Influence of Aspect Ratio on the Properties of Compressed Earth Cylinders and Compressed Earth Blocks

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Abstract (250 Words).

A large proportion of the human population still resides in earthen structures all over the world. The benefits of earth construction are widely reported, but there is a lack of scientific understanding relating to standard production and test methods which has led to inconsistencies in the reporting of engineering parameters, such as compressive strength.

This study investigates the use of small-scale Compressed Earth Cylinders (CECs) to predict the compressive strength of equivalent full-scale Compressed Earth Blocks (CEBs). A full-scale manual CEB machine and a small-scale CEC moulding rig were utilised for the production of test specimens and the results obtained from both production methods were examined.

Two soil types with different engineering parameters were utilised in this investigation. It was found that a sample of un-stabilised CEB with an aspect ratio of 0.67 achieved a mean compressive strength of 6.73N/mm^2 (Soil A) and 4.60N/mm^2 (Soil B). A selection of CECs with an aspect ratio ranging from 0.50 to 2.00 were used to determine a relationship between the aspect ratio and compressive strength for each soil type. The theoretical relationship was used to predict the compressive strength of the equivalent CEBs within ± 3.0%. The theoretical relationship was also used to predict the unconfined compressive strength of the samples and enabled the determination of aspect ratio correction factors of Soil A and Soil B.

Findings from this study reveal that the conversion factors between cylinders and blocks are dependent on numerous variables including compaction pressure, aspect ratio, soil type and density.

Keywords: Compressed Earth Blocks, Compressed Earth Cylinders, Aspect Ratio, Conversion Factors

1 Introduction

Due to the increased demand for low-cost and sustainable building materials, there has been extensive research and development into Compressed Earth Blocks (CEBs) in recent years [1]. The ongoing experimental investigation into CEBs has highlighted the need for standard manufacturing and test procedures to ensure the performance of CEBs can be measured in a reliable and consistent manner [2].

Due to the load-bearing nature of masonry, compressive strength is regularly used as a basic measure of performance and quality and is often empirically related to other engineering parameters. Currently, there are three main methods for testing the compressive strength of CEBs including the common direct (confined) compressive strength tests on single masonry units, the Réunion Internationale des Laboratoires et Experts des Matériaux, systèmes de construction et ouvrages (RILEM) method proposed by RILEM Technical Committee 164 [3], and indirect testing methods such as the 3-point bending test [4]. The compressive strength of a CEB is influenced by several factors including the material constituents, moisture content, density, and the magnitude of compaction pressure during manufacture, to name a few. However, assuming these parameters are all equal, the compressive strength of a CEB is known to be a function of the specimen size, geometry and aspect ratio [2,5–7].

The aspect ratio (height/width) of a test specimen may influence the Apparent Compressive Strength (ACS) of a sample, due to the interaction with the test apparatus. It is known that, as a vertical load is applied, the sample exhibits lateral expansion due to Poisson’s ratio effect [2]. Lateral expansion near the ends of the test specimen is restrained due to the friction developed between the test sample and the platens of the test machine. The restraint of the lateral expansion induces shear stresses which, when acting in addition to the uniaxial compression, causes a delay to the failure and results in an apparent increase in compressive strength [8].

The Unconfined Compressive Strength (UCS) is the measure of maximum compressive stress that a sample of material can withstand under unconfined conditions and is a fundamental engineering parameter used to assess the performance requirements of earthen construction [9–11]. The UCS is usually obtained by testing samples with an aspect ratio whereby part of the sample is free from the effects of platen restraint. Existing research into fired brick masonry [12] and soilcrete blocks [13] suggests that the UCS of cuboid samples is obtained when testing specimens with an aspect ratio greater than or equal to 5.0. The aspect ratio of most CEBs is less than 5.0, therefore the influence of platen restraint should be considered when undertaking compressive strength tests.

There are a few internationally recognised standard sizes of CEBs, with the most commonly reported to be 295mm (L) x 140mm (W) x 90mm (H), with an aspect ratio (H/W) of 0.64 [2,14]. Within existing literature, the size and aspect ratio of CEBs varies, as shown in **Table 1**.

Table 1. Common Block Dimensions

Block Dimensions (mm)			Aspect Ratio (H/W)	Reference
Length (L)	Width (W)	Height (H)		
295	140	125	0.89	[15]
305	143	105	0.73	[16]
290	140	100	0.71	[17]
300	140	100	0.71	[18]
300	150	100	0.67	[19]
295	140	90	0.64	[2]
300	150	95	0.63	[6]
203	191	121	0.63	[20]
295	145	90	0.62	[18]
305	152	89	0.59	[21]
320	150	80	0.53	[22]

Despite the range of size, geometry and aspect ratio found within the existing literature, there is often little or no regard for the influence of platen restraint on the results of compressive strength testing. This may be due to the lack of globally recognised standard manufacturing and testing procedures.

A recent publication by [23] outlines the current codes and standards for the manufacture and testing of earth construction. There are no specific British Standards (BS) or European Standards (EN) related to the manufacture or testing of CEBs, however, there is some technical guidance specific to un-stabilised compressed earth blocks, originating from Australia [9,10], and New Zealand [11,24,25]. New Zealand Standard, NZS 4297:1998 [24] provides a theoretical relationship between the characteristic compressive strength of an individual specimen (f'_e), the unconfined compressive strength of an individual specimen (f'_{uc}) and the compressive strength of wall construction (f_e), as shown in equations (1) and (2).

$$f'_e \text{ x } k_a = f'_{uc} \tag{1}$$

$$0.5 \text{ x } f'_{uc} = f_e \tag{2}$$

New Zealand Standard, NZS 4298:1998 [11] contains a table of aspect ratio factors (k_a) used to adjust the characteristic compressive strength of earth bricks, ranging from an aspect ratio of 0.4 to 5.0. These factors are based on work carried out by Krefeld [12] and are generally the same factors used for fired clay masonry units.

In contrast to cuboid samples, it is widely recognised that the UCS of cylindrical samples is obtained when testing specimens with an aspect ratio greater than or equal to 2.0 [8,12,26–30]. Cylindrical samples with an aspect ratio of 2.0 are commonly used to assess the unconfined compressive strength of different materials, including undisturbed cohesive soils [31], soil-cement composites [27], soil-lime composites [32], rock core samples [33] and concrete [28–30,34,35]. However, cylindrical specimens of other proportions are occasionally encountered. Several conversion factors have been published within existing literature to account for different aspect ratios of cylindrical samples of different materials, as shown in **Table 2**.

Table 2. Aspect Ratio Correction Factors for Cylindrical Test Samples

Material	Diameter (mm)	Aspect Ratio (H/D)	Correction Factor	Ref.
Rammed Earth	150	2.00	-	[26]
	100	2.00	-	
	105	1.10	0.70	
Soil-Cement Cylinders	71.1	2.00	-	[27]
	101.6	1.15	0.91	
ASTM: Cylindrical Concrete Specimens	150	1.80	-	[28]
		1.75	0.98	
		1.50	0.96	
		1.25	0.93	
		1.00	0.87	
ASTM: Concrete Core Samples	≥ 94	1.80	-	[29]
		1.75	0.98	
		1.50	0.96	
		1.25	0.93	
		1.00	0.87	
British Standards Institution: Concrete Core Samples	75	2.00	-	[30]
		1.00	0.82	

A limited number of existing studies have used cylindrical samples to test the compressive strength of compressed earth. One study [36] used cylindrical samples with an aspect ratio of 2.0 (80mm diameter x 160mm length) to test the compressive strength of soil reinforced with coconut and sisal fibres. The aforementioned study found that CECs with an aspect ratio of 1.2 achieved 23% greater compressive strength than CECs with an aspect ratio of 2.0. Another study [37] used CECs with an aspect ratio of 2.1 (57mm diameter x 120mm length) to test the unconfined compressive strength of nylon fibre-reinforced lime-stabilised soil. Silveira [38] established the relationship between the compressive strength of cubic specimens and the compressive strength of the cylinder, with a correction factor of about 0.94 for converting the cube strength to cylinder strength.

There are several practical advantages to the use of small-scale CEC test specimens, including a reduction in the time and materials required to manufacture test samples and the subsequent increase in the number of test specimens that can be made and tested using the same quantity of material, as shown in **Fig. 1**.

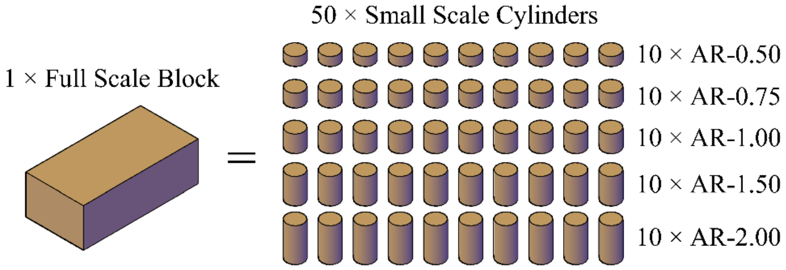


Fig. 1. Practical Advantages of Small-Scale CEC vs Full-Scale CEB

Furthermore, small-scale CECs can be manufactured using rudimentary cylindrical moulds, whereas the manufacture of full-scale CEBs requires access to full-scale CEB machinery. Access to such machinery is limited and the costs of procuring a block machine may discourage future research and development.

Several studies have investigated the influence of aspect ratio on compressed earth blocks [2,5,7,38,39] and the majority of which highlight the need for further investigation into the influence of geometric effects on compressive strength performance. This paper seeks to develop existing knowledge by investigating the influence of aspect ratio on un-stabilised CECs and assessing the potential relationship between the aspect ratio of CECs and CEBs. This investigation aims to utilise test results from small-scale un-stabilised CECs to estimate the ACS and UCS of CEBs.

2 Materials and Methods

2.1 Materials (Kent Brick Earth and British Standard - BS 8601 Subsoil)

Kent Brick Earth and BS 8601 Subsoil. Two soil types were used in this investigation. Soil A was a blend of Kent Brick Earth (KBE) obtained from Kent (southeast of England) with 20% additional non-uniform particle size marine sand by weight. Soil A was used to enable direct comparison with existing research undertaken by the authors [6]. Soil B was a BS 8601 [40] compliant subsoil, obtained from Hampshire (south of England).

A particle size distribution test (sieve analysis) was performed as per BS1377-2:2022, Part 10 [41]. Further analysis of the clay and silt content was undertaken using a Mastersizer 3000 laser diffraction particle size analyser [42]. Other material properties including Optimum Moisture Content (OMC), Maximum Dry Density (MDD), Liquid Limit (LL), Plastic Limit (PL) and Plastic Index (PI) were determined as per BS1377-2:2022 [41], the results of which are presented in **Table 3**.

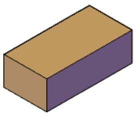
Table 3. Properties of Kent Brick Earth and British Standard - BS8601 Subsoil

Properties	**Soil Type**	
	Soil A: Kent Brick Earth with Marine Sand	**Soil B:** BS 8601 Subsoil
Proctor Test		
Optimum Moisture Content (%)	12.5	17.5
Maximum Dry Density (Mg/m^3)	1.92	1.68
Atterberg Limits		
Liquid Limit LL (%)	26.3	33.7
Plastic Limit PL (%)	15.3	25.9
Plastic Index PI	10.9	7.8
Soil Classification		
Unified Soil Classification System	CL	ML
Particle Size Distribution		
Gravel (> 2.0mm) (%)	0.0	0.0
Sand (2.0 – 0.063mm) (%)	38.8	68.0
Silt (0.063 – 0.002mm) (%)	50.1	15.0
Clay (<0.002mm) (%)	11.1	17.0

2.2 Methods

Summary of Test Specimens. A series of CEBs and CECs were manufactured and tested to determine the influence of aspect ratio, as shown in Table 4. A total of 25 un-stabilised CECs were manufactured (5 per test variable) from each soil type. The CECs were used to assess the influence of aspect ratio, ranging from 0.5 to 2.0. To provide a comparison, 3 full-scale CEBs were manufactured from each soil type with the same mix designs.

Table 4. Sample Dimensions

Sample Reference	Sample Dimensions (mm)				No. of Samples		Illustration
	Length	Width	Height	Diameter	Soil A	Soil B	
CEB	300	150	100	-	3	3	
AR-0.50	-	-	21.8	43.6	5	5	
AR-0.75	-	-	32.7	43.6	5	5	
AR-1.00	-	-	43.6	43.6	5	5	
AR-1.50	-	-	65.4	43.6	5	5	
AR-2.00	-	-	87.2	43.6	5	5	

Manufacture of Full-Scale Compressed Earth Blocks. To facilitate the study, a University of Portsmouth Compressed Earth Block Machine (UoP-CEB machine) was designed and manufactured by the authors, as documented by Cottrell et al. (2021). Unlike any other manual CEB machine found in existing literature, the design incorporates a hydraulic ram positioned beneath the baseplate (see **Fig. 2**) to measure the amount of compaction pressure being applied to the block during compression.

A target pressure was determined following a qualitative assessment of the CEBs produced at different pressures. This assessment was performed through observations such as the size of the block, the number of surface cracks and the regularity of compaction. To ensure consistency in the manufacture of the blocks, a target pressure of 1.25 MPa was determined, with an acceptable tolerance of +/-10%. At +1.5 MPa, the physical limitation of the UoP-CEB machine was observed as the operator is unable to lower the lever arm without applying excessive force.

The dosage into the UoP-CEB Machine was calculated based on the maximum dry density of the material at optimum moisture content, obtained using the method defined BS 1377-2:2022, Part 11.3 [41]. Solid blocks, with dimensions 300mm (L) x 150mm (W) x 100 (H), were manufactured and tested to provide a comparison with the results obtained from the small-scale cylindrical samples.

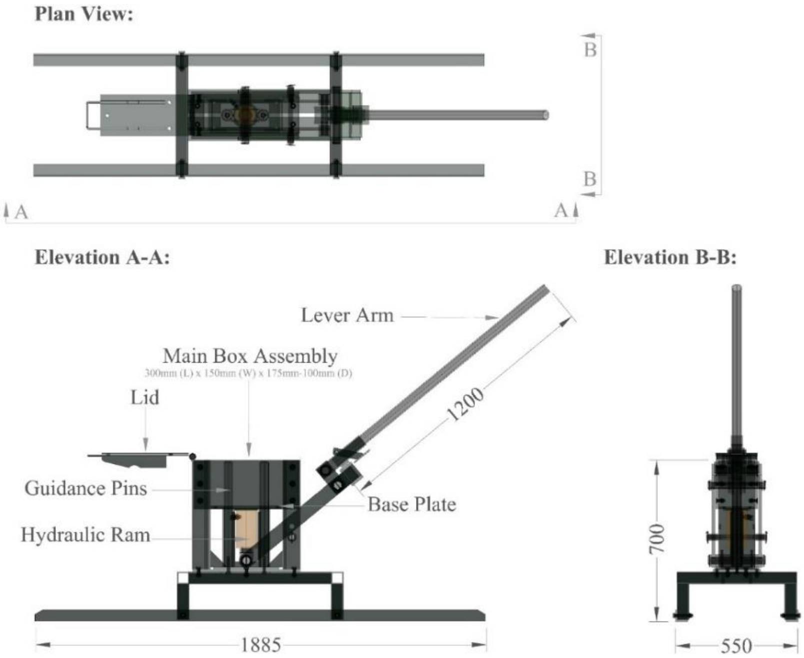


Fig. 2. Illustration of UoP-CEB Machine (50% Transparency to Show Hidden Critical Elements) Drawn in AutoCAD 2019 [6,43]

Manufacture of Compressed Earth Cylinders. Cylindrical test samples were manufactured using a 200mm long steel tube with a 43.6mm internal diameter, as shown in **Fig. 3**. A 200mm long steel rod, with an external diameter of 43.2mm, was used to compress the soil. The pressure was applied using a Zwick/Roell Z250 250kN Universal testing machine, at a rate of 20mm/minute. The cylindrical samples were ejected from the cylinder manually. The dosage of the CECs was calculated based on the maximum dry density of the material at optimum moisture content, obtained using the method defined BS 1377-2:2022, Part 11.3 [41]. To achieve the required size and density, the compaction pressure varied depending on the aspect ratio of the sample. The peak compaction pressure was recorded during the manufacturing process.

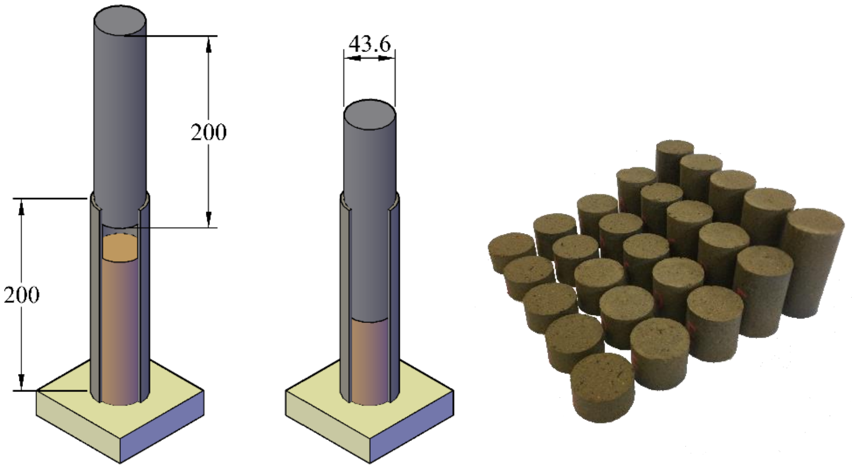


Fig. 3. Illustration of Apparatus used to Manufacture CECs (Left), CEC Samples (Right)

Sample Drying. Test samples were dried at 30 °C in a temperature-controlled Genlab MINO/100 oven [44] to replicate sun-drying conditions. The cylinders and blocks were re-weighed throughout the week following the procedure detailed in BS 1377-2:2022 [41] until a consistent weight was observed +/- 0.01 g indicating that the sample had reached hygrothermal equilibrium. Samples were found to reach hygrothermal equilibrium after 5 days. It is recognised that, due to the hygroscopic nature of the material, the samples may not be considered as fully dry. Prior to testing, the samples were re-weighed and re-measured at an ambient room temperature of 20°C ± 0.2 °C and relative humidity of 58 % ± 2 %, to determine the amount of shrinkage during the drying process.

2.3 Mechanical Testing

There are currently no standards within the UK for the testing of CECs or CEBs. Furthermore, the commonly referred NZS 4298 [11] for the Materials and Workmanship For Earth Buildings does not cover the testing of cylindrical samples, other than the testing of mortar and grout. Due to this, British Standards and/or Eurocodes for the testing of Concrete and Masonry were adopted where appropriate. This approach has been taken by numerous existing studies [6,17,45–48].

Compression Test of Cylindrical Samples. A Zwick/Roell Z250 universal testing machine was used to perform the compression test of cylindrical samples. The tests were conducted in accordance with BS EN 12390-3:2019 [49]. The size and aspect ratio of the test samples we notable derivations from the aforementioned standard. The deformation was measured and recorded by gauges installed in the Zwick/Roell Z250. The load at which the sample failed was recorded and maximum compressive stress was calculated as per Section 8 of BS EN 12390-3:2019. The method of testing remained the sample for all cylindrical samples, therefore this test is deemed appropriate for determining a comparison between samples.

Compression Test Blocks Samples. A Losenhausen 1000 kN universal testing machine was used to perform the compression tests of the CEB samples. The tests were conducted in accordance with BS EN 772-1 [50]. A 10mm steel plate was positioned on top and beneath the sample to ensure that the load was distributed evenly across the sample. The load was applied at a rate of 0.05 MPa/s, as per Table 2 of BS EN 772-1, until the block failed. The deformation was measured and recorded by gauges installed in the Losenhausen 1000 kN universal testing machine. The load at which the block failed was recorded and maximum compressive stress was calculated.

2.4 Statistical analysis

To assess the statistical significance of the results obtained from physical testing, statistical analysis (ANOVA with Tukey pairwise comparison) was undertaken with Minitab 17.3.1 [51]. Within the results, statistically significant differences are indicated by different letters (A, B, C) at p-value < 0.05 (5%).

3 Results

3.1 Properties of CEC and CEB Samples

The dimensions of the samples were recorded throughout the manufacturing process, and the aspect ratio of each sample type was found to be consistent, as shown in **Table 5**. This is due to an accurate dosing method and controlled method of production.

The mean dry density of all samples manufactured from Soil A was 1930.1kg/m^3 with a standard deviation (SD) of ± 7.4 kg/m^3. In contrast, the mean dry density of all samples manufactured from Soil B was 1742.7kg/m^3 with a SD of ± 10.6kg/m^3.

Table 5. Mean Aspect Ratio and Mean Dry Density of Test Samples

Material	Sample	Mean Aspect Ratio	Mean Dry Density (kg/m^3)
Soil A: Kent Brick Earth with Marine Sand	CEB	0.67 ± 0.01	1931.3 ± 4.1
	AR-0.50	0.50 ± 0.01	1922.5 ± 2.5
	AR-0.75	0.75 ± 0.01	1933.5 ± 4.1
	AR-1.00	1.00 ± 0.00	1934.0 ± 2.0
	AR-1.50	1.50 ± 0.01	1927.0 ± 9.0
	AR-2.00	2.00 ± 0.00	1933.4 ± 9.5
Soil B: BS 8601 Subsoil	CEB	0.67 ± 0.00	1742.3 ± 17.7
	AR-0.50	0.51 ± 0.01	1745.3 ± 5.5
	AR-0.75	0.76 ± 0.00	1738.0 ± 7.8
	AR-1.00	1.01 ± 0.00	1735.0 ± 6.0
	AR-1.50	1.51 ± 0.00	1743.8 ± 9.8
	AR-2.00	2.00 ± 0.00	1749.6 ± 1.2

Values represent mean ± standard deviation (σ).

3.2 Compaction Pressure

To achieve cylindrical samples of the correct size and density, the compaction pressure varied during the manufacturing process. The compaction pressure required to manufacture the CECs is presented in **Fig. 4**.

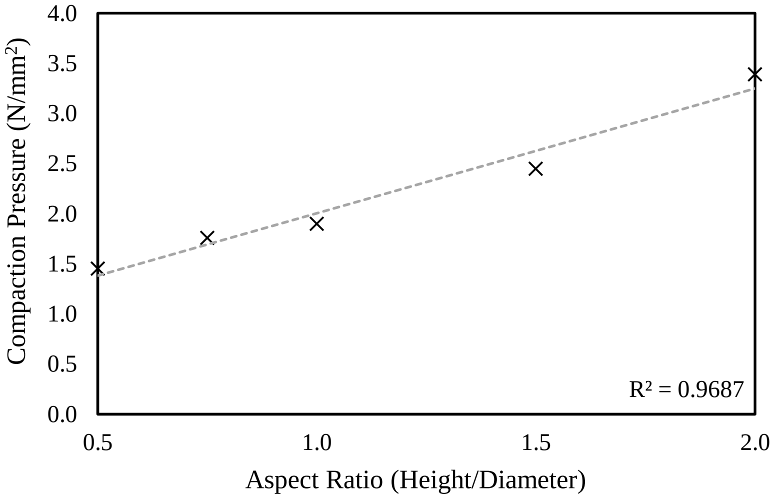


Fig. 4. Peak Compaction Pressure During Manufacture of CEC Samples vs Aspect Ratio (Soil A)

It can be seen from **Fig. 4** that during the manufacture of cylindrical samples with equivalent density, greater compaction pressure is required to manufacture samples of a greater aspect ratio. A similar relationship was observed during the production of samples made from Soil B.

Using equation (3) derived from the linear trendline in **Fig. 4**, it is possible to interpolate to determine the compaction pressure required to manufacture a CEC with an aspect ratio equivalent to a CEB is 1.59N/mm^2, whereby x = 0.67.

$$y = 1.2444x + 0.7598 \tag{3}$$

The CEBs were manufactured using the UoP-CEB machine at a consistent compaction pressure of 1.25 MPa, with an acceptable tolerance of +/-10%. The CECs required approximately 27% greater compaction pressure when compared to the CEBs to produce a sample with an equivalent aspect ratio and density. This may be due to friction and the boundary effects caused by the shape of the cylindrical versus cuboid mould.

The results in **Fig. 4** also show that a compaction pressure of approximately 1.38N/mm^2 is required to manufacture a CEC with an aspect ratio of 0.5, whereas a compaction pressure of approximately 3.25N/mm^2 is required to manufacture a CEC with an aspect ratio of 2.0, a difference of approximately 2.35 times. **Fig. 5** demonstrates the consequence of manufacturing a CEC AR-2.00 sample at a lower compaction pressure (2.0N/mm^2 - 62% of the required compaction pressure). The subsequent sample did not achieve the correct height, resulting in a lower dry density. Furthermore, the sample did not achieve uniform compaction through its height, which will adversely influence its compressive strength and cause areas of weakness in the sample.

This is an important observation and demonstrates the importance of utilising the correct compaction pressure when manufacturing CECs of equivalent density and different aspect ratios.

Fig. 5. Insufficient Compaction (Left), Uniform Compaction (Right)

3.3 Aspect Ratio Factors for Un-Stabilised Compressed Earth

The compressive strength of un-stabilised CECs at different aspect ratios is shown in **Fig. 6**. As can be seen, samples manufactured from Soil A achieved a higher compressive strength when compared to those manufactured from Soil B. This is likely due to the different soil constituents and differences in dry density. Within each dataset, the results presented show that cylindrical samples with a low aspect ratio achieved a greater compressive strength than those with a higher aspect ratio. This observation is consistent with existing studies on the aspect ratio of compressed earth samples [2,5,7,38,39].

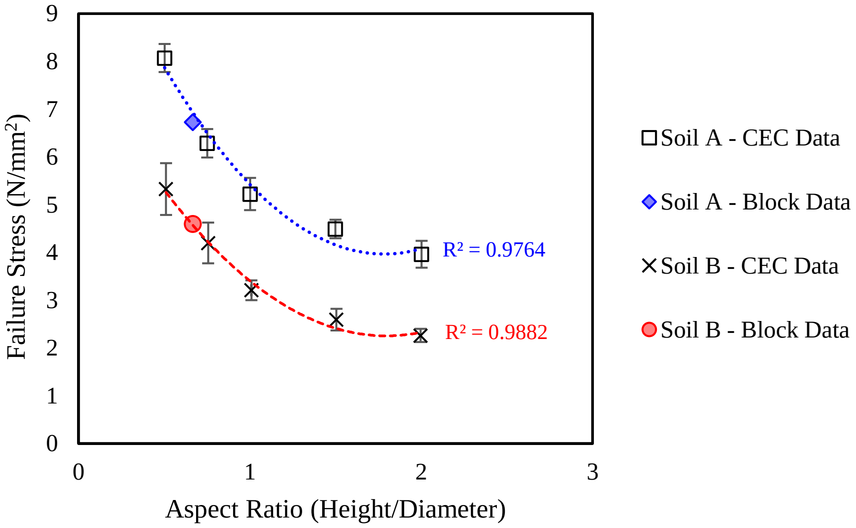


Fig. 6. Mean Compressive Strength of CECs and CEBS. Error Bars Represent the Standard Deviation.

A second-order polynomial trendline has been applied to each data set in **Fig. 6** with a coefficient of determination (R^2) of 0.9764 and 0.9882 for Soil A and Soil B respectively. This suggests that the trendline for each set of data is a close fit, and indicates that there is a non-linear relationship between compressive strength and aspect ratio.

Using equations (4) and (5) derived from the polynomial trendlines in **Fig. 6Fig. 4**, it is possible to interpolate to predict the ACS of a CEB sample with an aspect ratio of 0.67. Note, the interpolation between data points may be considered but extrapolation beyond the dataset is not advised. The predicted values and the results from the physical testing of CEBs, can be found in **Table 6**.

$$\textbf{Soil A: } y = 1.8175x^2 - 6.5305x + 8.1209 \tag{4}$$

$$\textbf{Soil B: } y = 2.3768x^2 - 8.4797x + 11.531 \tag{5}$$

Table 6. Predicted versus Actual Compressive Strength

Soil Type	**Predicted ACS of CEB, based CEC at Aspect Ratio of 0.67 (N/mm^2)**	**Mean ACS of CEBs obtained from physical testing (N/mm^2)**	**Percentage Difference (%)**
Soil A	6.92	6.73	2.78
Soil B	4.56	4.60	0.87

The relationship observed in **Fig. 6** may also be used to predict the UCS of the CEB, by considering the cylindrical test result at an aspect ratio of 2.0.

For Soil A, the CEB achieved an ACS of 6.73N/mm^2, and the equivalent CEC at AR-2.00 achieved a compressive strength of 4.08N/mm^2, suggesting a correction factor of approximately 0.61 is required to determine UCS. For Soil B, the CEB achieved an ACS of 4.60N/mm^2, and the equivalent CEC at AR-2.00 achieved a compressive strength of 2.33N/mm^2, suggesting a correction factor of approximately 0.51 is required to determine UCS.

This finding suggests that aspect ratio correction factors may be influenced by the relative strength of the samples. This theory is supported by Murdock and Kesler [52] who investigated the influence aspect ratio on concrete cylinders at different concrete strengths and found that lower-strength concrete is more affected by the height/diameter ratio of the specimen. The compressive strength of the CECs samples for Soil A and Soil B is shown in **Error! Reference source not found.**, whereby the compressive strength is presented relative to the strength of a sample with an aspect ratio of 2.0. A comparison is made with concrete cylinders, using data obtained from [8,52].

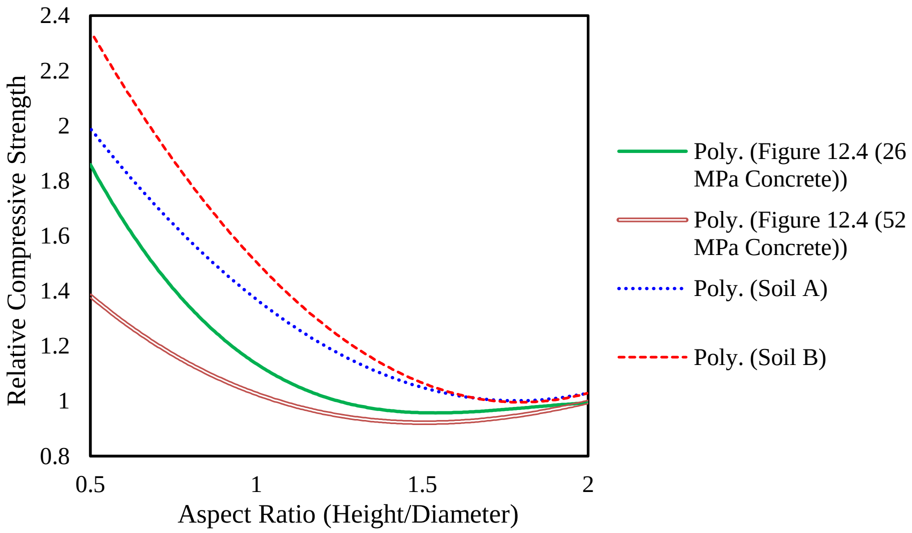


Fig. 7. Relative Compressive Strength of Samples versus Aspect Ratio. Data for 26 and 52MPa concrete was obtained from [8,52].

Fig. 8 contains aspect ratio correction factors, published with New Zealand Standards NZS 4298:1998 [11]. The standard allows linear interpolation between data points, therefore, a correction factor of 0.59 can be determined for a CEB with an aspect ratio of 0.67. When compared to the results of this study, the application of a 0.59 correction factor would underestimate the UCS of Soil A by approximately 4%, which is deemed acceptable. However, a 0.59 correction factor would overestimate the UCS of Soil B by approximately 16%. The result of this investigation indicates that a single correction factor for all soil types and densities may not be appropriate, leading to inaccuracies.

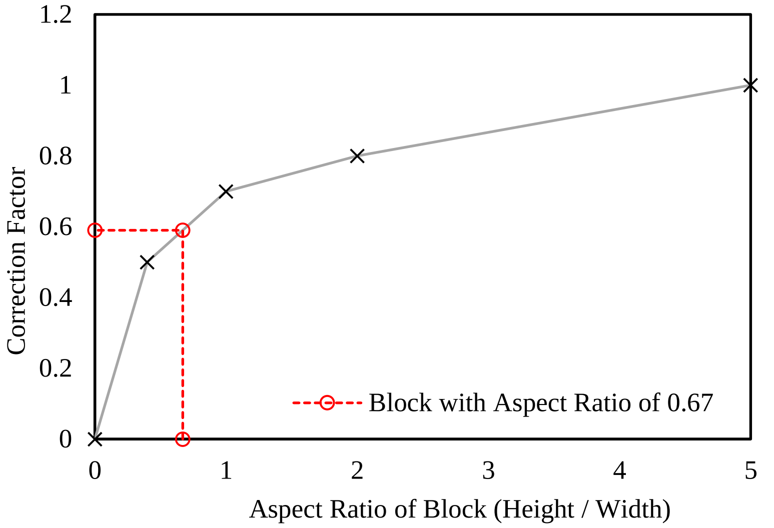


Fig. 8. Aspect Ratio Correction Factors, Published with New Zealand Standards NZS 4298:1998 [11]

It must be noted that the geometric features of a CEB, including the presence of vertical holes or frogs, also influence apparent compressive strength [6], therefore the aspect ratio factors presented in this study apply to solid CEBs only. Further correction factors should be investigated to correlate between cylindrical samples and CEBs with alternate geometric features.

Furthermore, the addition of fibre reinforcement highlights potential challenges associated with scaling and boundary effects. When fibres are incorporated into a soil mixture, the distribution and orientation of fibres is random and difficult to replicate. This often produces a wide range of results within an experimental investigation. Moreover, the addition of fibres will provide resistance to lateral expansion as the sample is subject to a vertical load. It is recommended that further testing should be carried out using fibre-reinforced CECs at aspect ratios of 0.50, 0.75, 1.00, 1.50 and 2.00 to assess and determine the relationship and influence of aspect ratio of fibre-reinforced CEBs.

4 Conclusion

The purpose of this study was to investigate the use of small-scale un-stabilised CECs to estimate the ACS of full-scale un-stabilised CEBs as well as the UCS of the material. The results obtained from the physical testing provide a greater understanding of the influence of aspect ratio on the compressive strength of un-stabilised CECs and CEBs. The important conclusions emerging from this study are:

- Small-scale un-stabilised CECs have been used to predict ACS of full-scale un-stabilised CEBs, with an accuracy of ± 3.0%.
- The use of small-scale un-stabilised CECs may be used to predict the UCS of the material.
- Results indicate that aspect ratio correction factors may depend on the relative strength, soil constituents and dry density of the compressed earth sample, and therefore care should be taken when applying generic correction factors.
- The results of this study demonstrate the importance of utilising the correct compaction pressure when manufacturing CECs of equivalent density and different aspect ratios.
- This study demonstrates several practical advantages to the use of small-scale CEC compared to full-size test specimens, including a reduction in the time and materials required to manufacture test samples and the subsequent increase in the number of test specimens that can be made and tested.

In addition to the potential benefits of using small-scale CECs to predict the compressive strength of full-scale CEBs, this study also highlights the limitations of using small-scale CECs and highlights areas for future research and development to determine aspect ratio correction factors for non-homogenous, fibre-reinforced CEB mixes. Further investigation is also required to determine aspect ratio correction factors for CEBs with alternative geometric features, including the presence of vertical holes or frogs.

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