AUROVILLE EARTH INSTITUTE

BUILDING WITH EARTH IN AUROVILLE

A case study
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AUROVILLE EARTH INSTITUTE

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“Auroville is the attempt towards collective realisation”.

The Mother, June 1968

Auroville wants to be the bridge between the past and the future. Taking advantage of all discoveries from without and from within, Auroville will boldly spring towards future realisations.

The Mother, Auroville Charter, 28th February 1968
LESSONS FROM THE PAST

Down through the ages, people have been using raw earth for building their living spaces. The tradition has grown out of an attempt to be in harmony with Nature, to use and yet respect her. Every single continent and nearly every country possesses a rich heritage of earthen buildings. At least 30% of the world’s population lives in earthen houses.

From the roof of the world in Tibet or in the Andes Mountains in Peru, to the shores of the Nile in Egypt or in the fertile valleys of China, many are the examples of earth used as a building material.

The oldest one can still be seen in Egypt, near Luxor, which was built around 1300 BC: the vaults of the Ramasseum, in the “rest” of Thebes. It has been built with adobes, the sun dried mud bricks.

Ramasseum, Egypt, ~ 1300 BC

India also shows very old earthen buildings, like the Shey palace in Ladakh, which was built with adobe in the XVIIth century. The oldest one has withstood 1006 Himalayan winters: the Tabo monastery in Spiti Valley, Himachal Pradesh, which was built with rammed earth in 996 AD.

Tabo Monastery, Spiti, HP, India – 996 AD

Shey Palace, Ladakh, India – XVIIth Century

Raw earth for building has been used worldwide for millennia but, during the 20th century, most of the skills of earth builders were lost and building with earth became marginal. We owe a lot to the Egyptian architect Hassan Fathy for the renaissance of earthen architecture in the middle of the XXth century.

The new development with earth construction really started in the nineteen fifties, with the technology of compressed stabilised earth blocks (CSEB): a Colombian research program for affordable houses proposed the first manual press, the Cinvaram. This has led to a renaissance of the tradition of earthen architecture and construction – a revival which is benefiting from the results of scientific research.

Auroville is attempting to revive these traditional skills and to demonstrate that earth is still a noble building material which can be used for manifesting modern, harmonious and progressive architecture.
EARTH TO BUILD WITH

The earth used for building is composed of four main elements: gravel, sand, silt and clay. According to the qualities and proportions of these components, the soils will have different behaviours and characteristics. Many soils can be used for building, but some may need improvement. The Auroville red soil got its colour from iron oxides which give excellent properties and make remarkable building materials.

Some may say, "Using soils for building will lead to the destruction of nature..."

True, if it is done without knowledge or with unconsciousness.
Wrong, if one is attentive to the management of resources and the balance of nature. First of all, one should plan how to use the excavation afterward. Topsoil should be scraped away, so as to be re-used for agriculture or gardens.

A modern practice is to stabilize the soil by using additives. They increase the mechanical properties and stabilize the earth against water. The most common additive is cement. Lime is also used, but to a lesser extent. In Auroville, the earth is stabilised with about 5% by weight of cement. The quality of the lime around Auroville is not high enough to be used.

COMPRESSED STABILISED EARTH BLOCK (CSEB)

CSEB is nowadays the most widely used earth technology worldwide, as well as in Auroville, because it represents a synthesis between traditional practices and modern technology. It benefits from scientific inputs.

The stabilized soil is mixed with a little water to become just humid, and then is compressed into a manual or a motorized press. In 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 stabilized soil cement mortar.

In Auroville, CSEB with 5% cement have an average dry compressive crushing strength of 50 kg/cm² (5 Mpa) and a wet compressive crushing strength of 25 kg/cm². The water absorption is around 10%. Country fired bricks have around 35 kg/cm² for the dry compressive strength and a 12% water absorption rate.

The Auroville Earth Institute has designed manual presses for CSEB, which are manufactured in Auroville by Aureka, one of its steel workshops. Today this equipment is sold worldwide.

RAMMED EARTH

This technology has traditionally been used in many countries. France, Morocco and the Himalayan countries show a wonderful heritage. Today, rammed earth is used with stabilizers in the USA and Australia where the process has been mechanized. In Auroville, the earth is rammed by hand.

Until 1994, Auroville had only one house made of raw rammed earth. The Auroville Earth Institute designed new forms and with the construction of Mirramukhi School, people discovered the exceptional potential beauty and versatility of stabilised rammed earth.
Building with earth today, we benefit from the countless customs and discoveries of humanity down through the ages.

But in the history of earth building, one thing captures our attention: all over the world and down through the centuries, one is amazed by the balance and harmony these buildings achieve with the landscape and the surrounding physical environment.

With new developments (i.e. CSEB on a semi-industrial scale) one should not forget the risk of creating ecological disasters through the mismanagement of resources.

On the other hand, proper management of the earth resources can create a new and harmonious balance between nature and the buildings, where each enriches and completes the other.

First of all, one should plan how the excavation will be used afterward. Topsoil should be scraped away, so as to be re-used for agriculture or gardens.

Auroville shows various possibilities for the use of quarries: as water harvesting ponds, waste water treatment ponds, pools, basement floors or shallow depressions which are used for landscape design, work or play areas, gardens, etc.
The international city of Auroville is under construction in Tamil Nadu, in the south of India. One of its aims is to harmonize material and spiritual research to give a living embodiment to an actual human unity. Mirra Alfassa, The Mother, who together with Sri Aurobindo worked for nearly half a century on the evolution of humanity, founded Auroville in 1968.

From the early days, different experiments have been made with earth building in Auroville, with mixed results. The creation of the Auroville Earth Institute in 1989, and the construction of the Visitors’ Centre, started a new era in earthen architecture.

This Visitors’ Centre of 1200 m² was granted the “Hassan Fathy Award for Architecture for the Poor” in 1992. Built of compressed stabilised earth blocks, it demonstrated the potential of stabilised earth as a quality building material.

Since then, the value of earth as a building material has been acknowledged for its economic advantage, as well as its comfort and quality, which promotes indigenous and sustainable development. Today, Auroville can show a wide variety of earthen projects: public buildings, schools, apartments and individual houses.

Most of the projects are built with compressed stabilised earth blocks (CSEB), as this technology benefits of half a century of research and development worldwide. In Auroville, these blocks present many advantages compared to fired bricks:

- Walls made of CSEB are always cheaper than fired bricks.
- The embodied energy is 15 times less than the bricks fired in the village.
- The strength of these blocks is most of the time higher than the local fired bricks.

Stabilised rammed earth used for walls is slowly getting known and a few projects already implemented this technique.

There are also three other earth techniques used in Auroville. These techniques are very marginally used as only 8 buildings have been built with them:

- Raw rammed earth, for only two buildings.
- Adobe blocks, the traditional sun dried mud brick, for two buildings.
- Wattle and daub which is mud plastered on a wattle made of split bamboo or palmyra tree, for 4 buildings.

Note for the photos of the following pages: when the technique is not mentioned, the buildings are made or compressed stabilised earth blocks.
HOUSES

Revelation community
House built with raw rammed earth

Newland community
House built with wattle & daub

Samasti community
House built with adobes

Samasti community
House built with CSEB

Samasti community

Dana community

Auromodele community

New Creation field
Aurobrindavan community

Utility community
House built with CSEB and straw bale

Auroville Earth Institute campus

Vikas community
Cost effective house
Vikas community
Cost effective house

Vikas community
Moveable house

Green belt

Green belt

Dana community

Vérité community

Cost effective house in a village

Experimental house in a village
PUBLIC BUILDINGS

Visitors Centre – “1992 Hassan Fathy Award for Architecture for the Poor”

Visitors Centre, entrance

Visitors Centre, information office and exhibition

Visitors Centre, access to the cafeteria

Visitors Centre, cafeteria
Pitanga Hall, Cultural Centre

Vérité Centre, Multipurpose Hall

Altecs, Electronic workshop

Solar collective kitchen for 1000 people
Kitchen side and dining hall

Solar collective kitchen
Kitchen side

Solar bowl, 15 m diameter
Deepanam School, vault with stabilised rammed earth and CSEB dome

Deepanam School, CSEB cloister dome, 5.70 m square

Deepanam School, CSEB vault 10.35 m span, 2.25 m rise

Shakti Vihara School at Pondicherry

Auroshika School

Auroshika School

Isaiambalam School

Kindergarten
VIKAS COMMUNITY

The creation of this community was based on a particular spirit, lifestyle and sustainable approach to development. The exclusive use of environmentally sound materials, appropriate building technologies, renewable energy sources and biological wastewater treatment was the basis of its material implementation.

This project was designed and built by the Auroville Earth Institute. It was the first development in Auroville which used stabilised earth from foundations to roof. To date, Vikas community still represents the most synthetic sustainable development which has been materialised in Auroville. Vikas was a finalist for the “2000 World Habitat Award”. The first prize was given to a similar project in the USA.

The community was built in several steps, from 1992 to 2000:

- **First development:** The collective kitchen was built first in 1992 and then, the first block of four apartments in 1993. The soil for building was extracted from the half underground reservoir and from the pond for the wastewater treatment. At this stage, the soil dug from these excavations was sufficient to build.

- **Second development:** The second block of six apartments was built in 1996. At this stage, there was still some soil left from the excavation of the wastewater treatment pond. But it was not enough to build the entire structure. The development of Vikas did not need any further excavations, so the soil needed to be supplied from another source. As quarries are often savage and as no control on the management of resources is possible, the concept of a basement floor was developed for the third building.

- **Third and last development:** The third block of thirteen apartments was built on four floors – A basement floor with three floors above it. The basement also had apartments, and it was half underground so as to get enough light for the rooms. This construction site started early 1997 and was completed early 2000.

**UNIQUE FEATURES OF THE THIRD BUILDING**

This building was conceived so as to be self-sufficient in its soil needs, an important consideration because of its size. The soil was dug from the basement floor (1.20m below the original ground level) to produce CSEB for building the 4-storied structure, with a carpet area of 819 m².

To protect the basement from the overflow of rainwater a particular landscape was designed. The immediately surrounding land was shaped into a shallow crater to drain rainwater into a percolation pit.

The foundations were done with stabilised rammed earth and the 13.40 m high walls were done with CSEB of 24 cm thick. All floors and roofs were made of very flat vaults and domes for the living rooms. These vaults and domes were built with CSEB by using the “Free-spanning” technique. All stabilisation used 5% cement by weight.

This building implemented various appropriate architectural designs which had previously been tested, such as:

- Sun protection with sunshades and a proper orientation of the building.
- Natural cross ventilation with a proper orientation of the building, to catch the summer wind. The ventilation is improved by an increase of wind velocity through pier walls.
A solar chimney to create a natural draft which cools the building, especially at night. The sun heats a heavy black slab laid on the chimney top: this creates a natural draft due to the temperature difference in the chimney.
SITE LAY-OUT

23 apartments with a collective kitchen for 50 people (1448 m² carpet area)
CROSS SECTION OF THE THIRD BUILDING
13 apartments on 4 floors
As the third building was built on a basement floor, it was essential to protect it from any rainwater intrusion. A drain, made of slotted PVC pipe, was laid against the foundation and the collected water was sent into an underground percolation pit (±10m³), which was filled with sand. This pit collected the rainwater which went underground. It had no connection with the surface rainwater.

The land immediately surrounding the building was shaped like a shallow crater to harvest rainwater. The latter was sent into a pit of about 73 m³, which was shaped into a conical crater with a few steps to access it. An extra pit of 44m³ was added as a back up in case of very exceptional rainfall. Any overflow of the main percolation pit would go into the second pit, which was filled with sand.

This system harvests rainwater which falls on the building and the crater immediately around it. The roof and the percolation system cover about 1200 m². The system is protected by a strong bund all around to avoid any intrusion of rainwater from the adjacent land.

An unusual and exceptional rainfall proved the effectiveness of the system. Auroville receives around 1250 mm of rainfall per year: about 3/4 during the 2 months of the winter monsoon (mid-October to mid-December) and about 1/4 during the summer monsoon (around June). It almost never rains in between.

February 2000 saw something very unusual: a 402 mm rainfall over 5 days from the 23rd to the 27th. The most intense rain was on February 26th, mostly at night, with 198 mm of rainfall. The rain slowed down on the morning of the 27th and after 4-5 hours the water level in the percolation system went down by 20 cm. This means that during this time the system percolated around 48 m³. The system collected about 450 m³ of rainfall in 5 days. One and a half days after the last drops, everything had percolated and the system was empty.
Half underground reservoir

Community kitchen for 50 people

The four first apartments

Apartment in the third building

First apartments

Apartments in the third building

Children pool
Excavation of the basement for the third building

Stairs of the third building

Third building, garden side

Third building, garden side

Third building, green street side

23 apartments, view from the green street

23 apartments view from the wind pump
The Auroville Earth Institute was previously named the Auroville Building Centre / Earth Unit, which had been founded by HUDCO, Government of India, in 1989. The development of the former building centre evolved in such a way that the Auroville Earth Institute came into existence in 2004.

The Auroville Earth Institute is researching, developing, promoting and teaching earth-based technologies that are cost and energy effective. These technologies are disseminated through training courses, seminars, workshops, publications and consultancy within and outside India.

One of the aims of the Auroville Earth Institute is to give people the possibility to create and build their habitat themselves, using earth techniques.

The Auroville Earth Institute is part of a world network with CRATerre (The International Centre for Earth Construction), ABC Terra in Brazil and a number of Indian NGO’s. A training agreement has been made with the School of Architecture of Grenoble, France, to provide long-term training courses to its students. A partnership agreement has been signed with UNESCO for the Chair “Earthen Architecture – Constructive Cultures and Sustainable Development”. The Auroville Earth Institute is today the South Asian representative and Resource Centre for this chair.

Over the past decade, the endeavour to promote and disseminate raw earth as a building material for sustainable and cost-effective development has brought a series of awards: nine national awards and one international award.

**TRAINING COURSE ACTIVITIES**

Training activities started in 1990 and since, regular courses of 2-week duration are scheduled in Auroville. Major programmes are also organised at Auroville or elsewhere in India at the request of GO’s or NGO’s. Some programmes are also conducted outside India, as has happened in Zaire, Eritrea, Sri Lanka, Saudi Arabia and Turkey.

Regular programmes are conducted every year in the following fields, at the Auroville Earth Institute:
- Production and masonry of CSEB.
- Theory and practice of Arches, vaults and domes.
- Long-term training for students of architecture.
- Awareness programs on appropriate building technologies.
- Special courses on earthquake resistance.

Since 1990, 3551 trainees have been trained in India and 62 abroad:

**INDIA**
- 1877 students, architects, project managers, during 1 or 2-day awareness programmes, in Auroville.
- 1301 Indian trainees with various skills, during 1-week courses in Auroville or elsewhere in India.
- 219 foreign trainees with various skills, from 30 countries, during 1-week or long-term courses.
- 40 Indian students or architects, during long-term courses (Several weeks to several months).
- 114 masons, with “on the job training”, on various construction sites (Auroville and Tamil Nadu).

**ABROAD**
- 132 trainees with various skills, during workshops, in Eritrea, Turkey, Sri Lanka and Zaire.
AURAM EQUIPMENT FOR EARTH CONSTRUCTION

A wide range of equipment for building with earth has been researched and developed from the very onset. It ranges from presses for compressed stabilised earth blocks, quality control devices for block making, handling equipment, hand tools, scaffolding, and rammed earth equipment.

Today, the press 3000 for compressed stabilised earth blocks is being sold worldwide – mostly in South Asia and in Africa. A few machines have also been sold in Europe, USA, Dubai and China. The press 3000 with hollow interlocking moulds was sold in large quantities to Gujarat-India, for the rehabilitation of the zones affected by the severe earthquake of January 2001.

Wide variety of compressed stabilised earth blocks.
APPROPRIATE BUILDING TECHNOLOGIES BASED ON EARTH

This research aims at making extensive use of raw earth as the main building material, thereby using a local resource to help develop technologies that are energy saving, eco-friendly and sustainable.

The main research and development is focussed on minimising the use of steel, cement and reinforced cement concrete (RCC).

Most of the technologies developed have now been mastered and the present research is focussed on alternative stabilizers to cement and alternative water proofing with stabilized earth, composed of soil, sand, cement, lime, alum and tannin.

Stabilised rammed earth

The soil is mixed with sand and stabilised with an average of 5% cement, and rammed by hand. Foundations are rammed directly in the trench and the walls are rammed in between formworks.

Composite basement and plinth beam

Basements are made with CSEB stabilised with 5% cement and the plinth beam is cast into a U shaped CSEB. The composite plinth beam acts also as a damp proof course.
**Composite columns**
Round hollow CSEB are reinforced with cement concrete. Reinforcements vary with the height and load, but the rod diameter cannot exceed 10 mm for the blocks 290 and 12 mm for the blocks 240.

**Composite beams and lintels**
U-shaped CSEB are with reinforced cement concrete. Reinforcements vary with the span, but the rod diameter cannot exceed 12 mm for the blocks 290 & 295 and 16 mm for the blocks 240 & 245. The bottom part of the beam is precast in a reversed position on the ground. Once cured, it is lifted and the middle and top parts are built on it. The blocks are used as lost shuttering, but they also help the compressive strength of the beam.
The earth is mixed with sand and stabilised with cement and a paste made of lime, tannin, alum (Ammonium sulphate) and water.

Tannin is extracted by soaking into water broken seeds of an Indian tree, named “kaddukai” in Tamil Nadu. Its botanical name is Terminelia Chebula. The lime paste is prepared by mixing powdered alum with lime and tannin juice and extra water.

Three coats of plaster are done with different proportions of these components. The last coat, which is the most waterproof, is done with a 5 mm thick plaster composed of soil, sand and lime paste.

No cement is added to the latter. Note that cement is giving strength to the plaster and also helping the waterproofing, but the effectiveness of this waterproofing is given by the combination of soil, lime, alum and tannin.

The results obtained with this waterproofing are excellent: see further on the feedback obtained for the training centre. But this research is still under way and therefore the recipes are not yet disseminated through documentation or training courses.
VAULTED STRUCTURES

The research with this kind of roofing aims to revive and integrate in the 21st century the techniques used in past centuries and millennia, such as those developed in ancient Egypt or during the period of Gothic architecture in Europe.

This R&D seeks to increase the span of the roof, decrease its thickness, and create new shapes. Note that all vaults and domes are built with compressed stabilised earth blocks which are laid in “Free spanning” mode, meaning without formwork. This was previously called the Nubian technique, from Egypt, but the Auroville Earth Institute developed it and found new ways to build arches and vaults.

The traditional Nubian technique needed a back wall to stick the blocks onto. The vault was built arch after arch and therefore the courses were laid vertically. The binder, about 1 cm thick, was the silty-clayey soil from the Nile and the blocks used were adobe. The even regularity of compressed stabilised earth block produced by the Auram press 3000 allows building with a cement-stabilised earth glue of 1-2 mm only in thickness.

The free spanning technique allows courses to be laid horizontally, which presents certain advantages compared to the Nubian technique which has vertical courses. Depending on the shape of vaults, the structures are built either with horizontal courses, vertical ones or a combination of both. All vault shapes are calculated to develop catenary forces in the masonry. Their thickness and span can therefore be optimised.
Starting a lunette

Lunette, 1.2 span

Lunette built in 3 days

Starting the squinche for a segmental vault

Completed squinche, starting the segmental vault

Segmental vault, 10.35 m span, 2.20 m rise, 6 m long with a squinche, built in 18 days with 4 masons
Semicircular vault, 6 m span, 11 m long

Semicircular vault, built in 37 days with 4 masons

Equilateral vault, 3.60 m span, 8 m long

Equilateral vault, built in 36 days with 4 masons

Cloister dome, 3.60 m square, 60 cm rise

Hemispherical dome on pendentives, 3.70 m span

Cloister dome, 5.70 m square, 2.15 m rise

Pointed dome on an octagon, 6.4 m span, 4 m rise
DISASTER RESISTANT BUILDINGS
Since 1995, research has been oriented towards the development of a cost-effective technology which is based on reinforced masonry with hollow interlocking CSEB.

Two types of blocks have been developed: the square hollow interlocking block 245, which allows building up to 2 storeys high, and the rectangular hollow interlocking block 295, which is used only for ground floors.

In June 1996, at the request of CRATerre and the United Nations (UNCHS/Habitat), the Auroville Earth Institute built a prototype of this technology for a 9 m² demonstration house – the Minimum Emergency House, at Istanbul-Turkey, during the “1996 City Summit / HABITAT”.

This house was precast in 10 days and assembled in 8 days.

In 1999, at the request of the Housing and Urban Development Corporation (HUDCO), the Auroville Earth Institute built another demonstration house of 23 m² – the AUM House, in New Delhi during the “All India International Trade Fair”.

This house was precast in 3 weeks int Auroville. It was transported by a lorry of 22.5 ton, over 2900 Km in 5 days, and assembled in New Delhi in 66 hours by an 18-man team. It was granted a Gold Medal by ITPO for the quality of the special demonstration.

Another AUM House was precast at Auroville and assembled in Gujarat, India, in 62 hours by a 20-men team. This demonstration started rehabilitation programmes in the zones affected by the severe earthquake which struck the district of Kutch d in 2001.

Since then, this technology has been developed and it has been transferred to The Catholic Relief Services (CRS), an NGO that implemented it for large scale rehabilitation of Kutch District. CRS designed various types of houses of 28m² and 4000 houses are being built in a year by local teams.

This technology has been approved by the government of Gujarat as a suitable method of construction for the rehabilitation of the zones affected by the 2001 earthquake.
BUILDING WITH EARTH FROM HEAD TO TOE: TRAINING CENTRE

To date, the main synthesis of the research on earth-based technologies is achieved with the training centre of the Auroville Earth Institute. This building is entirely constructed from the foundations to the waterproofing with stabilised earth.

Years of research and training courses have highlighted the need for training facilities, which could also be living examples of what could be done with these technologies. Hence the new premises of the Training Centre were entirely built with stabilised earth from foundations to vaults. The waterproofing, as well, was done with stabilised earth plasters.

The foundations and walls were made with stabilised rammed earth. All roofs were done with various catenary vaults, which were built “Free-spanning” with CSEB. The flooring was also done with CSEB tiles. The entire structure used earth stabilised with 5% cement. The stabilised earth waterproofing was made with three coats of various mixes of soil, sand, cement, lime, alum and tannin.

An exceptional rainfall in February 2000 showed the effectiveness of this stabilised earth waterproofing, when 402 mm of rainfall occurred in five days and there was neither leakage nor dampness inside the vaults. This comparative survey was measured with an electronic hygrometer:

<table>
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<th>Immediately after 402mm rainfall in 5 days</th>
<th>2 weeks after the rainfall, under full sun</th>
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<td>Outside</td>
<td>Inside</td>
</tr>
<tr>
<td>Vaults apex</td>
<td>100 %</td>
<td>31.6 %</td>
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<tr>
<td>Window sill</td>
<td>59.8 %</td>
<td>27.8 %</td>
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### MAIN SPECIFICATIONS

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<td>CSEB in stabilised earth-sand mortar 1: 6 6</td>
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<td>Composite with U blocks 240 and RCC</td>
<td>5% cement CSEB filled with concrete 1: 2: 4</td>
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<td>5% cement CSEB tiles, laid on cement-sand mortar 1: 4 + cement milk</td>
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TRAINING CENTRE OF THE AUROVILLE EARTH INSTITUTE
Ground floor plan
SECTION OF THE EGYPTIAN SHAPED VAULT OF THE TRAINING CENTRE
Details of the various techniques implemented
Entrance of the lecture hall

Lecture hall

Kitchen of the trainees

Detail on a bull eye

Backside of the Training Centre
EARTH VERSUS OTHER BUILDING MATERIALS

The traditional building material used around Auroville is fired brick. Villagers fire their own bricks in country kilns which are not very efficient. They consume a lot of wood, pollute a lot and, in the end, give poor quality building materials. Good quality fired bricks are also available from factories and they are called wire cut bricks.

Half CSEB 240
(24 x 24 x 9 cm)

Wire cut fired brick
(22 x 10.5 x 7.2 cm)

Country fired brick
(± 22 x 10.5 x 6.5 cm)

COST EFFECTIVENESS

Earthen buildings have the advantage of using local resources and being labour intensive. Therefore, most of the time, they cost less than conventional materials and technologies. The final cost of a building will depend mainly on the design, the type of finishes and the project management. In all cases, the technologies implemented will be cost effective.

In the context of Auroville, a finished m³ of CSEB masonry is always cheaper than fired bricks: 19.6% less than country fired bricks and 53.3% less than wire cut bricks (November 2002 costs).

Walls made of compressed stabilised earth blocks are already less costly than fired bricks, but stabilised rammed earth walls are even lower in cost than CSEB masonry. The material for CSEB or rammed earth is the same, but the difference comes from the fact that the blocks have to be cured on the ground, then lifted and built by masons later on. In the case of rammed earth, the walls are made by semi-skilled labour and they stand in place at the end of the day.

Therefore, a finished m³ of rammed earth wall costs 22.6% less than CSEB wall, 37.8% less than country bricks and 63.9% less than wire cut bricks.

THE ENVIRONMENTAL COSTS

Costs are too often limited only to a monetary value. Another important aspect is the energy consumption involved in the material. The production of earth-based materials consumes much less energy and pollutes much less than fired bricks. CSEB and rammed earth are much more eco-friendly.

They have these advantages compared to fired bricks:

<table>
<thead>
<tr>
<th>Pollution emission (Kg of CO₂ /m²)</th>
<th>Energy consumption (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 times less than wire cut bricks</td>
<td>4.9 times less than wire cut bricks</td>
</tr>
<tr>
<td>7.9 times less than country fired</td>
<td>15.1 times less than country fired</td>
</tr>
</tbody>
</table>
bricks

(Source: Development Alternatives, New Delhi, 1998)
# COMPARISON OF BUILDING MATERIALS IN AUROVILLE

<table>
<thead>
<tr>
<th>Brick size (L, W, H, in cm)</th>
<th><strong>WIRE CUT BRICKS</strong></th>
<th><strong>COUNTRY FIRED BRICKS</strong></th>
<th><strong>CSEB 240</strong> (Wall cast in situ)</th>
<th><strong>RAMMED EARTH</strong> (Wall cast in situ)</th>
</tr>
</thead>
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<tr>
<td></td>
<td>22 x 10.5 x 7.2</td>
<td>22 x 10.5 x 6.5</td>
<td>24 x 24 x 9</td>
<td></td>
</tr>
</tbody>
</table>

| Volume of brick            | 1.66 Litres         | 1.50 Litres               | 5.18 Litres                       |                                     |
| Weight per unit            | 3.12 Kg = 1876 Kg/m³| 2.81 Kg = 1871 Kg/m³      | 10.00 Kg = 1929 Kg/m³            | ± 1950 Kg/m³                        |
| Stabilisation              | Fire                | Fire                      | 5% cement                         | 5% cement                           |
| Wastage of raw material    | 3 %                 | 12 %                      | 5 %                               | 0 %                                 |
| Product Information       | 601 No.             | 666 No.                   | 193 No.                           | No bricks                           |
| Pollution emission (CO₂) * | 39 Kg / m³          | 126 Kg / m³               | 16 Kg / m³                        | 16 Kg / m³                          |
| Energy consumption *       | 539 MJ / m²         | 1657 MJ / m²              | 110 MJ / m²                       | 110 MJ / m²                         |
| Dry crushing strength      | 100 Kg / cm²        | 35 Kg / cm²               | 50 Kg / cm²                       | 50 Kg / cm²                         |
| Water absorption           | 9 to 11 %           | 10 to 14 %                | 9 to 12 %                         | 8 to 11 %                           |

| Wall thickness             | 22 cm               | 22 cm                     | 24 cm                             | 24 cm                               |
| Daily output per team      | 3.3 m² = 320 bricks | 4.6 m² = 490 bricks       | 3.8 m² = 150 blocks               | 8 m²                                |
| Mortar Qty per m² of wall  | 72.4 Litres         | 76 Litres                 | 36.1 Litres                       | No mortar                           |
| Units per m² of wall       | 98 (with 1.5 cm mortar) | 106 (with 1.5 cm mortar) | 40 (with 1 cm mortar)             | No bricks                           |
| Mortar used                | 1 cement: 5 sand    | 1 cement: 5 sand          | 1 cement: 6 soil: 6 sand          | No mortar                           |

| Mortar per m³              | 1481 per m³         | 1481 per m³               | 726 per m³                        | No mortar                           |
| Finished wall per m³       | 2724 per m³         | 1810 per m³               | 1334 per m³                       | 1061 Per m³                         |
| Finished wall per m²       | 599 per m²          | 398 per m²                | 320 per m²                        | 255 Per m²                          |

| Sieved sand                | 360 per m³          | Mason : 150 per day       | Labour male : 100 per day         |                                     |
| Sieved soil                | 70 per m³           | Helper : 75 per day       | Labour female: 60 per day         |                                     |
| Cement (43 grades)         | 150 (50 Kg bag)     |                          |                                   |                                     |

**NOTES**
- All costs are in Indian Rupees
- Value: Auroville, April 2005, 1 US $ = ± 43.5 Rs.
- * Source: Development Alternatives, New Delhi, 1998
- ** The cost of raw material include the wastage
- Country fired bricks are also called village bricks
- The CSEB price is the production cost on site
- Blocklaying team = 1 mason, 1 helper, 1/2 labour male, 1/2 labour female
- Team for producing CSEB = 9 labour male
- The labour cost includes the yearly bonus and the employee providence fund
- Rammed earth team = 5 labour male

**ENVIRONMENTAL COST**
- CSEB and rammed earth are more eco-friendly than fired bricks
- CSEB and rammed earth are: 2.4 times less than wire cut bricks

**MONETARY COST**
- CSEB and rammed earth always cost less than fired bricks
- A finished m² of CSEB wall is: 26.3% cheaper than country fired bricks

**STRENGTH**
- CSEB and rammed earth are: 1.4 times stronger than country fired bricks
<table>
<thead>
<tr>
<th>7.9 times less than country fired bricks</th>
<th>51.0 % cheaper than wire cut bricks</th>
<th>41.4 % cheaper than country fired bricks</th>
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<tr>
<td><strong>Energy consumption:</strong></td>
<td><strong>A finished m³ of rammed earth wall is:</strong></td>
<td>0.5 times weaker than wire cut bricks</td>
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<td>4.9 times less than wire cut bricks</td>
<td>20.4 % cheaper than CSEB wall</td>
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<tr>
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<tr>
<td></td>
<td>61.0 % cheaper than wire cut bricks</td>
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Building with earth has a great past, but also a promising future, especially in Auroville. It is definitely an appropriate, cost and energy-efficient, and eco-friendly technology which can promote a sustainable future. Obviously, one has to master the material the techniques so as to obtain the optimum possibilities for a harmonious, durable, agreeable and efficient architecture. One can note these advantages of earth as a building material:

- The earth is a local material, contributing to sustainable development.
- The production of the building components demands a lot of semi-skilled manpower.
- The technology is easily adaptable and transferable.
- The monetary and environmental costs are much lower than that of most other materials.
- The thermal comfort and vibratory atmosphere are very positive.

One has also to master the disadvantages of the material which, normally, are variations in the soil quality, and hence the block quality and the production of blocks on site. These reductive aspects can be underlined:

- Mechanical qualities are less regular.
- Sensible building details are required.
- The constraints of organizing and managing the production of one’s own building material on site.

Despite the possibilities and advantages offered by stabilised earth materials, building with earth in Auroville is still not the common practice. Either people don’t want to acknowledge the advantage of this material or they don’t want to get the burden to organise the block production on their site and manage everything themselves.

The generalised use in Auroville of compressed stabilised earth blocks and other earth techniques needs a centralised production of blocks and a coordinated management of resources – physical and human. This development step would insure a controlled and more regular quality of raw materials and finished products. This is one of the aims for the next years to come.

The challenge in front of us:
How can realize architecture which is full of light, suppleness, simplicity, imagination and beauty with a dark, heavy and formless mud?

This is what we are trying to achieve in Auroville.

“Auroville, the city the earth needs”