivalent), a spreadsheet, pen and notebook, camera.
  6.1.6. Cleaning: running water and a brush, a clean cloth to dry the equipment.

Figure 1: Set-up with equipment mentioned in text.

6.2. The mould:
  6.2.1. The mould was manufactured from Polytetrafluoroethylene (PTFE) polymer due to its non-stick characteristic. The mould was manufactured in the Department of Industrial and Manufacturing Engineering (DIME) Workshop.
  6.2.2. The following engineering drawing in Figure 2, drawn by DMME lab staff (Borg, J.) at the University of Malta, shows the dimensions of both the male (upper - A on the drawing) and female (lower - B on the drawing) parts.

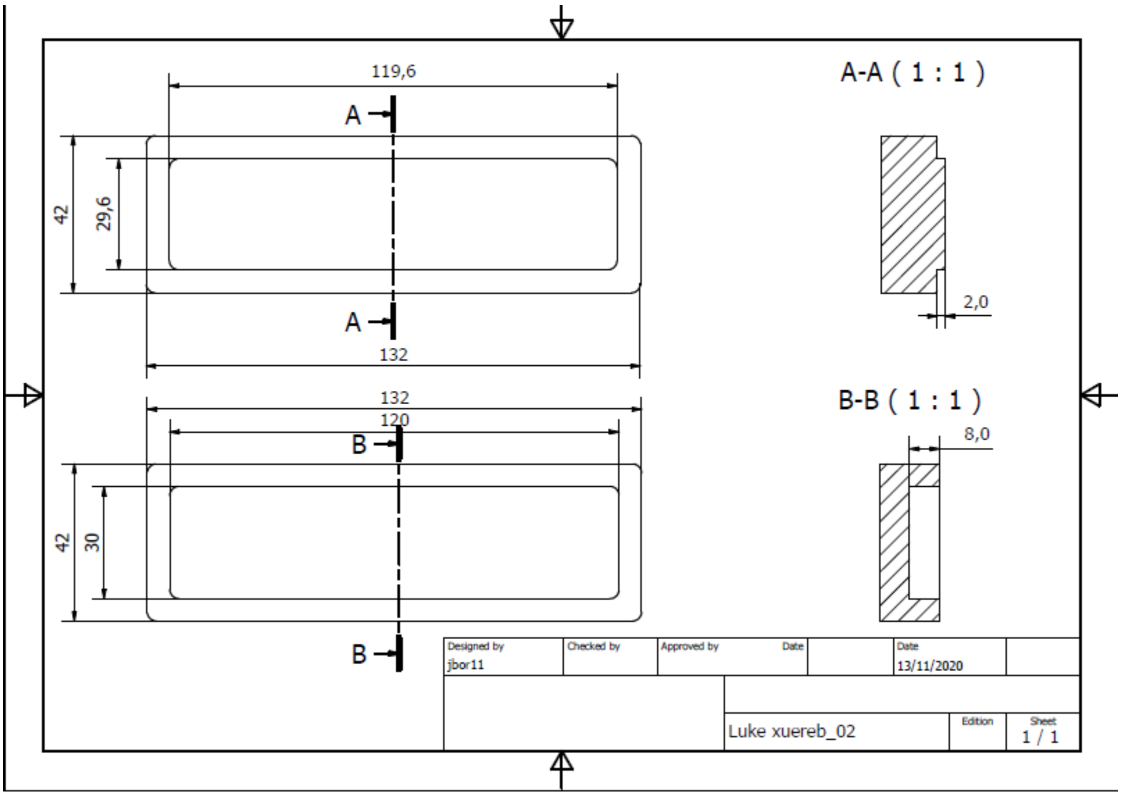

Figure 2: Engineering drawing of the mould used in this SOP. Drawn by J. Borg.

6.3. **Sampling from a larger sample of clay**: This procedure has been adopted in this SOP and a previous SOP on wet-sieving environmental samples written by the Department of Classics and Archaeology. This procedure is to be followed if only part of the sample is needed for manufacture. The aim of sampling is to get a representative / homogeneous part of the whole sample. For this, the methodology described in Pirone (2017) can be followed. If a coring tool was used to sample, for instance, a researcher might be interested in getting a sample for manufacture as representative as possible of the full sample (varying depth).

6.3.1. The whole sample is emptied into a flat low tray. Using a plastic scraper, the sample is mixed for at a few minutes or until the material is homogeneous. The sample is flattened and divided into four quadrants.

6.3.2. Two of the opposite quadrants are removed back into the original sample bag and excluded from the sample for manufacture. The two remaining quadrants are then mixed together again and the procedure is repeated until one of the quadrant is of desired weight. The weight is verified with an electronic balance and recorded.

6.4. **Manufacturing of the slabs**:

6.4.1. The sample can be weighed in batches if the maximum capacity of the balance is limited. Each batch will be recorded separately. The weights are recorded in a spreadsheet.

6.4.2. The water of plasticity range for the batch is calculated. According to Cuomo Di Caprio (2017), the weight of the water of plasticity normally ranges from 15 to 25% of the weight of the clay.

6.4.3. The dry clay is crushed using a mortar and pestle to enhance the workability of the clay. The clay can be crushed as finely as the experiment design allows it, depending, for example, if the researcher wishes to keep possible inclusions in the clay. Some inclusions might not be crushed by the force of the pestle or could abrade the mortar. Larger lumps of clay will take longer to incorporate water and reduce homogeneity.

6.4.4. The crushed clay is then transferred into a container used for manufacturing. A toothbrush can be used to collect any remaining clay powder accumulating at the bottom of the mortar or on the pestle.

6.4.5. Following the calculation used in 6.4.2, the lowest end of the range for water of plasticity (15% of the weight of the clay batch) is then weighed (in g) using the electronic balance inside a beaker/container rather than a measuring cylinder for precision. A pipette can be used to be more accurate.

Figure 3: Water is weighted and the precise weight is recorded

6.4.6. The correct volume of water is added to the crushed clay. Wearing gloves, the clay is then homogenised by hand as much as possible. If more water is needed, increments of approximately 10 g are added. The exact weights are recorded in a spreadsheet. The total amount of water (representing the actual water of plasticity for the batch) that was added is then calculated and compared to the range mentioned above.

6.4.6.1. The clay is homogenous when no lumps can be felt and it is plastic enough to retain a bent U shape without breaking

6.4.7. Both parts of the mould are covered with cling film so that the slab can be easily removed from the mould.

6.4.8. The homogenised clay is pressed inside the mould until the whole lower part of the mould is full. The upper part of the mould is used to flatten the surface of the slab. (Figure 4 and 5)

6.4.9. The cling film is then lifted with the slab and transferred to a tray. The surplus clay projecting out of the slab should be cut away using a knife/blade.

Figure 4: The two parts of the moulds are covered with plastic film and the clay is pressed.

Figure 5: After pressing, the resulting briquette can be lifted out from the mould.

6.4.10. It is possible to manufacture more than one slab from one single batch if the quantity of clay and water is large enough. There is no need to clean the equipment between slabs from the same batch. However, between batches, all the equipment is to be cleaned with a brush, ensuring no clay is left, and dried thoroughly with a clean cloth.

6.4.11. Notes and photographs are to be taken from the manufacture procedures. Notes can include (for example) challenges, possible contamination or observations on the clay texture, colour.

6.5. **Drying and recording**:

6.5.1. Two shallow marks 10 cm apart are indented into the slab with a knife (Figure 6), with measurement made using a ruler (or calipers). This is carried out in order to provide a gauge length permitting measurement of the shrinkage of the slab as it subsequently dries.

6.5.2. The knife is also used to create indents within the slab 3 cm apart in order to easily break it down into briquettes. The slab should not down until shrinkage is measured during air drying, and after it is fully dried in the drying oven before firing.

6.5.3. The briquettes can be named following a reference system and using letter/number punches or equivalent means. Letter and number punches can be used (Figure 7).

6.5.3.1. E.g. Batch 1. Slab name: A. Briquette names: A1; A2; A3; A4.

6.5.4. The slab is placed on a surface which supports it whilst keeping the lower surface exposed to air, such as an open mesh. Slabs should be left to dry in a clean, dry location.

6.5.4.1. The slabs are left to dry for seven days in open air whilst recording weight/length on a daily basis. It is important that the place where the slabs are placed is free of contamination such as dust or animal hair.

6.5.4.2. The distance between the initial 10cm marks is measured every day for seven days using a ruler (or callipers), and recorded in the spreadsheet. (Cordell et al., 2017).

6.5.4.3. It is best to keep a record of the drying environment (e.g. humidity, exposure to sun, temperature) as well as the exact days and time of recording.

6.5.4.4. The weight of the slab is measured and recorded in the spreadsheet straight after manufacturing, and then every day for 7 days at regular intervals (that is, taking measurements at the same time each day).

6.5.5. After seven days, the slabs are dried in the drying oven at a temperature of 105 ° C (Cordell et al. 2017: 99) for one hour to ensure complete evaporation of the water.

6.5.5.1. After drying, the slabs should be weighted again.

6.5.6. The slabs are then placed in containers filled with dry silica gel with lint-free paper separating this from the slabs. The slabs should also not touch each other. This ensures no contamination as well as prevents any humidity to reach the slabs.

Figure 6: Two marks are indented 10 cm apart as shown in the picture. Here 1 slab is composed of four briquettes

Figure 7: Letter and number presses are used to name the newly indented briquettes

7. References

7.1. Cordell, A., Wallis, N. and Kidder, G. (2017) 'Comparative clay analysis and curation for archaeological pottery studies.', *Advances in Archaeological Practice*, 5(1), pp. 93–106.

7.2. Cuomo Di Caprio, N. (2017) *Ceramics in archaeology: from prehistoric to medieval times in Europe and the Mediterranean: ancient craftsmanship and modern laboratory techniques: Volume I*. Rome: L'Erma di Bretschneider.

7.3. Pirone, F. S. (2017) *Trade, Interaction and Change: Trace Elemental Characterization of Maltese Neolithic to Middle Bronze Age Ceramics Using a Portable X-ray Fluorescence Spectrometer*. Scholar Commons.

7.4. Rice, P. M. (2015) *Pottery analysis: a sourcebook*. University of Chicago Press.

7.5. General Laboratory Practice for the Department of Classics and Archaeology SOP CAR-015-**.

7.6. Occupational Health & Safety Policy, 2020, [Online], Available at https://www.um.edu.mt/hrmd/secure/policies/OccupationalHealthandSafetyPolicy.pdf [Accessed 19th April, 2021].

7.7. Health and Safety Risk Assessment – Department of Classics and Archaeology – Faculty of

8. List of Appendices/Worksheets

8.1. N/A