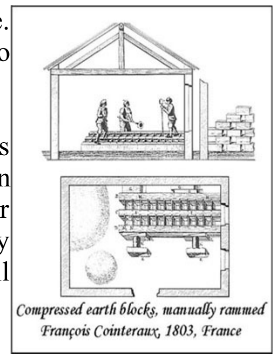
Compressed Stabilised Earth Block

The first attempts for compressed earth blocks were tried in the early days of the 19th century in Europe. The architect François Cointereaux precast small blocks of rammed earth and he used hand rammers to compress the humid soil into a small wooden mould held with the feet.



First attempts for compressed earth blocks in 1803

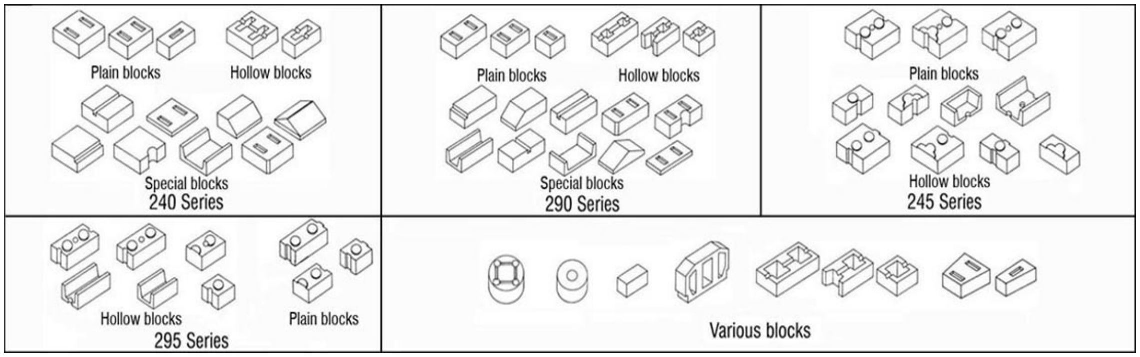
The first steel manual press which has been produced in the world in the 1950's was the Cinvaram. It was the result of a research programme for a social housing in Colombia to improve the hand moulded & sun dried brick (adobe). This press could get regular blocks in shape and size, denser, stronger and more water resistant than the common adobe. Since then many more types of machines were designed and many laboratories got specialised and skilled to identify the soils for buildings. Many countries in Africa as well as South America, India and South Asia have been using a lot this technique.

The soil, raw or stabilized, for a compressed earth block is slightly moistened, poured into a steel press (with or without stabiliser) and then compressed either with a manual or motorized press. CEB can be compressed in many different shapes and sizes. For example, the Auram press 3000 proposes 18 types of moulds for producing about 70 different blocks.

Compressed earth blocks can be stabilised or not. But most of the times, they are stabilised with cement or lime. Therefore, we prefer today to call them Compressed Stabilised Earth Blocks (CSEB).

The input of soil stabilization allowed people to build higher with thinner walls, which have a much better compressive strength and water resistance. With cement stabilization, the blocks must be cured for four weeks after manufacturing. After this, they can dry freely and be used like common bricks with a soil cement stabilized mortar.

Cinvaram, the first press for compressed earth blocks



Compressed stabilised earth blocks by the Auram press 3000

SUSTAINABILITY AND ENVIRONMENTAL FRIENDLINESS OF CSEB

- Earth is a local material and the soil should preferably be extracted from the site itself or not transported from too far away
- Labour costs for CSEB production amount to 40 to 45% of the total cost. This promotes endogenous development.
- It is a cost and energy effective material.
- The embodied energy of CSEB is 10.7 times less than country fired brick.
- Carbon emissions of CSEB are 12.5 times less than country fired brick.

INITIAL EMBODIED ENERGY PER M^3	**CARBON EMISSIONS (Kg of CO_2) PER M^3**
CSEB = 572.6 MJ / m^3 Country Fired Brick (CFB) = 6,122.5 MJ / m^3	CSEB = 51.5 Kg / m^3 Country Fired Brick (CFB) = 642.9 Kg / m^3

Note: Data for Auroville and Pondicherry, India, 2005.

SOIL SUITABILITY AND STABILIZATION FOR CSEB

Not every soil is suitable for earth construction and CSEB in particular. But with some knowledge and experience many soils can be used for producing CSEB. Topsoil and organic soils must not be used. Identifying the properties of a soil is essential to perform, at the end, good quality products. Some simple sensitive analysis can be performed after a short training. Cement stabilisation will be better for sandy soils. Lime stabilisation will be better suited for clayey soils.

GOOD SOIL FOR COMPRESSED STABILISED EARTH BLOCKS

The selection of a stabilizer will depend upon the soil quality and the project requirements. Cement will be preferable for sandy soils and to achieve quickly a higher strength. Lime will be rather used for very clayey soil, but will take a longer time to harden and to give strong blocks.

Soil for cement stabilisation: it is more sandy than clayey	Gravel = 15%	Sand = 50%	Silt = 15%	Clay = 20%
Soil for lime stabilisation: it is more clayey than sandy	Gravel = 15%	Sand = 30%	Silt = 20%	Clay = 35%

The average stabilizer proportion is rather low:

	Minimum	**Average**	**Maximum**
Cement stabilisation	3 %	5 %	No technical maximum
Lime stabilisation	2 %	6 %	10%

These low percentages are part of the cost effectiveness of CSEB.

ENERGY EFFECTIVENESS

Initial embodied energy (MJ/m^3 of materials)	**Carbon emission (Kg of CO2 /m^3 of materials)**

CSEB are consuming 11 times less energy than country fired bricks:	CSEB are polluting 13 times less than country fired bricks:
CSEB produced on site with 5 % cement = 548.32 MJ/m^3 Country fired bricks = 6,122.54 MJ/m^3	CSEB produced on site with 5 % cement = 49.37 Kg of CO_2 $/m^3$ Country fired bricks = 642.87 Kg of CO_2 $/m^3$

COST EFFECTIVENESS

CSEB are most the time cheaper than fired bricks and concrete blocks. In Auroville, a finished m^3 of CSEB masonry is always cheaper than fired bricks: between 15 to 20% less than country fired bricks (April 2009). See [Comparison of building materials in Auroville](). The cost breakup of a 5 % CSEB produced in Auroville with an AURAM press 3000 is as follow (July 2012):

Labour (soil sieving and block making): ~45 %	Raw materials (soil, sand, water): ~ 27 %	Cement: ~25 %	Equipment: ~3 %

Of course this breakup will vary a lot according to the local context, but in general the labour cost (which includes the soil digging, its preparation and the block making) and the cement cost are the highest. Therefore if the productivity decreases, the cost of the block will increase proportionally a lot. In general, to reduce the cost of the block one should optimise the productivity of workers and reduce the amount of cement if 5% cement is not required. Further, the cost of the equipment is not so high and therefore, one should not try to cut down the cost of the lock by buying cheap quality machines, which would not last long and would not give strong blocks.

BASIC DATA ON CSEB

PROPERTIES	SYMBOL	UNIT	CLASS A	CLASS B	CLASS C
Dry compressive crushing strength (@ 28 days, +10% after 1 year)	σ_{Cd}	MPa	5 -7	4 - 5	3 - 4
Wet compressive crushing strength (@ 28 days, after 24 hours immersion)	σ_{Cw}	MPa	3 - 4	2 - 3	1.5 - 2
Tensile crushing strength, dry (on a core @ 28 days)	τ	MPa	0.5 - 1	0.5 - 1	0.5 - 1
Bending crushing strength, dry (@ 28 days)	σ_{Bd}	MPa	0.5 - 1	0.4 - 0.8	0.3 - 0.6
Shear crushing strength, dry (@ 28 days)	τ	MPa	0.4 - 0.6	0.3 - 0.5	0.2 - 0.3
Total water absorption	-	% weight	8 - 10	10 - 12	12 - 15
Apparent bulk density	γ	Kg/m^3	1900 - 2000	1800 - 1900	1700 - 1800
Poisson's ratio	μ	-	0.15 - 0.35		
Young's Modulus	E	MPa	700 - 1000		
Coefficient of thermal expansion	-	mm/mºC	0.010-0.015		
Swell after saturation (24 hours immersion)	-	mm/m	0.5 - 1		
Shrinkage (due to natural air drying)	-	mm/m	0.2 - 1		
Permeability		mm/sec	1.10^{-5}		
Specific heat	C	KJ/Kg	0.65 - 0.85		
Coefficient of conductivity	λ	W/mºC	0.81 – 0.93		
Damping coefficient	m	%	5 - 10		
Lag time (for 40 cm thick wall)	d	h	10 - 12		
Coefficient of acoustic attenuation (for 40 cm thick wall at 500 Hz)	-	dB	50		
Fire resistance *	-	-	Good		
Flammability *	-	-	Poor		
Embodied energy (for 5% cement stabilised and produced by hand press)	-	MJ/m^3	572.58 **		
Carbon emission (CO_2/m^3 raw material)	-	CO_2/m^3	49.37 **		

Notes

- 1 MPa = 10.197 Kg / cm^2 = 145 PSI
– These values can be obtained with 5 % cement stabilisation and a compression pressure of 2 to 4 MPa.
– The strength of blocks is influenced by the soil quality, type & amount of stabiliser, quality of workmanship and curing.
– These values are obtained after 6 weeks (4 weeks for curing and 2 weeks for drying).

– These values are obtained after 6 weeks (4 weeks for curing and 2 weeks for drying).
– Classes A, B and C are defined by the wet compressive strength of the blocks.
– The other values mentioned in the table above are indicative to give an idea of the characteristics to be expected.
– These values are the result conducted in laboratories by recognized authorities. They give an idea of what can be reasonably expected of a product made in accordance with the state of the art.
– Sources: "Earth Construction, a comprehensive guide" – CRATerre, Hugo Houben and Hubert Guillaud
Research of the Auroville Earth Institute (Dry & wet compressive crushing strength, bending crushing strength, water absorption, embodied energy and carbon emission)
* No scientific tests on fire resistance have been conducted, to our knowledge till now.
** To be compared with: county fired bricks (6,122.54 MJ/m^3), reinforced cement concrete 1: 1.5: 3 (4,913.56 MJ/m^3) and solid concrete blocks (1,156.00 MJ/m^3)

ADVANTAGES OF CSEB

• A local material **Ideally, the production is made on the site itself or in the nearby area. Thus, it will save the transportation, fuel, time and money.** **• A bio-degradable material** **Well-designed CSEB houses can withstand, with a minimum of maintenance, heavy rains, snowfall or frost without being damaged. The strength and durability has been proven since half a century.** **But let's imagine a building fallen down and that a jungle grows on it: the bio-chemicals contained in the humus of the topsoil will destroy the soil cement mix in 10 or 20 years… And CSEB will come back to our Mother Earth!** **• Limiting deforestation** **Firewood is not needed to produce CSEB. It will save the forests, which are being depleted quickly in the world, due to short view developments and the mismanagement of resources.** **• Management of resources** **Each quarry should be planned for various utilisations: water harvesting pond, wastewater treatment, reservoirs, landscaping, etc. It is crucial to be aware of this point: very profitable if well managed, but disastrous if unplanned!**	**• Energy efficiency and eco friendliness** **Requiring only a little stabilizer the energy consumption in a m^3 can be from 5 to 15 times less than a m^3 of fired bricks. The pollution emission will also be 2.4 to 7.8 times less than fired bricks.** **• Cost efficiency** **Produced locally, with a natural resource and semi skilled labour, almost without transport, it will be definitely cost effective! More or less according to each context and to ones knowledge!** **• An adapted material** **Being produced locally it is easily adapted to the various needs: technical, social, cultural habits.** **• A transferable technology** **It is a simple technology requiring semi skills, easy to get. Simple villagers will be able to learn how to do it in few weeks. Efficient training centre will transfer the technology in a week time.** **• A job creation opportunity** **CSEB allow unskilled and unemployed people to learn a skill, get a job and rise in the social values**	**• Market opportunity** **According to the local context (materials, labour, equipment, etc.) the final price will vary, but in most of the cases it will be cheaper than fired bricks.** **• Reducing imports** **Produced locally by semi skilled people, no need import from far away expensive materials or transport over long distances heavy and costly building materials.** **• Flexible production scale** **Equipment for CSEB is available from manual to motorized tools ranging from village to semi industry scale. The selection of the equipment is crucial, but once done properly, it will be easy to use the most adapted equipment for each case.** **• Social acceptance** **Demonstrated, since long, CSEB can adapt itself to various needs: from poor income to well off people or governments. Its quality, regularity and style allow a wide range of final house products. To facilitate this acceptation, banish from your language "stabilized mud blocks", for speaking of CSEB as the latter reports R & D done for half a century when mud blocks referred, in the mind of most people, as poor building material**

SOME LIMITATIONS OF CSEB

• Proper soil identification is required or unavailability of soil. **• Unawareness of the need to manage resources.** **• Ignorance of the basics for production & use.**	**• Low technical performances compared to concrete.** **• Untrained teams producing bad quality products.** **• Over-stabilization through fear or ignorance, implying outrageous**	**• Under-stabilization resulting in low quality products.** **• Bad quality or un-adapted production equipment.** **• Low social acceptance due to counter examples (By unskilled people, or bad soil & equipment).**

• Wide spans, high & long building are difficult to do.		

DIVERSITY AND SELECTION OF THE PRODUCTS

The development of CSEB proposes nowadays a wide range of products, from different size and shapes.
To select the most adapted product to one's need, one should pay specially attention to these factors:

Module of the block	• **It is the block size plus the mortar thickness.** • **Choose preferably an easy module, in the decimal system, to avoid wasting time for the design calculations.** • **Select also the module with the thinnest mortar joint possible.**
Possibilities of different wall thickness	• **According to the module of a block, which thickness of wall can be achieved with easy bonds?** • **According to the thickness, one can know if a block can be load bearing or not.**
Area of the block	• **The bigger it is, the weaker the block will be.** • **A large area will require great compaction energy:** **A manual press with 15 Tons capacity will not be able to compress properly more than 600 cm².**
Plain, hollow or Interlocking blocks…?	• **Each of them has different possibilities:** - **Plain ones will be laid with a thick mortar (1 to 1.5 cm)** - **Hollow ones will be laid with a thin mortar (0.5 to 1 cm)** - **Interlocking blocks will require a thin mortar (0.5 cm), very special details and are meant for earthquake resitance.**
Mould possibilities	• **Whether a mould can do full size, 3/4 of half block.** • **To do proper bonds, one needs to use these 3 sizes in order to achieve a good quality, without breakage.**

TYPICAL BLOCKYARD ORGANISATION

Six production stages

There are 6 stages for the production of CSEB.
The following details are given for an Auram Press 3000 which can produces 1000 blocks 240 per day:

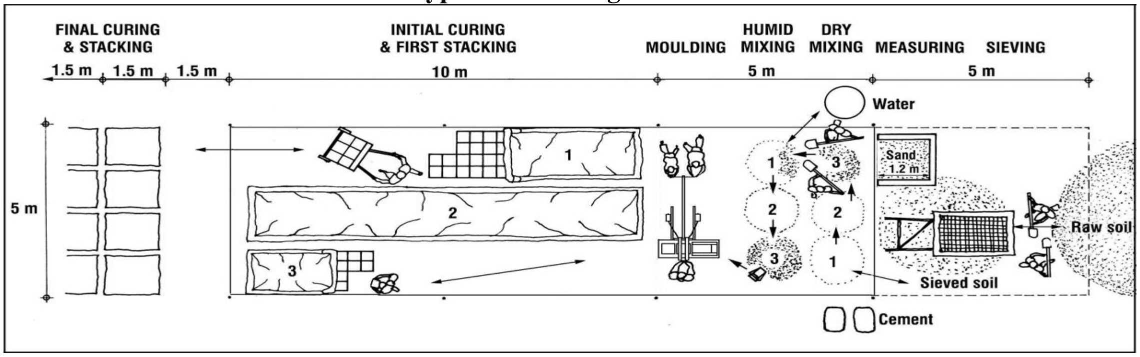
Preparation (Digging + Sieving)	**2 to 4 people**
Measuring	**1 people**
Mixing (dry + wet)	**2 people**
Pressing	**3 people**
Initial curing and first stacking	**1 people**
Final curing and stacking	**2 people**
Total No.	**11 to 13 people**

Notes for the production stages:
The number of persons for digging & sieving will vary with the type of soil.
The number of persons for the final curing & stacking will depend of the transportation distance.

Key words for the organisation of the blockyard

• **Reduce the distance of transportation.** • **Optimise the ratio output / number of workers, to get the best efficiency.** • **Organize the block-yard as close as possible from the site.** • **Organise the storeroom as close as possible from the blockyard.** • **Organise the final stacking area as close as possible from the blockyard.** • **It is preferable to have a linear organization but a circular one can also be suitable.**

Typical linear organization



Typical blockyard layout for an Auram Press 3000

OPTIMIZATION OF INVESTMENT / OUTPUT / QUALITY RATIO

- Light manual equipment presents the advantage of being cheap, but the disadvantage of a low durability, a low output and not very well compressed blocks.
- Heavy manual equipment presents a more interesting ratio, with more output, more durability and more strength for a subsequent increase of costs.
- Motorized equipment steps into another category of cost: it will produce better quality blocks with more output, but more expensive.

Therefore, heavy manual presses are most of the time the best choice in terms of optimisation for the investment/output/quality ratio. Mobile-units are always coming far behind. Industrialization is not adapted to the production of CSEB. Semi industrialization is the best: it offers the advantage to be more flexible and easily adapted to a local context. It increases the quality without increasing tremendously the cost of a block. Semi industrialization should be understood here as a centralized production, but rather with manual presses than motorized ones.

DIVERSITY AND SELECTION OF THE EQUIPMENT

Many attempts were tried to use concrete equipment to produce CSEB. All failed, as the requirements of the materials and the working conditions are different. Today, available on the market are a wide range of specialized equipment adapted to each need and scale of production. Today one can find manual presses, light or heavy, motorised ones where the compression energy is given by an engine. One can also find mobile units, which also integrates a crusher and a mixer in the same machine.

A cheap manual press, thus light and attractive in price, will not be so long lasting. A motorized press will present the advantage of a high productivity, with a better and more regular quality. But it will require energy and a more complicated maintenance, and its cost will have no comparison with a manual press. Besides a press, one should not forget all the other equipment required: sieve, maybe a crusher, wheelbarrows, maybe a mixer, quality control devices, all small tools, PVC sheets, etc.

Therefore, in a developing country where a lot of labour is available, manual and heavy presses are better adapted than motorised ones, as they would employ more people and would produce quality materials at cheaper rates. In India today despite 1.2 Billion people, there are nowadays difficulties to get labour for construction sites. This trend seems a worldwide pattern as people don't like anymore to do the hard work of a construction site and they are reluctant to work with their hands. Thus it becomes necessary to mechanize the process and use motorised presses.

SOME EQUIPMENT WORLDWIDE

Manual presses

Terastaram - Belgium

Unata – Europe

Elson Block Master – India



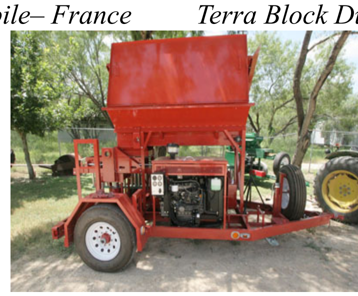
Balram – India *Astram - India* *Auram Press 290 – India* *Auram Press 3000 – India*



Pact 500 – France *Hydraulic press - India* *AECT Impact 2001 – USA, Texas*



Pact 500 mobile– France *Terra Block Duplex II - USA* *Terra Block - USA*




AECT Impact 3000 – USA, Texas *AECT Impact 5000 – USA, Texas*

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