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PHARAM SINGH THAPA[1], GOVIND PRASAD LAMICHHANE[1]
[1]Pokhara University, Kaski, Nepal

ANALYSIS AND RECOMMENDATIONS ON SANDY CLAY BRICKS WITH CEMENT MIX

Abstract. *In order to contribute to the sustainability of the brick construction sector, this work studied the formation of economic and environment friendly sandy clay brick. Therefore, the goal was set to be developed, a "sandy clay brick with cement mix", which has more structural durability, less weight, low cost, together with high performance with respect to indoor air quality. In this research, variation on soil – cement brick with gradual increase in cement content replacing soil material and how the soil- cement brick may be studied using soil and cement as binder by fulfilling the requirement of National Building Code (NBC). The water cement ratio was kept controlled and all other material properties used were same. The effect was seen on compressive strength because the 28 days strength of brick is slightly more when soil is replaced by 15% cement content then no replacement of soil by cement strength. Taking about 11 samples starting from 0 % to 50 % cement content it was found that sandy clay soil – cement brick with compressive strength up to 23.44 MPa with traditional value may be achieved.*

Keywords*: soil-cement mortar stabilized, moisture absorption cement content, surface porosity.*

ПХАРАМ СИНГХ ТХАПА[1], ГОВИНД ПРАСАД ЛАМИЧХАНЕ[1]
[1]Университет Покхара, Каски, Непал

ПЕСЧАНО-ГЛИНЯНЫЙ КИРПИЧ С ДОБАВЛЕНИЕМ ЦЕМЕНТА

Аннотация. *Статья посвящена вопросам изготовления песчано-глиняного кирпича для обеспечения потребностей строительной отрасли Непала в экономичном и экологически чистом мелкоштучном строительном материале. Цель настоящего исследования состояла в подборе оптимальных составов для изготовления песчано-глиняного кирпича с добавлением цемента, который бы обладал достаточной прочностью, малым весом, низкой стоимостью и высоким уровнем экологической безопасности. В настоящей статье рассмотрены варианты составов песчано-глиняных кирпичей при постепенном увеличении доли цементной добавки, вводимой вместо песка и глины, и методика их испытаний для выполнения требований Национальных строительных норм Непала (NBC). При проведении испытаний контролировалось, чтобы водоцементное отношение и другие параметры материалов, используемых для изготовления кирпича, были одинаковыми для всех образцов. Испытаниями было установлено, что по истечение 28 дней прочность на сжатие образцов, в которых доля цемента составляла 15%, незначительно возросла. Испытания 11 образцов с долей цементной добавки от 0 до 50% от объема показали возможность получения песчано-глиняных кирпичей с прочностью на сжатие до 23.44 МПа.*

Ключевые слова: *грунтово-цементный раствор, влагопоглощающий цемент, пористостая поверхность.*

1 Introduction

Soil cement is a mixture of local soil or assembling totals with estimated measure of Portland cement and water that solidifies after compaction and curing to form a solid, tough and ice safe stone work units. Soil cement is upon by blending Portland cement-with weak soil, the cement – bound, granular material turns out to be increasingly reasonable for mortar and brick and give an increase capacity or load bearing application. Sandy clay handled a manufacture sand and rock alongside crushed stone are sorts of soil ordinarily utilized in soil cement stabilization [1-7]. Brick work is the structure of structures from individual units laid in and bound together by mortar. The term masonry can likewise allude to the units themselves. In traditional definition, brick used to be essentially characterized as the structure units made of clay soil to be utilized as crude material (Local clay brick). In current days, brick can be characterized as a rectangular prism of appropriate size that can be handled conveniently (burnt clay brick). Sandy clay bricks used to be fabricated by expelling (solid sandy clay) or trim (delicate shape), at that point drying in air [8-13]. Assembling procedure of bricks is long, costly and naturallynonviable.

The plan of each structure exposed to seismic development should thought about that the non-structural components in the building, for example, roofs, boards, windows and entryways, as well as equipment, mechanical and sanitary installations and so on., must withstand the movement of the structure. In addition, it ought to be borne at the top of the priority list that the excitation of the non – structural components, brought about by these movement of the structure is in general more prominent than excitation at the foundation and in this manner it very well may be said that the security of the non – structural components is more compromised much of the time that safety of the structure itself. In spite of the previous, the seismic design of structures more often gives little significance to these components, to such an extent that many design codes do not include standards measures in such manner. Involvement with ongoing quakes in many cases appears as excellent behavior of the structure designed as per present day criteria of seismic resistance, joined sadly by a poor reaction of the non –structure components. However, if the safety of the inhabitants of a structure and of individuals jeopardized by the breakdown of such components is considered, as the expense of replacing these components and the losses associated with interference the tasks of the structure itself, the significance of seismic design of the non – structural components inside the general design of the structure can be comprehended [14-20].

In order to come up with new approach, it is important to track back to its history have they made and used. Mostly brick was made with local clay with water which has properties of low price availability in large amount, good fire resistances; easy to use through it has some disadvantage like durability and its strength. In continuous rainy season, wind, frost action may damage and reduces the durability. For the enhancement of existing earth brick researcher has conducted many research and development project. Normally moderate amount of clay content is desired in soil. As clay has cohesive nature. It gives the plasticity to the soil under the moisture condition which adhere the particle of soil and other together. Even though clay has high affinity toward water, it swells or expands in existence of water and shrinks in the absence of it. This causes volume instability. So cement is used for stabilizing this problem.

The Development of bricks in Nepal was first sun dried sandy clay bricks then followed by burnt clay bricks. Most of the houses in rural areas of Nepal are built with burnt clay bricks and stones masonry structures. Even in RCC structures in urban areas, brick walls are used as partition as well as in-filled walls. Originally sandy clay bricks were used, and then followed by burnt clay bricks for constructing brick masonryhouses.

The brick is one of the most -oldest known structure materials going back to 7000BC where they were first found in southern Turkey and around Jericho. The first bricks were sun dried sandy clay bricks. Fired bricks were observed to be progressively impervious to harsher climate conditions, which made them a substantially more reliable bricks for use in lasting structures, where sandy clay bricks would not have been adequate. Fired brick were likewise helpful for capturing any warmth created for the duration of the day, at that point discharging it around evening time. The Romans further distinguished those which had been dried by the sun and air and those bricks which were burnt in a kiln. Using mobile kilns, the Romans were successful inintroducing kiln fired bricks to the whole of the Roman Empire. The Greeks likewise viewed as perpendicular brick wall more solid than stone wall and utilized them for public structures They also realized how the modern brick was less susceptible to erosion than the old marble walls.

During the 12th century bricks were reintroduced to northern Germany from northern Italy. This created the brick gothic period which was a reduced style of Gothic architecture previously very common in northern Europe. The building around this time was fundamentally built from fired red clay brick. Brick Gothic style structures can be found in the Baltic nations Sweden, Denmark, Poland, Germany, Finland, Lithuania, Latvia, Estonia, Belarus and Russia.

During the renaissance and Baroque periods, exposed brick walls became unpopular and brickwork was generally covered by plaster. Only during the mid-18th century did visible brick walls again regain some popularity. During 2007 the new „fly ash" brick was created using the by-products from coal powerplants.

The Negative rate of increase in development action in recent years has brought about increase of brick ovens, which have returned with great quantity of dirt smoke and harmful gases in environment causing decrease of air quality. The brick kilns are the significant single source of SO_2 and CO_2 emission in nature. The problems are as follows:

- Occupation of large cultivated land and severe loss of fertilesoil.
- Great challenges for the replacement of burnt claybricks
- Deforestation.
- Losses of wellspring.
- Environment pollution (air, wateretc.)

The General objective of this study is to modify the eco-friendly clay brick to replace the burnt clay brick. The aim is to study sandy clay bricks if it can replace burnt clay bricks on strength so that eco- friendly bricks shall be achieved .To study design mix of cement replacement on sandy clay bricks to improve strength.

The specific objectives are:

To study and analyze sandy clay brick with inclusion of cement content

To investigate and analyze the minimum required content of cement to give the required breaking strength of brick as per NBC.

To modeling on relationship between strength and cement content percentage which may further enhance NBC code.

The scopes of this thesis project are as follows:

- Localmaterial: Production is made on site itself or in the nearby area. Thus it wills safe transportation, fuel, time andmoney.
- Unlike natural stones, brick is free from defects andflaws.
- It can be manufactured to desired strength with an economy.
- The durability of brick is veryhigh.
- It can be cast to any desiredshape.
- The deterioration of brick is not appreciable withage.
- The brick can withstand hightemperatures.
- As a sound proofing material brick could beused.

Today, burnt clay bricks are considered as the major construction material for both masonry houses as load bearing wall and for RCC houses as infill walls or partition walls. Such trend has emerged three major problems as:

- It increases of pollution in urban and semi – urban area due to emersion of high amount of SO_2 and CO_2 from brickfactories.
- The cost of burnt clay brick becoming more expansive being difficult to be afforded by commonpeople.
- It covers large cultivation land and loss of fertilesoil.
- It increasesdeforestation.

In this aspect, it is vitally important to carry out the research work and develop new construction material (brick) which may completely replace burnt claybricks.

Similarly, the buildings that are constructed earlier will be destroyed as their life span will be completed. Hence, it is important to carry out the research work to develop binder by partial soil replacement with cement.

- Live load: - 2.5 KN/m^2
- Floor finish load:- 1 KN/ m^2
- Partition load:- 1KN/ m^2
- Staircase load:-2KN/ m^2
- EQ-X and EQ-Y applied along X and Y direction as per IS 1893-2002 and the load case is Response Spectrum
- Load Combination as per IS 456-2000

2. Methods

Research methodology explains the activity of research that describes the process used to collect information and data for purpose of making final decision. The methodology of research shows the legitimate and reliable data for the problem under investigation. The methodology adopted to complete this research work is shown on chartbelow (figure 1).

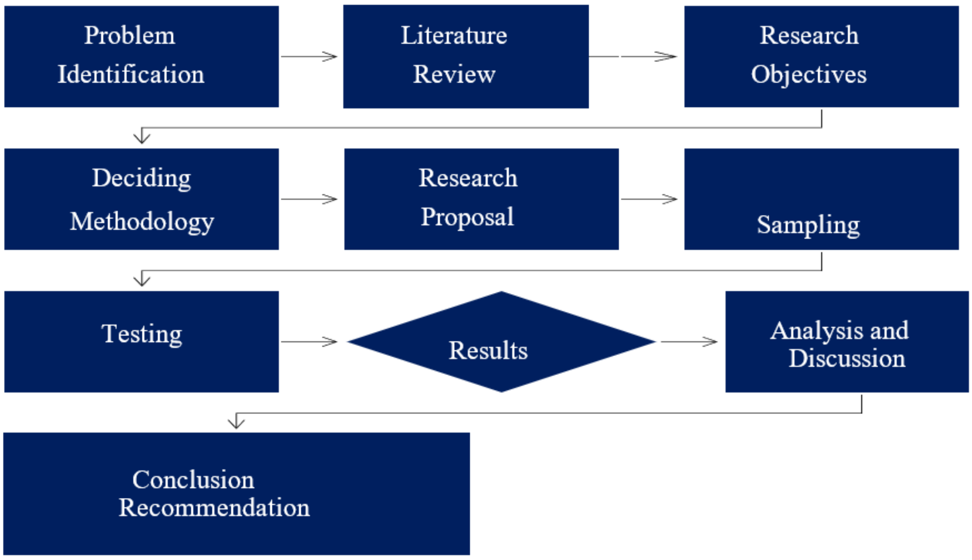


Figure 1 - Methodology chart

Sampling of clay in site of Furse DandaLekhnath of different specimen and testing using sieve analysis and laboratory tests works includes the collection of sandy clay soil from site followed by removal of impurities. Extracted sandy soil then mix with varying proportion of cement with water for standard mixdesign then brick compressive strength is tested. The following flow chart shows the sampling and testing procedure (figure 2).

3. Results and Discussions

3.1 Laboratory Procedure

The brick mound was self-designed with size of 240×115×57 mm^3 according to NBC code 109 – 1994 (Nepal National Building Code). Three bricks were casted in mound with same proportions for making single brick material required were batched and mixed (figure 3 a-d). Then casting was done in three layers. The first layers were tamped by 18 mm rod for getting better compaction. No segregation and bleeding were seen. After completion of casting work brick were placed in air dry for about 24 hours. After air dry, mound was removed with same noticeable of air voids (figure 4 a). The sample was then immerged in water until the test time (figure 4 b). Strength development depends on ingredient with proper curing with proper temperature and humidity gives the higher strength anddurability.

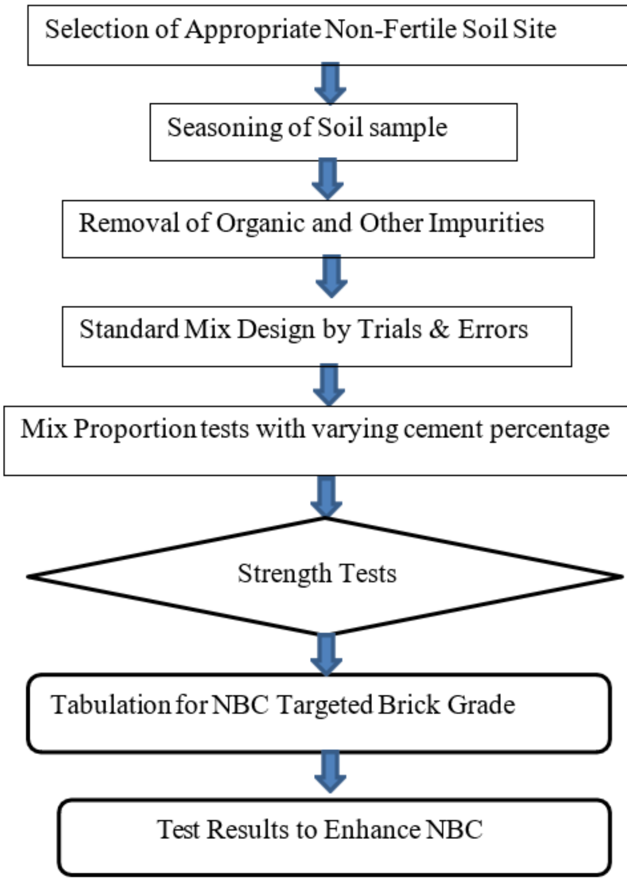


Figure 2 - Flow Chart Showing Laboratory Process

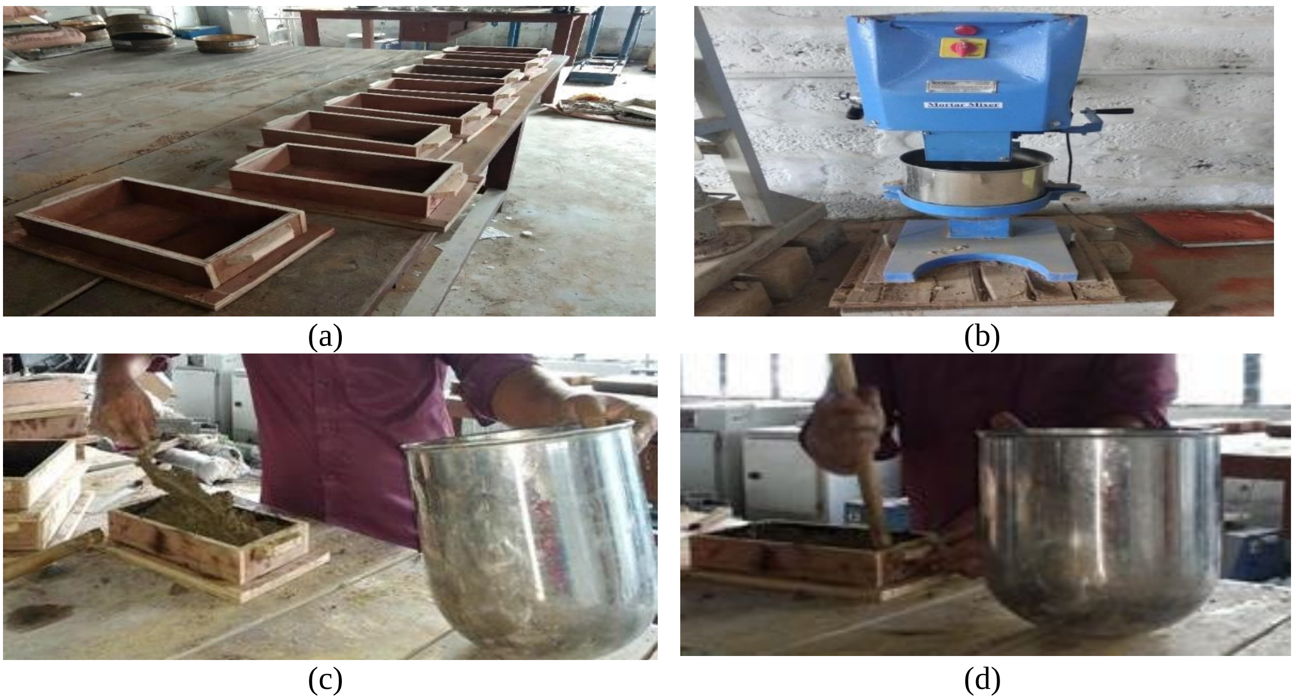


Figure 3 – Samples' production: Brick Molds size 240×115×57 mm^3 (a); Mixing in Mortar Mixture (b); Casting of Brick Sample (c); Compacting of Sample (d)

(a)

(b)

Figure 4 - Seasoning (a) and Curing (b) of Brick Samples

3.2 Testing

Workability of mortar describes the ease or difficulty with which the mortar is handled, transported and placed. Workability is important because if the soil cement mortar is too wet, coarse soil particle settle down at bottom that is mortar become non uniform composition. Water plays the important role in workability. Higher the workability, higher will be the water content resulting in low strength. Since, we use the fixed w/p ratio so, water content is fixed. Since, cement is high water absorbent material, un increasing cement proportion, workability was decrease accordingly.

The unconfined compressive strength of soil cement mortar has been utilized adequately to describe mechanical properties of soil cement mortar (Shihata and Baghdadi 2001). Research performs by Mohammad, Raghavandra and Huang (2000) showed information that demonstrates mixture with higher cement content show higher strength than mixture with low. The soil can influence essentially the impact of cement addition. The compressive strength of cement soil mortar was measured for a relieving time of cement equivalent to 7 and 28 days. Obviously the soil type is controlling component on the rate of increment of compressive strength with increasing cement content. Other factor influencing quality is the curing time of cement and optimum water content [22].

The parameter which impact essentially the quality of cement stabilize soil are the water content, soil fine content the liquid limit, amount of added cement and curing time. In the present investigation, diverse soil types were mix with cement at differentcement proportion and compacted utilizing the standard proctor test at maximum dry density. The compressive strength of cement treated soil was decided for a curing time of the cement equivalent to 7 and 28 days. Clearly the soil type is controlling factor on the rate of increment of compressive strength with increased cement content. Moreover, the compressive strength of soil-cement mixture for a curing time of 28 days is essentially higher than those for a curing time of 7 days. Similar studies on sandy soil have demonstrated that cement addition to soil expands stiffness, brittleness and peak strength [23].

Soil type impacts essentially the increase of unconfined compressive strength because of cement addition. The addition of cement content to all soil kinds increase the compressive strength and stiffness of soil cement mortar. Cement mixing has recently being utilized to confront this issue by improving the quality and lessening the distortion of soil. The parameter which impact the strength of cement stabilized soil are water, soil content, liquid limit, amount of added cement, curing time. The compressive lab work was completed in ordered to investigation of compressive strength of sandy clay soil demonstrated that compressive strength was relied on the variety of cement content and time of curing. Compressive strength test for mortar were carried out in compressive testing machine. The loading rate was uniform without any shock. The maximum load at failure was noted. The compressive strength test of break was tested at 28 days [15].

3.3. Test Results

Compressive strength of the brick is the maximum force applied to the surface of brick vertically within which it can withstand until it gets failure. It depends on the water

cement ratio and cement content of brick. Since, I fix the w/p ratio in each sample. So, on increasing cement content, compressive strength of brick also increased. After completion of 28 days of casting, bricks were tested. Total of 33 samples were tested. Cement content of 3 brick sample were used. On increasing the cement content by replacing the clay soil, brick become hard and compressive strength increase. In testing yet UTM (Universal Testing Machine) machine (figure 5), maximum collapse load was noted for each sample. Three sample of each batch (same content proportion) were taken and calculated as average value for further work. The compressive strength of sample brick is calculated using the relation givenbelow.

Compressive strength (N/mm^2) = maximum load at failure (N) / Area (mm^2).

Here, Area of brick = 26450mm^2

Maximum load at a failure and compressive strength of each sample of brick is shown in table below (table 1).

Table 1 - Failure Load and compressive strength of all Brick Samples

Cement Content (%)	28 days breaking load(KN)	28 days Compressive Strength(MPa)	Cement Content (%)	28 days breaking load(KN)	28 days Compressive Strength(MPa)
0	15.87	0.6	30	365.01	13.8
5	39.675	1.5	35	440.128	16.64
10	75.118	2.84	40	529.7935	20.03
15	162.932	6.16	45	569.9975	21.55
20	239.9015	9.07	50	619.988	23.44
25	324.806	12.28			

3.4 Stress - Strain Relation ofBrick

The 28 days strength vs. strain curve for each sample of brick is shown below as obtained during the compressive test on universal testing machine. The three samples of each batch were tested and average of three specimens was taken to get the final curve for all samples.

The maximum compressive strength of brick at 0 % cement content was 0.6 Mpa (figure 6).

3.5 Density of Brick

The mass of every sample of brick were measured by weighting machine and noted. Then average mass of total sample was calculated. The density of brick was calculated as follow ingrelation (table 2).

Table 2 - Average Mass vs. Density of Brick

Cement Content (%)	Average Mass(gm)	Density (kg/m3)	Cement Content (%)	Average Mass(gm)	Density (kg/m3)
0	2480	1579	30	2872	1829
5	2586	1647	35	2884	1836
10	2683	1708	40	2906	1850
15	2746	1749	45	3025	1926
20	2822	1797	50	3028	1928
25	2864	1824			

Density (ρ_b)=Mass/Volume. Volume of brick = 0.00157 m^3.

Figure 5 - Universal Testing Machine for Testing of Sample

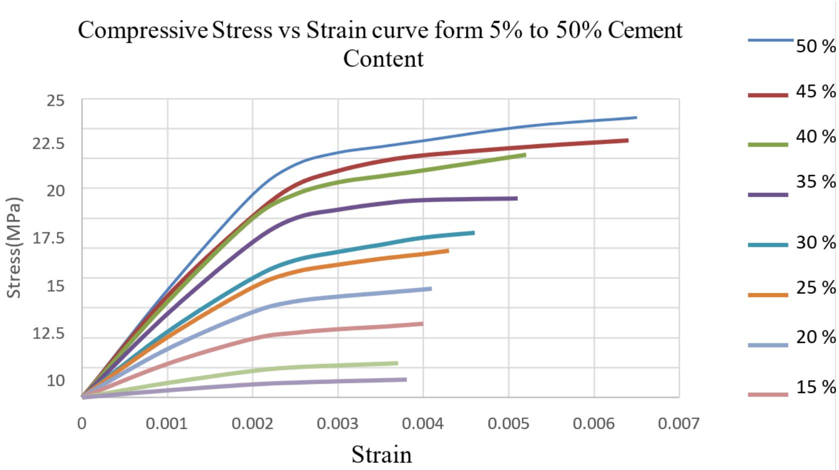


Figure 6 - Compressive Stress vs. Strain Curve for all Brick Samples

3.6 Discussion

The compressive strength of the brick depends upon the water cement ratio and cement content. The w/c ratio is kept constant for all samples and cement is varied. So, from the result we find that compressive strength gets increased on increasing the cement content (table 3).

The curve giving maximum strength of the sample with respect to the increase in cement content is plotted in graph (figure 7). The maximum compressive strength of the sample according to the percentage of cement content is given by the equation as: Equation for increasing in strength is givenby

$$f_{cb} = -4\cdot10^{-7}x^5 + 6\cdot10^{-5}x^4 - 0.003x^3 + 0.0711x^2 - 0.2052x + 0.697,$$

where, f_{cb} = Compressive Strength of Brick (MPa), x = Cement Content (%).

Table 3 - Change in Compressive Strength of Brick with increase in Cement Content

Cement Content %	Maximum strength	% change
0	0.6	0
5	1.5	150
10	2.84	373.3333
15	6.16	926.6667
20	9.07	1411.667
25	12.28	1946.667
30	13.8	2200.00
35	16.64	2673.333
40	20.03	3238.333
45	21.55	3491.667
50	23.44	3806.667

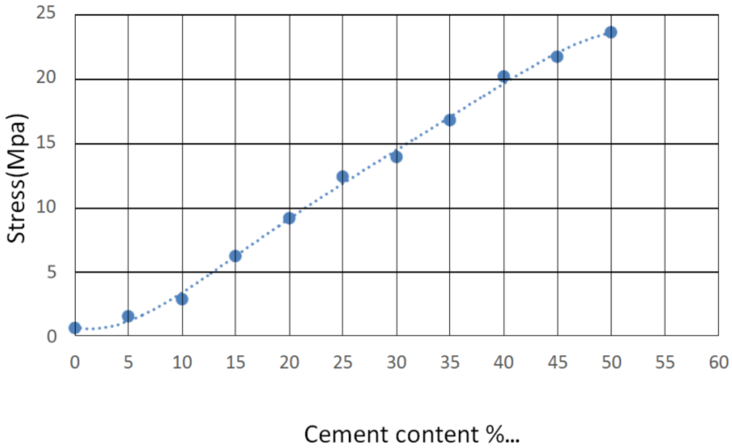


Figure 7 - Maximum Compressive Strength vs. Cement Content Curve

Maximum strain vs. increase in cement content of each sample of brick is plotted. The strain gets increased on increasing the cement content. The curve giving the maximum strain of the sample with respect to the increase cement content is plotted (figure 8). The maximum strain of the sample according to the percentage cement replacement is given by the equationas:

Equation is given by:

$$E_b = -2{\cdot}10^{-9}x^3 + 2{\cdot}10^{-6}x^2 - 2{\cdot}10^{-5}x+0.0038.$$

Where, E_b= Maximum Compressive Strain, x = Cement Content (%).

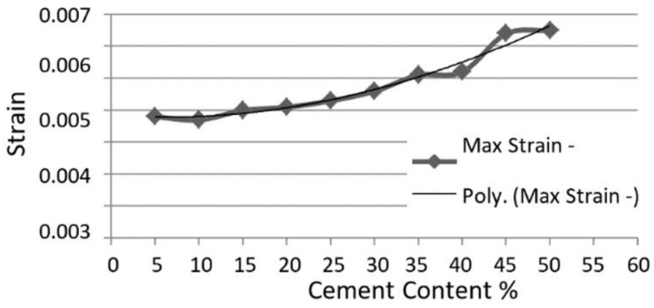


Figure 8 - Maximum Compressive Strain Vs. Cement Content

On increase in cement content the density of the brick increase. The curve giving the density of the sample with respect to increase in cement content. The variation in mass with respect to increase in cement content is plotted in graph as shown below (figure 9 a).

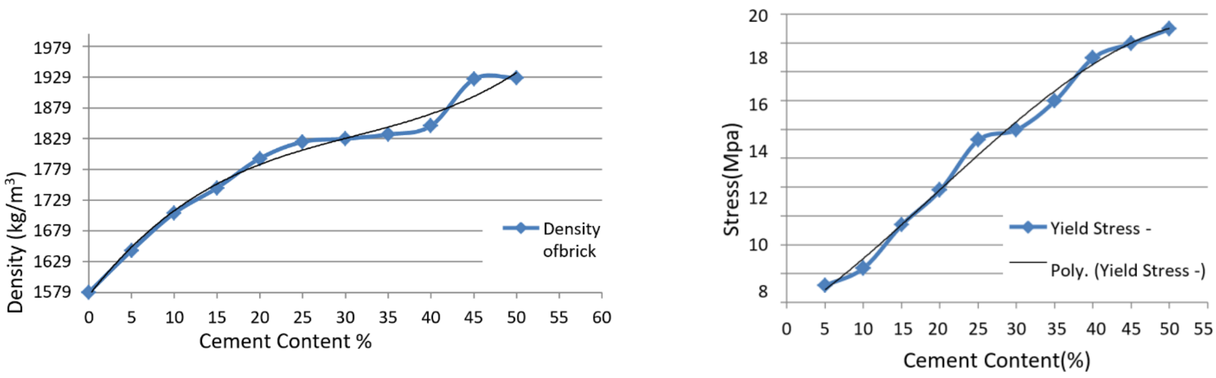
$$\rho_b = 0.005x^3 - 0.4642x^2 + 17.94x+ 1573.9.$$

Where, ρ_b = Density of Brick (kg/m^3), x = Cement Content (%)

Yield strength is the strength at which the behavior of material changes from elasticity to plasticity. From the yield strength, brick start to deform plastic in nature. Yield strength of brick for the samples are calculates from the strength strain curve (figure 9 b). The obtained value of yield strength is shown in graph below with the most matching equation.

$$F_y = -0.0001x^3 + 0.007x^2 + 0.3497x-1.04.$$

Where, F_y = yield strength (N/mm^2), x = cement content (%)



(a) (b)

Figure 9 - Density vs. Cement Content (a), Yield Stress Vs. Cement Content (b) Brick Curve

Young's modulus of material shows the relationship between strength and strain. It is the ratio of strength to strain. It is the mechanical property of solid material that indicates the extent at which material resist deformation in response to applied force. Young's modulus of brick for the samples are calculates from the strength strain curve. The obtained value of young‟s modulus (table 4) is shown in graph below (figure 10 a) with the matching equation.

$$E_b = -0.1041x^3 + 6.9699x^2 + 57.406x + 216.2.$$

Where, E_b = Young‟s modulus of brick. x = Cement content %.

Yield strain is the point in strength – strain curve of material from where materials begin deformation permanently or plastically. Its shows the failure point of material initiation when it is applied by force. Yield strain of brick for the samples are calculates from the strength strain curve. The obtained value of yield strain is shown in graph below (figure 10 b) with the equation.

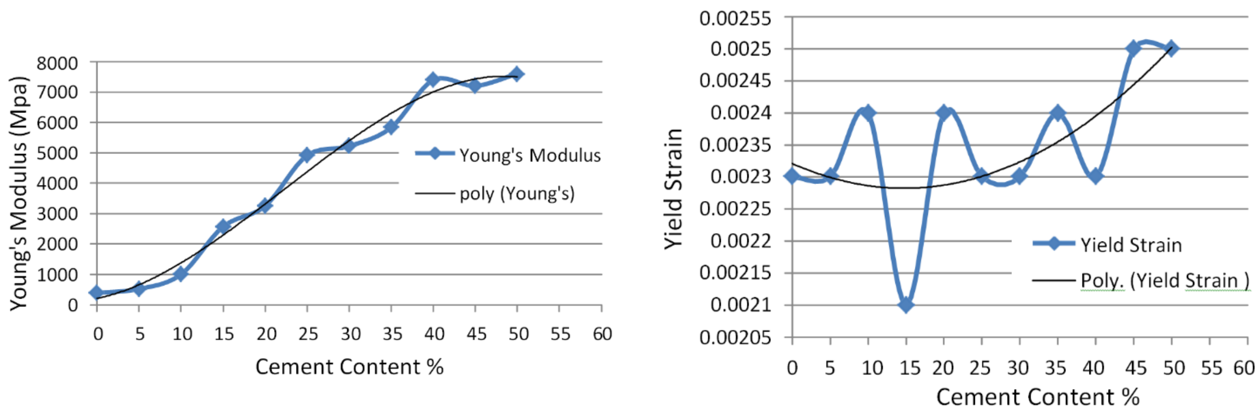
$$Y_{yb} = 2E\text{-}07x2 - 5E\text{-}06x + 0.0023.$$

Where, Y_{yb} = Yield strain of brick, x = Cement content %.

After testing the brick, it was noticed that failure pattern was somehow similar for each sample. The pattern noticed is shown in figure below (figure 11).

Table 4 - Comparison Study of Sandy Clay Cement Brick and Normal Burnt Brick

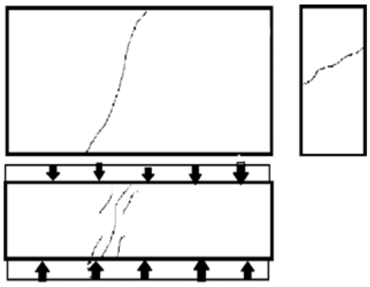
S.N.	Properties	Sandy Clay –Cement Brick	Normal Burnt Brick
1	Compressive strength (Mpa)	0.6 -23.44	3.5-20
2	Density (kg/m^3)	1579-1928	1600-1900
3	Young's modulus (Mpa)	700-7600	300- 3500



(a) (b)

Figure 10 - Young modulus vs. Cement (a) and Yield Strain vs. Cement (b) content curve

(a)



(b)

Figure 11 - Failed Brick Samples (a), Failure Pattern of Brick (b)

The Minimum crushing strength of bricks (N/mm^2) to use for the construction of masonry structures as code are 7.5 (class A1), 5 (class B1) and 3.5 (common type) for the construction of singe storey and 2 storey buildings. The obtained experimental data of 28 days compressive strength of brick is shown in table below with the brick class matching with the coderequirements (table 5).

Table 5 - Code Requirement

Cement Content (%)	Brick Strength (N/mm^2)	Brick Class
0	0.6	-
5	1.5	-
10	2.84	-
15	6.16	B1
20	9.07	A1
25	12.28	A1
30	13.8	A1
35	16.64	A1
40	20.03	A1
45	21.55	A1
50	23.44	A1

4 Conclusions

In this research, soil with a composition of Sand (57.60%), Silt (4.8%) and Clay (35.60%) is used as raw material for soil cement mixture. The increase in cement content result in an increase in the compressive strength value of bricks made at the same constant compaction pressure. The moisture absorption capacity of the brick could be significantly related to its durability. The increase in the cement content of brick results into a reduction of its initial rate of water absorption. The amount of water for soil – cement mixture needs to be carefully controlled. There needs to be sufficient moisture for the cement to fully hydrate but no excess of water which would reduce the final density, increase porosity and reduce finalstrength.

From the experimental data on the compressive strength of brick, it is concluded that soil can be partially replaced by cement. On replacing the soil by 15% cement, the compressive strength of brick is greater than compressive strength of zero percentage cement content**.**

New type of brick with compressive strength up to 22.50 Mpa has been development from this research by using cement content. These brick up to 50% soil replacement by cement has meet all requirements given in Nepal. The building code can be used as masonry unit according to need. For important structures bricks can be developed and used according to required compressive strength. Similarly, for the reconstruction of traditional building S_{40} sample (soil replaced by 40% cement content) of brick giving 20.03 Mpa can be used.

After completion of this research work, some of the very important conclusions need to be recommended.

- Government of Nepal and private sector producing brick are recommended to use soil types as “SandyClay”.
- Government of Nepal and national Reconstruction Authority are recommended to

use mix proportion of S_{15}mortar for the reconstruction of structural wall of heritage building.

- Government of Nepal and private sector are recommended to use up to S_{15} for brick as masonry unit in masonry structural and infill wall in RCC building for the construction of commercial and residential building according to the need of requiredstrength.
- Government of Nepal and contractor are recommended to use mix proportion up to S_{15} for mortar used in the construction of commercial and residential building according to the need of requiredstrength.

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Information about authors:

Pharam Singh Thapa
Pokhara University, Kaski, Nepal,
assistant Instructor of Faculty of Science & Technology, School of Engineering.
E-mail: psthapa@gmail.com

Govind Prasad Lamichhane
Pokhara University, Kaski, Nepal,
associate professor of Faculty of Science & Technology, School of Engineering.
E-mail: govindkhec@gmail.com

Информация об авторах:

Пхарам Сингх Тапа
Университет Покхара, Каски, Непал,
ассистент инженерной школы факультета науки и технологий.
E-mail: psthapa@gmail.com

Говинд Прасад Ламичхане
Университет Покхара, Каски, Непал,
доцент инженерной школы факультета науки и технологий.
E-mail: govindkhec@gmail.com