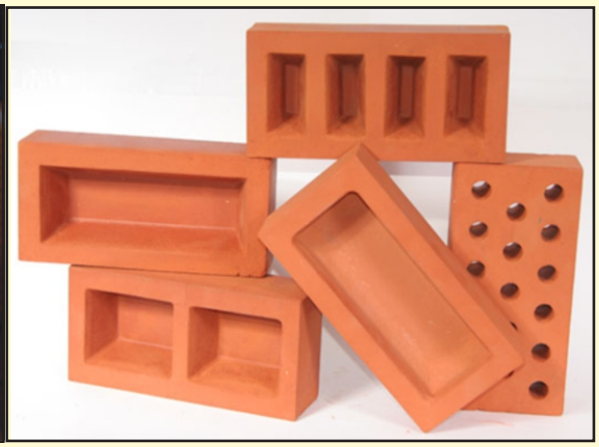
Ceramic clay brick making project from Ukraine, using vacuum extrusion and tunnel kiln firing process, to make 60,000 to 2,00,000 bricks per day



1. Introduction -

A brick is a block of ceramic materials used in construction. It has been regarded as one of the longest lasting & strongest building materials used throughout history. Clay is the most common material for making bricks.

In India, clay bricks have been extensively used for centuries & are the prominent construction materials even today. However, brick making is a traditional, unorganised industry, generally confined to rural & semi-urban areas.

In the developed world, clay bricks are formed either by extruding the mud in a die and then wire-cutting to the desired size or by dry-pressing into the desired size. The shaped clay is subsequently dried and fired by burning in a kiln to achieve the required strength. The action of heat gives rise to a sintering process that causes the clay particles to fuse & develop extremely strong ceramic bonds in the burnt clay bodies. Such bonds are highly stable & the bricks can withstand the severe weathering actions and are inert to almost all normal chemical attacks.

GoodRich offers automatic ceramic clay brick making plants from Ukraine, in the following capacities –

- Automatic plants to make 1,00,000 bricks per day, using the vacuum extrusion & tunnel kiln process (investment Rs. 25 crores); &
- Automatic plants to make 60,000 bricks per day, using the vacuum extrusion & tunnel kiln process (investment Rs. 18 crores).

Both the above plants use a unique inner combustion technology, where the clay is mixed with a small quantity of coal / carbon bearing materials, so that 85-90% of the energy is supplied from inside the brick. This arrangement will reduce the total energy requirement by nearly a half.

China has more than 5,000 automatic clay brick plants & Russia (including other CIS countries) has more than 1,400. Even Vietnam has set up more than 400 tunnel kilns since the 1990's. On the other hand, Indian clay brick industry is highly unorganised, with 1,00,000 brick fields making 140 billion (14,000 crore) bricks per year, employing 80-100 million seasonal labourers. The quality is poor with large variations in size, low strength & high water absorption. The compressive strength of a common household brick is only 20-30 MPa. When made with a mechanical plant, it is 75-200 MPa. The handmade brick industry has become uneconomical now, due to high cost of production & shortage of seasonal labour. Hence, there is a potential to establish at least 1,000 automatic ceramic clay brick making plants in India over a period of the next 10 years.

Brick is the most popular building material for various structures - from simple fencing to luxury villas. A variety of colours & shapes of bricks give the building a unique appearance, in harmony with the architecture. Bricks are versatile and durable building & construction materials, with good load-bearing properties & high thermal insulation. Mechanized clay brick plants produce high quality bricks with precise geometric proportions, with high strength & durability.

Advantages of using ceramic clay bricks –

1) Aesthetic appeal, with natural & pleasant colors of burnt clay.
2) Thermal & acoustic insulation, better than concrete. Bricks absorb & release the heat slowly & thus keep the house cool during the day & warm during the night. The thickness & density of the bricks will deflect the noise from the streets & neighboring houses. The noise insulation of a clay brick is generally 45 decibels for $4^1/_2$ inch thickness or 50 decibels for 9 inch thickness.
3) Zero maintenance cost – the clay bricks are free from rotting, denting, warping, rusting, splitting, peeling, fading & termite attacks.
4) Fire resistance – clay bricks resist a fully developed fire.
5) Flexibility in application – clay bricks can be used from individual houses to massive public buildings & also in bridges and viaducts. They can be produced in convenient shapes & sizes.

In most cases, the length of the brick is twice its width–about 9 inches, width is $4^1/_4$ inches & the depth is $2^3/_4$ inches (230 mm X 110 mm X 70 mm). With a nominal 10 mm mortar joint, the bricks form a size of 240 mmX120 mmX80 mm, in the ratio of 6:3:2.

The construction sector is booming in India. It has a major linkage with the building material manufacturing industry. The prices of good quality bricks are increasing now-a-days & this is the best time to invest on a present & future opportunity. The investment will be on a proven technology to make a well-known product, which is in high demand.

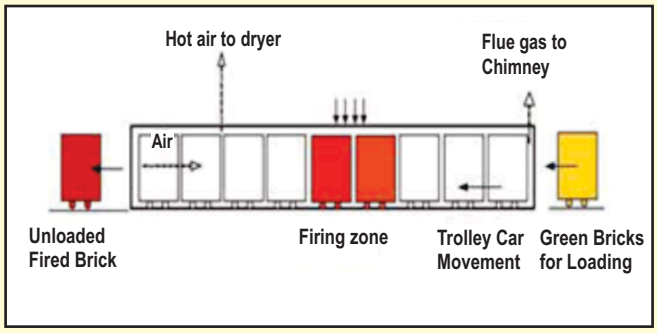
2. Modern brick making technology -

Developing countries like India use different types of kilns such as fixed chimney / movable chimney, bull's trench kiln, Hoffmann kiln, vertical shaft brick kiln, etc. The firing process takes 7 days or more & such kilns can make bricks in a small scale (5,000 to 10,000 bricks per day). India has around 1,00,000 such kilns.

On the other hand, developed countries use tunnel kilns or ring kilns, which can make large quantity of bricks (60,000 to 200,000 bricks per day).

In the clay brick making process, raw material fineness should be less than 2 mm. The temperature of baking is 900-1,100^{0}C, depending on the ash & clay content in the brick. After forming the bricks, they are dried in a tunnel drier, using the residual heat from the tunnel kiln. After drying, the bricks enter the tunnel kiln for baking. Finally, the bricks are baked in the tunnel kiln & the total time of baking is 30-36 hours. The volumetric weight of the brick is normally 1.5 tons per m^3 (each cubic meter makes 555 standard bricks of 2.7 kgs each). The bricks can be either solid or hollow.

In a modern tunnel kiln, the fire is always burning & the bricks are being warmed, fired & cooled simultaneously in different parts of the kiln. The heat in the flue gases is utilised for heating & drying the green bricks & the heat of the fired bricks is used for pre-heating the air for combustion. Due to the above features, such kilns are highly energy efficient.



The tunnel kiln for brick firing

Brick firing is the final operation of the ceramic brick production technology, which determines the properties of the finished product - strength, density, resistance, etc. Firing involves many physical & mechanical processes - dehydration, amorphization, crystallization of new phases, carbonate dissociation, burning-out of volatiles, oxidation & reduction which take place with equal speed within different ranges of temperature & time.

The raw materials for clay brick making –

The main raw material of the clay brick is silty or sandy clay, whose main composition includes SiO_2, Al_2O_3 & Fe_2O_3. Due to different geological formations, the clay may also contain small amounts of alkaline earth metal oxides.

Normally, bricks have the following composition –

1. Silica (sand) - 50% to 60% by weight
2. Alumina (clay) - 20% to 30% by weight
3. Lime - 2% to 5% by weight
4. Iron oxide - less than 7% by weight
5. Magnesia - less than 1% by weight

Russian standard for ceramic clay bricks –

The overall geometric dimensions of the bricks should have an accuracy of measurement of $\pm$1 mm as per Russian standards. Water absorption is measured in 48 hours, which should be less than 12%.

According to the Russian standard GOST 530-95, the following types of bricks can be used for general construction-

M-75 – each brick can take 22.5 tons of load

M-100 – each brick can take 30 tons of load

For Indian tropical weather, M-75 is most preferable.

Indian standards for bricks-

IS: 2222-1991 mentions the dimensions & tolerances of 'non-modular' bricks, as under–

- Length (mm) - 230 ($\pm$10)
- Width (mm) - 110 ($\pm$7)
- Height (mm) - 70 ($\pm$4)

For perforated bricks, the standard specifies that the area of perforation shall be between 30% & 45% of the total area of bricks.

Physical requirements –

a) Compressive strength –

Bricks when tested in accordance with the procedure laid down in IS: 3495-1991 shall have a minimum average compressive strength of 70 kg/cm^2(7N/mm^2) on net area.

b) Water absorption –

Water absorption of bricks, when tested in accordance with the procedure laid down in IS: 3495-1991 after immersion in cold water for 24 hours, shall not be more than 20% by weight.

c) Warpage –

The average warpage of bricks when tested in accordance with the procedure laid down in IS: 3495-1991 shall not exceed 3%.

Firing of bricks with internal fuel –

In Russia, Ukraine, China and Europe, it is a common practice to mix the powder coal along with clay, while making bricks. The bricks have a considerable amount of internal fuel, making it possible to fire the bricks by adding only a small amount of external fuel. The energy requirement is 440-480 kcal per kg of brick in Russia in cold conditions, when natural gas is fired from the outside. It can be reduced to 350-400 kcal per kg of brick in a hot country like India, by adopting inner combustion techniques.

Practice has proven that the effect of 1 kg internal combustion is equal to 2 kgs of external combustion. Normally, 85-90% of the energy is provided by the coal waste inside the clay & the remaining 10-15% is supplied by top-charging of 20-30 grams of coal powder per brick.

3. Automatic clay brick plants from Ukraine -

Before the development of a modern plant for the production of ceramic brick, it is important to conduct physical, chemical & technological researches of the basic clay materials.

Such researches are done by using the modern precision instruments & by applying scientific methods for optimizing the technology & process parameters. They answer to many questions concerning the equipment selection. For example, thermal analysis of the clay materials is essential to know their behaviour during the heating & cooling processes. This helps to develop precise drying, firing & cooling conditions. The data obtained as a result of complex physical, chemical & ceramic-based technological analysis of raw materials validate the choice of raw materials & forecast the properties of future ceramic products. They are also required for the documentation of the manufacturing processes.

Details of the machinery manufacturer in Ukraine-

The machinery manufacturing & brick plant engineering company in Ukraine was established in 1870 & it is 145 years old now. Their equipments are widely used in Belarus, Ukraine, Moldova, Mongolia, Vietnam, Bulgaria, Poland, Czech Republic, Slovakia, Cuba, Romania, Hungary, Russia & other CIS countries. In Vietnam, they have supplied 30 extruders. The machinery manufacturing company has also established an in-house research laboratory to undertake the following studies –

- Study of chemical & mineral composition & physico-chemical properties of the raw materials by chemical, thermal, petrographic & X-ray phase analysis.
- Study of dilatometric characteristics of clay raw materials that determine its behaviour in firing.
- Study of the properties of raw clay (particle size distribution, the content of coarse inclusions, ductibility, moisture of moulding, drying behaviour & so on).
- The study of the properties of raw materials & kiln performance (firing, caking, fire shrinkage, water absorption, density, tendency to form defects in the operation etc.).

- Study on the optimisation of the technological parameters for the production of ceramic bricks by vacuum extrusion or by dry-pressing, including the additives that neutralise the harmful effects of lime inclusions in the clay.

The research & analysis takes around 60 days.

Bricks made in the laboratory, using different clay types & different firing temperatures

Vacuum extrusion, tunnel drier & tunnel kiln firing process–

The extrusion technique was first developed about 160 years ago in Germany. It eliminated the hand work in brick manufacturing, but the required drying process continued to be the same. The method of moulding a plastic brick through vacuum extrusion is a classic method of forming the bricks at 15-25% moisture. It has the following advantages–

1) Wide sizes & shapes of solid & hollow bricks can be manufactured in different qualities, using a single extruder.
2) The bricks are durable, wear-resistant & environmentally friendly.
3) Hollow bricks with emptiness of up to 40% can be made for brick's weight reduction, for reduction in the thermal conductivity & to improve the appearance. Voids accelerate the drying of products & reduce the shrinkage during the drying process. Voids also reduce the heating of bricks, reduce the fuel consumption & ensure a uniform temperature distribution within the brick, which ultimately provides a more accurate geometry of bricks and an almost complete absence of cracks.

Manufacturing process for brick making in the extrusion method –

Digging & excavation of clay & soil and storage for 3-6 months

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Clay preparation by crushing, waste coal mixing for inner combustion and aging for 15-20 days

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Brick moulding in vacuum extruders

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Auto brick cutting

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Loading into trolley cars by robotic lifters

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Drying in tunnel driers

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Sintering in Tunnel Kilns at 900 - 1,100°C

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Unloading

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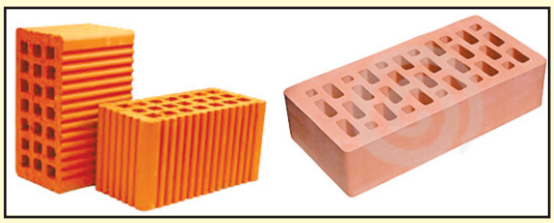
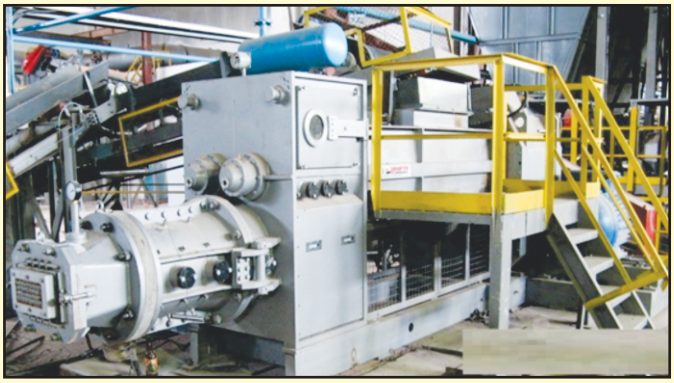
Finished bricks for sale

Different sizes & shapes of perforated bricks made by the Vacuum extrusion plants



GoodRich offers automatic clay brick making plants, using vacuum extrusion, robotic brick lifting & tunnel kiln sintering technology from Ukraine, in capacities from 60,000-2,00,000 bricks per day.

Photos of vacuum extruders



Clay crushing, Brick cutting & Robotic brick stacking into the kiln trolley cars




The brick plant, coal injector, tunnel kiln, raw and finished bricks in the trolley cars






4. Indian clay brick industry –

The construction sector is an important part of the Indian economy, with a contribution of 10% in the GDP, and is registering an annual growth of 9%. Clay-fired bricks are the backbone of this sector. India is estimated to produce more than 14,000 crores of bricks annually, mostly by adopting age-old manual, traditional processes. The total number of brick making units is estimated to be around 100,000 in India. With the increasing labour costs & non-availability of seasonal labour, these brick making units are unable to make profits.

It is estimated that about 1,000 billion fired clay bricks are made every year in the developing countries of Asia. India is the second largest producer of bricks in the world after China, with an estimated annual production of 140 billion bricks. The Indian brick industry consumes 24 million tons of coal along with huge quantities of biomass fuels. The total CO_2 emissions are estimated to be 41.6 million tons, which account for about 4.5% of the total GHG emissions from India.

The traditional brick industry in India often uses good quality top soil from agricultural fields. Production of 140 billion bricks per year requires 350 million tons of soil. Assuming the average depth of excavation as 1 metre, around 250 square kms of agriculture land is adversely affected by brick production every year. Coal consumption by the brick industry is approximately 8% of the total coal consumption in the country.

The industry employs low technology, manual & inefficient methods like hand-moulding, sun drying & open clamp firing. Since drying is done in the open, bricks cannot be dried during the rainy season and hence the industry is seasonal & operates for 6 to 8 months in a year, mostly from November to June. They are normally set up on leased-out lands near the clay sources. Owing to their temporary structure, low technology, pollution & absence of professional management including quality control, the clay bricks do not command consumer respect.

Silt deposited by rivers, dams, tanks, etc., or surface soil excavated from uncultivated / barren / hilly lands are the main sources of supply of clay. Shale, coal ash, wood and many agricultural wastes are used as fuels in the open clamp firing, where the extent of under / over burnt bricks vary up to 20%. The standard brick size is 9" X $4^1/_4$" X $2^3/_4$" & the standard weight is 2.5 to 3 kgs in most of the states. In Maharashtra, 'double' bricks of 9"X6"X4" size are common. IS specification classifies the Indian bricks into 11 classes with minimum compressive strengths varying between 35 & 350 kg/cm^2, but most of the bricks do not even reach the lowest strength of 35 kgs /cm^2.

India is the only developing country in the world that produces bricks by hand, while the rest of the world uses clay processing machinery. The need of the hour is to modernize brick-making processes to produce high-quality green ceramic building materials, by optimizing the usage of resources without endangering the environment and human health.

Following are the facts & figures of the Indian clay brick industry –

- Brick production: > 140 billion/year
- No of units: > 0.1 million
- Employment: 80 to 100 million people
- Energy and Environment -
  Coal: 24 million tons
  CO_2 generation: 41.6 million tons
  Top Soil consumption: 350 million tons
  (Source: TERI -2007)

The quality of handmade bricks is extremely poor. They display poor dimensional accuracy with variations of up to $\pm$ 10 mm; poor compressive strength of less than 35 kgf/cm^2; high breakage during transportation of up to 15% & high porosity. There is also a high consumption of cement mortar due to irregular shapes. This has resulted in the widespread use of cement hollow bricks. Their use pushes up the building costs, as they weigh twice as much as clay bricks; for instance, a 400 X 200 X 200 mm cement block weighs around 24 kgs, as compared to 12 kgs of burnt clay hollow block of the same dimension & the same strength. Hence, more labour is required in the construction and heavy foundations & concrete structures are needed. Moreover, cement is not a green product. Cement blocks cannot be used without plaster. They consume more power in air-conditioning.

Automatic clay brick projects offer a number of advantages in production as well as in end use applications, as under –

- Uniform product size & better finish
- Low water absorption (<10%)
- Improved crushing strength
- Resource saving – energy up to 50% & clay up to 50%.
- Reduction in masonry costs &
- Reduce cooling /heating requirements in the houses.

In China, the annual output of solid burnt clay brick was 600 billion in 2004 & the share of clay brick in the total wall materials was 65%. More than 50,000 vertical shaft brick kilns in the villages & more than 5,000 modern tunnel kilns are running in China.

Even in Vietnam, more than 400 tunnel kilns came up, each with an annual production capacity of 10-20 million bricks per year. In 2006, Vietnam produced 18 billion bricks & the tunnel kilns contributed to 35% of the total production. More than half of the bricks produced in Vietnam are perforated, with 10-40% hollowness.

5. Demand for clay bricks in India -

The Indian economy has been growing at a rate of between 7-8% since 2001. In an approach paper prepared by the Planning Commission of India in 2006, it was stated that the 11th five year plan (2007-2012) targets a higher economic growth of around 9% with an objective to double the real per capita income in the next 10 years. The rate of urbanization

in India has also been rapid with a decennial growth rate of 31.3% between 1991 and 2001 (Census of India, 1991; 2001).

The overall urban population increased from 217 million to 285 million during this period. The number of towns and cities has also increased from 4,689 to 5,161 between 1991 and 2001.

The country's housing shortage was estimated to be as high as 24.7 million units at the end of the 10th five year plan, of which about 70% is in rural areas (Government of India, 2007).

Building construction in India is estimated to grow at a rate of 6.6% per year from 8.0 billion square meters in 2005 to 41.0 billion square meters in 2030 (McKinsey and Company, 2009).

The growth of India's economy and population coupled with urbanization has resulted in an increasing demand for residential, commercial, industrial and public buildings as well as other physical infrastructure. Various studies indicate that, out of the total constructed area existing in India in 2030, about 70% would have been constructed between 2010 and 2030. The building stock is expected to multiply by five times during this period, resulting in a continuous increase in demand for building materials.

The Planning Commission has targeted a GDP growth rate of 7.4% up to 2015 and infrastructure growth has been identified as one of the major vehicle of growth, to achieve this target. Growing economy, population growth and rapid urbanization have caused a boom in construction activities in India. There is a strong correlation between these three factors and demand for building materials. The demand of building materials has been stimulated not only by the growth of infrastructure and urban buildings, but also higher demand for housing for people at large.

A consequence of all these factors is the rapidly growing demand for building materials such as cement and bricks. The projected demand of total floor space in India both in the commercial and residential sectors invariably points out the increasing usage of bricks.

The large demand for bricks in urban centers has resulted in mushrooming of brick kiln clusters at the outskirts of major towns and cities. It is estimated that about 1000 billion fired clay bricks are made every year in the developing countries of Asia (U. Heierli & S Maithel, 2008). Indian brick industry is the second largest producer of bricks in the world after China.

Brick – A wonder building material :

Burnt clay brick is perhaps the only man-made material that has defied time gracefully ever since it was invented 5,000 years ago. Unlike metals and organic materials, brick weathers beautifully with time. Also, it is an extremely good thermal insulating material.

The long-lasting and excellent thermal insulating property of the brick has earned it an enviable and indispensable position among today's building materials. Like cement no alternative material has yet been able to threaten burnt clay brick seriously, on technical as well as commercial grounds. In the early eighties, concrete blocks appeared to replace it as a walling material in metropolitan and big cities. But they soon lost their charm on account of improper mixing & curing practices followed by their manufacturers, the poor 'nailability', water seepage resistance and poor insulating properties of the material. Their use is now mainly restricted to areas where poor insulating properties are of little or no consequence, like compound walls, factory / commercial buildings, the so-called 'low-cost' housing schemes, etc. Non-availability or unacceptable quality of bricks or preference for large-scale captive production (utilizing huge quantities of freely available aggregates / filler materials) prompted the continued use of concrete blocks.

6. Investments, cost of production & profitability estimates for automatic clay brick plants -

A. Investments -

(Rs. in crores)

		Plant capacities (for solid bricks of 230 mm X110 mm X 70 mm size, each weighing 2.70 kgs)	
Sl. No.	**Description**	**3 crore bricks per year**	**1.8 crore bricks per year**
	Type	Automatic with vacuum extrusion & tunnel kiln	Automatic with vacuum extrusion & tunnel kiln
1.	Land	Existing (10-12 acres)	Existing (6-7 acres)
2.	Land development	0.60	0.60
3.	Factory buildings	2.90 (7,200 sq.metres)	2.40 (6,000 sq.metres)
	Total	**3.50**	**3.00**
4.	Plant & machinery, including import duties & taxes, transportation, electricals & all other equipments to be fabricated at site	13.00	8.00
5.	Tunnel kiln, tunnel driers, refractories, coal firing system & trolley cars	6.00	5.00
6.	Erection, commissioning & start-up expenses	1.50	1.25
7.	Contingencies	1.00	0.75
	Total	**Rs. 25.00 crores**	**Rs. 18.00 crores**

B. Cost of production & profitability estimates -

(Rs. in crores)

Sl. No.	Description	Plant capacities (for solid bricks of 230 mm X110 mm X70 mm size, each weighing 2.70 kgs)	
		3 crore bricks per year	1.8 crore bricks per year
	Type	Automatic with vacuum extrusion & tunnel kiln	Automatic with vacuum extrusion & tunnel kiln
1.	Raw materials		
	- Clay @ Rs. 200 per ton	2.00 (1,00,000 tons)	1.20 (60,000 tons)
	- Coal waste / shale / char / other gaunge materials (average heat value is 800 kcal/kg) @ Rs. 200 per ton	-	-
	- Indonesian thermal coal @ Rs.5,000 per ton	3.00 (6,000 tons)	1.80 (3,600 tons)
2.	Electricity consumption in units (kWh) @ Rs.7 per kWh	3.50 (50,00,000)	2.10 (30,00,000)
3.	Labourers & staff @ average Rs. 20,000 per month	1.92 (80 persons)	1.92 (80 persons)
4.	Wastages & rejections @ 3% on the cost of production	0.31	0.23
5.	Factory maintenance, administration, selling & other overheads @ 5% on the sales	1.20	0.72
	Total cost of production	**11.93**	**7.97**
6.	Revenue - Sale of bricks @ Rs. 8 each in the extrusion method (plants will be set up near the cities)	24.00	14.40
7.	Profit before taxation	12.07	6.43
8.	Total investment	25.00	18.00
9.	Pay-back period at 100% capacity utilization	25 months	34 months

7. Ceramic clay brick project- invest on a proven technology for mass production of a highly demanded product –

More than 70% of the infrastructure needed for a developed India is yet to be built (McKinsey 2009) and that gives great opportunity to build green with clay brick products.

Automatic ceramic brick projects offer a number of advantages in production as well as in end-use applications. These include the following –

- Uniform product size and better finish
- Low water absorption (<10%)
- Improved crushing strength of mechanized products (75 to 100 kg/cm^2)
- Resource savings – energy (up to 50%), and top soil (up to 50%)
- Reduction in masonry costs and plaster requirements
- Reduced cooling/heating load requirements.

The traditional brick industry has to change with time now. The yearly productivity of the Indian skilled labour is 30,000 to 40,000 bricks for 200 days of working in a year, using the manual brick making process. A modern tunnel kiln-based enterprise in Europe requires only 1 person to produce 1 million bricks per year.

The brick business cannot continue 'as usual' now. A structural change will occur in India & the following are the 5 most likely reasons for the changes ahead-

1) Rapid urbanisation - This trend is not compatible with hand-made bricks of poor quality. The demand for better quality & hollow bricks will increase sooner or later.

2) Regulation & building standards - The new suburbs are occupied by the fast-growing middle class, with heating & air-conditioning equipments installed in their houses. Stricter regulation on energy consumption on buildings will increase the demand for high quality bricks.

3) Supply constraints of labour - Overall economic growth will increase the employment opportunities, leading to a shortage of cheap seasonal labour. This will in turn lead to mechanization in the brick industry.

4) Importance of quality & branding - In the construction sector, most of the building materials such as cement, steel & plywood available in the market have uniform quality & brand image. Handmade bricks are un-branded, with varying dimensions & poor quality, as against the present trend of branding & quality assurance.

5) Environmental standards - The traditional brick making units need high quality clay from the top soil. They are also energy-inefficient, discharging uncontrolled emissions. With new regulations on earth-quarrying, ban on the use of agriculture soil and strict emission control measures, small brick units will have to close down in future, paving the way for new, mechanized clay brick plants.

Thus, the mechanized ceramic clay brick project provides a safe investment opportunity, with a proven technology for mass production of a highly demanded product.

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