VSBK CESEF

VERTICAL SHAFT BRICK KILN PROJECT

CLEAN BUILDING TECHNOLOGIES FOR NEPAL

GREEN BRICK MAKING MANUAL

skat_ Swiss Resource Centre and Consultancies for Development

Development Alternatives

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About this publication

This publication has been developed as part of the VSBK technology transfer process in Nepal. It gives the reader a more scientific insight into green brick making. The need for it is based on the experience which the VSBK technology transfer has had in India and Nepal. It is intended for individuals who have established or intend to establish clay brick firing units. The publication is a practical approach and will provide the reader with "hands-on" experience to improve the quality of the products.

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PREFACE

In most of the Asian countries the art and science of green brick making is often the most neglected but most important aspect of achieving systematically good quality fired bricks and other ceramic products. The art of brick making has been kept informally within families and has been passed on to generations through traditional knowledge. There has been no recorded attempt to transfer the art and science of this aspect of brick making know-how to "outsiders" in a scientific and systematic way. Therefore, until today, except the practising moulders, many professional brick making entrepreneurs know very little about the best green brick production practices and the reasons thereof.

This green brick production manual has been written by VSBK technology related professionals with the aim to transfer the know-how of best green brick production practices, especially for the new VSBK firing technology, to all professionals and brick making practitioners who aspire to know more about the HOW and WHY of green brick making. It also deals with the basic knowledge and understanding the science of the entire process, from soil selection to making a product ready for firing.

This manual is divided into 4 chapters. Chapter 1 deals with the basics of good quality green brick making, meaning the basic know-how of soil. Soil differs from place to place and withhin short distances, therefore, entrepreneurs need to know which soil is good and which is not for brick production in a VSBK, this is eventually fundamental brick making know-how. In chapter 2, soil testing methods is described that provides useful information about the characteristics of soils. In chapter 3, the economisation and fine tuning methods to select the best possible soil for the brick business is described in a very practical manner. And finally, in chapter 4, the entire green brick making process is described step by step.

This manual does not claim to cover all aspects of the vast topic of 'Green Brick Production', but focuses on providing the basic and practical understanding of correlation between different parameters which are required for making a green brick. It provides the why and the how in such a way that brick making practitioners and professionals willing to take up this profession will understand.

The more traditional and improved brick making know-how can be disseminated to the brick production industry the more awareness will be created to conserve nature and the entire environment, thereby contributing to reduce CO_2 emissions and global warming. It is our endeavour to see that modern brick practicing entrepreneurs and professionals adopt the same and support in conservation of natural resources i.e. soil and coal.

The VSBK programme Nepal would like to acknowledge the contribution of Dr. Soumen Maity, Development Alternatives and the VSBK Programme Nepal engineers, Mr. Suyesh Prajapati, Mr. Anil Datta Bhatta, Mr. Bijay Lal Shrestha and Mr. Heini Müller, Senior VSBK Programme Advisor for writing this manual. Thanks also go to Mr. Keshar Joshi for his creative inputs. Without their practical working experience, this publication would not have been possible.

Thank you.

Urs Hagnauer

Programme Manager
VSBK Programme Nepal

1 BASIC SOIL KNOWLEDGE FOR BRICK MAKING

1.1 INTRODUCTION

Soil is a period in a lengthy process of deterioration of the parent rock and its physico-chemical evolution. Depending on the parent rock and climatic conditions soil appears in an infinity of forms possessing an endless variety of characteristics.

It is essential to be aware of the properties of a soil before using it for further processing, especially for VSBK technology brick making. These properties fall into the following categories; grai (particle) size and its distribution, colour and other physical as well as chemical properties.

Many types of soil have been used for fired brick making, including clay, loam and even materials from anthills and termite mounds. Good quality clay ensures a strong and durable brick and it must have specific properties that confer a high degree of plasticity when mixed with water, so that it can be moulded into a brick. In addition, the clay must have sufficient tensile strength to stay within its moulded shape and its dead weight.

1.2 ORIGIN AND FORMATION OF SOIL

The ground is the solid part of our planet. At its surface it becomes soil - a loose material of varying thickness, which supports vegetation, and bears humanity and its structures. Soil is the result of the transformation of the underlying parent rock under the influence of a range of physical, chemical and biological processes related to biological and climatic conditions and to animal and plant life.

The transformation of rocks into soil is termed as soil formation or soil development. Soil formation starts primarily with the weathering of rocks. The weathering processes are primarily destructive in nature and help to change the consolidated rocks into unconsolidated soil. Weathering processes are of two types:

1.2.1 PHYSICAL WEATHERING

This is a mechanical process, causing disintegration of massive rocks into smaller particles without any chemical change or formation of newer products. Physical weathering is caused by the following factors.

TEMPERATURE

The alternate expansion and contraction of rocks due to variation in temperature produces cracks. The number of cracks slowly increases and the rock gets broken into pieces.

WATER

In cold regions, water freezes in rock joints and expands in volume. Due to this tremendous pressure the rock splits into a loose mass of stones. Rain water falling on the rocks also causes some abrasion. Moving water due to rains in rivers and flood plains has tremendous transport capacity and by its rolling actions further grinds the stones into smaller pieces. Water through its erosion forces removes the weathered parts and deposits as fine sand, silt or clay.

WIND

Wind carrying particles in suspension, like sand from rock fragments, when blowing constantly over a rock at great speed exerts a grinding action whereby the rock gets disintegrated.

1.2.2 CHEMICAL WEATHERING

Essentially the origin of a soil is largely determined by the nature of the parent rock, the climate, the vegetation and the topography.

Chemical weathering takes place mainly at the surface of rocks with the dissolution of soluble minerals and formation of secondary products. This is called chemical transformation. No chemical weathering is possible without the presence of water. The rate of chemical reactions increases with dissolved carbon dioxide and other solvents in water. Higher temperatures and humid climates also greatly aid in chemical weathering. This is the reason for finding a high amount of soil in tropical climates.

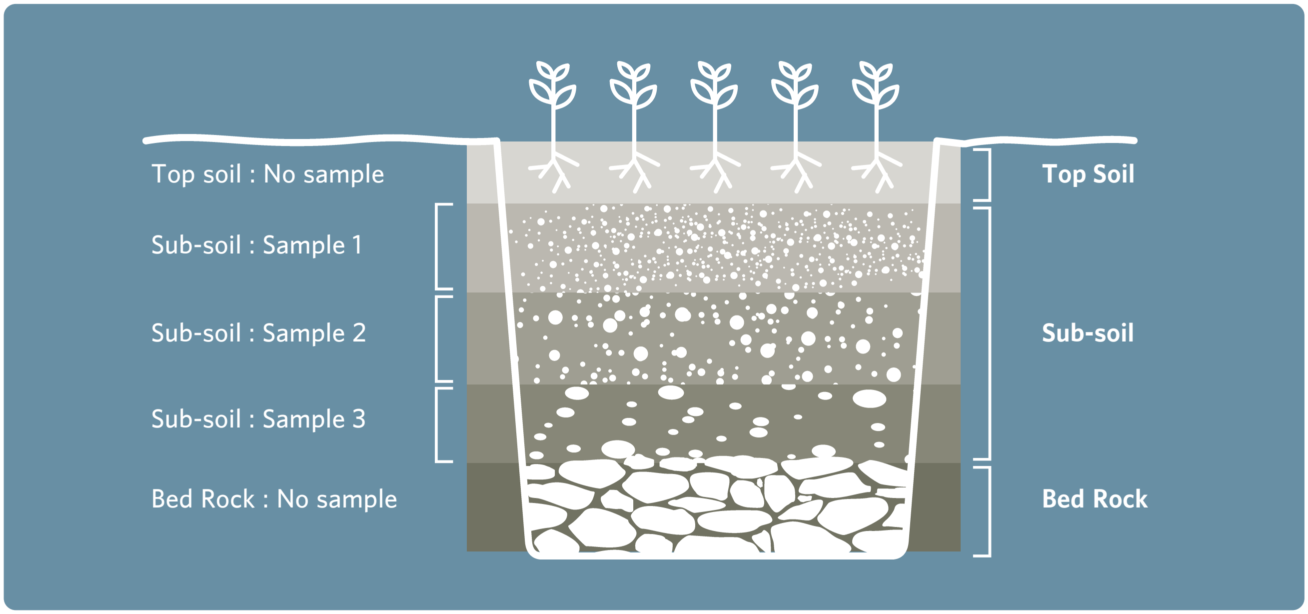
1.3 TYPES OF SOIL

The most suitable soil for brick making comes from the subsoil layers.

A typical soil profile can be divided into three parts: top soil containing large quantities of organic matter; subsoil containing little or no organic matter; and bedrock, which may or may not be broken down into lumps.

1.3.1 MAIN HORIZONS OF SOIL OCCURRENCES FOR BRICK MAKING

A cross section of the ground makes it possible to observe the various soil layers.



The subsoil layer is called an Impure Clay Layer containing various amounts of iron, calcium, magnesium and other ingredients, which are essentially referred to as brick clay. Indeed, the main chemical composition of brick clays are minerals like silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3), lime (CaO_2), magnesia (MgO) and alkalis (K_2O, Na_2O, etc.). Although there are no definitions of ideal composition, changes in the amount of chemicals affects the quality of the fired bricks in a VSBK firing system. Further the presence of some harmful constituents like iron nodules (hard reddish to dark brown spherical lumps), stone particles, soluble salts and limestone in the soil has a detrimental effect on the quality of the fired brick.

To be suitable for brick making in a VSBK firing system, the basic constituents of soil must have around 60-70% finer materials i.e. clay and silt and lesser than 30% coarser material such as sand.

Though the constituents of the soil are necessary for obtaining high quality bricks, practically it seems to be an ideal case because it is very difficult to get such quality everywhere. For example while examining the soil of a brick making site if the required constituents are achieved in one particular soil sample, it may vary with the other sample in the same area. The different constituents affect the working properties of clays and can greatly vary even within a distance of metres.

A high plastic clay is suitable for pottery use but unsuitable for making bricks. Similarly a non-plastic clay is unsuitable for making fired bricks.

The only sure way to determine the feasibility of a particular clay for brick making is to make the desired product on a trial basis and analyze the results after firing.

1.3.2 GRAIN SIZE

The grain size and its distribution of a soil have a decisive influence on its moulding properties and the resultant fired brick quality. Grain size refers to the mean or effective diameter of individual mineral grains or particles. Grain size is classified as:

Soil that contains particles greater than 2mm is not suitable for good quality brick making in VSBK technology.

CLAY

Grain sizes of clay are smaller than 2µm i.e; (0.002 mm).

SILT

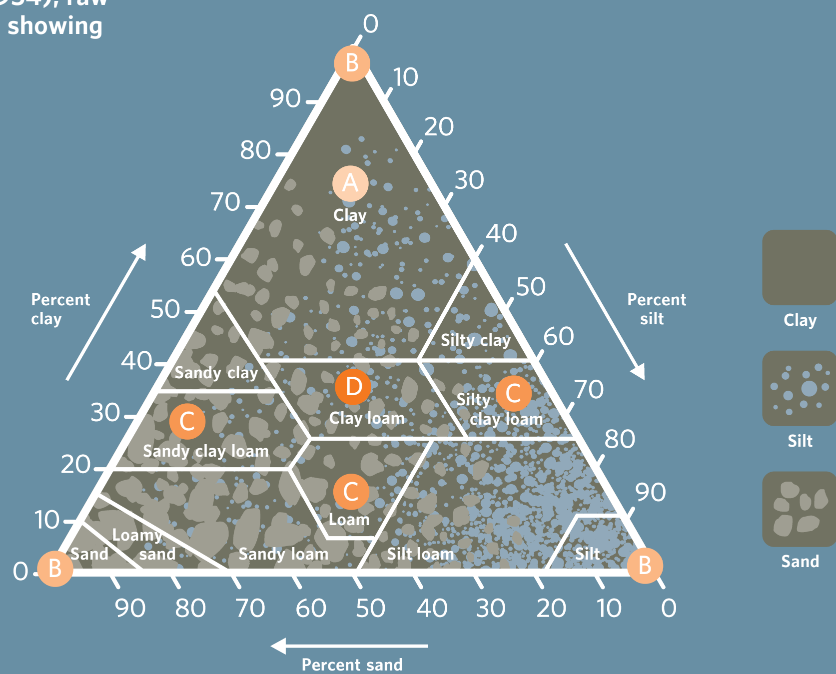
Grain sizes of silt ranges from 2 to 63µm.

SAND

Grain sizes of sand are greater than 63µm.

Niesper (1958) and Winkler (1954); raw material classification diagram showing clay, silt and sand distribution.

- A Suitable for making tiles or potteries
- B Unsuitable for quality bricks in any brick kiln
- C Medium suitability for VSBK bricks
- D Highly suitable for bricks fired in VSBK



Clay content in green brick increases the workability and fired strength, however too much (>70%) deteriorates both the green and fired brick quality.

CLAY

Clay grains are always smaller than 2µm. They differ from other grains in their chemical composition and physical properties. In chemical terms they are hydrated alumina-silicates formed by the leaching process acting on the primary minerals in rock. Physically speaking, clay very often assume a platy elongated shape. Their specific surface is infinitely greater than that of rougher round or angular particles.

Presence of a recommended amount of clay is a must in any brick making activity. It imparts the workability and green strength in bricks. It also helps in binding the coarser particles with each other during the vitrification process and contributes to achieve the fired brick strength. However too much clay content in any soil reduces the workability during brick moulding and increases the shrinkage rate thus forming cracks during drying of green bricks.

SILT

The grain size of silt ranges from 0.002 to 0.063 mm. From the physical and chemical point of view the silt component is virtually identical to the sand component, the only difference being one of size. Silt gives soil the stability by increasing its internal friction. The films of water between the particles grant a certain degree of cohesion to silty soil.

Presence of silt is of utmost importance in brick making. It acts as a mediator between sand and clay by reducing the plasticity content and preventing high shrinkage cracks during drying process. Although it does not aid in binding activity, but fills up the gaps between coarser sand and finer clay thus providing a homogenous structure resulting in high fired strength.

SAND

The grain size of sand is greater than 0.063 mm (63µm). However for good quality brick making in the VSBK firing system, sand particles coarser than 2 mm are not suitable. Sand is often made up of particles of free silica (SiO_2) or quartz (polymorphic transformation of silica). The open structure and permeability are typical of sand. Hence water retentivity of sand is very poor.

Sand (lesser than 30%) is also essential in brick making, since it helps in opening up the fine-clay structure and making it workable for manual moulding so that the brick making soil does not stick to the hand or to the mould during the molding process. During the firing of a brick it prevents high firing shrinkage thus avoiding firing cracks, warpage and abrupt achievement of vitrification. Since in a VSBK the green bricks are stacked vertically, the compressive strength of the bricks during vitrification are vital to avoid any sagging and hence any deformation of fired bricks during the firing process. An appropriate amount of sand evenly distributed within the green brick provides this essential strength to withstand the load of brick stacks during the vitrification stage.

1.3.3 GRAIN SIZE DISTRIBUTION OF SOIL AND ITS TECHNICAL IMPORTANCE

The soil distribution refers to the relative proportion of sand, silt and clay, irrespective of chemical or mineralogical composition. They have a decisive quality influence depending on the selected firing technology. Sandy soils are called coarse-textured, and clay-rich soils are called fine-textured. Loam is a commonly used terminology defining the textural class representing about one-fifth clay, with sand and silt sharing the remainder equally. However loam is considered not feasible for good quality VSBK brick making since it does not conform to the recommended (30% clay, 70% silt and sand) grain size distribution.

Traditional brick making uses the open atmosphere (sun and wind) for drying of green bricks. Use of sand prevents faster drying especially during summer months thereby reducing chances of shrinkage cracks and deformation.

Workability and drying behaviour of the clay body are especially determined by the content of fractions of less than 2μm. Fine grained clays generally have high drying shrinkage rates. However, even within each type of clay the drying parameters varies, depending on the grain size distribution and mineralogical association.

The extent of linear drying shrinkage also depends on the amount of water added for homogenization and workability. A freshly moulded green brick shrinks until the added water is evaporated and the particles of clay body have formed as a stable framework. The addition of sand alone does not result in such a gradation or spread in particle sizes. Raw materials should be added therefore which complements the existing grain size distribution, e.g. silty loams.

If the unfavorable drying properties of clay are corrected merely by high sand additions the workability of the clay body will also be adversely affected. Therefore, to solve the problem of high shrinkage rates, it is recommended to add a mixture of various clays or silts, if necessary with sand additives, to obtain a body with uniformly good properties.

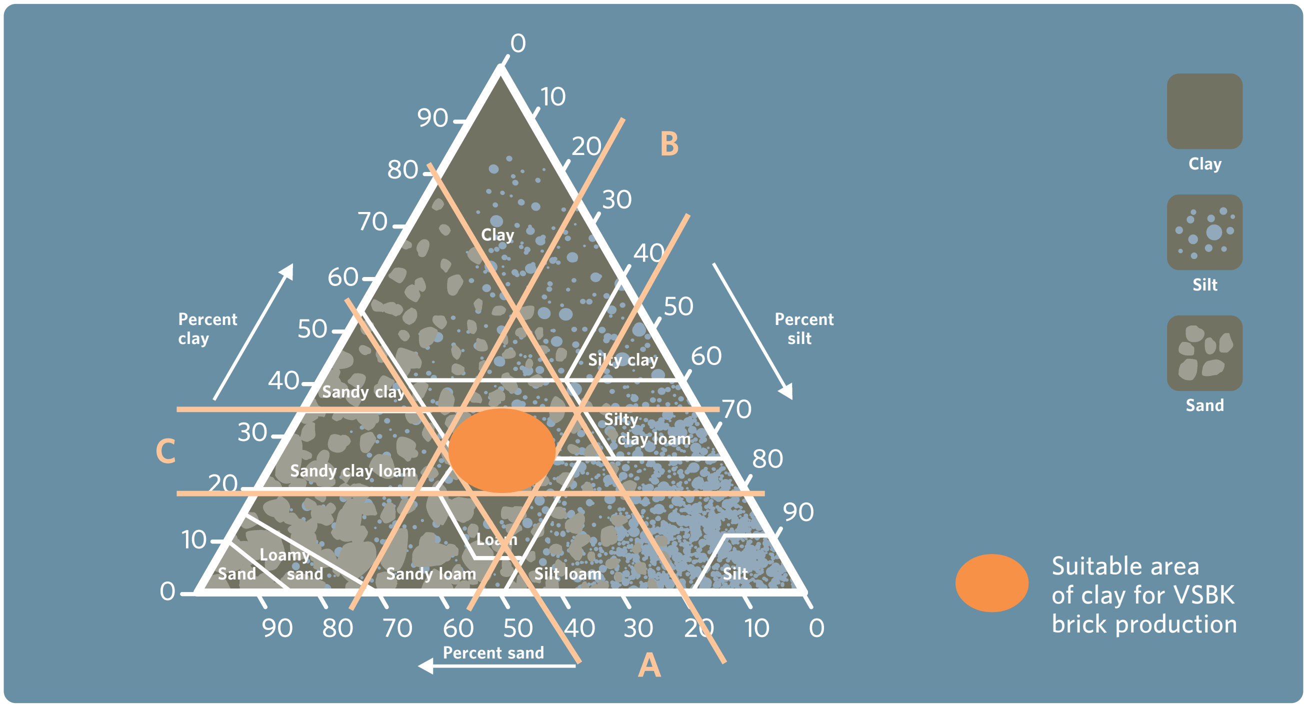
The increase in finer fraction grain size distribution on fired bricks should also be noted. An increase in grain fraction of less than 2μm (clay fraction) often produces at the same time higher firing shrinkage thereby creating greater chances of warpage and distortion.

As well as the vitrification behavior, the grain size distribution also influences the strength of products and their frost resistance. Bricks and tiles produced from coarse clays possess lower frost resistance and lower strength. The properties of clays for brick product, (which are dependent on grain sizes) are significantly affected by the mixing process. Mixing in a pug mill results in a partial homogenization and densification of clay mineral aggregates and hence an improvement in properties (compressive strength, water absorption, shape and size, ring, etc.) of the green and resultant fired brick.

In general for achieving a good quality of fired bricks, the ideal distribution of grain size in a soil should be as given in the 'Table 1'. The values given in the table below are plotted into the Niesper (1958) and Winkler (1954) raw material classification diagram shown overleaf.

TABLE 1. IDEAL DISTRIBUTION OF GRAIN SIZE FOR VSBK BRICKS

S.N.	Elements	Size	Recommended Value
1.	Sand	2 mm - 0.063 mm	20-45%
2.	Silt	0.063 mm - 0.002 mm	25-45%
3.	Clay	< 0.002 mm	20-35%



STEP 1

Plot the percentage of sand 20-45% on the diagram as shown by lines A.

STEP 2

Plot the percentage of silt 25-45% on the diagram as shown by lines B.

STEP 3

Plot the percentage of clay 20-35% on the diagram as shown by lines C.

Thus the composition of 30% sand, 40% silt and 30% clay is at the cross point of line A, B and C. This composition is ideal for VSBK brick production.

1.3.4 COLOURS OF SOIL

Soil colour is a result of various chemical processes acting on soil. These processes include the weathering of geological material, the chemistry of oxidation-reduction actions upon the various minerals of soil, especially iron (Fe_2O_3), calcium (CaO) and manganese (MnO_2), and the biochemistry of the decomposition of organic matter. Other aspects of earth science such as climate, physical geography, and geology all influence the rates and conditions under which these chemical reactions occur. Soils tend to have distinct variations in color both horizontal and vertical layers. Iron (Fe_2O_3), gives a characteristic red colour to the soil, whereas calcium (CaO) gives a whitish colour and manganese (MnO_2) provides a black colour to the soil. The characteristic colour of a soil depends on the amount of mineral present. However, sometimes also the colour of an individual mineral is masked due to the presence of high percentage of another mineral. For example a soil with 6% iron can give a dark yellow colour instead of characteristic red if the calcium content is more than 2%.

INTERPRETING SOIL COLOUR

Colour is also a sign of the mineralogical content of a soil. Iron minerals, by far, provide the most and the greatest variety of pigments in earth and soil (see Table 2). By identifying the possible minerals present in a soil through observing the colour, it is possible to predict the behaviour of the soil during the firing process and the resultant colour and properties of the fired brick. However only very experienced brick making professionals are able to interpret the fired brick quality and behaviour according to the colour of the soil.

TABLE 2. PROPERTIES OF MINERAL AND ITS COLOUR CONSTUENTS

Mineral	Formula	Size	Colour
Goethite	FeOOH	(1-2 mm)	yellow, brown
Limonite	Fe_2O_3		yellow
Hematite	Fe_2O_3	(~0.4 mm)	red
Magnetite	Fe_3O_4		black
Ferrihydrite	$Fe(OH)_3$		dark red
Iron sulfide	FeS		black
Humus			black
Calcite	$CaCO_3$		white
Dolomite	$CaMg(CO_3)_2$		white
Magnesium	MnO_2		black
Quartz	SiO_2		light gray

EFFECTS OF COLOUR IN BRICK QUALITY

Generally, in Kathmandu valley, black coloured and pale yellow type of soil are found and used for brick making. Black coloured soil has high organic matter content hence while firing lower energy input is needed. Black soil has a high degree of shrinkage and is likely to crack during the drying process if not properly protected. On the other hand yellow soil requires higher energy input since there is very less organic matter present. The drying shrinkage with yellow soil is less compared to black. Therefore, bricks with yellow soil have uniform shape and size.

Quality of fired bricks cannot be linked only to the colour of the soil. It also depends on various factors such as firing process and temperature, grain size, chemical content of the soil etc. Due to its high plasticity, black soil has higher water absorption rate i.e; higher moisture content than the yellow soil. Thus bricks with black soil (containing humus[1]) will need longer time for drying than the yellow one. Generalizing, one can say that fired bricks made out of black soil have better colour (cherry

Garbage IN

red) than fired bricks made out of yellow soil. Colour of soil does not have direct impact on the ring or strength of fired product. But generally it has been observed that fired bricks made out of black colour soil tend to give better ring than the yellow one. Dark black soil is not very suitable for brick making, because it contains a high degree of humus and is difficult to mix with water during the clay preparation process due to its high plasticity and occurrence as hard lumps. They have a very high degree of shrinkage so are more susceptible to cracks during drying and even firing process. Red soil colour is due to the oxidation of iron. The higher the iron content, the lower will be the vitrification temperature of the brick (under the condition that it fulfils the required grain size distribution), thereby saving energy. Yellow colour of a soil can be due to the presence of iron (goethite, limonite) or high content of calcium (>2%). The yellow coloured soil containing the polymorphs of iron during firing will give a characteristic red colour in fired bricks. However even if the soil contains a high amount of iron and more than 2% of calcium (CaO), then during firing the red colour from iron present in the soil gets masked by the white burning calcium and a resultant dark to pale yellow colour of bricks are observed.

1.3.5 SOILS OF NEPAL

Soils of Nepal can be divided broadly into the following 5 major groups.

RED SOILS

Red colours in soils are due to the presence of various oxides of iron. They are either formed in situ or from products of decomposition of rocks washed to a lower level. They generally include soils locally known as red sandy soils and red alluvium. They are mostly formed under sub-humid climate from an assorted rock formation. Their main features are light texture, porous structure, absence of lime and organic matter. In the upper part of a typical soil deposit silty red soils are found. With depth the clay fraction increases with the presence of granular particles of morrum or stones.These types of soil are suitable for brick making with a deep cherry red fired colour. However due to possible high presence of silt and sand particles, in some red soils desired strength might not develop. Caution should be exercised in selecting these kinds of soils since at depths they might contain coarser particles.

LATERITIC SOILS (PALE RED COLOR)

They are found mostly in areas with a high rainfall. They are light in texture and have an open free draining structure. They are deficient in lime and thus highly suitable for brick making. Laterite soils formed at high levels have a pale red colour and are highly gravelly in composition.

---

[1] Humus is a complex organic substance which is in the form of a dark, spongy, jelly like substance and amorhorous in nature. It is extremely important for the fertility of soils used for agriculture. It helps the soil to retain moisture. Humus can hold the equivalent of 80 to 90 % of its weight in moisture, and therefore increases the soil's capacity to withstand drought condtions.

Those formed at lower levels have a darker colour due to accumulation of humus and a slightly finer texture.

These types of soils are also suitable for brick making but it requires preparatory work that will not be profitable for ordinary bricks. However due to the sandy nature they must be well compacted by mechanical means (pug milling) to avoid breakage and attain the desired strength.

BLACK SOIL

Black soils are developed from Basaltic rocks under semi-arid conditions. The soils are typically black or dark brown in color with high content of lime nodules. They are locally known as regur, or black cotton soil, deep and medium black soils. Their texture ranges from sandy clay to heavy clay. Some black soils are porous. However the majority of them are highly compact and impervious. One of the characteristics of black soil is that it swells when wet and shrinks and cracks when dry. These types of soils are highly unsuitable for brick making.

ALLUVIAL SOILS (YELLOWISH, GREY OR GREYISH BROWN)

This is the best available soil for both agriculture and brick making. These types of soils are characterized by extreme depth and yellowish to grey or grayish brown in colour. The texture varies from sandy clay to silty clay and even clayey in case of river delta areas. The structure is also variable, loose and free draining in the case of sandy soils and compact and impervious in the case of clayey soils.

Due to its medium plasticity and high silt content they are most suitable for brick making. Due to its high plasticity, a non plastic material in the form of white sand is mixed to avoid shrinkage cracks. The best brick quality can also be achieved with this soil.

TARAI SOILS (MULTI COLOURED)

In general, Tarai soil is very suitable for VSBK brick making.

Tarai soils have a wet regime and high water table conditions for most part of the year. Soils found under these conditions are thickly vegetated and swampy. They are derived from materials washed down by the erosion from mountains. The parent materials are of alluvial sediments and consist of hard clay.

These types of soils are highly suitable for brick making. Special care is taken to select soil devoid of organic matter. Some of the best qualities of bricks are manufactured from this type of soil.

1.3.6 CHEMICAL PROPERTIES OF SOIL

MINERAL CONTENT

The most common constituents of soil are clay, free silica and some constituents of iron (depending upon the colour of the soil). Clay

Garbage IN

minerals are layer silicates that are formed usually as products of chemical weathering of other silicate minerals at the earth's surface. Clay minerals are found most often in shells, which is the most common type of sedimentary rock. There are many types of known clay minerals. Some of the most common types of clay minerals related for brick making are described here;

Kaolinite

This clay mineral is the weathering product of feldspars. It has a white, powdery appearance and is usually fine grained. Kaolinite is named after a locality in China called Kaolin. Kaolinite is the purest form of clay and consist of hydrated alumina-silicates. The chemical formula of Kaolinite is $Al_2O_3.2SiO_2.2H_2O$. It is used for making pottery or ceramic materials. Normal brick making soil does not contain any appreciable amount of kaolinite.

Illite

This is one of the most common forms of clay available in soil. Basic mineral substitutions are Mg (magnesium) and K (potassium) in the crystal structure. Illites because of their high K_2O content usually have low melting points (1050°C to 1150°C). Firing close to these limiting values is strongly recommended since at this temperature the stable phases are formed in the brick body. Illites often contain iron also in the lattice, which is released at about 900°C firing temperature in the form of red hematite. The red colouring of the brick persists as long as no CaO is present.

Montmorillonite

In Montmorillonite the Al ion is partially substituted by Na and Mg. The resultant crystal structure has a capacity to absorb high water content and expand. Consequently they have a considerably higher drying shrinkage. Due to their high plastic nature, in very small amounts, preferably not exceeding 3%, they can increase the plasticity of non-plastic materials thereby increasing the compressive strength of the fired bricks. Montmorillonites after drying, rapidly reabsorb moisture from the atmosphere. This causes renewed swelling of the green products and accelerated drying in the kiln usually with high breakage. Therefore montmorillonite clays are not suitable for use in VSBK brick making.

Never use Black soil and Montmorillonite soil for VSBK brick making. !

CHEMICAL PROPERTIES

The elements that are found in soils in the highest quantities are O (oxygen), Si (silica), Al (aluminium), Fe (iron), C (carbon), Ca (calcium), K (potassium), Na (sodium), and Mg (magnesium). These are also major elements found in the Earth's crust and in sediments. Oxygen is the most prevalent element in the Earth's crust and in soils. It comprises about 47% of the Earth's crust by weight and more than 90% by volume.

In any representative soil variety, the clay content may vary from 15 to 80% (alumina (Al_2O_3) content of this clay might vary from 10 to 30%),

TABLE 3. COMPARISON OF CHEMICAL ANALYSIS OF GOOD AND ORDINARY SOIL SAMPLE FOR VSBK FIRING

S.N.	Test parameters on dry basis (% by mass)	Good sample	Ordinary Sample	Effects on fired brick property in a VSBK firing system
1.	Loss of Ignition	3.2	7.7	Measure of organic matter in soil. Too high LOI is deleterious, giving high porosity, shrinkage and chances of black coring increases due to fast firing system in VSBK.
2.	Silica as SiO_2 (as structural silica within the clay mineral and free silica as sand/silt)	61.8	80	Structural silica within clay mineral gives strength in the fired brick whereas free silica gives strength and rigidity to the green brick. Silica is the primary constituent of any soil. Gives strength in a green brick and helps in maintaining the shape and size when fired at vitrification temperatures. Silica (structural silica) present within the clay reacts with alumina to form mullite, which is also responsible for giving the required strength in a fired brick.
3.	Iron as Fe_2O_3	>3	0.9	Gives a strong red color to the brick when fired at appropriate temperatures.
4.	Alumina as Al_2O_3	23	14.6	In combination with silica forms mullite ($2Al_2O_3.3SiO_2$) at high temperatures. The mullite is in the form of criss-crossing needles which are responsible for developing strength in a fired brick. An increased strength of a fired brick will only happen if the amount of alumina content is being equalized with silica in the ratio of 2:3.
5.	Sodium as Na_2O	0.1	0.2	Indication of montmorillonite clays. More than 1% content will affect the fired brick properties giving a white scum in the fired bricks when in contact with water
6.	Potassium as K_2O	2.76	Trace	Indication of Illitic clays. Higher quantities present in the clay will lead to lower vitrification temperatures but with a high firing shrinkage.
7.	Calcium as CaO	Trace	Trace	In lump form is extremely deleterious resulting in lime bursting. However in fine state and more than 2% will mask the red color given by iron, resulting in a buff coloured fired brick.
8.	Magnesium as MgO	1.2	1.2	Indication of Illitic clays. Is beneficial for fired brick properties since it acts as a catalyst during the vitrification stage and aids in a denser and stronger brick.
9.	Organic carbon as C	0.82	0.66	Measure of heat producer within the soil. Acts as an internal fuel thus reducing the external fuel consumption. Higher amounts will result in black coring, warpage, cracks due to the fast firing pattern in VSBK.

the free silica or sand from 5 to 80%, the oxides of iron from 1 to 10%, the carbonates of lime and magnesia together, from 1 to 5%, and the alkalis from 1 to 4%.

The chemical association of clay and its technical importance

The chief chemical composition of brick clays is silica, alumina, iron oxide, magnesia, lime and alkalis. Either more or less than the required amount of any of these constituents may make a substantial difference in brick quality especially in short cycle firing systems like VSBK.

The recommended value of Alumina, Iron oxide, Silica and Magnesium content in clay suitable for VSBK firing system are:

Alumina	-	Preferably above 20%
Iron Oxide	-	>3%
Silica	-	50-60%
Magnesium	-	>1.2%

The alumina and the iron content in clay plays a decisive role in determining the brick quality. Alumina determines the plasticity in the soil which is an important component for high strength bricks. The higher percentage of hydrated alumina silicates (clay), in the soil results in stronger bricks. However there is a practical working limit to the maximum amount of hydrated alumina silicates (clay), present in a soil which will be suitable for brick making. This quantity is usually not greater than 30% in a VSBK firing system. It should also be remembered that along with the clay content, the fineness (grain size distribution) of the clay also plays a major role for achieving the strength of the fired brick. The higher the alumina content in a soil, the higher will be the firing shrinkage. However to compensate for the high firing shrinkage due to high alumina content, free silica in the form of sand or silt can be added to clay. Alkalis (e.g. soluble salts of K, Na, etc.) when present in higher quantities (>1%) produces higher fired body densities.

Iron oxide representing 3 to 8% within a clay will produce a reddish brick when fired at around 900-1000°C. If the temperature of firing increases then the colour of the brick turns from red to deep cherry red to blackish. Similar conditions can also be obtained if the alkali content of the clay is greater than 3%.

Contents of alkali oxides are of decisive significance for the vitrification behaviour of clay. Higher alkali oxide of >3% (MgO, K_2O, Na_2O, etc.) contents results in low temperature vitrification and increases the firing shrinkage.

1.3.7 ADDITIVES

In green brick making additives are of the following types:

- Internal fuel
- Anti shrinkage material
- Structure opening material

INTERNAL FUEL

For firing of green bricks in VSBK in an energy efficient and economical manner, addition of internal fuel is an option and under circumstances desirable. Without internal fuel content, firing of solid green bricks

thicker than 70 mm in a VSBK is not recommended. Internal fuel not only reduces the external fuel consumption but also reduces the stack emission. Addition of internal fuel also upgrades the fired bricks quality.

Internal fuel can be coal or waste material produced by the process industries, such as:

- Coal dust
- Industrial waste like boiler ash, distillary waste, sponge iron waste
- Agro waste like rice husk, saw dust, etc.

For brick making, internal fuel is mixed with the soil during mixing and pugging process. Quantity of addition depends on the quality of the soil and the calorific value of the internal fuel.

ANTI-SHRINKAGE MATERIAL

To transform highly plastic soils for brick making, anti-shrinkage materials are added. This is to avoid high shrinkage and resultant cracks during drying under direct sunlight. Depending upon the availability the following types of anti-shrinkage materials can be added.

Never use sand for VSBK brick production that contains 'mica'.

Fine river sand

Should not be bigger than releasing sand, depending on the fineness of the clay a maximum of 30% fine river sand can be added (exclude mica sand[2]).

[2] River sand which shines should be checked for mica. Mica are flaky materials generally white or brown in colour. When heated at lower temperatures, it expands considerably. Thus its presence within a green brick during firing will result in cracks. The bigger size of the mica flakes the higher the chances of cracks in the fired bricks and dull sound.


Fine river sand


Medium sand


Stone dust


Sandy soil

Medium sand

<2 mm grain size, in case of plastic clays a maximum of 15% can be added.

Stone dust

<2 mm grain size, in case of plastic clays a maximum of 15% can be added.

Sandy soil

It is usually used in Kathmandu as a releasing agent during moulding. In case of plastic clays a maximum of 30% can be added.

The exact quantity of anti-shrinkage material to be added always depends on the plasticity of the clay. It is advisable to contact a professional and qualified brick making expert to determine the most appropriate amount and mixing technique of anti shrinkage material required.

> ! The correct amount of 'anti-shrinkage' materials must be practically tested with the Brick Bats Method (see 2.6.1).

STRUCTURE OPENING MATERIAL

During periods of very low humidity and high temperature e.g. (March, April, May, June in Terai region of Nepal) a structure opening material could be used in green brick making to avoid rapid drying damage of green bricks, especially shrinkage cracks and warping. Structure opening material also performs anti shrinkage functions. The materials generally used for structure opening are:

- Rice husk
- Saw dust
- Mustard husk


Rice husk


Saw dust


Mustard husk

The exact quantity of pore opening material to be added always depends on the plasticity of the clay. It is advisable to contact a professional and qualified brick making expert to determine the most appropriate amount and mixing technique of pore opening material required. In general with any kind of plastic to semi-plastic soil a maximum of 2% by weight of dry green brick, pore opening material should be added. Too much addition reduces the strength and increases the water absorption rate of the fired brick.

2 SOIL TESTING FOR BRICK MAKING

2.1 INTRODUCTION

The quality of fired bricks depends largely upon the soil properties, skill of the moulders and the firemen, no matter which technology is used for firing the bricks.

The basic constituents of soil are the clay and silica minerals which contain minerals like alumina, potassium, iron, calcium, sodium, etc. These mineral constituents have various characteristics on brick forming, drying and firing. Good brick quality cannot be achieved from all types of soil. The only way to determine the fired brick quality from a particular soil is to make the desired product on a trial basis and analyze the results. Confirmatory chemical and physical tests of soil are also performed to explain and understand the resulting product quality.

2.2 SUITABILITY FOR BRICK BUSINESS

The very first step to determine the first feasibility of soil for a brick production site is to check its quality and availability. For economic viability it has been calculated that a VSBK business requires at least a local soil for a minimum period of 3–5 years. Therefore, the required soil quality/suitability is an important VSBK site selection criteria. The soil quality testing is made by visual inspection of site and performing primary soil tests at the site followed by a production scale test for confirmation.

2.2.1 VISUAL TEST

The visual test gives a quick GO or NO GO decision for selecting the brick production soil for further testing. The following rough criteria should be considered:

VSBK SITE SELECTION

- Enough soil at site to last for a period of 3-5 years keeping the economics of brick business point of view.

There must be enough soil at site to last for a period of 5 years keeping the economics of brick business point of view.

- Site should not be nearby the river areas, (because near river areas in Nepal there is a high presence of sand due to the inherent characteristic of water flow).
- Site must be free from tree plantation, (because of probability of high organic content within the soil e.g. roots, leaves etc. Further tree plantations will provide a shadow on the green bricks thus taking more time to dry).
- Site should not be near the forest area to prevent damage to forest trees by the emission during the firing process.

VSBK SOIL SELECTION

- Soil should not contain any lime stones (because presence of lime stone particles greater than 1 mm results in lime bursting in a fired brick).
- Soil should be free of stone particles as it damages the brick during the firing process due to unequal thermal expansion which results in high breakage rate of fired bricks.
- Soil should be plastic i.e. it should retain its formability for forming a strong green brick.

2.2.2 SOIL RESERVE CALCULATION

The soil reserve calculation is needed for mainly two reasons:

- To ensure that the raw material lasts for a period that guarantees the recovery and achievement of profit against the initial investment.
- To ensure that the same raw material quality is available for producing consistent quality of fired product.

The soil reserve calculation can be made in the following way:

TABLE 4. EXAMPLE OF SOIL RESERVE CALCULATION

Assumption: **Selected site boundary is rectangular or square in shape**
Suppose, Length = 200 meter Breadth = 200 meter Depth = 2 meter

Therefore, Total volume of soil deposit = 200x200x2 cu.m. = 80'000 cu.m.
Volume of brick = 25x12.5x6 cu.cm = 0.001875 cu.m.
Total number of bricks that can be produced =

$$\frac{\text{Total Volume of soil}}{\text{Volume of brick}} = \frac{80'000}{0.001875} = 42'666'666\ (\approx 42'700'000\ \text{bricks})$$

Taking compaction factor = 0.2, Actual numbers of bricks that can be produced
= 42'700'000 – (0.2 x 42'700'000) = 34'160'000

Annual production of a 4-shaft VSBK assuming a 300 days per year production rate
1 shaft 5000 bricks per day 4x5000x300 days = 6'000'000 bricks

Thus life of soil availability for VSBK production $= \frac{34'160'000}{6'000'000} = 5.7$ years

SOIL TESTING

Garbage IN

If all the above criteria are positive (site selection, soil quality and quantity) then soil sampling should be done for further confirmatory tests towards its suitability in VSBK firing.

PRACTICAL DETERMINATION OF SOIL DEPTH

The boring methodology is used to practically determine the soil reserve depth for brick making. The boring methodology is a simple and practical approach to determine the depth of soil reserve in the moulding area. Procedure (same as sinking shallow tube well):

- Select a place in the anticipated moulding area.
- Dig a small pit and pour water in it. Leave it for at least half an hour so that the soil absorbs water to a certain depth.
- Pour more water in the pit as soon as the first water has been absorbed.
- Insert vertically a hollow metal pipe dia. of 5 cm and 200 cm in length through the pit.
- Hold the pipe and try to insert it with to and fro motion. In this motion the pipe bores a hole of its diameter size making a path downwards. While penetrating inside the soil layer, water soluble with soil particles comes out through the pipe.
- Analyze the colour of water solution that gives an idea of type of soil present inside. While continuing the process if the colour of the water solution changes then it shows that there is another layer of soil. If the stone particle comes out mixing with water solution then it shows the end of soil availability.
- Take out the pipe and measure the total inserted height. The measured height gives an idea of total depth of soil reserve in the moulding area.
- Repeat this process to check the soil reserve depth in various places in the moulding area.

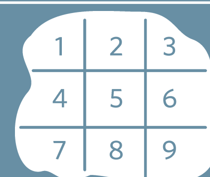
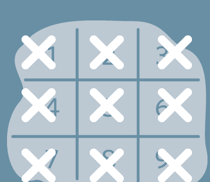
SOIL TESTING

Garbage OUT

2.3 SOIL SAMPLING METHODOLOGY

Soil sampling for green brick production is an often underestimated issue in the brick industry. It is not feasible to test soil samples from the entire area since this would be too much time and resource consuming. Therefore the '9-Grid' representative soil sampling methodology is applied which provides a fairly accurate idea of the soil quality available for brick making.

TABLE 5. '9-GRID' SOIL SAMPLING METHOD

Steps	Quality Issues	Implementing Issues
1. Select the site/ area for excavation/mining of clay.	Top soil should not be used, since it preserves the mineral content and can be reused for agriculture. Common agricultural land should be selected where there is a previous history of brick making. Selected area should not have any large trees. These types of trees commonly have large roots and are difficult to remove during mining. Area should not be rocky in nature. Otherwise soil will not be able to be found at greater depths. These types of soils will also contain boulders and stones, which are deleterious to brick making.	1 m^3 of soil will approximately produce 700 nos. of green bricks of approximate dimension 230 mm x 110 mm x 55 mm having a dry green weight of 2400 gms. Volume of a green brick = 0.0013915 m^3 Number of bricks to be made in 1 m^3 of soil = 700
2. Mark the four corners of the mining area. (Covering total mining area)	This is to ensure maximum representation of the overall soil quality within the marked area.	The marking can be done by lime or by using wooden peg & thread.
3. Divide the whole area into 9 equal square grids.		
4. At the center of each grid dig a small pit and take representative soil sample for making test. 	Take out approximately 30 cm of the topsoil and store it in a different place. After taking out 30 cm if organic matter occurs in pockets, then take them out individually. Ensure that the soil sample does not contain any foreign matter, like stones, gravels, roots, leaves, plastics, etc. Before taking the soil for sampling, break the large chunks of soil manually and mix it thoroughly to get a uniform representation.	Dig the pit with a shovel. Take care that the pit is not too deep. Approximately it should be 50 cm in diameter and not more than 50 cm deep. After digging, mix the soil in the pit thoroughly by hand. Take about 5 kg of soil for performing field tests. This test gives the idea of clay and sand proportion in the soil of that area.

Repeat STEP 4 for each of the nine grids.

THE '9-GRID' SAMPLING METHODOLOGY

For taking representative samples and simulating the actual working principles the widely followed '9-Grid' methodology is followed. The resultant steps for this methodology are described in Table 5.

2.4 SOIL TEST METHODS

There are mainly two methods to determine the parameters of the soil for brick making: Practical field low cost methods and complex laboratory analysis. Low cost field methods test for the soil are mainly performed to obtain a first impression of its properties to produce good quality bricks. For confirmative tests it is always recommended to get the soil tested for its constituents from an accredited laboratory.

2.4.1 FIELD TESTS

There are a few basic field tests that an experienced brick maker or VSBK technology expert must master. Although indicative, a good professional will always derive the correct conclusion out of the field based tests. Few Prevailing Field test are:

SMEARING TEST

Take some loose soil from the possible brick making soil and put an appropriate amount of water into it in order to make a sticky paste.

After the soil is saturated with water, mix the soil paste by hand. Try to make a ball with this soil. Roll the moist ball in the hand enough so that the ball is dried out a little bit.

SOIL TESTING

Pinch out a little bit of the soil with the thumb and the index finger and smear on the thumb by the index finger at one go. The smearing should be done as fine as possible.

During this process feel for any coarse particles. It will be felt by the fingers. After the smearing, if the soil does not form a smooth and thin layer, then the soil is sandy. If the thin soil layer is shiny and evenly spread out over the thumb then the soil is plastic in nature.

Let the thumb dry out. After drying, if the soil layer falls off easily or can be removed then the soil is sandy or silty in nature with probably low plasticity. However if the soil sticks to the thumb and index finger after drying then it is plastic in nature.

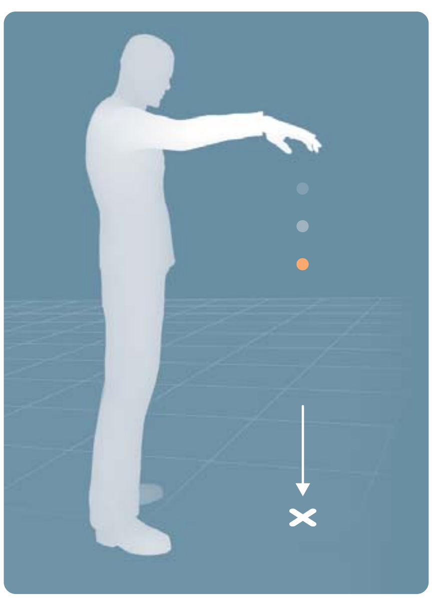
BALL TEST

Ball test is mainly for getting a first feeling about the soils sand and clay proportion.

Take a handful of soil and put some water in it. Water should be enough to make the soil moist and make a dough by hand.

With the hand and fingers mix the soil and water thoroughly. After uniform mixing try to make a ball out of the soil. This activity might take some time depending on the amount of water added. If the water content is too much then add more dry soil.

Observe the smoothness of the surface of the ball. For plastic soils the surface will be shiny and uniform. For sandy soils the surface will be dull and rough. Also with sandy soils it will be difficult to make a round shaped ball.



Wet Ball test

Immediately after the ball is reasonably well formed, drop the ball from a height of at least 1 meter. Alternatively the ball can be dropped from shoulder height with hands straight. Take care that the surface on which the ball is dropped is leveled and clean – preferably a concrete surface or a hard surface. Never do the test on a wet or a loose surface. Observe the ball on the floor. If the ball retains its shape with little amount of deformation at the bottom only, then the soil is plastic clayey in nature. However if the ball flattens out upon hitting the floor, then the soil is sandy in nature.

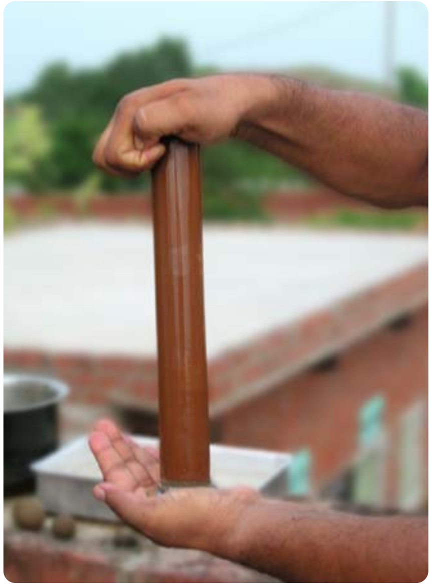
Dry ball test

Repeat the tests by making balls and dry them under atmosphere or under a small open fire. Cool the balls and repeat the test. If the ball cracks into many pieces after contact with the floor then the soil is sandy in nature. However, if the ball breaks into two to three pieces then the soil is clayey and plastic in nature.

SEDIMENTATION TEST

This process is also known as 'Bottle Test' for determining the proportion of clay and sand particles in the soil. It also gives the idea of percentage mixture of sand and clay in the soil.

Fill one-fourth quantity of the glass beaker with the required soil. Add half teaspoonful of salt (to accelerate the deflocculation process) into the soil. Add water to about 50% above the soil level. Wait for a few minutes till the water percolates to the bottom (there will be a distinct colour difference between dry and wet soil). Stir the soil and water mixture vigorously with a spoon for at least 2 minutes. The colour of the stirred material should be uniform.


Pour the stirred slurry into a measuring cylinder. Add some more water in the beaker and drain off the entire soil into the measuring cylinder. Repeat the process of adding more water in the beaker until it is totally empty. While pouring the soil into the measuring cylinder ensure that no soil is sticking to the sides of the measuring cylinder to avoid distortion of proportions.

Place the measuring cylinder on a level platform and allow it to stand for at least 12 hours or until the water becomes clear at the top.

As soon as the water is clear, there will be distinct granulation layers which represent the fineness/plasticity or coarseness/non-plasticity of the taken sample. Firstly measure the height of the bottom most visible layer which is classified as sand and calculate the percentage of sand. Secondly measure the topmost visible layer which is classified as clay and calculate the percentage of clay. The layers between the top (clay) and bottom (sand) represents the silt content of the soil sample. A representative soil mix of clay, silt and sand for good brick production is mentioned in Table 7.

SOIL SHAPE TEST

Take some loose soil from the possible brick making soil and put an appropriate amount of water into it in order to make a soil ball.

Try to form the soil mixed with water into a smooth and uniform ball with one hand only. If after repeated attempts the soil daub does not form into a round ball, then the soil is sandy. During this process, if water is released out of the ball then the soil is silty/sandy. However if after a few attempts, a good, smooth and round ball is formed, then the soil is semi plastic to plastic in nature.

Wash hands with water. If washing is easy then the soil is silty/sandy with low clay content. However if after repeated washing, soil is sticking

into the palms then the soil is clayey in nature. After washing, if the soil still sticks to the corners of the finger nails then the soil has probably a very high clay content.

LIME TEST

Lime is one of the most dangerous mineral for brick making. The presence of lime in soil defines whether to start a brick business or not if no other alternative soil is available. The presence of lime needs to be detected during the initial soil testing stage only. It does not affect the green brick quality. However after firing if the lime nodules containing fired bricks are kept in the open, it absorbs water from the atmosphere and expands, thereby bursting the solid brick. The more lime that is present in a soil the more bricks will be damaged. Hence profitability of the business is questioned. Therefore determination of lime is of utmost importance for making a GO or NO-GO decision in the brick business.

Soil that contains any lime traces must never be used for brick making.

The following method describes a simple field test of determining whether the soil contains lime or not.

Take a lump of soil from the required area or depth from the selected brick making soil. Try to avoid loose soil collection since the lime nodules (if any) might not be contained within a small amount of loose soil. Look for soil lumps which have white spots in them.

Take a representative soil sample. Ground the soil into a loose form by hand. Place a small amount of soil in the Petri dish. Do not put water into the soil, since it will delay the process of reaction with the acid.

Take a small amount of acid (any acid found in the common market e.g. toilet cleaner) by a pipette and put it over the soil sample in the Petri dish. Observe the reaction it creates. Lime is present if the reaction causes effervescent (type of melting) or bubbling action.

SOIL TESTING

If the soil does not show any effervescent, repeat the test with a separate soil sample. Since it is very important to detect lime at the initial stages of establishing a brick business, this test should be repeated as many times as possible with soils from various areas until no doubt is there.

2.5 LABORATORY TEST

2.5.1 CHEMICAL ANALYSIS

Mineral content of the soil is found out by chemical analysis. Chemical analysis has been one of the most reliable indicators to predict the quality of soil suitable for VSBK. The important chemicals to be analyzed are percentage of Alumina, Silica, Iron oxide, Calcium Oxide, Manganese oxide, Sodium oxide and Potassium oxide.

Chemical analysis of soil is carried out using a different methodology such as Furnace ignition, Gravimetric analysis, and titrimetric analysis in a well equipped laboratory with trained staff.

TABLE 6. CHEMICAL ANALYSIS OF SOIL SAMPLE

S.N.	Test parameters on dry basis (% by mass)	Example of Good Results	Method Used
1.	Loss of Ignition	4.7	Furnace ignition
2.	Silica as SiO_2	61.8	Gravimetric
3.	Iron as Fe_2O_3	>4	Atomic Absorption Spectrophotometry (AAS)
4.	Alumina as Al_2O_3	25	Calculation
5.	Sodium as Na_2O	0.1	AAS
6.	Potassium as K_2O	2.76	AAS
7.	Calcium as CaO	Trace	Titrimetric
8.	Magnesium as MgO	1.2	Titrimetric
9.	Organic Carbon as C	0.82	Titrimetric

2.5.2 PHYSICAL ANALYSIS

Percentage of clay, silt and sand can be determined by physical analysis. This are usually done through wet sieve analysis method in well established laboratories. Similarly plasticity index, liquid limit and plastic limit of soil are also determined by physical analysis. Good brick making soil possesses the following physical properties:

TABLE 7. PHYSICAL PROPERTIES OF SOIL

Elements	Percentage
Sand	20 to 45
Silt	25 to 45
Clay	20 to 35
Liquid limit	25 to 38
Plasticity index	7 to 16
Volumetric shrinkage	15 to 25

Too much clay content in any soil reduces the workability during brick moulding and increases the shrinkage rate thus forming cracks during drying of green bricks.

Too much of sand distorts the plasticity of the soil and results in high rate of breakage.

2.6 PILOT SCALE TEST

Prior to any real scale production of bricks it is advisable to test out the results of different soil qualities. Through this process the best soil can be selected, its properties experienced and necessary preparatory mechanism set in place. A practical and progressive result oriented approach must be selected in order to economize the soil quality testing. The pilot scale testing is divided into three phases, namely:

- Brick bat production and analysis (at the kiln site).
- Small scale test production and analysis.
- Limited full scale production and analysis.

2.6.1 BRICK BAT PRODUCTION AND ANALYSIS

It is time consuming and difficult to test the suitability of soil on a large scale and also it is not easy to introduce changes in the process while experimenting with real bricks, in such cases these brick bat test are extremely helpful. Brick bats are miniature bricks with reduced

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SOIL TESTING

dimension facilitating and expediting the brick making procedure at an accelerated scale. It is a practical test that gives the primary indication of clay quality for brick making. It gives the indication on ring, colour and hardness. The drying and firing shrinkage of the particular soil can also be measured with this test.

STEP 1. MINING OF CLAY FOR BRICK BAT PREPARATION

In order to get a representative indicator of the feasibility of the soil for brick production in VSBK, soil samples need to be collected from various points of the selected area. During collection of soil for preparation of bats special care needs to be taken on soil collection from the source. The top soil (generally 20 cm) needs to be removed and kept aside. Soil should always be collected from below 20 cm. If after the required depth of 20 cm, the soil still contains organic matter (e.g. roots, leaves, etc.) then the soil should be rejected and samples should be collected from a greater depth. The quantity of soil needed for brick bat testing depends upon the number of Bats required or desired. Generally 5-6 bats are prepared from one soil sample which requires approximately 2 kgs of dry soil.

STEP 2. MIXING OF CLAY FOR BRICK BATS PREPARATION

- Crush the soil sample into fine powder preferably in a container (e.g. kadai or plastic etc) to avoid contamination.
- Take out all undesired particles (greater than 2 mm) from the crushed soil.
- Slowly add water to the soil and mix it thoroughly (replacing soil ageing) by hand until a smooth consistency for moulding is achieved.

STEP 3. MOULDING OF BRICK BATS

- Clean the bat metal frame and oil the inside surface for easy removal of clay.

- Put the conical bat metal frame on a piece of paper and on a plain surface such as a ceramic tile with the smaller dimension facing downwards.
- Take about 1.5 times (of the volume of bat frame) of mixed soil and place it in the bat frame.
- Press the clay into the metal frame and ensure proper and evenly dense filling including the corners.
- Cut away with a metal ruler the excess clay above the metal frame and smooth out the surface.
- Cover the bat with a piece of paper and place another ceramic tile on top of the metal frame.
- Put the sandwiched metal frame upside down.
- Take out the ceramic tile at the top, and slowly lift the metal frame gently pressing the clay out of the frame onto the paper.

STEP 4. PHYSICAL ANALYSIS OF GREEN BRICK BATS

- Mark the de-moulded brick bat with a standardized die-punch (shrinkage bar of 100 mm length) across both the diagonals. Care should be taken to ensure that during the pressing of the die-punch no deformation of the brick bat takes place.

- Mark the number of the de-moulded bats and record in standardized 'Brick Bats Analysis Report Form'. (See Table 8)
- Weigh the soil bat along with the ceramic tile and the paper immediately after de-moulding. Deduct the weight of the previously measured ceramic tile and paper. Record the weight of the green soil bats in standardized 'Brick Bats Analysis Report Form'.
- Place the green bats in a moist atmosphere (inside a room) until leather hard to avoid warpage and shrinkage cracks.
- Take out the brick bats and place them in the sun for drying. Ensure that the bats are turned on their flat surfaces regularly to achieve uniform drying on all sides.
- Weigh the bats on a daily basis and record. Once the weight of the brick bats are constant complete drying has been achieved.
- Measure the length of the shrinkage bar and the weight of the bats and record in standardized sheets.






STEP 5. FIRING OF BRICK BATS

- After the brick bats are fully dried (no change in dry weight and colour) they are ready for firing.

In order to make a representative quality assessment of the brick bats, the fire zone must be at the center of the shaft and the max fire temperature must be known.

- Place the dried brick bats lengthwise inside the 'chulha' layer. Remove the coal nearby the brick bats to avoid melting.
- For firing the brick bats the fire must be stabilized in the centre of the shaft with the appropriate firing temperature.

STEP 6. PHYSICAL ANALYSIS OF FIRED BRICK BATS

- Measure the shrinkage bar, weigh the fired brick bats and record in standardized 'Brick Bats Analysis Report Form'.
- Assess the colour, ring, and hardness for each of the samples and record in 'Brick Bats Analysis Report Form'.
- Assess the fired brick bats visually for presence of any cracks, warpage or any damage and record in 'Brick Bats Analysis Report Form'.

Similar brick bat test should also be applied for testing soil performance with internal fuel. The procedure for making the bats along with the various additives and firing them are similar as described above. The amount of internal fuel to be added, has to be weighed and mixed with the crushed clay (freed from unwanted particles) in the dry stage, before mixing the clay with water.

Percentage of recommended amount of internal fuel to be added must be translated into practical implementation practice. This might require experimenting at the site until satisfactory brick quality is achieved with internal fuel.

TABLE 8. BRICK BATS ANALYSIS REPORT FORM

VSBK Enterprise :

Date	Sample No.	Material Composition	Wet Weight (gm)	Dry Weight (gm)	Weight Loss on drying (%)	Dry bats mark length (mm)	Weight after firing (gm)
			Ww	Wd	$\frac{(Ww-Wd)}{Ww} \times 100$	dm	Wf

* NOTE: Where Lw is wet length = 100 mm

Loss on ignition (%)	Fired bats mark length (mm)	Drying shrinkage (%)	Total Shrinkage (%)	Physical Properties			Remarks
$\frac{(Wd-Wf)}{Wd} \times 100$	Lf	100-dm	100-Lf	Colour	Ring	Hardness	

The soils which show the best potential for good brick quality during the brick bat testing will be selected for further testing. It is to be stated very clearly that brick bats do not represent the final quality but provide a preliminary information and indicator of possible brick quality. Final selection of soil depends on successful pilot scale testing.

CAUTION: Bricks produced with a soil without prior testing can lead to extremely poor quality with very high breakage. This might ruin a brick enterprise due to high losses and bad reputation.

IN CASES WHERE PROPER SOIL TESTING PROCEDURE IS NOT FOLLOWED RESULTING IN ECONOMIC PROBLEMS, THE VSBK TECHNOLOGY CANNOT BE HELD AS A CAUSE FOR THE SAME.

2.6.2 SMALL SCALE TEST PRODUCTION AND ANALYSIS

The pilot scale production trial is made only from the soils which produced a positive result from the brick bat testing. The pilot scale trial is done with full size bricks that undergoes the same procedures of preparation, mixing, moulding, drying, firing and analysis as normal brick production. It is recommended to make the pilot scale test production for about 1500 green bricks for each selected soil. The green bricks are made as per the standard green brick making practice described in chapter 4. The bricks are dried under natural sun drying process. Fully dried bricks are fired in the VSBK shaft under the same firing condition as for brick bats. The qualities of bricks are analyzed and further modifications in additives, drying method and firing schedule are done if needed. The pilot scale test indicates the real qualities of the bricks such as colour, strength, ring, deformation, cracks and shrinkages under actual production conditions.

2.6.3 FULL SCALE PRODUCTION AND ANALYSIS

Once the production scale trials confirm the quality as well as the economics as per the entrepreneur's satisfaction, the selected soil and its composition is now finalized for full scale production.

It is at this point that a brick entrepreneur needs to constantly reassess the full cycle of brick production. Changes in any parameters other than that defined during the brick bat tests and the pilot scale trials must be recognized immediately and adjusted to the new situation. This is of utmost importance to ensure consistent quality as well as desired profitability for the VSBK brick enterprise.

3 ECONOMIZATION IN BRICK PRODUCTION

3.1 INTRODUCTION

Economization in brick production in a VSBK firing system can be achieved through reduced energy consumption and mechanization. This chapter will deal only with methodologies related to reduction in energy consumption. The major factors of economization of energy in a VSBK firing system are:

3.1.1 PRODUCTION OF HOLLOW GREEN BRICKS

In any brick firing process the energy input is used to heat up the mass of the soil used. Hollow bricks reduces the mass to be fired thereby reducing the energy consumption. In a VSBK a maximum hollow percentage between 15-18% per brick can be fired in countries where use of full bricks are a custom. However in Vietnam, 25-30% hollow per brick are being produced through a different type of brick. The percentage of hollow in a brick is approximately proportional to the amount of possible energy being saved.

3.1.2 USE OF CHEAP INTERNAL FUEL

The use of internal fuel (such as coal dust, boiler ash, rice husk and others carbonaceous industrial wastes) in the VSBK brick making process has been promoted since its introduction in India in 1996. The Chinese VSBK brick makers have used internal fuel as standard practice. The use of internal fuel however is not without challenges. The external fuel liberates the energy very quickly, and in turn the internal one heats up the brick from inside in a time wise reverse process with the external energy. If the bricks are unloaded too quickly, thermal shock will develop, rendering the fired brick inferior.

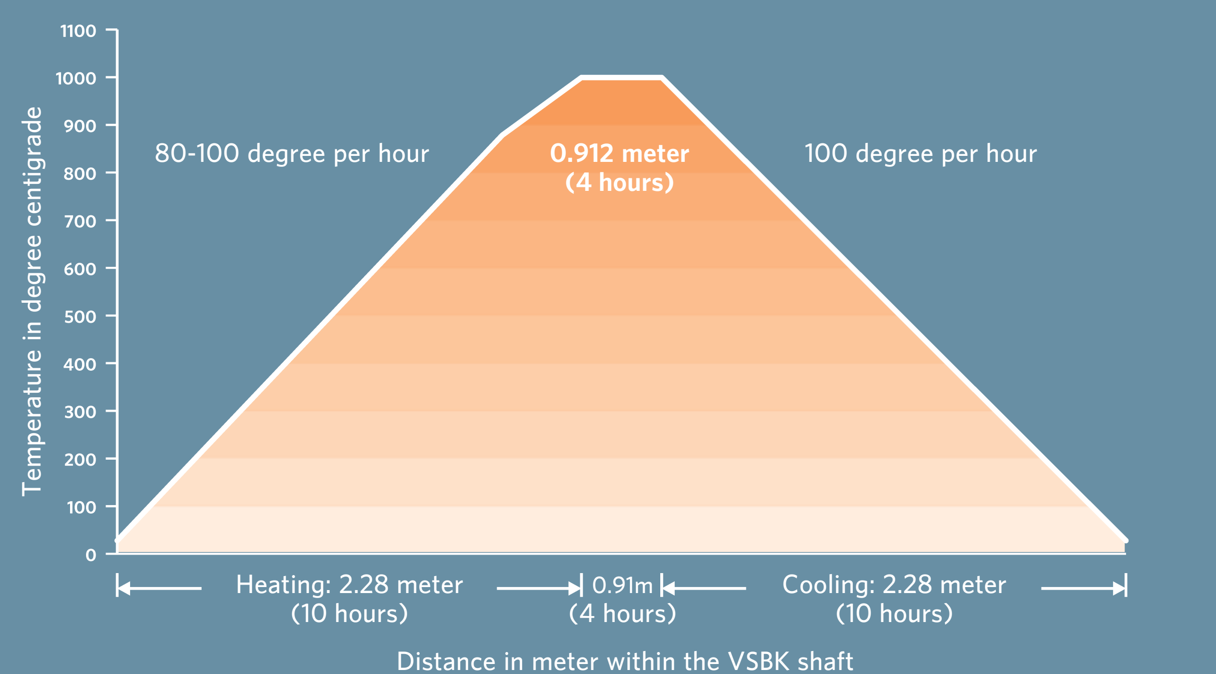
Internal fuel based brick production is having an effect on:

- Brick quality
- Energy economization
- Environmental effects

3.2 BRICK QUALITY

One of the most critical issues of using internal fuel in a VSBK firing system is the ability to maintain an appropriate firing schedule resulting in a good fired brick quality. In the VSBK firing system, the approximate heating and cooling time is completed within 16-20 hours whereas vitrification and soaking time is 2-4 hours.

Fire schedule of VSBK (24 hours)



ECONOMIZATION

Garbage IN

TABLE 9. FIRE AND ICE

ICE	BRICK
In order to create an ice block the ambient temperature must be at least minus 1 degree Celsius. The duration to fully freeze an ice block depends on the size, temperature and time. Therefore;	The very same principle applies for the firing of a brick. However, contrary to the ice block, the fired brick develops defects during this uncompleted process.
A) If an ice block is not given enough time to fully freeze, the very core of the block is still liquid, only the outer layer is ice.	A) If a green brick is not given enough time to fully burn, (due to the thickness) the very core of the brick is not vitrified (kind of melted) only the outer part of the brick is vitrified. **The brick is under-fired and results in high percentage of breakages, bad ring and bleak colors.**
B) On the other hand, if a fully frozen ice block is being unfrozen for too short a time, the very core remains ice and only the outer layer becomes liquid again.	B) On the other hand, if a fully vitrified brick is being cooled down for too short a time (due to its thickness), the very core remains still too hot and only the outer layers can properly cool down. **The brick is getting a temperature shock due to the sudden exposure of high brick temperatures with the ambient outside temperature of the shaft and will develop cracks, resulting in too high percentage of breakages and bad ring.**

To facilitate the vitrification process (crucial for achieving the desired strength) chemical reactions need to be completed within a green brick. This chemical reactions take place at appropriate temperatures during the firing process. Thus it is essential that during the firing process the temperature is evenly distributed throughout the green brick. To achieve uniform temperature within a green brick enough residence time of a green brick at required temperatures must be ensured. The thickness of a green brick is naturally defining the required residence time, hence for a VSBK fast firing system, the thinner the bricks the better, the more uniform is the heat distribution.

Due to the considerable thickness of the bricks while firing, the external heat takes a significant time to penetrate into the core of a brick to facilitate vitrification reactions. This is truer in mechanized green bricks due to high compaction. Use of internal fuel simultaneously releases heat from within the green brick and enhances the vitrification reactions within a short time. Thus a uniform quality of fired brick is achieved. However the art of using internal fuel made bricks depends mainly on:

> Internal fuel addition having a grain size of >2 mm makes the brick porous, hence increasing the water absorption capacity. Therefore, all internal fuel must be sieved in a 2 mm mesh before use.

- Types of Internal fuel and its energy value
- The amount of Internal fuel to be added
- The physical structure; grain size
- Uniformity while mixing with the soil

Uniform mixing of internal fuel with the soil needs to be achieved during the raw material preparation. Non uniform mixing will result in clustering of the internal fuel within the green brick. It will result in localized melting. This is commonly faced during manual mixing process. To overcome this it is always suggested to adopt mechanized mixing process through a pugmill for achieving the required homogeneity.

3.3 ENERGY ECONOMISATION

Use of internal fuel in green brick making minimizes the external coal consumption and therefore helps in reducing environmental pollution too.

Any carbonaceous material having calorific value >1000 Kilo calorie per kilogram (Kcal/kg) is suitable for use as an internal fuel. Therefore, before using any carbonaceous materials as internal fuel, the calorific value should be tested and the most economic amount to be added to the green brick must be calculated. It has to be granular to powdery in nature having grain size less than 2 mm.

Important and useful internal fuels generally being used in VSBK technology in Nepal are:

- Boiler Ash <300 Kcal/kg
- Saw Dust >1600 Kcal/kg
- Coal dust <5000 Kcal/kg

The basic criteria for selection of internal fuel in brick making are:

- Calorific value
- Availability
- Cost

CALORIFIC VALUE

Any internal fuel should preferably be an industrial waste material. Internal fuel use reduces the external coal consumption. In Indian VSBK generally sponge iron waste having a calorific value of >2000 Kcal/kg is used as an internal fuel. This has resulted in a reduction of external coal consumption between 60 to 80%.

AVAILABILITY

The amount of internal fuel for at least one brick production season must be available from one source of the same quality. Any change in the type of internal fuel during one brick season might result in interruption of regular brick production quality.

COST

It is advisable to look for an industrial waste material for use as an internal fuel. These are generally dumped near the industrial sites and are available free of cost. Cost of production greatly depends upon the rate of fuel. Generally it is economical to use internal fuel, which is available (including transportation costs) at less than half the price of external fuel.

3.4 ENVIRONMENTAL EFFECTS

In any brick firing technology the source of environmental pollution is the use of external fuel. Use of high sulphur and high ash content fuel as well as incomplete combustion leads to high environmental pollution. High sulphur content releases high amount of SO_2 gas. High ash content coal and incomplete combustion of the same releases higher amount of suspended particulate matter in the atmosphere. Additionally, incomplete combustion of coal during the firing process releases appreciable amount of CO in the atmosphere. Thus use of internal fuel reduces the external fuel consumption, thereby reducing the environmental emissions. Environmental advantage of producing bricks with internal fuel is that harmful gases and particulate matters remain harmlessly trapped within the brick body.

3.5 DETERMINATION OF INTERNAL FUEL TO BE ADDED

LABORATORY TEST

To have a fair idea of the approximate amount of internal fuel consumption needed for achieving good brick quality, the following basic information is required.

- Average coal consumption of present brick firing technique.
- Calorific value of coal.
- Calorific value of internal fuel.
- Average weight of dried green brick.

In order to know the calorific value of a specific coal, the heat value is tested by a bomb calorimeter. In commonly practiced brick production processes, e.g. fixed chimney Bulls Trench Kiln, movable chimney Bulls Trench Kiln, the higher the heat value of coal, the faster is the firing process. However a high calorific value coal is also costlier. In VSBK technology generally a coal having a medium calorific value ranging between 4500–5500 Kcal/kg is preferred due to slower release of heat and hence easier fire regulation. High heat value coal is usually highly volatile in nature rendering it unsuitable for VSBK operation due to faster release of heat. This creates problems in controlling the fire schedule and also creates localized melting.

A brief example of calculation procedure of internal fuel consumption is shown overleaf.

! Adding of internal fuel depends on many factors and hence, it must be tested/practiced during an imperical process.

Garbage IN

TABLE 10. ENERGY CALCULATION SHEET

Sample calculation showing energy consumption of a given brick size

1.	Size of green brick	255x120x80	mm
2.	Average weight of dry green brick	3.75	kg
3.	Present fuel consumption in nearby fixed chimney BTK	20	Tons per 100,000 bricks
4.	Calorific value of External fuel (coal used in BTK)	5400	Kcal /Kg
5.	Calorific value of selected internal fuel	4000	Kcal /Kg

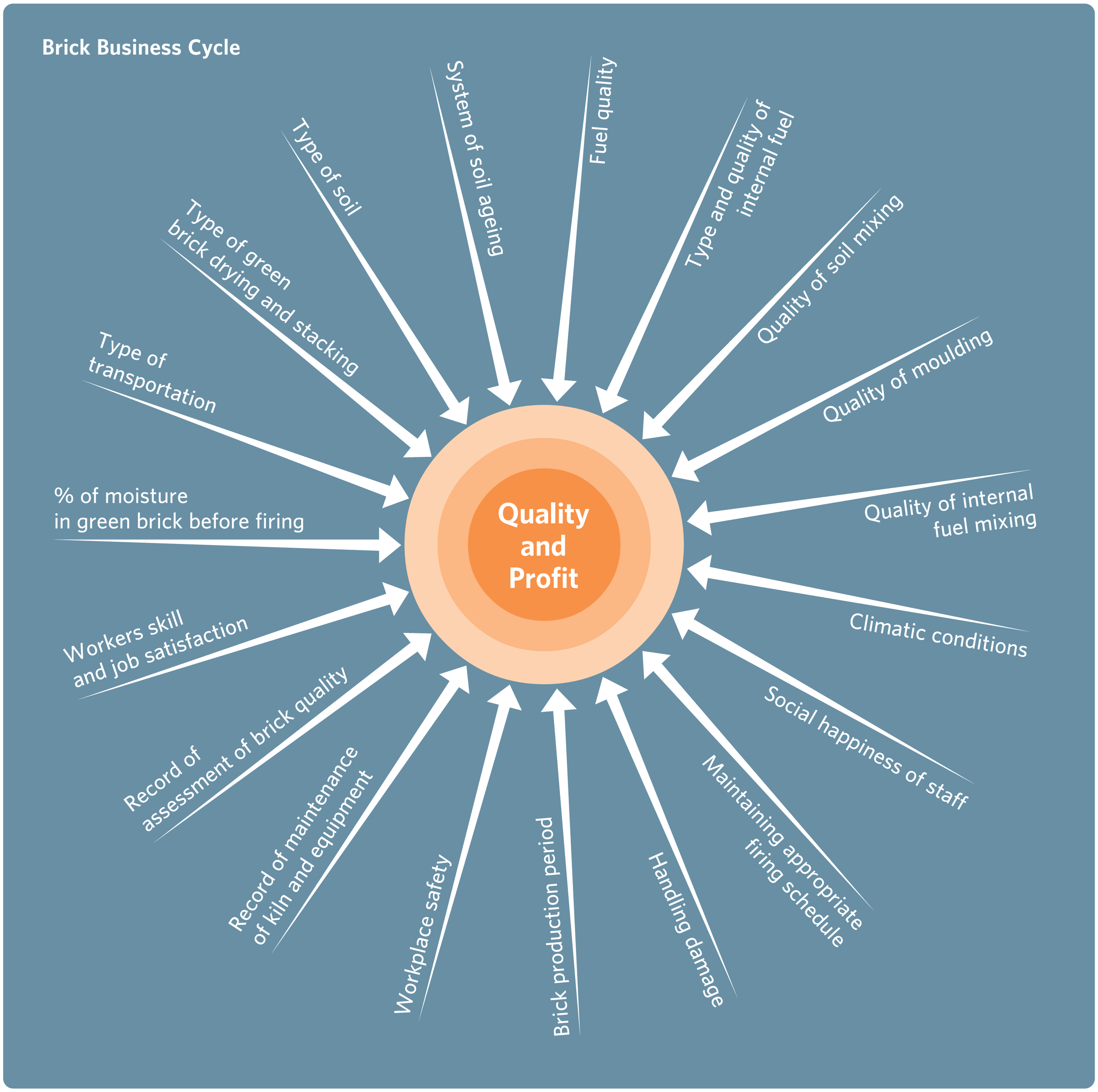
Calculations

1.	Average fuel saving in VSBK (Assuming 30% fuel saving compared to Fixed Chimney)	6	Tons per 100,000 bricks
2.	Fuel required to produce similar quality bricks in VSBK (assuming 70% out of 20 tons required only)	14	Tons per 100,000 bricks
3.	Heat value of fuel consumption in VSBK firing practice (14 tons x 1000 x 5400 Kcal)	75600000	Kcal per kg per 100,000 bricks
4.	Required heat value from external fuel (assuming 60% of total heat value from external sources)	45360000	Kcal per kg per 100,000 bricks
5.	Required heat value from internal fuel (assuming 40% of total heat value from internal fuel)	30240000	Kcal per kg per 100,000 bricks
6.	Required quantity of internal fuel (30240000 / 4000)	7560	Kg per 100,000 bricks
7.	% by weight of internal fuel addition (7560/100,000)*100/3.75	2.0	% by weight of green brick
8.	Required external fuel (45360000 / 5400)	8.40	Tons/100,000 bricks
9.	Make the same calculation with 40% external fuel and 60% internal fuel as an example	3.0	% by weight of green brick
10.	If selected 2% internal fuel, then the fuel consumption will be	7560	Tons per 100,000 bricks
11.	If selected 3% internal fuel, then the fuel consumption will be	11340	Tons per 100,000 bricks

Select the actual percentage of internal fuel to be added based on the quality tests of brick bats and pilot scale production.

3.6 CYCLE OF BRICK BUSINESS FINE TUNING

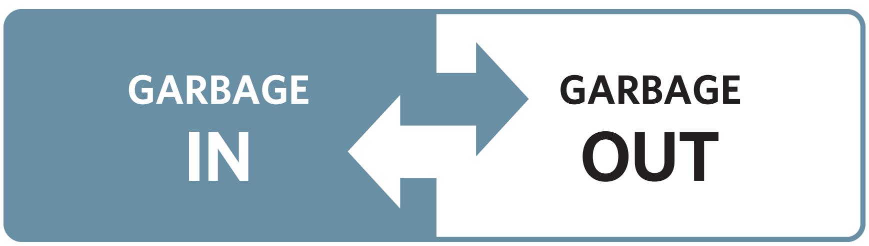
A professional brick maker is permanently overseeing the entire production process and looks out for possibilities to increase the profit through innovative ideas. The production flow parameters, starting from the source of the raw materials up to the firing of the bricks are constantly varying. Hence, the awareness and alertness of potential changes in parameters is a 'must ability' of any professional brick maker. The very bottom line criteria of a brick enterprise are quality and profit. Therefore, the cycle of brick production fine-tuning is focusing on these two criteria.



4 GREEN BRICK PRODUCTION PROCESS

4.1 INTRODUCTION

The green brick production process is the most important aspect in any type of brick making to achieve quality and profitability. Each step of the entire green brick production system is interlinked. Neglecting any one process will affect the final product quality. The VSBK firing system is a fast firing process with very little tolerance for errors. Therefore, the quality of the green brick must be nearly perfect. However this aspect of the VSBK technology is never recognized, resulting in coincidental, but mostly bad brick quality. This has a direct effect on the fired product resulting in deteriorating profits. This is not understood by many brick makers thus putting the entire blame on non performance of the VSBK technology.



The following chapters describe the best green brick production practices where no mechanization has yet been introduced.

4.2 SOIL EXCAVATION

After finalizing the soil quality for brick making through brick bats testing and pilot scale production trials the excavation of the selected soil starts. The first step in this process is to cut the grass and do a general cleaning, removing all surface vegetation and stones from the area. The second step is to excavate only the selected soil. If required remove soil that is preventing the excavation of selected soil. Tradition and economics defines the use of equipments for soil excavation. Mostly for economical reasons, nowadays modern and mechanized machines are also being used in Nepal.

Generally brick makers use whatever soil is available nearby for brick production. Therefore the prevailing bad excavation practice to excavate topsoil, subsoil and bedrock soil in one go is difficult to change. There is no provision of separating these three layers as described above and taking out only the selected soil. Due to these malpractices, the quality of bricks produced is deteriorating. Thus most of the brick kilns in Nepal are facing quality problems with inferior brick quality, high breakage rate, and poor surface finish.

4.2.1 BEST PRACTICES OF SOIL MINING

TOP SOIL CONSERVATION

Never use top soil for VSBK brick production since it is containing too much of organic matters that will reduce brick quality.

Once the excavation area has been cleaned from bushes, stones and other foreign materials the top layer is removed providing access to the sub soil layer. The topsoil layer, because it contains organic matter is highly fertile, which is necessary for vegetation growth and must be preserved for maintaining agricultural growth. The top soil should be preserved separately and reused for land restoration after the required soil for brick making has been excavated.

HORIZONTAL AND VERTICAL MINING

Horizontal mining in Nepal is understood if soil excavation takes place for only one soil layer. The advantages of horizontal mining are:

- Ensures homogeneity in the soil (provides a consistency in the final brick quality).
- Land can be re-used for agricultural purposes.
- Is less time consuming.

Vertical mining in Nepal is understood if soil excavation takes place for two or more layers of soil. The advantages of vertical mining are:

- Proper mixing of two or more different soil layers.
- Once excavated, site can be utilized for water storage, fish ponds.
- More suitable option for mechanized pugging.

MECHANIZED EXCAVATION

Mechanization for soil excavation as well as green brick mixing is slowly becoming an integral part of green brick making in Nepal. Brick entrepreneurs are attracted to mechanization due to various reasons mainly due to human resource management problem, high brick demand and competition among the brick entrepreneurs for producing quality bricks.

Therefore the use of hydraulic excavators is gaining popularity in Nepal. The use of excavators promotes vertical mining and is suitable for use of Pugmill. It requires fewer workers and is more efficient. However the major drawback is the high initial investment for acquiring the machine.

4.3 SOIL STORAGE

Sooner or later the proper and adequate storage of raw material for the production of bricks becomes a conditioning element and will gradually develop into an independent stage of the brick production process. Two prime factors, among others, will play a decisive role in this development.

- Availability of suitable land for soil mining purpose will diminish.
- Tightening of environmental, conservational and pollution control regulation.

Due to these facts, it will become necessary to increase efforts aimed at exploiting particular raw material sites that were previously regarded as being of inferior quality. In such cases, the primary objective of raw material preparation, namely the long term provision of an adequate uniform supply of prepared material for the production of bricks, can hardly be met without the aid of a raw materials storage system and its conditioning function.

4.3.1 FUNCTIONS AND IMPORTANCE OF RAW MATERIAL STORAGE

The functions of the raw material storage are many. However, in the context of Nepal they are mainly the following:

THE BALANCING FUNCTION

The storing of raw material prior to use serves as a means of balancing out fluctuations in the arrival of raw materials from the mining place, especially in case of seasonal bad weather (monsoon rain) or other circumstances (transport or labour strike).

SOIL BLENDING FUNCTION

In case two or more different soil types need to be utilized, it is necessary to thoroughly cross-mix the soils by way of desertification, i.e. to combine them to the point of producing a consistent material composition over a considerable period of time.

The blending effect is for the most part achieved by depositing the different soils according to a systematic, layer-by-layer method.

OPENING-UP/AGEING FUNCTION

'Opening up' is a comprehensive term covering the entire weathering processes in combination with uniform moistening of the body and swelling of the argillaceous soil.

During this process the moisture content diffuses uniformly throughout the soil lump through the effects of capillary force, hence, the individual particles of soil combined together to build agglomerates or clusters.

A homogeneous soil mixture can only be achieved with good ageing practices.

In the course of the opening-up process, the water loosens, surrounds and penetrates into the soil lump enabling it to soften and break into smaller pieces. At the same time, the water enveloping the particles ensures adequate cohesion and mobility i.e. the actual source of plasticity/ductility.

After an appropriate time of opening-up or ageing (the longer the better, but is mostly defined by economical limitations) the raw material is now ready for further homogenization by mechanized means (e.g. pugmills).

4.3.2 METHODS OF RAW MATERIALS STORAGE

Although there are several systems of raw material storage applied in highly mechanized brick production industries, for Nepal, under the prevailing brick production situation, the most appropriate and cost effective raw material storage type is the open air, longitudinal stockpile.

The open air stockpiles are directly exposed to the weather; the raw materials are alternately dried out by the sun and saturated by rain.

Garbage IN

Consequently, the brick production process should not be dependent upon material taken directly from the ongoing open-air storage facility. It has to be somehow stored and unused for a few days as there is no any predefined duration for storing. The longer storage always leads to better quality product if kept permanently in a moist condition.

Soil stored under dry condition is not ageing, always keep the soil in a moist condition so that the ageing process is maintained.

Therefore, it is advisable to divide the material up between two stockpiles, one of which is being used up, while the other is being build up and remains unused for ar few days.

FLAT-TOP STORAGE

The most appropriate storage type is the 'Flat-top deposit' method. It consists of individual horizontal layers which are produced while depositing the raw material. It is of advantage if the individual layers are not exceeding 20 to 30 cm in order that the ageing and blending process is efficient.

ROOF-TYPE STORAGE

Perhaps the most simple storage type is the 'Roof-type' stockpiling. This method has however one disadvantage, while depositing the soil, the coarse grain has the tendency to roll towards the bottom, hence the upper layers consist primarily of fine grained material, while the bottom layers contain mostly coarse grained material.

TABLE 11. SOIL STORAGE

Theoretical soil storage amount example:

For a single VSBK shaft, producing 5000 brick per day (Kathmandu size bricks) the raw material storage capacity for one year would be:

5000 bricks x 2.5 kg (25 x 12.5 x 6 cm) = 9.375 or 10 m^3/day

10 m^3 x 365 days
= 3650 m^3 or 730 trucks (5 m^3 capacity)
= a space of 60 m length x 20 m width having a height of 3 m

A 6 shaft VSBK will therefore need a deposit of 21900 m^3 raw material or 4380 trucks.

4.3.3 SEASON FOR SOIL STORAGE

As brick production in a VSBK can go all year around, the supply of green brick production raw material has to be regular to maintain this continuous operation. In this regard, the piling up of soil has to be done during the months of November-June. During the monsoon season i.e. from July to October, no stock piling can be done since no land is available for excavation due to rice paddy cultivation practices.

Garbage OUT

4.4 PUGGING OF RAW MATERIALS

Pugging of raw materials ensures homogeneity of soil with various additives. The more thoroughly the process is done the greater the homogeneity of the brick. Before the pugging process care should be taken to remove systematically all foreign particles e.g. stones, brick bats, plastic, wood etc. If the proper process of pugging is not followed then soil lumps of various sizes remain within the clay to be moulded. This not only causes cracks in the green bricks during drying and firing process (major cause of breakage) but also reduces the strength of the fired bricks.

Both manual and mechanized pugging are generally practiced for preparing the soil for moulding. In manual pugging process, the soil is dug out and spread out on the ground, watered and left to soak overnight. The mixture of soil and water is then pugged manually by foot. In mechanized pugging, the moist soil is dug out from the store and fed directly into the pug mill while the required water amount to achieve the needed consistency is added manually during the pugging process.

To achieve the best green brick quality 'Mechanized Pugging' is required. Therefore this chapter deals only with Mechanized Pugging. The advantages of mechanized pugging are:

- Soil is properly mixed.
- Good homogeneity of the clay can be achieved.
- Supports uniformity in shape and size of green bricks.
- Increases the green brick strength.
- Reduces considerable labour drudgery thereby increase in productivity.

4.4.1 AN INTRODUCTION TO PUGMILL

Pugmill is a machine used for uniform mixing of soil for green brick making. Two types of pugmill are available, Horizontal and Vertical. However Vertical pugmill is the most widely used machine in Nepal. A pug mill consists of a barrel (cylindrical trough) which is incorporated with the replaceable blades mounted on the main shaft. The main shaft rotates with the help of a worm gear which is attached to it at the top. The shaft speed is maintained between 7 to 9 revolutions per minute. The worm gear is coupled with the gearbox which is then directly connected to the diesel engine or electrical motors by means of belt pulley system. A V-belt is used to serve the purpose. The gear box is powered with at least 12 horse-power (hp) diesel engine or a 7 to 10 hp three phase electric motor.

CAUTION: Increasing the speed of the shaft will pug more soil but it might also result in improper mixing. More water needs to be added to the soil for high speed operation. If the water content is too low, high pressure is exerted on the blades which might break the blade apart.

BRICK PRODUCTION

Garbage OUT

The shaft when rotateing along with the blades, crushes and mixes the soil lump inside the barrel. Below the barrel, openings are provided through which the pugged soil is squeezed out. Generally two openings are provided at the bottom of the Pugmill. The output is about 15-20 tonnes of soil per day, with 8 operating hours. However the output of pugged soil can be fine tuned by increasing or decreasing the speed of the shaft or by varying the number of openings at the bottom of the Pugmill.

4.4.2 PUGGING PROCESS

In general there is no standardized practice for operating a pugmill. Each site has its specific characteristics that will be important to take advantage of. Various factors such as facilities available at the site, entrepreneur's desire, site topography etc must be utilized before pugging work starts. It is the responsibility of the entrepreneur to develop economical and still professional pugging practices at his site.

PREVAILING PRACTICES

The prevailing practice of adding internal fuel is not professional and results in non-uniform and bad brick quality.

The prevalent practice is to use stored soil. Before operation the stored soil is dug and dragged near to the Pugmill. The quantity of soil taken is enough to operate the Pugmill for a full day. After the soil is dug out and spread, it is watered through pipe connections. The internal fuel, generally saw dust or coal dust, is then manually sprinkled on the top of the watered and spread out soil. In the entire process, the quantities of internal fuel to be mixed is made arbitrary resulting in a coincidental mixing proportion. The soil is left for final ageing for approximately for 12 to 14 hours before using in the pugmill.

PROPER PUGGING PRACTICE

In this method, two trenches are dug near to the Pugmill location. The distance between the trenches is set about 3 m apart and about 1m behind the Pugmill. The dimension of each trench is 5 m x 3 m x 1 m. Each trench can hold approximately 20 tonnes of soil.

The stored soil is transported to the trench by a small truck. Depending upon the amount of soil being transported by one truck the number of bricks that can be moulded is calculated.

Pugging is a soil homogenization process and does not replace the function of soil ageing.

TABLE 12. QUALITY ISSUES

How to check proper mixing of pugged soil?
Take a handful of pugged soil and check for the presence of soil lumps within it. If soil lumps are present then either the soil has not been aged properly or the pugging process is made too fast.

Consequences of improper mixing
Improper mixing not only causes crack in the green bricks during drying and firing process (major cause of breakage) but also reduces the strength of the fired bricks.

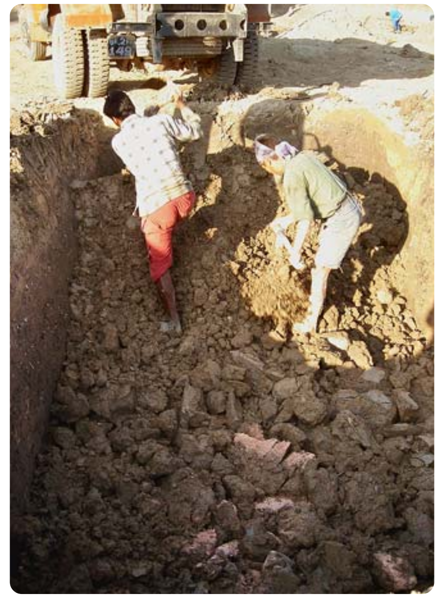
How to check the correct proportion of water in pugged soil?
Take a handful of pugged soil and form a ball by hand of roughly 5 cm in diameter. Place the wet ball on a hard and even surface. If the amount of water is correct the ball will remain in shape. However if the water content is high then the ball sags and deforms.

Consequences of insufficient water
Less quantity of water in the soil will result in a dry mix and most likely result in the presence of dry soil lumps. Too much dry soil will exert an excessive pressure on the shaft and its blades which might even result in broken blades. Moulders will reject a too densely pugged soil with less water due to difficult mouldability.

Consequences of excessive water
There are two main consequences of excessive water addition, namely:

- It reduces the friction between the soil layer and the inside surface of the metal barrel due to a thin film of water present. This results in slipping of the entire soil lump inside the barrel and hence no output of mixed soil is generated.

- It results in a too wet soil mass that cannot be properly moulded. Excessive amount of water in a demoulded brick also results in deformation due to sagging.



> **QUALITY CONTROL:** Always keep the soil in moist condition especially during excessive heat periods.

The soil is unloaded into the trench and then leveled manually. During the leveling process the bigger lumps of soil are manually crushed into smaller size and the foreign materials such as stone, grass roots are also removed manually. On the leveled soil, quantified amount of internal fuel is sprinkled and also mixed manually. The water is then sprinkled on top of it. This process is repeated for each truck of soil.

The soil in the trench is aged for 48 hours. Thereafter for pugging alternate uses of the respective trenches are made. The soil is dug out from the trench either manually or with the help of an excavator. The soil is placed aside the Pugmill on the empty space (to create this empty space the trenches were dug 3 m away from the Pugmill). The process of digging the soil out of the trench and placing it aside the Pugmill accomplish the first step of wet mixing. This 'well aged soil' is finally fed into the Pugmill for a second wet mixing.

Advantages of this procedure:

- Two times wet mixing increases the uniformity and density of the soil.
- Good control of internal fuel mixing practice.

Disadvantages of the procedure:

- Space and time consuming.

4.5 MOULDING

Moulding is the process where the pugged clay is placed in a mould in order to form specified shapes of bricks.

4.5.1 THE MOULD AND ITS DESIGN

The mould is the device that gives the brick its shape. There are two major parameters which are important to design a mould.

THE MOULD BOX

It is the rectangular box where the brick is formed. The mould is usually made of good quality seasoned wood. In some places metal moulds made of MS sheets or aluminium are also used. Usually the mould is reinforced on the outer surface of the corners by metal angles. Sometimes the inner surface of the mould is lined with a thin metal sheet to minimize wear and tear. The wooded surface of the mold is extended beyond the rectangular section to provide better handling of the mold box.

THE FROG

The frog in all types of moulds is made from wood. It is used to form a cavity or a trade mark of a brick producer on the longer surface of the brick. The deeper the frog, the lesser will be the brick weight and simultaneous savings of soil. It also allows the brick to dry faster and gives the brick a form, which improves its adherence to cement mortar during construction. The presence of a frog also acts as an advertisement for the brick manufacturer and enables him/her to brand his/her product.

4.5.2 MAKING A WOODEN MOULD

For making a wooden mould the final size of the fired brick and the overall (both green and fired) shrinkage of the soil needs to be determined. Once the fired brick size has been decided, the interior dimensions of the mould can be calculated based on the shrinkage rates during the brick bat testing. In brick making the clay shrinkage rate varies between 4-10%.

Soils with shrinkage lesser than 4% will not develop any binding properties making the brick weak and fragile. Soils with shrinkage higher than 10% will be more susceptible to drying shrinkage cracks and also the fired dimensions will be difficult to control. Moreover the greater the shrinkage, the higher the chances of the green brick warping during drying.

CAUTION: Always use the green brick mould size as a basic for calculation of all shrinkage rates. Do not wrongly add the shrinkage % to the fired brick size. It will give a wrong dimension of the mould size.

For any brick production to get a balance between reasonable strength and productivity with minimal green brick rejection a shrinkage rate between 6-8% is ideal. The following table gives the interior dimension of a mould for various soil shrinkage rates which will produce a 230 mm x 110 mm x 65 mm fired brick.

TABLE 13. SHRINKAGE RATES AND MOULD SIZES

Fired brick size: 230 mm x 110 mm x 65 mm

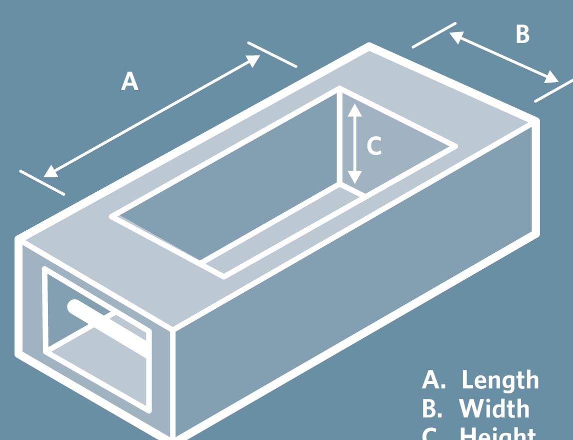
Shrinkage rate	Interior mould dimensions		
	Length	**Width**	**Height**
5%	242 mm	116 mm	68.5 mm
6%	245 mm	117 mm	69 mm
7%	247 mm	118 mm	70 mm
8%	250 mm	120 mm	70.5 mm
9%	253 mm	121 mm	71.5 mm
10%	256 mm	122 mm	72 mm

To achieve the 230 x 110 x 65 mm fired brick size the mould must be designed as follows:

Assuming shrinkage rate of the soil as 10% and final length of fired brick (L2) is 230 mm
Length of fired brick (L2) =
Length of mould (L1) - 10% of L1
⇒ 230 = L1 - 0.1L1
⇒ L1 = 256 mm (230/0.9 = 256)
Thus length of the brick mould = 256 mm

Assuming shrinkage rate of the soil as 10% and final width of fired brick (W2) is 110 mm
Width of fired brick (W2) =
Width of mould (W1) – 10% of W1
⇒ 110 = W1 - 0.1W1
⇒ W1 = 122 mm
Thus width of the brick mould = 122 mm

Assuming shrinkage rate of the soil as 10% and final height of fired brick (H2) is 65 mm
Height of fired brick (H2) =
Height of mould (H1) – 10% of H1
⇒ 65 = H1 – 0.1H1
⇒ H1= 72
Thus height of the brick mould = 72 mm



BRICK PRODUCTION

4.5.3 RELEASING AGENT

The releasing agent is a fine, non plastic, dry material which prevents the soft soil from sticking to the sides of the mould and also helps the green brick to slide easily out of the mould. Depending on the realising sand quality the fired brick adopts a colour that might be different from the brick colour. Therefore the most important property of a releasing agent is its fineness and burning colour. The finer the material, the better the finish of the green brick.

To test the firing colour of the releasing sand, take a small quantity in a flat clay container. Make a three stone fire and heat the releasing sand till it is red hot. After cooling observe the colour of the releasing sand. It gives a fair indication of the fired colour it will impart to the green brick. Normally the releasing agent is fine sand. Use of coarse sand as a releasing agent is not recommended since it decreases the finishing of the green brick.

4.5.4 MOULDING AREA PREPARATION

Moulding area is the place where the green bricks are shaped and de-moulded. Before the start of moulding, considerable time and effort needs to be spent for preparing the ground for de-moulding.

Ideally the first step is to cut the soil (as required, usually 30 to 40 cm) and preserve for agriculture use. However, this is not practiced in Nepal for economical reasons, still, the grass or other vegetation should be removed and the ground should be leveled as flat as possible with the help of a spade. All vegetation and traces of roots should be taken out. The ground should be cleaned so that there are no other foreign particles such as roots and stones on it.

CAUTION: Proper rain water drainage must be made around the periphery of the moulding area to avoid rain water flooding and damaging of green bricks.

The day before moulding the ground should be sprinkled with water. Enough water should be sprinkled so that the surface is moist. After about 6-8 hours, the ground is further leveled with a curved round base metal tool (Levelling ring). Before moulding, releasing agent is sprinkled over the ground so that freshly laid bricks do not stick to the ground. After every 4-5 de-mouldings the ground is again leveled with the help of the cutting tool. If the ground is not properly levelled, the soft green bricks will warp due to undulation.

4.5.5 ACCESSORIES FOR MOULDING

Moulding is a tedious task, which requires skill and special equipments to execute. Moulding accessories can be categorized according to the moulding process:

SPADE

This is used to dig the soil and prepare moulding area.

WHEELBARROW

A simple cart made of either wood or metal for carrying the prepared soil up to the moulding area.

LEVELLING RING
It is a circular metal ring which is used to level the ground.

BROOM
This is used to clean the moulding area.

MOULD
This is used to prepare green brick.

BOW CUTTER
The bow cutter is a simple instrument used to cut the excessive soil from the top of the mould box. After the wedge of soil is thrown into the mould, the excess soil over the mould needs to be removed and the surface smoothed. The bow cutter cuts and smoothes at the same time as it moves along the top of the mould.

The bow cutter is made of a 10-12 mm Square MS rod and bends in the form of a small bow or a rectangular U. The length of the bend area should be at least 10 cm more than the mould breadth. A fine wire is tied at both ends of the U shaped MS rod to obtain the bow cutter.

CLEANING TOOL
If the wedge is not covered properly with releasing agent, or if it was not thrown correctly into the mould, the soil will stick to the sides of the mould. It will then be necessary to clean the stuck soil from the mould with a cleaning tool after the green brick is removed. Apart from this after repeated mouldings, soft soil tends to fill the sharp corners of the mould and the depressions of the frog. This imparts a rough finish to the green brick.

To take care of this and ensure a smooth and sharp finish to the green brick a cleaning tool is required by which the stuck soil is cleaned off from the mould. A simple sharp blade is required to take out soil from the depressions. A flat blade is required to clean the soil sticking to the mould sides.

Generally by experience, after approximately 10–15 mouldings the mould needs to be cleaned. In case soil has hardened and it is not possible to clean with the cleaning tools, the mould should be dipped in water and cleaned thoroughly. After each such cleaning, the mould is sprinkled with releasing agent for further fresh mouldings.

WATER BUCKET

Wooden mould boxes are dipped into the water bucket after the end of moulding to prevent cracking of the wood.

4.5.6 MOULDING PROCESS

Moulding is the process by which the prepared soil is formed into the shape of a brick. There are two methods of moulding namely manual and mechanized. The most common method of moulding followed in Nepal is sand moulding. Mechanized moulding consists of pressing and extrusion. Apart from these there are more sophisticated methods of brick making e.g. mechanical pressing, hydraulic pressing and stiff extrusion. The latter methods are out of the scope of discussion since they are out of bounds for small scale brick makers due to the extremely high investment cost.

STEP 1: TRANSPORTATION OF PREPARED SOIL

The pugged soil is transported to the moulding yard for green brick making generally by wheel barrow. The soil is transported and unloaded at the different areas of the moulding yard as per the convenience of the moulders.

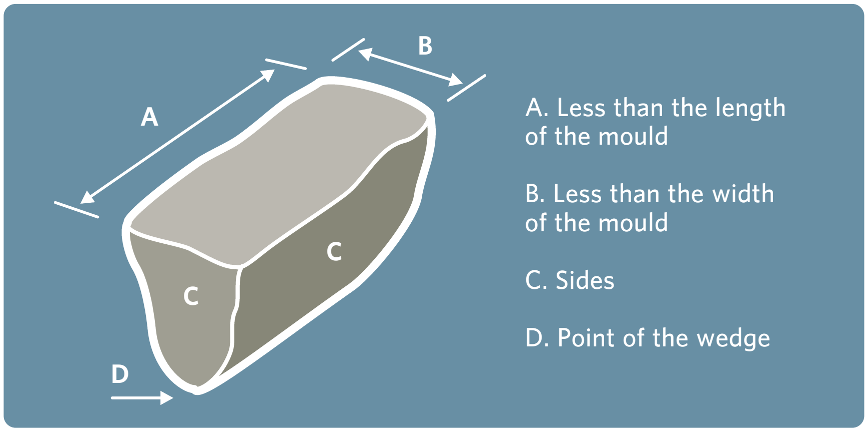
STEP 2: SOIL MATURATION

Ensure that the pugged soil is entirely covered with plastics and that the plastic sticks to the soil.

The pugged soil is stored in individual moulders working yard in such a way that it provides an additional 24 hours ageing time. The soil is a longitudinal manner roughly 80 cm width and 40-50 cm height and covered with a plastic. Once moulding work is starting the moulder uncovers the plastic as little as possible to enable access to the soil for preparing the dough.

STEP 3: DOUGH PREPARATION

Dough is a lump of prepared soil which is rolled over the releasing agent to decrease the adhesiveness between the dough and the mould box. The dough preparation requires skill in order to cut the correct amount of soil from the stored pile. Too much cutting of soil implies unnecessary waste of energy as well as wastage of processed soil. Too little soil implies adding soil in the mould with the risk of creating a texture.



STEP 4: FORMING OF WEDGE

The wedge is a triangular shape of soil having a length slightly shorter than the mould length. When the wedge has been coated evenly with the releasing agent, it is thrown into the mould with force.

STEP 5: THROWING OF WEDGE INTO THE MOULD BOX

After the preparation of the wedge it is thrown into the mould box. To generate a natural force it is usually thrown from approximately a height of 30-40 cm above the mould. The art of good moulding is to get the correct angle and force of throwing the wedge into the mould. The shape of the wedge is very important. When thrown, it should enter the mould and strike the bottom of the mould first without touching the sides. To do this, the length and the width of the throwing wedge should be slightly less than the length and width of the mould. When the wedge is made and thrown correctly, the soil will spread out along the bottom of the mould first before filling the sides of the mould. The releasing agent prevents the clay from sticking to any part of the mould and as a result allows the green brick to slide easily out of the mould. When the wedge is poorly made or thrown, the brick will not slide out

QUALITY CONTROL: !

Ensure that the wedge is always properly coated with releasing agent.

Ensure that the wedge is thrown into the mould with force.

Picking, placing and pressing of the wedge inside the mould box should be discouraged.

BRICK PRODUCTION

of the mould easily. This happens because the mould has cut off the releasing agent from the side of the wedge causing the exposed soil to stick to the mould. Forming and throwing the wedge is a skill. Experience has shown that it may take 100 practice throws before a new brick moulder is able to make and throw a wedge correctly. If the brick does stick to the mould or the finishing of the green brick is not sharp the mould should be cleaned properly with cleaning tools – especially the depressions before attempting to throw a new wedge.

QUALITY CONTROL: The dough should be compacted uniformly especially at the four corners.

The excessive cut soil MUST be stored separately and re-pugged. Mixing of cut soil that contains a layer of sand leads to texture damage.

STEP 6: COMPACTION OF DOUGH

After the wedge is thrown into the mould box with force, it is compacted by hand. Care should be taken not to produce excessive pressure at a particular region. This makes the brick irregular in shape.

STEP 7: CUTTING OF EXCESSIVE DOUGH AND LEVELLING

Once the dough is compacted the excess soil on the top of the mould must be removed and cut by bow cutter. Care should be taken that the cutting is straight and in a horizontal line. Excessive pressure should not be used during the cutting since this will cut the dough in an irregular and concave manner thereby reducing the thickness of the brick.

STEP 8: RELEASING AND LEVELLING

After the soil is properly compacted in the mould, the green brick is demoulded in the moulding yard. The green brick is released from the mould with great care. It should be pulled gently and in a perpendicular direction of the brick. The consequence of rough or irregular pulling destroys and bends the corner of the green brick. After the brick is demoulded into the ground, it is pressed gently by the bottom of the mould. This ensures that all corners are straightened and the edges are sharp.

STEP 9: CLEANING OF MOULD

Moulds should be cleaned after forming of roughly 10 to 15 bricks. If the mould is not cleaned regularly the finish of the green bricks decreases.

Once moulding work is completed the wooden box must be dipped into water and left overnight until the next moulding. This ensures that no cracks will develop, the box keep its correct shape and increases it's life span.

4.6 DRYING AND STACKING

4.6.1 IMPORTANCE OF DRYING

Brick production consists of four main processes: raw material preparation, moulding, drying and firing. Each process has an influence on the fired brick production and quality. Although drying does not assume importance in favour of the other processes, still it is one of the most critical processes for getting an appropriate fired brick quality.

The primary objective of this section is to understand the drying process and the factors which control its properties. This would help in finding a balance between the property required in the fired brick and the time of drying that can be allowed. Drying assumes more importance in a VSBK firing system, since it is a short cycle firing system. Naturally the drier the green bricks are the less energy is required and damages during heating up phase can be avoided. Proper drying of green bricks in VSBK firing system assumes importance since even with 3% free moisture present in the green brick about 15% of total heat input is wasted in driving off this moisture.

4.6.2 PRINCIPLES OF BRICK DRYING

Drying in brick making commonly refers to the process of thermally removing moisture to yield a solid product. Thermally removing the moisture can be attained by either mechanical heating (dryer) or atmospheric drying (exposure to sun rays). For brick making in Nepal, atmospheric drying is the most common practice.

THE DRYING PHASES

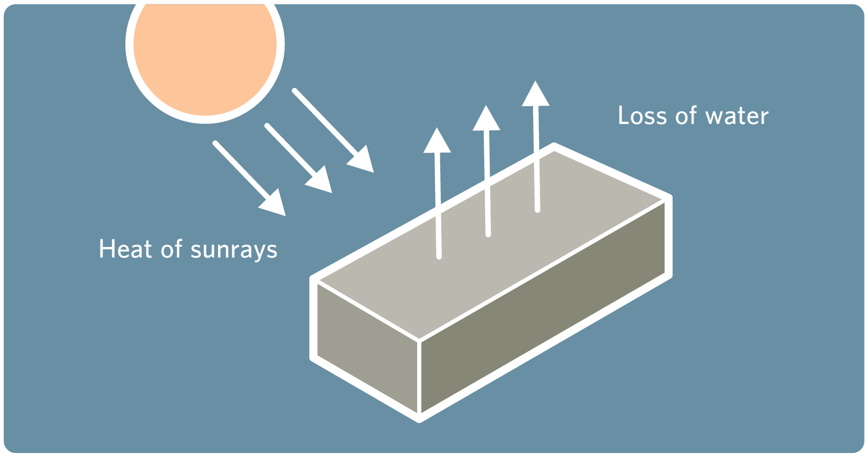
When a freshly moulded green brick is subjected to atmospheric drying, two processes occur simultaneously:

First drying phase

In this phase the energy, mostly as heat from sunrays is transferred from the surrounding environment to evaporate the surface moisture from the green brick.

Second drying phase

Upon completion of the first phase, the internal moisture within the green bricks is transferred to the surface and is subsequently evaporated.



The rate at which drying is accomplished is governed by the rate at which the two processes proceed. Energy transfer as heat from the surrounding environment to the freshly moulded green brick can occur as a result of convection, conduction or radiation. In some cases drying occurs as a combination of all three effects. In most cases heat is transferred to the surface of the green brick and then to the interior.

4.6.3 FACTORS AFFECTING BRICK DRYING

The following factors affect the drying rate of a brick. In most of the cases two or more factors contribute to the effect.

EXTERNAL FACTORS

Atmospheric temperature

Increased atmospheric temperature (e.g. summer months) provides higher energy input. Hence higher drying rates are expected. Thus during the day time in summer months highest rates of drying are experienced. Depending upon the climatic conditions sometimes the rates are so high that outdoor drying of freshly moulded bricks results in dry shrinkage cracks within a few minutes.

Covering the green bricks at night with plastic will speed up the drying rate of the green bricks.

Relative humidity

Relative humidity in the atmosphere gives a measure of the moisture content in the atmosphere. The higher the moisture content the lesser will be the capillary action for evaporation of water from the pores of the brick. Lower relative humidity means lower vapour pressure in the air thus increasing the drying rates.

It is evident that initial drying rates are highly affected by the humidity of the atmosphere. However the final drying rates are not heavily dependant on the humidity factor in the atmosphere.

Air flow rate

During drying of a green brick, due to excess removal of moisture and its higher density than the air, there is a tendency for a moisture gradient to be established around the green brick. These situations retard the drying process. It is therefore necessary to have enough movement of air across the drying surface and around the drying brick to drive off this moisture. Increase in the air velocity thus enhances the drying rates.

INTERNAL FACTORS

Moisture content within the brick

During manual moulding of green bricks the minimum moisture content varies between 25 to 35%. The moisture content is a factor of the ease of workability of the soil and moulder habits. High moisture content within the green bricks will take a longer time to dry compared to those moulded with lesser water, and on top, it will be more porous.

Soil characteristics

Soil plasticity and the grain size is an important characteristic to determine the drying time. The finer the grain size the higher will be the plasticity resulting in more closed packing of the grains. This will result in lower amount of open pores or finer size of them. The more sandy soil the higher will be the amount of pores and their chances of interconnectivity. Bricks with larger concentration of pores i.e. sandy soils will dry faster compared to bricks made with clayey soil due to enhanced capillary action.

> The more water is used for moulding soil, the porous the brick will be!

Brick moulding type

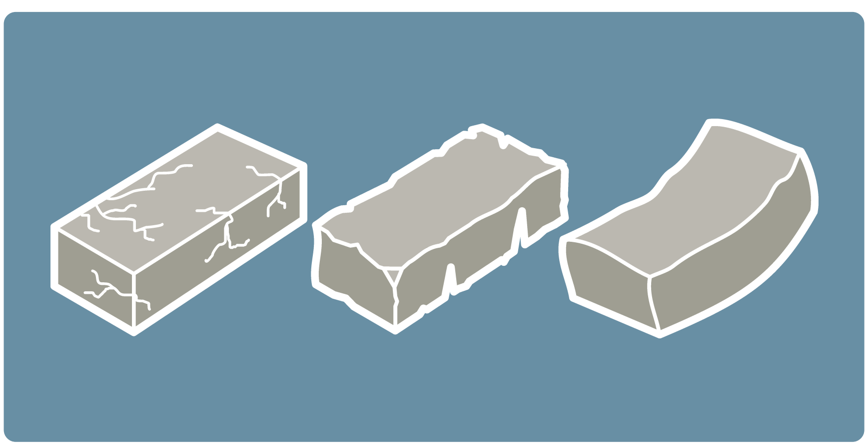
Brick moulding patterns also have a role to play in determining the drying rate. The more compact the brick, the lesser will be the amount of pores and the water content. Thus it will dry faster. Thus hollow soil blocks dry much faster due to greater surface area exposed to atmosphere and higher area of surface diffusivity.

4.6.4 BEHAVIOUR OF A BRICK DURING DRYING

The main and irreversible damages to a green brick are made during the initial drying phase up to the leather-hard stage.

The drying of green bricks is done in the open air in Nepal. The actual ambient conditions at the drying yard keep on changing all the time.

There is a marked difference between the drying rate during the night (or more precisely when there is no sunlight) and day (when there is sunshine). The drying rate is very fast during the day and slow during the night. Even during the initial period there is no drying during the night. At the latter part of the drying even condensation takes place during the night.



STAGE 1

The green bricks are laid flat on the surface; the exposed top portion dries out much faster than the surface in contact with the ground.

If at this stage the drying takes place too fast, then there is a risk that the bricks will develop cracks due to differential drying rates between the surface and the part that is in direct contact with the ground.

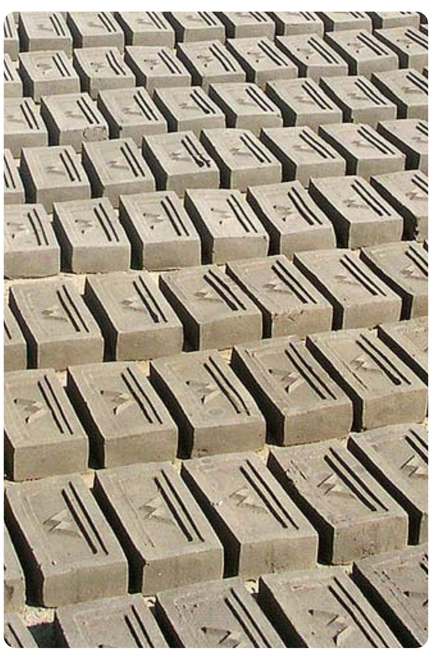
STAGE 2

After 1-2 days (depending on local atmospheric conditions) the bricks are turned from the flat position to the upright (the smallest surface) position. This will ensure a uniform green brick drying from all directions. During this stage, the maximum shrinkage accompanied by moisture removal occurs and the green brick reaches the 'Leather Hard' condition.

Cracks developed due to non uniform drying are called shrinkage cracks. Sometimes these shrinkage cracks can hardly be seen by the naked eye. These cracks eventually expand during the firing process resulting in cracks during firing and hence loss of strength.

STAGE 3

After the 'Leather Hard' form of the green brick the remaining water in the interstitial spaces gets dried over time through the forces of diffusion activated by the dry and relatively hot ambivalent conditions. It is worthy mentioning here that the removal of water is not any more through capillary action but through diffusion within the soil structure procedure. Completion of this process results in a 'Bone Dry' brick.



A 'Bone Dry' brick should have less that 5% moisture content for firing in a VSBK. If more than 5% moisture content green bricks are fired in the VSBK, the trapped water turns into steam, expands and will try to force its way out through the shortest or weakest part of the brick. This results in the so called 'Brick Splitting' damage.

4.6.5 FIELD BASED TESTS FOR DETERMINATION OF DRYING STAGE

The following simple drying tests, if carried out regularly, not only help master the drying process but also enable a judgement to be made of the final quality of the product.

WEIGHING TEST

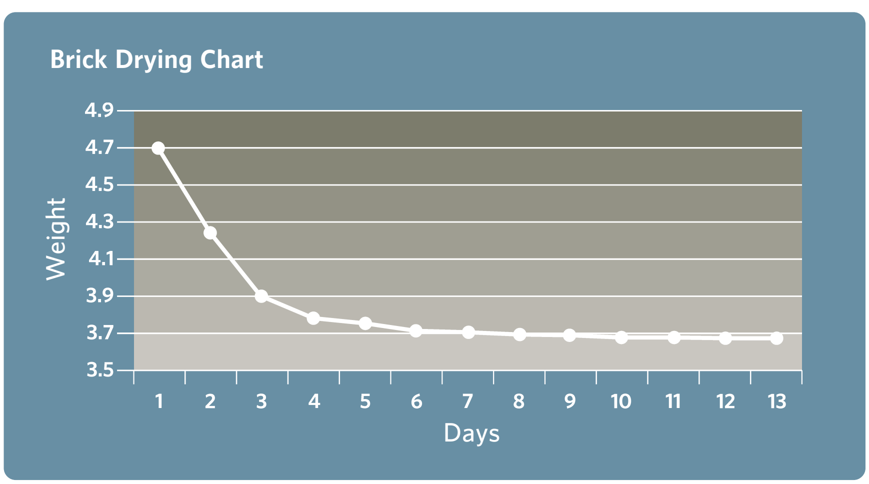
Procedure

Weigh 10 green (just moulded) bricks. List down their weights, dimensions and the time of moulding and record. Each day weigh the green bricks and record the weights.

Inference

The difference between wet and dry bricks is used to determine the rate of drying.

When the weights of the dry green bricks become constant and do not change for 2-3 days of measurements, the green bricks are optimally dried.



WATER VAPOUR TEST

The vapour test can be carried out as an indicative moisture content test without weighing.

Procedure

Select any brick considered to be dry. Take a transparent airtight plastic bag, put the green brick inside it and seal the opening. Keep the sealed plastic bag with green brick in the open sun for about 2-3 hours.

Inference

The brick will start to heat up inside the sealed bag. Any resident water inside the brick will start to evaporate. If moisture appears on the inside of the sealed plastic bag, then the bricks are not properly dried yet.

BREAKING TEST

To physically see the actual drying stage of a green brick it is advisable to break a green brick and observe for any colour differences between the surface and the core.

> ! To avoid brick splitting due to high moisture content, drying test must be carried out!

Procedure

Select any green brick considered to be dry. Break it into two halves. Look at the central surface of the broken pieces.

Inference

If there are no visible colour difference then the bricks are absolutely dry. However, if there is a distinct colour gradation between the periphery and the central core than the bricks have not dried properly.

SOUND TEST

Experienced brick makers can assess the moisture content of the brick by making a sound test.

Procedure

Take two dried green bricks from the stack. Hold the two bricks with two hands. Strike them lightly.

Inference

If there is a dull sound then the bricks have not dried properly. However, if the bricks make a sound similar as when two wooden pieces are struck, then the bricks are sufficiently dried.

4.6.6 STACKING PATTERNS AND ITS EFFECT ON DRYING

In order to stack the green bricks they must be 'Leather Hard' to avoid physical damage (such as finger prints, corner damages, breaking) and stacking deformation.

The 'Leather Hard' green bricks are lifted and stacked in rows to achieve the final bone dry stage. The stacking of the 'Leather Hard' green bricks fulfills two major purposes namely:

- Allowing full airflow circulation for total drying.
- Creating space for new moulding.

'Leather Hard' condition is determined physically by the condition when there will be no finger prints on the green bricks during handling and they can be handled with four fingers of a hand. Also during stacking they should be able to bear the load of the entire stack without deformation.

Stacking of green bricks requires special attention and only well trained workers can do it in a well managed way. Generally the green brick stacking is done by moulders themselves. Various patterns of stacking are followed in Nepal. In some parts a herringbone pattern of stacking is made, in some parts honey comb and in other parts closed packed stacking and in other parts cross stacking. The herringbone pattern is the most efficient since it allows for faster and even drying.

For VSBK bricks, it is essential that herringbone stacking is practiced.

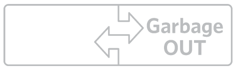
In the cross stacking patterns, a total height of 10 brick layers are made. This height is also made due to convenience to provide easy access to the top layer for brick transporters.

The stacking must be uniform and a proper air gaps must be provided to ensure a uniform drying pattern. The brick surfaces should never be in contact with each other otherwise this contact will always remain moist. Whatever the stacking pattern applied, there should always be a gap of 3-4 cm between each and every brick for proper airflow.


Close stacking


Cross stacking


The herringbone stacking



4.7 PREPARATION OF DRYING AND STACKING YARD

4.7.1 PREPARATION OF STACKING BASE

Before start of moulding it is necessary to construct the stacking base for further drying of the green bricks. The stacking base is generally prepared all along the periphery of moulders respective moulding yard.

Before preparation of the stacking base calculate the length needed for stacking of bricks based on the daily production and drying time. Never keep more than two parallel layers. For preparation of stacking base initially clean and level the area. Place at least one layers of fired bricks on the flat surface. Ensure that the fired brick surface is absolutely leveled. This is necessary to reduce breakage due to weight of green brick stack. If needed level the surface by spreading a layer of fine sand.

Always remember that the height of the stacking base should be at least one brick height more than the ground level. This is to ensure that water (from unseasonal rains) does not damage the bottom layers. If the bottom layers are damaged then the whole stack will fall down. Also keep a plastic sheet ready near each stacking base. During any indication of rains cover the stack with the plastic to protect the green bricks from being damaged.

4.8 STORING OF GREEN BRICKS

Green bricks are mainly stored for firing during the rainy season. The driest months for the year must be utilized to produce green bricks on store. During the summer months green bricks dry faster. Thus the rate of production will be very high. There are three important things to be considered for green brick storing. Firstly, the storing pattern should be such that damage due to rain will not occur. Secondly, it should be economical and not occupy much space. Thirdly, there must be necessary manpower to produce sufficient bricks for regular consumption and storage.

For making a storing chamber the number of bricks needed to be stored needs to be known. It is advisable to make a number of small stores rather than a single very large store. This is done to avoid excess losses due to damage by rain leaking, etc.

Depending upon the dry green brick strength the total stack height usually varies between 20 to 30 brick height.

Once the area is calculated, and the site selected for storing, clear the area from any vegetation. After cleaning the land should be leveled properly. Place at least three layers of fired bricks to make the base. The level might be varied so that during rain water does not flow over the green bricks.

Now start placing the green bricks from one corner. Ensure that there should be no gap between the bricks. Always begin stacking of bricks from one side only. If haphazard stacking is done then there will be the chance of gaps when the stacks meet together.

Initially the stack should be vertical. The height of this type of stacking might vary. Generally it is half the length of the total stack. After reaching the desired height the stacking of the green bricks should be made in such a way that a sloping roof is made.

Note: Always remember to prepare a storage stack near to the VSBK loading ramp. It will save on transportation costs.

The height of the base should be made keeping in mind the water logging level in the area.

Always keep the bricks on the length side. This will ensure a lesser amount of cracking.

Always ensure airtight packing of green bricks in the stack. Do not allow gaps between the bricks to occur in order to avoid monsoon moisture absorption.

After completion of the stack, cover the top with a thick plastic. Be careful that the plastic covers only the top to protect the bricks from rain damage. On top of the plastic put red bricks all along. Alternatively you can put a layer of burnt coal ash and then a layer of red bricks. This is done to prevent the red bricks from slipping during heavy rains.

During monsoon operation keep the green brick stack as airtight as possible.

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GREEN BRICK MAKING MANUAL

VERTICAL SHAFT BRICK KILN PROJECT

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