



Redo of stone wall base in March 2022

5.1 Stone wall base

To build a stable and strong earth wall, a well-built and water-resistant base is crucial. The project team first reached out to some experienced workers, they helped remove soil debris at the two side of rammed earth wall, and also attempted to build a stone wall base.

However, the result was not as pleasant as expected, thus other craftsmen were hired to redo the stone wall base. It turned out flat, balanced and more appealing.

The stone wall base is consisted of local big stone, cement, sand, and soil. Building the stone base requires specific skills of stone picking and arranging technique, skilled labour is essential to build a functional and aesthetic stone base.



Construction of stone wall base in September 2021

5.2 Preparation

Rammed earth wall construction requires preparation ahead and labour-intensive. The below steps are recurring after the start of construction, which can keep the progress on-going without insufficient soil mixture.



Step 1 - Dry and granulate soil

- Dry under the sun
- Granulate the soil with the granulator
- Pack with plastic bag/ dry and sheltered space at the end of the day



Step 2 - Crush stone

- Find fist-size stone
- Crush into 0 - 2mm diameter size
- Store crushed stones in covered dry place (Box or canvas)



Step 3 - Mix soil and stone

- Mix well with mixer
- Add water slowly and evenly (Water content approx. 8-10% (~11L water))
- Pinch test with hand



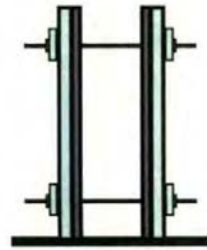
Step 4 – Let soil mixture rest

- Place in canvas/bucket/trolley
- Cover well with canvas for 1-2 days

5.3 Construction procedures

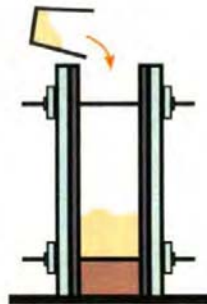
Step 1 - Set up formwork

- With aluminum formwork
- Leveling
- Apply lubricant oil on the inner surface of the formwork



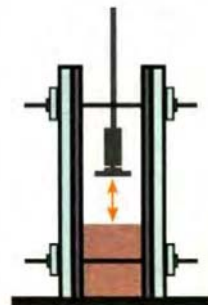
Step 2 - Add water and/or cement

- In the soil mixture, add water if too dry
- Add small amount of Portland cement and mix well, to increase the strength of wall



Step 3 - Ramming process

- Use feet of timber pole to press down soil first
- Use electric hammer to press down soil mixture
- Add max. 200mH soil mixture and ram to 100mH



Step 4 - Let dry

- Can remove formwork directly after ramming
- Let dry under sheltered space for at least 1-2 weeks
- If not yet completed, cover well with canvas to prevent drying out or rainwater going in.





Construction of rammed earth wall in 2022



First trial (2021.11.13 – 2022.1.8)

The project team had started the first trial of rammed earth wall in November 2021, with the help of HKIC and public volunteers, all without experience working with rammed earth wall. Combining the skills and data from previous experiments, the sample wall of 1800lx300wx600h was finished in January 2021.

From the previous experiment and trials, with only soil, stone and water, the best and most feasible proportion is: soil: stone - 1:1 (in weight), and water 8-10%. In the mixing machine, not more than 3/4 should be filled, thus the following table shows the mixture data for this trial for one mix.

Each mix could produce a 1.8m x 300w x 100h wall. Hence for Trial 1, the project team used 6 of the above mixtures to build the wall section.

Shortcoming:

- Water content too high
- Strength not enough (can be easily break with hammer)
- Soluble in water
- Stone sizes too large.

Unit	Soil	Stone	Water
Weight per bucket	13.4kg	16.9kg	11kg/L
Bucket (11L)	5	4	~1
Weight per mix	67kg	67.6kg	10-12L

Limitation

Although many experiments and trials were made in the lab and CUHK, the site conditions affected the preparation and construction a lot, which largely reduced the accuracy of the soil mixture.

Since there is no cement or lime added to the mixture, clay is the only bonding agent to stick sand and stone together, and its strength and performance will be affected by the water content. The proportion between clay and sand+stone should also be taken more precisely since the ratio of clay determine the success rate of the wall. Too much clay would result in cracking while the mixture may not bind well if too little amount of clay was added.

Limitation	Problem	Details
Weather fluctuation	Imprecise water content	The weather condition largely affects the drying of soil and the water content in the mixture, this made it hard to get precise water without professional machines. The range of the hand pinch test is very large and cannot be used to determine whether the mixture is good to ram.
Insufficient small stone	Grain size too large	Due to the insufficient small stones and high transportation fee, a stone crushing machine was bought to Mui Tsz Lam to crush the larger stones to under 2mm in size. However, the machine could not crush perfect 2mm sizes, which made some larger than 2mm, while the proportion from 0-2mm was also unpredictable. Without knowing the grain size precisely in the mixture, the grain size curve would not be the same as done in the lab which further led to the failure of the wall.
Lack of workers	Slow progress and unprofessional skills	Mui Tsz Lam as a remote area, it was hard to hire experienced workers at a reasonable rate. Hence, the project team experimented with public volunteers and was assisted by HKIC. However, most of them did not have experience in building rammed earth walls, leading to overall slow and inefficient progress.



Second trial (2022.3.9 – now)

After reviewing the previous trial, it is concluded that soil mixture with only all natural ingredients (soil, stone, water) are not feasible in Mui Tsz Lam village. Taking the suggestion from experienced craftsmen, lime and small amount of cement were decided to add to the soil mixture, which would raise the overall strength of the wall.





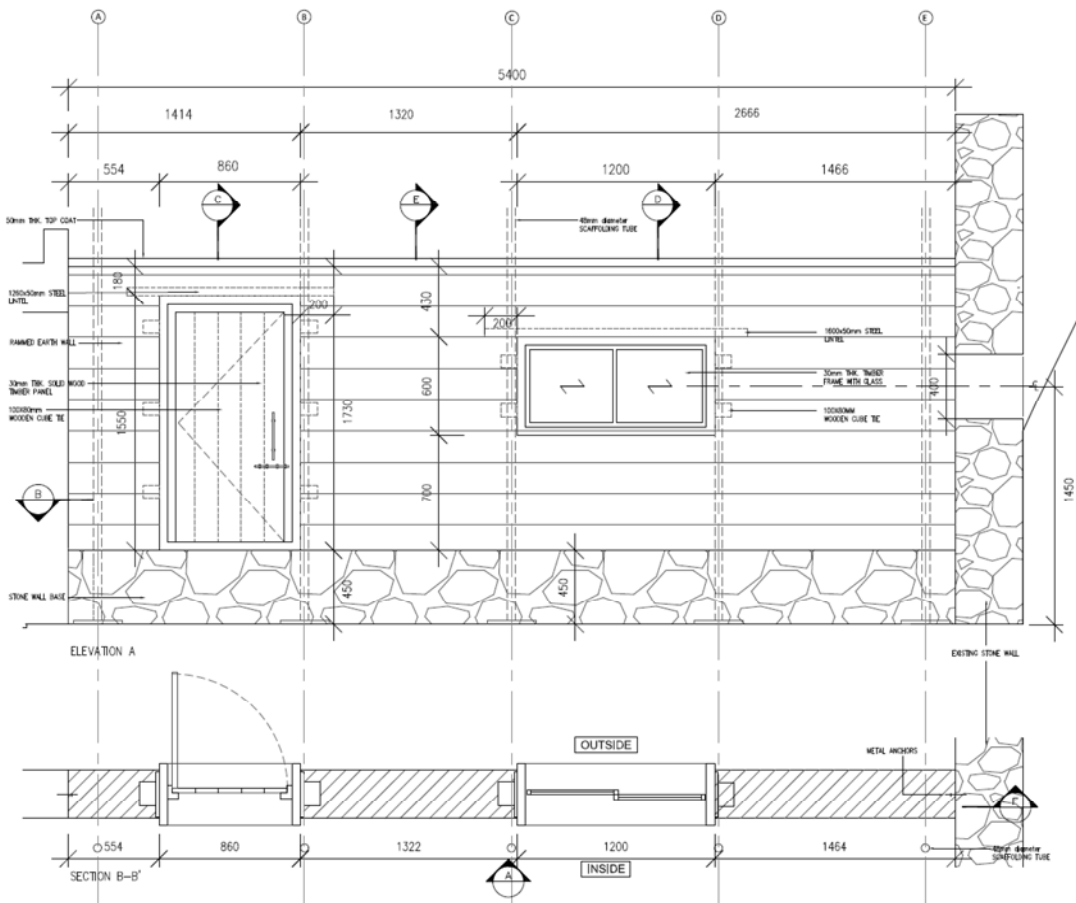
The result of Trial 2 turned out much more appealing. Not even completely dried yet, the wall is already strong enough to withstand punching and hammering.

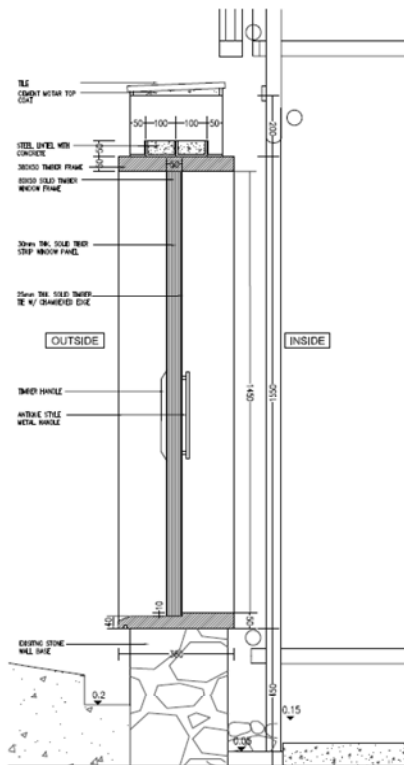
One concern was some of the surface turned out not smooth and stuck some soil to the formwork. It was then fixed by applying the soil mixture to the surface like a mortar, and smooth it out. Experienced craftsmen were able to handle it well.

	Lime	Cement	Stone	Existing soil
Amount added	~1.5kg	4kg	45%	50% (with some stone inside already)
Mixing	Mix with soil mixture in mixing machine	Add just before ramming process, mix with hand	Crushed with machine before mixing with soil	

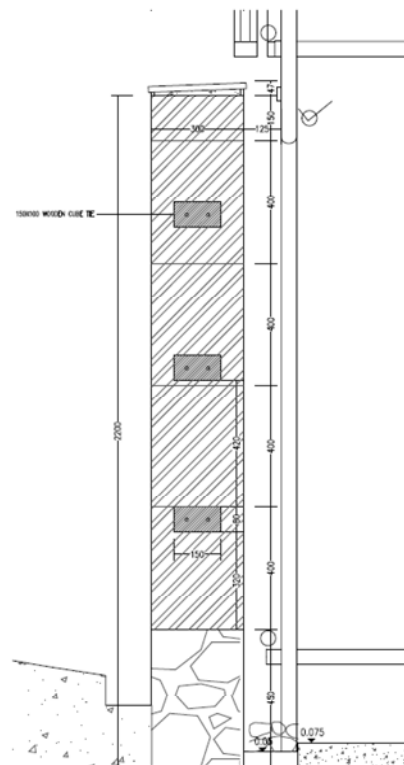
5.4 Design drawings and openings

For experimenting rammed earth wall in Mui Tsz Lam, Mural House was chosen to be the site for building the wall. The design includes two opening, with different materials and opening methods. The location of openings is according to the grid lines of the scaffolding, and also the center line from the existing wall opening at the back.



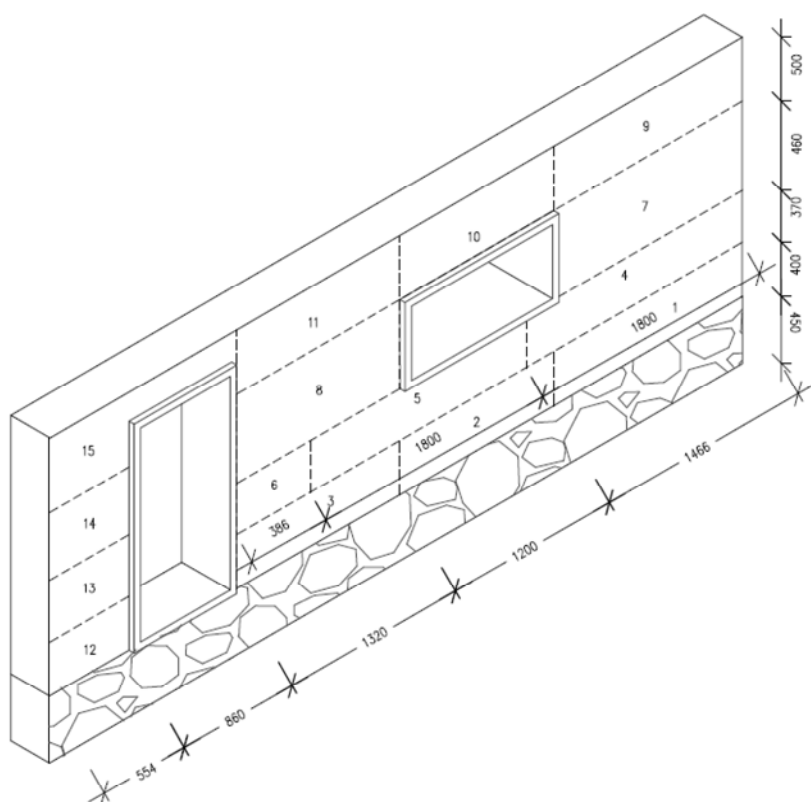


SECTION C-C'



SECTION E-E'





5 buckets of soil and 4 buckets of stones (each 11L)

Each layer (200mm height):
 $200h \times 1800 \times 300 = 135\text{kg soil} + 14\text{kg water}$ ($9 \times 7L = 63000\text{cm}^3$
 $= 0.063\text{m}^3$)
 $= 150\text{kg}$ of soil-water mixture each time

Total amount of soil needed
 Volume: 2.24m^3
 $= 4800\text{kg}$ of soil mixture (2400kg stones + 2400kg soil)

Ram for 36 layers x 135kg soil mixture





