An innovative way to engage students in green building techniques
Introduction

In August 2007, Evergreen partnered with Banyan Tree, a grassroots organization with a mission to educate youth on building sustainable communities. Together, we designed and raised funds for a pilot program that engaged Grade 8 students from Winchester Junior & Senior Public School in St. James Town, an inner-city Toronto neighbourhood, in a natural-building workshop: making rammed earth bricks and building a flower bed.

Based on a flexible curriculum plan, a backgrounder on Rammed Earth (Appendix A) and a map to the site (Appendix B), youth were invited to register for the course that would run over two consecutive weekends. Beginning with a nature hike to Evergreen Brick Works at the heart of Toronto’s ravine system, eight committed students learned the history of rammed earth construction, its uses as a building technique, how to design their own project, how to make bricks themselves and finally how to build the structure they envisioned.

The plan also provided an opportunity to hand over the project coordination reins to five 20-something, aspiring environmental educators. These resourceful and committed volunteers went far beyond the call of duty, investing months of preparation and planning time, making sure this educational workshop was fun for all involved.

The result was a messy, engaging workshop that entertained and inspired a terrific group of kids to re-evaluate what they were capable of and what is possible in their community. All participants agree that it was a tremendous success, as reflected in the picture gallery and evaluation results.

Designed for optimum replicability and accessibility, with low costs and minimal skill requirements, it also served as a useful case study for incorporating a versatile building technique into future school ground and other community greening projects across Canada. Funded by The J.W. McConnell Family Foundation’s Green Street program, the initiative met their Benchmarks for Excellence in Environmental Learning & Sustainability and Student Engagement, which were designed to initiate programming that actively engages youth in environmental stewardship. We are grateful to the foundation for its generous support.
What is Rammed Earth?

Rammed earth is a soil mix (made from varying amounts of locally available and renewable materials such as gravel, clay, sand and silt) to which water is added. The resulting moist, soil-based mix is loaded into a mould or press and compacted by ramming or with a manual hydraulic press. Once dried over a period of a couple of days (there is no need for firing bricks), the bricks have similar structural integrity and durability levels to normal bricks, without the energy use.

Although still largely unknown in North America, rammed earth and similar constructions are among the oldest and most durable forms of construction. No one knows for sure where it originated; all that is known is that it was used in ancient times by numerous cultures from African to Europe. Even parts of the Great Wall of China were built using rammed earth.

Today over half of the global population is estimated to live or work in earth-based shelters.1

Natural building techniques like rammed earth use renewable, recycled and/or salvaged resources to create structures that are more environmentally friendly than those constructed through traditional building practices, using materials such as wood, steel, and concrete. “Conventional” building materials generally require a lot of energy (such as fossil fuels) and natural resources to be produced, transported and, eventually, installed.

Rammed earth does have limitations as a building material in the Canadian context. One of the major limitations is its susceptibility to water damage. Rammed earth walls do not do well if they are improperly exposed in a wet environment. When exposed to water, erosion of the wall begins, causing the surface layer of the wall to start losing its adhesive bond. Water can also penetrate the wall and when the outside temperature gets cold, the expansion of the water will cause the wall to crack. That’s why, throughout history, earth structures have not been common in areas where flooding is likely. Earth construction can work in rainy climates, as long as a stabilizer is added, it is properly covered with a roof and built on a foundation of “cooked” bricks or rocks, preventing exposure to moisture at the base.

Due to the impermanent nature of earth construction, it is ideal for formal school grounds because it can be easily changed or replaced according to need or circumstances. Conversely, left alone, it will naturally erode over several years, offering lessons in the transitory, evolutionary aspects of nature. However, when treated with a clear non-toxic natural water-based sealant, the structure will last longer and require less maintenance (visit www.greenbuildingsupply.com for more information).

What are the Environmental Benefits of Rammed Earth?
Earth-based construction offers many advantages over common construction methods practiced today. It is cleaner, less wasteful of water and forest resources and is by definition easily reused.

One of the first and most obvious benefits is that the structure is made from soil, a naturally occurring and locally available material that is affordable and easy to work with. Structures can generally be built without heavy equipment, or much fuel or electricity, extending the environmental benefits of this low impact construction process.

1 Source: Earth Architecture
Of course, when building a structure, one of the first steps is to dig out a foundation (or hole) to create a level base. With standard practices, this dug-out soil is not used in the construction of the building and is typically either trucked away or spread out around the property. With rammed earth construction, this soil will instead be used as the primary building material.

Another crucial advantage of earth construction (in particular, rammed earth) is the low cement content in the mixture. Concrete is the world's most widely used building material and is made up of 10-25% cement by volume. The problem is that cement is one of the most energy-intensive products to manufacture, requiring large quantities of fuel and heat. As a result, it is one of the largest single contributors to greenhouse gas emissions and accounts for 7-8% of the world's carbon dioxide emissions. Because rammed earth construction has minimal cement content, typically less than a quarter of the amount found in concrete mixtures, its use would lead to significantly reduced greenhouse gas emissions, limiting a key contributor to global warming.

A key component of most modern construction techniques is finished wood, leading to significant forest depletion. Indeed wood building materials account for 25% of the world's wood consumption. Since rammed earth construction does not use wood resources it does not contribute to forest depletion.

In addition, rammed earth construction uses very little water to create and facilitate the bonding and compaction of the earth. On the flip side, concrete, steel and plastic are major consumers of this valuable and increasingly precious resource in their production stages.

Finally, rammed earth walls are made from renewable materials that can be very simply reused when the building is no longer wanted or needed.

**What are the Health Benefits of Rammed Earth?**

Rammed earth walls are made from soil that is extracted deep enough in the ground to avoid the inclusion of any organic materials. Without organic materials like leaves and seeds, there is no food in the mixture and therefore no danger of attracting animals, insects or mold growth.

Particularly important to occupant health is the presence of clay within the mixture. Clay is a hydroscopic material, meaning that it has the ability to absorb and release moisture in the air. This is particularly useful to regulate the amount of humidity, which not only affects our comfort level within a structure, but also limits fungus and mold growth that could otherwise leads to respiratory problems. An eight-year study in Germany demonstrated that earth walls are effective at regulating internal relative humidity at between 40% and 60% all year round, regardless of the outdoor humidity levels.

Remarkably, the dense and compacted material also acts like a storage container for heat. When the sun strikes the wall, the energy from the sun is stored in the wall for hours, eventually finding its way into the structure. The walls act like a temperature regulator or thermal mass: when it is hottest outside and the sun is at its most intense, the energy is stored in the walls until it is released when the ambient temperature is colder.
The Concept

Bricks of the Earth is designed to give youth a creative outlet, a new skill and the tools to initiate a similar project in their community or school. The ultimate goal is to encourage youth to experiment with a new material in an active hands-on way, while learning valuable lessons about sustainability and global environmental issues.

First presented in September 2007 by Evergreen and Banyan Tree Initiatives, the Bricks of the Earth workshop focused on sustainable design and construction. Bringing together youth from St. Jamestown, an at-risk neighbourhood in Toronto, the group built a raised garden bed over the course of two weekends and learned a great deal about green building techniques. The workshop enabled youth to interact with a multi-disciplinary team of volunteers and professionals from fields that were new to them.

Project Rationale

Issues around sustainable urban development and environmental construction are for all intents and purposes completely absent in both the school curriculum and existing community initiatives aimed at youth growing up in Toronto. This project was designed to address this. Furthermore, because the project was carried out at Evergreen Brick Works, it allowed for broader discussion of the site’s geological, cultural and environmental contexts and the broader role nature plays in community and city building. For instance, as the site is prone to periodic flooding, rammed earth was suitable as an organic, non-disruptive project that could highlight significant issues and yet be inexpensive to repair or replace.

In addition, facilitators were able to reinforce the values of teamwork, inclusiveness, careful listening, environmental awareness and action. This workshop provided a rare and much-needed opportunity for these young people to reveal undiscovered talents and skills in a safe and supportive learning environment.

Different Ways You Can Use the Bricks of the Earth Concept

Rammed earth bricks can be used in a wide variety of projects. The various projects listed here can be initiated and undertaken by students, teachers and community leaders or volunteers. Engaging individuals experienced with earth-based building may be desirable depending on the scope of the project and the skill level of the participants.

Raised garden beds
Building a raised garden bed out of rammed earth allows for an organic shape that acts as a retaining wall for an herb and vegetable garden. This was the project used for the pilot workshop of Bricks of the Earth. That being said, rammed earth construction is not considered an ideal building material for exposed garden beds, but for the limited timeframe of this workshop, it was considered acceptable.

Walkways
Bring a team of youth together to build a series of natural brick walkways—discovery paths, perhaps. These will slowly go back into the ground over time, creating opportunities for learning about sustainability and natural processes such as erosion, while encouraging ongoing experimentation and community project.
Storage shed
For the more ambitious groups, creating a storage shed could be an invaluable component to a community or school garden. It is recommended that the foundation bricks contain some concrete for durability. Another option is to incorporate light wood framing.

Sitting areas
More manageable than a shed, a bench can be a quick and fun activity. The design could integrate existing materials such as logs, wood beams or recycled steel.

Art and sculpture
True art has no boundaries... allow your participants to use their imagination and create wonderful long-lasting sculptures made from rammed earth.

Other ideas
There are plenty of other ideas for more ambitious projects which would require input from leaders with some experience with these materials.
Project Planning and Design

Choosing the Right Ingredients
It is critical that the ingredients within the soil be suitable for this type of construction and that they
be well mixed and blended together in a specific ratio of gravel, sand, clay and silt. Each material plays
an important role. To produce a strong and durable wall or brick, the soil must be a well-graded blend
of different-sized particles. Large particles provide the bulk and strength of the mixture, while smaller
particles fill the gaps, creating a crucial bond. When the soil is compacted, these small particles will fill
all the empty air space, improving the strength and durability of the wall.

Clay is an ideal small particle within the mixture. Because clay is sticky when wet but hard when dry,
it acts like a glue using water to bond big particles with smaller ones. Interestingly, clay particles are
electrically charged and act like magnets drawing water molecules to the surface. This unique characteristic
of clay allows it to hold neighbouring particles together. With too little clay, the components will not
hold and the mixture will fall apart. With too much clay, the walls will shrink and crack.

Fine silt also plays a crucial role filling in gaps in the brick or wall. When the material is compacted,
the silt will fill tiny gaps and in doing so, limit the amount of air and water that can be trapped within.
Too little silt content will produce a wall that is somewhat fragile because it is insufficiently dense.
Conversely, too much silt in relation to clay content will prevent the mix from achieving the proper
consistency for effective drying and setting.

Cement is also typically added to the mix to increase the strength of the finished wall and improve the
resilience to water and erosion. The amount of cement added varies and depends on the soil properties,
but is typically a very small percentage. In some cases, it can be withheld from the mixture altogether,
depending on the quality of soils used.

By adding water to the blended soil mixture, the bonding between the clay and the other particles is
activated. When the damp soil is compacted, the clay is forced to bond with the other particles in the
mixture, creating a strong wall. Too much water in the mixture will not allow for proper compaction and
will cause cracks when drying. Too little water will prevent the ingredients from bonding with the clay,
and the mix will not hold together.

Getting the Right Mix
The exact ratio of silt, sand, gravel and clay depends on the specific properties of the ingredients in the
soil in use. You can use the following ranges (by mass) as a guideline:

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<tbody>
<tr>
<td>Sand and Gravel</td>
<td>45-80%</td>
</tr>
<tr>
<td>Silt</td>
<td>10-30%</td>
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<tr>
<td>Clay</td>
<td>5-30%</td>
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<tr>
<td>Cement</td>
<td>4-8%</td>
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As a general rule, the strength of the wall is increased by the compaction effort (or resulting density)
and is reduced by increasing moisture content and clay content. When heavy compaction of moist soil
is combined with cement stabilization, compressive strength and water resistance is significantly
improved in comparison with traditional adobe blocks.
Assessing your Site

Making rammed earth projects can be a lot of fun, but is also a lot of work. To avoid wasting time, it is best to verify that the soil can be used. This is the first and most important step before beginning any project. Will your site support rammed earth blocks? It’s easy to conduct a quick site assessment to determine if the available soil is suitable for ramming. Here are two simple ways to do it prior to contacting an expert:

**Method A:**
Mix a sample of soil (1-2 cups) and with a lot of water in a jar. As the soil settles, various layers of silts, organic matter, sand and stones will create unique layers that will help to determine how much sand and clay is at the site. The approximate ratios should fall within the following range:

<table>
<thead>
<tr>
<th>Material</th>
<th>Range</th>
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<tbody>
<tr>
<td>Sand and Gravel</td>
<td>45-80%</td>
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<td>Silt</td>
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<tr>
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**Method B**
Take a small handful of soil and moisten it so that it feels damp, but not wet. Form it into a firm ball. Next, drop the compacted ball on the floor and see how it breaks. If it crumbles, then there is probably not enough clay. If it only separates into a few larger clumps or remains as a whole, the soil is reasonably good. If its splats, too much water has been mixed into the soil sample so try again with less moisture.

If the results look positive, we recommend that you have an expert to confirm your initial test results. Some recommended sources are as follows:

- Local universities and colleges may have a soil lab like the one in George Brown College’s Department of Construction Engineering;
- Local landscapers may be able to test it themselves or can recommend someone who can
The Project

Creating your Community

In our experience, Grade 8 students are an ideal age to participate in a rammed earth project because they have the physical strength to do the work and they have the intellectual curiosity and mental acuity to be interested in the various issues and themes which emerge, including the differing environmental impacts of conventional and natural construction. Projects should not be undertaken with children younger than sixth graders unless the format is altered to deliver a demonstration-based project. This will require more front-end or background work by the project organizers.

Friend-raising is often just as important as fundraising if you want your project to be a success. After all, this is a complex and challenging undertaking that requires a lot of people with different skills and experiences. Among the friends you should be looking for are those interested people who have partnered with a school before, have the time and capacity to help you, and who are active within a larger network or pool of volunteers.

Among the many sources for the type of friend or supporter you need, we recommend the following:

• Local community centres
• Nearby faith-based community and church groups
• School councils/parent-teacher associations
• Principals and teachers
• Environmental and social justice organizations
• Local building supply companies (they may offer material for free or at a reduced rate)
• Students looking to earn their community hours
• Youth groups such as guides or scouts
• Service clubs

Financials

There are going to be costs associated with a project this ambitious so it is best to think of creative ways of raising funds and defraying costs. Partnering with a group such as Evergreen or Banyan Tree Initiative can making sourcing all the materials for a project easier and less costly. You may also be able to get access to equipment through in-kind donations from local contractors, landscaping companies, hardware stores or big box stores like Rona or Home Depot. Also, most schools have a lot of the needed equipment on hand through the janitorial department. If money does need to be raised, you will have to consider a variety of fundraising events, perhaps having solicited local businesses to provide matching funds. Successful fundraising plans source diverse streams of revenue. If your project is on a daycare or school ground, consider applying to Toyota Evergreen Learning Grounds Grants for the planting material [http://www.evergreen.ca/en/lg/lg.html](http://www.evergreen.ca/en/lg/lg.html)
**Determining timelines and milestones**

Developing a schedule at the start of the project is critical. Be generous when estimating the time the project will take, especially if this is your first time building with rammed earth. Remember, your schedule will be affected by weather so choose your start date carefully and consider scheduling rain dates.

Conduct a meeting with your core team (3 or more people) and set a couple of major milestones for the project in a workback format. Here's an example (working back from point of completion):

- Certificates of completion awarded
- Site cleaned up
- Last brick laid and secured
- Bricks stored for curing
- Bricks made and stored
- Machine arrives at site
- Materials and equipment delivered
- Materials ordered
- Participants confirmed
- Students engaged
- Teachers engaged
- Brochure designed
- Budget determined
- Planning meeting completed
- Initial stakeholders meeting completed
- Reading the Bricks of the Earth Toolkit

**Laying the Groundwork**

Of course another important part of getting the project off the ground is to ensure you have all the go-aheads, okays and buy-ins you will require. These will include the

- School-related approvals
- Proper mentor support
- Banyan Tree support
- Evergreen approvals

**Setting the Agenda**

In order for any project to be a success, you need to ensure that you have planned it all carefully. This must include the setting of effective, realistic and actionable agendas. Here is an example.

**Sample Workshopping Agenda**

- Examine the types of construction materials commonly used to build Canadian school grounds
- Uncover the rationale behind material selection and the corresponding environmental ramifications
- Explore the role school grounds play in learning
- Create a sense of shared space through a visioning and sketching exercise
- Presentations of before/after sketches. (Perhaps invite a professional to explain possible sustainable construction materials.)
- Explore examples of what is possible on school grounds. The session will conclude with a focus on rammed earth.
Determining the Scope
Of course, a large part of the launch must focus on the scope and location of the project. This will require a well-attended and organized planning meeting. It is up to the participants themselves to determine as a group the size, shape and location of a project so that it will work well on their chosen site.

Another crucial step is determining how many bricks will be needed (bearing in mind that there may be a significant number of pre-made bricks supplied). The session will conclude with preparation activities such as drafting, clarifying role expectations and practicing use of the equipment.

Understanding the Brick-Making Process
You need to outline the whole process in advance, including describing the various work stations and roles that will maintain project momentum and ensure quality control. Have each student work through each station step-by-step (typically three students together move through each station at a time). It should look something like this:

Station 1: Mixing
  a) Materials leader (typically staff leadership): makes sure materials and tools, gloves, etc. are sufficient, readily available and clean
  b) Ratio leader: remembers the right amounts of sand, silt and water and knows (by touch) when there is a need for more or less
  c) Timing leader: makes sure that the supply of mixed material is working in harmony with the speed at which bricks are being pressed. If there is an over-production of mix, a bottleneck will occur as there is only one press to mould the material. If the mix is left to air dry for longer than 20 minutes (depending on weather conditions), it will no longer be suitable for the press. Efforts to revitalize the mix by adding water are not particularly effective.

Station 2: Pressing and Drying
  a) Packers: 1-3 students will be needed to move pre-mixed materials from wheelbarrow into the brick press form.
  b) Presser: work with the staff leader operating the press
  c) Dryer: this person delicately lifts the new brick from the press to the drying station. It is important that they handle the brick with wide, distributed support across the sides of the brick with the full expanse of their hands.

Tools and Materials
Materials and equipment needed to complete a rammed earth project include:
- Brick press or forms (can be made with plywood)
- Shovels
- Wheelbarrows
- Large and small buckets for mixing and water
- Gloves
- Soil (sand, clay, silt and gravel)
- Water
- Potentially some cement to strengthen the mix
- People... and lots of them!
**Setting a Pace**
It generally takes about one hour of trial and error after the initial training session for the kids to get the hang of things and fall into a routine. They will need on-going reminders of proper and safe machinery operation techniques, as well as effective material ratios for the best bricks. After about two hours, brick making will seem a bit tedious and the kids will need a break for water and snacks and then some time to blow off steam doing something else entirely. You may choose to allot 20 minutes or a full hour for a break (depending on the time of day). It is important to outline how long the break will be, and what will be expected on their return, to allow for a better transition back into the brick-making process. This time also proved to be very helpful for the staff leaders to replenish materials and adjust agenda timelines based on their progress.

**Connecting to the Curriculum**
There are a great many ways in which a teacher can connect these activities to academic requirements. For instance, there are many issues surrounding local heritage such as learning what resources were used to build your city? Where did they come from? How were they developed? Another fertile topic is, as discussed above, climate change, and the need for alternative resource use and attitudes in construction. Science teachers might consider using the project to explore the earth sciences, discussing the natural processes (chemistry, physics, etc.) that are involved in rammed earth building.

**At the End**
After all the planning, hard work, fun and learning, organizers should ensure that there is time left for a shared discussion and evaluation of the workshop. Youth will leave not only with a certificate, they will have new skills, new information and perhaps most importantly they will have learned how to work in a group toward a common goal, bringing together parents, teachers, peers and other disparate participants, firmly grounding them in their schools, neighbourhoods and broader communities.

**Conclusions**
On the final day, sitting in a circle in a hay-bale maze, the eighth graders and youth leaders shared personal perspectives on common barriers to urban greening projects. They ranged from simple issues like vandalism to complex discussions on city building. It was in this setting that we realized how effectively a natural building project can engage youth. By creating multiple meaningful roles for different skill levels, we established an equitable foundation for all involved to contribute.
Appendices

Links to other Rammed Earth Resources in Canada and the United States

Tuckers Pottery Supply http://www.tuckerspottery.com/

Earth Architecture http://www.eartharchitecture.org

Terra Firma Builders http://www.terrafirmabuilders.ca

Rammed Earth blog http://rammedearth.blogspot.com

Fernco Metal http://www.ferncometal.com/


Natural Resource Canada http://www.ecosmartconcrete.com/enviro_cement.cfm

Ecosmart Concrete http://www.nrcan.gc.ca/media/archives/newsreleases/2002/2002220a_e.htm

Building with Earth: Design and Technology of a Sustainable Architecture, by Gernot Minke

Earth Construction Handbook: The Building Material Earth in Modern Architecture, by Gernot Minke

Green Building Encyclopedia http://www.whygreenbuildings.com
Who is Banyan Tree?
Banyan Tree Initiatives provides hands-on education about sustainable living for diverse youth. The organization is committed to promoting and building sustainable housing for vulnerable urban and rural populations. Through their efforts they aim to teach at-risk and homeless youth to build environmentally and economically sensible communities at a low cost, as an alternative form of social housing.

www.lift.to/banyantree/home.htm

Who is Evergreen?
Founded in 1991, Evergreen is a not-for-profit organization that makes cities more livable. By deepening the connection between people and nature, and empowering Canadians to take a hands-on approach to their urban environments, Evergreen is improving the health of our cities—now and for the future. We motivate people to create and sustain healthy, natural outdoor spaces and give them the practical tools to be successful. We do this through four core programs:

- Learning Grounds - transforming school grounds
- Common Grounds - conserving publicly accessible land
- Home Grounds - for the home landscape
- Evergreen Brick Works - Evergreen Brick Works will be a year-round destination in central Toronto for experiential learning, collaboration, fun and celebration on the themes of Nature, Culture and Community. Intended to transform the way we think about our cities, the innovative facility will demonstrate and promote practical solutions that make our communities sustainable and more liveable, and our urban lifestyles healthier.

www.evergreen.ca

Thanks and Acknowledgments
Banyan Tree Initiatives and Evergreen would like to thank the following:

- Green Street and The J.W. McConnell Family Foundation for funding the project
- Hearty Catering for their generous donation of healthy lunches and snacks
- The enthusiastic students from Winchester Junior & Senior Public School
- Chalo Barrueta and Richard MacIntosh for their coordination efforts and rammed earth expertise
- Henry Wiersma for ongoing design and leadership consulting
- Nora and Jim Hallock for their ongoing support and guidance
- Josephine Grey of Low Income Families Together
Resurfing Interest from the past 50% of the world lives in earth housing

Portions of the Great Wall of China were built using rammed earth, over 2000 years ago.

Earth housing is prehistoric and provides shelter for ~50% of the global population. The ancient civilizations of the Middle East were built using rammed earth or mud brick, including churches, monuments, housing and temples. Earth construction remained in regions of wood scarcity, low annual rainfall and an abundance of labor.

During the Great Depression, Tom Hibben, a self-taught rammed earth builder employed 14 unskilled builders. The final house was built in 5 days for less than $2700.

In the 1920s, the following countries and U.S. organizations conducted studies and recommended rammed earth construction as a building material for housing:

- The U.S. Department of the Army and Agriculture
- The Bureau of Standards
- Housing and Urban Development
- The Agency for International Development
- The Bureau of Public Roads

Historically proven/ Globally inhabited/
Community building/ Affordable/ Internationally recognized/
Thermal comfort/ Humidity balance/ Improved indoor air quality/ Reduced greenhouse gasses/ Locally available/ Thermal mass/

Construction methodology

Soil Characteristics
Suitable soils should be well graded and meet the following criteria (by mass):
- Sand and Gravel content: 45-80%
- Silt: 15-30%
- Clay: 5-30%
- Linear shrinkage: < 5%
- Plasticity Index: 2-30
- Organic matter content: < 2%

Ideal Soil Mixture
- Gravel: 15%
- Sand: 50%
- Silt: 15%
- Clay: 20%
- Water content: 6-10%
- Cement content: 3-6%

Process
Most soil is pored into the formwork, mould or press and compacted by ramming or hydraulic press. Using forms, the moist soil is pored in layers of 10 to 15 cm thick and compacted down to the
- The strength of the wall or block is dependent on the soil characteristics and the compaction density.

Building comparison in Cairns:
The effect of wall thickness and material (Buildings of equal volume)

Formwork
Formwork typically consists of two parallel walls separated and interconnected by rigid spaces. Formwork typically accounts for 25-60% of the construction time.

Environmental benefit

Reduced cement content
Concrete is the World's most widely used material and comprises of 10-18% cement by volume. The cement component in concrete accounts for 5-10% of the World's CO2 emissions. Unstabilized rammed earth eliminates the use of cement, relying on the natural bonding strength of the soil and the compaction density for compression strength.

Stabilized rammed earth uses 4-8% cement content.

Reduced energy load
Rammed earth construction is made from locally available and recyclable building materials, resulting in reduce transportation and material processing requirements.

- Slightly porous earth walls provide passive air ventilation.
- High thermal mass of earth walls and floors reduce energy loads for heating and cooling space.
- Exterior or interior insulating techniques have expanded the market for rammed earth homes, now suitable for colder climates.

References
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- Rauch, Martin. Rammed Earth. McLaren 2001
- Peter Walker. Rammmed Earth: The Building Analyst's Earth in Modern Architecture. 1987
- McLaren. 2001
- Williams, David H. Earth in Modern Architecture. 1987

Examples

“Civilizations can be defined as the act of making the earth serviceable to human kind”. Rauch.