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Original Article

Production Of Paving Blocks Through Labour Based Technology

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ABSTRACT

The production of concrete paving blocks came into existence during post war Europe reconstruction in the late 1940's for the purpose of revitalizing the ancient technique of producing pavement. This technique grew out of exigencies of reconstruction because of the advantages offered against other construction materials. They then gained fast popularity in many countries as an alternative to concrete and asphalt paving, with about 400 million m² produced and installed yearly. They are precast solid concrete products of various sizes and shapes, produced to interlock with adjacent blocks. The use of paving blocks for road works has proven the ability of low maintenance and high resistance to deterioration from moisture, point loads, abrasive actions, resistant to skid and petrochemicals. The blocks are produced from a combination of Portland cement, coarse and fine aggregate with sufficient water to produce zero-slump concrete, moulded in specialised equipment under vibration and extreme pressure and sometimes admixtures are added to increase certain engineering properties thereby reducing likelihood of efflorescence and decreasing water absorption. Good quality paving blocks are produced from a homogeneous mixture of cement, fine and coarse aggregates, mixed together in the right proportions, to produce a dense material. When water is added to the mixture, its chemical reaction with cement enables it to harden and make the complete mixture easy to handle and transport to the moulding place. Fine aggregate fills up voids between the paste and the coarse aggregates, provides the bulk and the strength of concrete, while the cement binds individual particles together. Moulding paving blocks, requires mixing concrete responding to the desired specifications, then filling moulds with the mixture, vibrating or compacting on the vibration table to remove air bubbles or voids, curing blocks and carefully demoulding, not forgetting to select the right mould, ensuring proper concrete consistency and carefully handling blocks during the curing process. The moulding process requires concrete constituents be mixed in their correct proportions such as cement, gravel, sand and water. The mixture is chosen based on loads to be transmitted, environmental conditions, quality materials and design mix. However, there are technical specifications providing nominal and standard concrete mixes for various construction works based on experience and testing [Mishra, 2017]. The emphasis in labour based technology approach is on employment, training and development, ensuring that cost and quality of the infrastructure are similar to those of equipment based approach. Construction equipment and specialised tools are only used where appropriate and necessary, while employees are treated with dignity and respect and paid fair wages. This approach contributes to poverty alleviation and economic growth, promotes community participation and in-corporates environmental friendly practices relating to the quality of local materials while minimizing waste. It also offers many advantages in developing coun-tries, where scarce resources are sacrificed for developing and maintaining infrastructure, at the same time reducing unemployment [ILO, 2012]. Quality control is a systematic process that ensures products meet specified standards, requirements and client's expectations. It comprises monitoring and controlling various stages of production or delivery of services to early identify and correct errors or deviations that occur. One of the greatest challenges in moulding paving blocks is to ensure compliance with established specifications and consistency to acceptable quality. Systematic process and set of activities ensures certain predefined quality criteria and standards are met. The quality control of paving blocks is accomplished in three distinct stages that is control before, during and after moulding. Generally certain tests such as workability, cohesiveness and compressive strength tests are conducted. The compressive strength test is done with cubes of 15x15x15 cm or cylinders, while workability is checked by conducting various tests like Slump test, Compacting factor test and Vee-Bee test.

Keywords: Exigencies of reconstruction, Efflorescence, Revitalizing ancient techniques, Homogenous mixture, Errors and deviations, Systematic processes, Zero slump concrete, Specialised equipment, Decent work, Fair wages, Poverty alleviation, Dignity and respect, Economic growth, Specified standards, Workability, Compressive strength, Quality

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control, Client's expectations, Slump test, Established specifications

INTRODUCTION

The production of paving blocks was developed after post war Europe reconstruction, in the late 1940's that saw the revitalisation of ancient techniques of pavement production, following the introduction of modern and cheaply mass-produced concrete paving blocks. This development grew largely out of the exigencies of reconstruction after the war because of the advantages offered against other types of pavements and there was nothing to hinder the use from spreading beyond Europe. They were introduced in North America by early 1970's and this method of paving became widely accepted with 400 million m^2 produced and installed yearly [27, 39]. This type of paving blocks were embraced for pavements because of aesthetics and patterns offered as well as high structural strength, slip resistance, and durability. Most paving blocks were initially used for commercial and residential areas. But nowadays there are thousands of successful projects design and constructed with paving blocks that have proven the ability to low maintenance and high resistance to deterioration from moisture, point loads, abrasive actions, resistant to skid and petrochemicals. The projects have widen the use of paving blocks for pavements of high traffic loads [27, 39].

They are produced from high quality concrete composed of a combination of Portland cement, coarse and fine aggregate with sufficient water to produce zero-slump concrete, moulded in specialised equipment under vibration and extreme pressure. Admixtures are sometimes added to increase various engineering properties and reduce likelihood of efflorescence while decreasing water absorption [11, 31]. They are precast solid products of various sizes and shapes to interlock with adjacent blocks.

Labour based technology as in my last research "design and construction of interlocking pavements through labour based technology" is an approach that uses a mixture of labour/equipment giving priority to labour, while supplementing it with appropriate equipment where necessary, integrating quality and cost. This way infrastructures are constructed to standards with minimum cost, where those employed are treated with dignity and respect and are paid fair wages including opportunities for personal development and social integration [37, 38]. However, producing paving blocks through this approach is cost effective and a sustainable approach that utilizes local resources while producing quality products. This approach leads to the creation of employment, contributes to poverty alleviation and economic growth, promotes community participation including infrastructure ownership and can incorporate environmental friendly practices such as use of high quality local materials while minimizing waste. The promotion of this technology provides many advantages to developing countries, since they have limited resources for infrastructure development and maintenance through adoption, where the technology and economy are able to support [37, 38].

2.1. Purpose Statement

The purpose statement of this study is to explore how paving blocks are produced through labour-based technology. This approach can be a perfect solution for solving the problems of infrastructure deficit in developing countries. It can contribute immensely to knowledge transfer, protection of infrastructure against vandalism and early damage and sustainable development. It also discusses the different processes and technics for moulding paving blocks.

2.2. Main objective

The main objective is to understand how paving blocks are produced through labour-based technology and how it stands to benefit stakeholders and the beneficiaries. The most important aspect involves understanding the characteristics of materials used and quality control. Having this in mind, knowing the moulding of paving blocks is affected by several parameters directly influencing quality. The labour based technology can be a perfect tool to promote sustainable development especially in developing countries.

2.3. Limitations and challenges of labour based technology

The labour based technology emphasizes on the use of labour and skills in the construction industry, but do have several limitations and challenges, such as:

- Labour based technology requires a large work force which can be time consuming and costly.
- Labour based technology demands skilled labour force, which can be in short supply especially in areas with limited training programs.
- Labour based technology can be less productive than equipment based, particularly for large scale projects.

- Ensuring consistent quality can be challenging, since it relies on individual workers skills and attention to details.
- Labour based technology can be difficult to scale up for large projects.
- While labour based technology can be cost effective for small scale projects, it can become expensive for large projects due to labour cost.
- Labour based technology can be slow, especially for projects requiring high level of precision or details.
- Labour based technology can be weather dependent, which can lead to delays and disruptions.
- Labour based technology can pose safety risks, especially if workers are not trained or equipped.
- Labour based technology may not be as innovative as equipment technology, which can limit its potential for reforms and deficiency gains.
- Access to quality materials may be limited in some areas.

It is very important to overcome these challenges before engaging this technology for the implementation of any project by applying essential rules, in the following ways:

- ✓ Investing in worker training and development programs.
- ✓ Implementing efficient project management and planning techniques.
- ✓ Using labour based technology in conjunction with machine based technology.
- ✓ Focus on small scale projects that can benefit from labour based technology.
- ✓ Develop innovative solutions that combine labour based approach with modern materials and techniques.

1. MATERIALS FOR PRODUCING PAVING BLOCKS

Good quality concrete paving blocks are manufactured from a homogeneous mix of cement, fine and coarse aggregates. When mixed together in their right proportions, a dense material is produced. The addition of water to the mix reacts chemically with cement enabling it to harden and makes the complete mix easy to handle and transport where they are moulded. The fine aggregate fills up voids between the paste and the coarse aggregates, acts as fillers, providing most of the bulk and the strength of concrete, while the cement binds all individual particles together. Admixtures can also be used to increase engineering properties as necessary [9, 11, 12, 31, 32]. Here below is a description of the materials to be used for the purpose and must conform to technical specifications:

Figure 1: Fine and coarse aggregates

3.1. Cement

Cement is the binding material, which when combine with water hydrates and binds aggregates together. Generally rich mixes (with more cement) provides more strength. Setting time starts from half an hour and ends after 6 hours. Hence paving blocks must be moulded before half an hour of mixing with water and should not be subjected to any external forces till final setting has taken place. The type used shall be CPJ42.5 Portland cement conforming to ASTM C150/C150M and shall be free from moisture, satisfy general conditions laid down by regulations in force. Storage shall be on dry and ventilated surfaces while priority toward usage will systematically adhere to the supply calendar [11, 12, 22, 31, 32].

3.2. Fine aggregate

Fine aggregate is natural sand from quarries and rivers which must be free from oxide and organic materials from animals or plants. The seizes of sand for the production of concrete paving units shall vary from 0.16-5 mm and shall be stored at a convenient place on the site as required. Before sand is used tests must be carried out to determine if it is usable for concreting, hence the quantity of harmful dusty clay particles have to be determined [9, 12, 23, 32]. The first method is to perform a rapid field test by rubbing it on both palms and if palms remain clean then the sand is recommended or rejected when they are dirty. The second method is to perform a Sand Equivalent Test where specialised equipment and materials are used [12, 32].

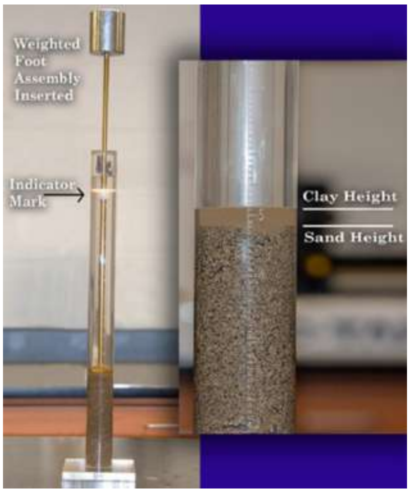

Figure 2: Sand equivalence test

- Add fine aggregate to a solution of calcium chloride and glycerine in a graduated cylinder.
- Shake well either manually or mechanically.
- Introduce more solution to flush fine particles to suspension.
- Fines will settle on top of the solids in the column.
- After sedimentation, the level of the top of the clay suspension is observed and recorded as the clay reading.
- A weighted-foot assembly is lowered into the cylinder to rest on the sample to determine the sand reading.
- The value can be calculated from the formula

$$S.E = \frac{h2}{h1} x100$$

Where,

✓ h1 is the level of suspension (total height of sand and clay or fine particle suspension)

✓ h2 is visual height of sand.

Results of test

- S.E ≥ 80%, sand is good for concrete
- 70 ≤ S.E < 80, use sand with Portland cement
- S.E < 70%, wash sand to eliminate fine particles.

3.3. Coarse aggregate

The accepted maximum grain sizes of coarse aggregate for reinforced concrete is 25 mm however, the maximum grain size for paving blocks may not exceed 15 mm due to the thickness of paving blocks or is specifically selected to achieve a particular surface texture. If coarse aggregate of larger particles, or too much coarse aggregate is used in the mix, it can be difficult to achieve quality compaction and acceptable surface texture. [9, 12, 23].

These aggregates are generally crushed and well graded stones of good quality, from igneous rocks without fine dust particles, and must be clean. The résistance of gravel to abrasive forces is determined through a common test known as the Los Angeles abrasion test. This test measures aggregate toughness and resistance to abrasion. It is done by using AASHTO T 96 or ASTM C 131: Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in Los Angeles Machine. [9, 12, 23].

3.4. Admixtures

Admixtures are products added to fresh concrete to obtain certain specific properties. They can be accelerators, retarders and water-reducing agents used to obtain specific properties such as increasing workability, reducing absorption of water or shortening setting time. Some admixtures affect properties of harden concrete by increasing strength and durability. Dosage of admixtures are specified by the manufacturer (sikalite, etc). They must comply with ASTM C494/494M and ASTM C260 respectively for chemical and air-entraining admixtures. [9, 12, 23].

3.5. Water

The quality of water used for mixing concrete intended for paving blocks should be clean and free from all forms of impurities as well as salts that can affect the final strength of the products. It activates hydration of cement and forms a plastic mass. As it sets completely concrete becomes hard mass. Excessive water in a concrete mix may facilitate easy placement but can lower the quality of the finish product in terms of strength. Water renders concrete workable which means water makes it possible to mix the concrete with ease and place in its final position [9, 12, 23, 41].

3.6. Grading of aggregates

Grading of aggregates refers to the distribution of particles sizes within an aggregate material, such as sand, gravel or crushed stone. It involves separating the aggregate into different sizes and determining the percentage. It is an important characteristic of aggregates, as it affects their performance in various applications such as concrete, drainage and asphalt.

The grading of aggregates is typically determined using a sieve analysis test, which involves passing aggregates through a series of sieves with different mesh sizes. The percentage of materials retained on each sieve is then calculated to determine the grading curve. This grading cure is represented as a graph showing the percentage of materials passing through each sieve size [15, 16, 31].

A well graded material has a smooth, continuous curve indicating good distribution of particle sizes and also facilitate compaction. Poorly graded materials has a curve with gaps or irregularities, indicating lack of some particles sizes. However, uniformly graded curve with narrow range of particle sizes, indicates a uniform distribution. Moreover, if an aggregate is unsatisfactorily graded for use on its own, good grading can be achieved by blending two or more materials. This is particularly true for crushed sands [15, 16, 31]. The aggregates used to produce paving blocks are fine and coarse. Coarse aggregates are those passing through 15 mm sieve and retained on 4.7 mm, while fine aggregates are of sizes less than 4.7 mm.

The grading of aggregates is specified in various standards such as ASTM C 33, ASTM C 144, CSA-A23.1-FA1, etc.

Table 1: Coarse aggregates grading for paving blocks (ASTM C33)

Sieve size (mm)	Percentage passing
13,2	100
9,5	90-100
4,75	70-85
2,36	50-65
0,30	10-25
0,15	5-15
0,075	2-10

Table 2: Fine aggregates grading for paving blocks (ASTM C33)

Sieve size (mm)	Percentage passing
9.52	100
4.75	95-100
2.36	80-100
1.18	50-85
0.600	25-60
0.300	5-30
0.150	0-10
0.075	0-1

4. MOULDING PROCESS OF PAVING BLOCKS

The moulding of paving blocks, requires preparing a concrete mixture responding to the desired specifications, filling designated moulds with the mixture, vibrating on the vibration table to remove air bubbles, curing the units to in a controlled environment and then carefully demoulding them, including also selecting the right mould design, ensuring proper concrete consistency and carefully handling blocks during the curing process. [31, 34].

The manufacturing of paving blocks requires concrete be mixed in correct proportions of constituents such as cement, gravel, sand and water. The mix is chosen based on the type of construction, loads to be transmitted, environmental conditions, quality of materials and design mix. However, building codes provides nominal and standard concrete mixes for various construction works based on experience and testing (Mishra, 2017).

4.1. Concrete mix designs

a) Nominal Concrete

Nominal Concrete Mixes are generally 1:2:4 for M15, 1:1.5:3 for M20.

b) Standard Mix

The letter M refers to the mix and the number specifies cube strength at 28 day of the mix in MPa or N/mm^2. The mix grades M10, M15, M20 and M25 corresponds to mix proportions of (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively (Mishra, 2017)

c) Design Concrete Mix for paving blocks

In all mixes the designer specifies the performance of concrete while mix proportions are determined by the producer of the concrete. [18, 41].

Table 3: Technical Specifications

Concrete Grade	Mixture	Comprehensive strength MPa (N/mm^2)
Nominal Concrete Grade		
M5	1:5:10	5 MPa
M7.5	1:4:8	7.5 MPa
M10	1:3:6	10 MPa
M15	1:2:4	15 MPa
M20	1:1.5:3	20 MPa

Standard Concrete Grade		
M25	1:1:2	25 MPa
M30	1:1:1	30 MPa (5/15) type used for pavements
M35, 40, 45, 50, 60		

4.2. Specifications for paving blocks

Specifications can serve as a general guide for producing paving blocks and thickness vary in function of engineering properties of materials used as well as supported loads. However, it's essential to consult local building codes, industry standards for specific requirements and/or qualify civil engineer specialized in this domain [21, 26, 36]. Table below illustrates standard specifications for the design of paving blocks.

Table 4: Design specifications for paving blocks

Thickness (mm)	Traffic type	Recommendation
60	Light	Pedestrian, residential driveways, parks, gardens etc.
80	Medium	Low traffic, urban roads, commercial pavements, etc.
100	Heavy	Factory floors, industrial area, service stations, etc.
120	Very heavy	Ports, dock yards, air-ports, highways, etc.

Note 1: The various thickness of blocks are 60, 80, 100 and 120 mm, but the last two are rarely economical to produce. However, requirements for heavy and very heavy duty blocks should be reviewed by a qualified engineer in the domain [31].

Note 2: The blocks with overall length to thickness ratio of 4:1 or greater must not be used on roads where vehicle traffic is concern. Those with ratios between 4:1 and 3:1 can be used on roads with limited vehicles e.g. residential driveways, while those with ratios of 3:1 or less are quite suitable for all vehicle traffic roads [21, 26, 36].

4.3. Paving blocks production stages

There are several stages involved in the manufacture of concrete paving blocks for example batching, mixing, transportation, placing or moulding, compacting or vibrating, curing and packing finished products. They stages are described in more details here, in order of occurrence: [31].

4.4. Sampling aggregates

Sampling aggregates is the first step for a construction project. It is the process of randomly extracting representative samples from different sources for the purpose of studying their properties leading to informed decisions about their quality, with the purpose of selecting one having required properties which are considered to represent large volumes of aggregates from which samples are extracted. A sample therefore, is a small portion of a large quantity of aggregates such as a quarry, stockpile, etc., from which usable data is needed. In order to obtaining this data, it is advisable to perform 3 to 5 tests on each sample and the average calculated. Therefore, test results reveal average properties of aggregates and also indicate variability. The acceptance or non-acceptance of aggregates is made based on results obtained leading to important decisions only when samples are correctly taken and with respect to a predetermined sampling plan and specifications. [8, 32].

4.4.1. Concrete batching

Good quality concrete is obtained from a proper and accurate measurement of all the quantities of materials used for moulding concrete generally known as concrete batching and different materials must be measured with accuracy. The parameters affecting batching methods are the volume of concrete produced, required daily production rate and the standards of concrete. For most important works weigh batching is recommended. Concreting work starts with batching, mixing, transporting, placing, vibrating and packing. Where works are important weigh batching is recommended. Concrete batching is achieved using two methods: [31, 32, 41].

- Weigh batching
- Volume batching

a) Weight batching

Weight batching is more preferable than volume batching, since it provides more accurate and uniform ratios of all materials used. It doesn't have uncertainties related to bulking. If large weighing scales are not available, then mixing by volume is usually the only practical option. [31, 32].

b) Volume batching

This method is best for small volumes of concreting and involves the use of:

- Gauge boxes of known volume to measure the proportions of constituents.
- The volume of each gauge box must be equal to that of a bag of cement. The best method is to fill the material loosely in the boxes without compaction.
- A bucket levelled with a straight edge or a fabricated gauge box is best. [31, 32].

c) Measuring water for mixing concrete

The quantity of water added to a mix is critical to the final strength of concrete. If water is insufficient the chemical reaction of cement will be incomplete and the workability of the mixture will not be achieved. However, if too much is introduced it will replace aggregates in the mixture leading to a low quality concrete. To obtain good workability and maximum strength of concrete consider a water: cement ratio ranging from 0.5 to 0.6 by weight when mixing manually and from 0.4 to 0.45 by weight when using a concrete mixer [32, 41].

Note: The water: cement ratio includes water contain in aggregate. The actual volume of water to be added must be adjusted depending on the state of dryness or wetness of aggregate.

4.4.2. Mixing concrete

The manufacturing process of paving blocks is a precise operation with a lot of quality control to ensure high quality products are produced. One of these controls require constituents like aggregate, cement, water and admixtures be combined in correct proportions and well mixed to form a homogeneous mixture and achieving acceptable grade of paving blocks. When moulding different grades of blocks, materials must be combined according to the mix design to achieve the desired strength. Mixing concrete is a complex process that requires care and producing good quality concrete requires the respect of standards and specifications during the process. [31, 32, 41].

4.4.2.1. Mixing methods

Proper and sufficient mixing of materials is essential for the production of uniform concrete and the process must ensure concrete is homogeneous and consistent. The mixture depends on the strength to be achieved. In the case of a mix ratio of 1: 3: 6, it means 1 part cement, 3 part sand, and 6 part gravel to be combined for concrete. The most common concrete mixing methods used on construction sites are: [31, 32].

- Manual concrete mixing
- Mixing concrete with a mixer

a) Manual mixing

Manual concrete mixing is recommended for small concreting works. This method requires special skills and care during the process for the production of good quality paving blocks. Precautions and standard procedures prescribed for manual concrete mixing must be respected during the process. For this method to achieve sufficient strength compared to mixing with mixer, it is advisable to introduce 10% more cement to compensate for the inferior concrete produced. [9, 42]. If manual concrete mixing is the only means, ensure the respect of standards as follows:

- Mixing must be done over an impervious concrete slab to prevent loss of water.
- Measure and spread evenly fine aggregate, then spread cement over it.
- Mix the cement and fine aggregate on the platform three times dry until the mix is homogeneous, having a uniform colour.
- Measure and spread a uniform layer of coarse aggregate over the mixture of fine aggregate and cement.
- Add water and mix until the concrete appears to be homogeneous and the desired consistency is obtained.

Finally the concrete sample is obtained.

Figure 3: Manual concrete mixing

b) Mixing with a mixer

For many construction sites, there is usually need to mix concrete in a proper manner in order to end up with a mixture with the right form. When it comes to large scale volumes or high quality work, mixing concrete with a mixer is the most convenient and quick method for producing high quality concrete. The use of the concrete mixer for mixing is not only efficient but also economical when large quantities of concrete are produced. Some mixers produce concrete batch by batch, whereas continuous mixers produce concrete continuously without stoppage till such time the plant is working. The process is continuous and the material for the next batch are is filled by screw feeders and they are continuously mixed and discharged [31, 32, 34].


Figure 4: Mixing with a mixer

c) Concrete transportation

Concrete transportation for the moulding paving blocks must be done before setting time, without letting it loss homogeneity obtained at time mixing until it reaches moulding station [31, 32, 42]. It is done using the following methods:

- Mortar Pan
- Wheelbarrows
- Concrete buckets
- Dumpers

	
Dumper	**Wheelbarrow**
	
Concrete buckets	**Mortar Pan**

Figure 5: Concrete transportation equipment

d) Moulding of paving blocks

Before starting moulding of paving blocks, a careful consideration is made in choosing the appropriate type of materials such as cement, coarse and fine aggregates based on intended application and the desired strength as well as the required equipment. Further select or design the mould with the desired shape, size and interlocking features and finally apply a release agent inside the mould to facilitate easy removal of the blocks. The selection of the type of mould depends on specifications and exigencies of the client including the availability of technical expertise. There are two methods for the production of paving blocks. That is wet cast technique and hydraulic press technique. In the case of this research, wet cast technique is used, since it concentrates basically on small or local manufacturers similar to our case. [31]. This technique is used to produce concrete blocks with a unique appearance, design and texture requiring high strength and finishing. In general plastic moulds are used because of economical price, durability, easy handling, low maintenance, producing consistent quality blocks and perfect interlock. [31].

The procedure consist of filling concrete into the moulds and progressive compaction through vibration until expected height is obtained. Variations of density can occur, if gauged quantities are not consistent or the mix is not uniformly distributed within the mould. [9].

Figure 6: Types of plastic moulds

e) Compaction

Compaction is the process of densifying a product by removing air bubbles and voids, eliminating segregation that occurred and forming a dense homogeneous concrete block. This is especially achieved through vibration on the vibration table, since voids are essentially responsible for the reduction of concrete strength. This implies that the density and durability of concrete depends on highly level of compaction [32].The maximum period of vibration is determined through experiments from equipment which is between 3 and 12 seconds. Good compaction is very difficult to obtain with thick blocks and those with acute angles. Therefore concrete blocks thicker than 80 mm are rarely produced. The frequency and intensity of vibration should be optimized for specific materials used and the number of blocks being produced per cycle [31].

Figure 7: Vibration table

f) Curing

Concrete gains strength and hardness due to chemical reactions between cement and water. This action needs moisture, favorable temperature and time referred to as the curing period. The curing of freshly produced concrete is very important for optimum strength and durability. As such, sufficient amount of water should be made available for this task to permit concrete gain full strength. The process of keeping concrete damp for this purpose is known as curing [12, 31, 32, 34, 41].

The objective of curing is to prevent the loss of moisture from concrete due to evaporation, supply additional moisture and moisture to accelerate the duration to gain strength whenever need arises. Cure concrete for a recommended period of at least three weeks and should not be less than seven days.

Concrete can be kept moist by various means consisting of either supplying extra moisture during early hardening by spraying, sprinkling, etc., or avoiding loss of moisture by sealing the surface with membrane formed curing compounds.

4.5. Quality control

Quality control is a systematic process to ensure products meet well-established standards, requirements and client's expectations. It comprises of monitoring and controlling various stages of production or delivery of services to early identify and correct errors or deviations that occur. One of the greatest challenges in moulding blocks is to logically achieve products conforming to specified requirements [15, 16, 42]. Quality control of a construction site likewise that of paving blocks is accomplished in three distinct stages that is control before, during and after moulding.

After mixing and removing concrete from the mixer, quality checks are conducted on site by taking concrete samples. Generally workability, cohesiveness and compressive strength tests are conducted on site.

A cube test is performed to check compressive strength, while workability is checked by conducting various tests like Slump test, Compacting factor test and Vee-Bee test.

a) Quality control before moulding paving blocks

The slump test is the simplest workability test for paving blocks with less expenses providing results immediately. It determines the compacting energy when moulding blocks and the concrete used for this test must correspond to the desired proportions and specifications of the project. This control is performed using a slump cone to verify the workability of concrete mix prepared on the site. A workable concrete is one that can be easily mixed, placed, and compacted. The test is performed from batch to batch ensuring respect of the quality of concrete. The test is performed by filling the slump cone with concrete in 3 layers of 100 mm each and compacting 25 times evenly over the surface. Level the surface after third layer and remove extra concrete before removing the slump cone by lifting it straight up, avoiding any lateral movement. Measure the distance between the top of the original concrete surface and that of the slump concrete surface. The distance is the slump value [15, 16, 42].

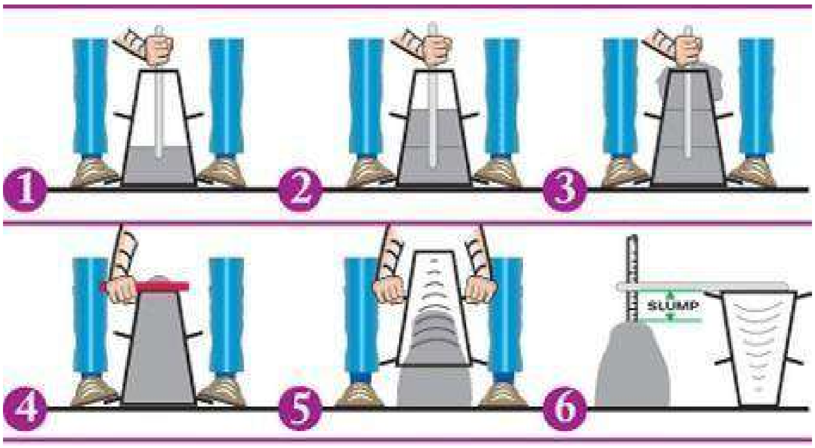

Figure 8: Slump test

During this operation record the results since they represent the slump value that is used to estimate concrete workability. High slump value signifies a more workable mix, while low value signifies a less workable mix [15, 16].

Table 5: Interpretation of slump test

Slump (mm)	State of concrete	Compaction or vibration
0-20	Very stiff mix	Mechanical vibration
25 to 50	Still	Good Vibration (manual or mechanical)
50 to 90	Plastic	Normal vibration
100 to 130	Soft or watery	Pricking or Knocking the formwork
140	Very soft or Very Watery	Light pricking or light knocking

b) Quality control during moulding paving blocks

Quality control when moulding paving blocks is crucial to ensure final products meet required standards. Therefore, thorough supervision when producing paving blocks is very necessary at all levels of operations involved in the process such as batching, mixing, transporting, moulding, compacting and curing including materials. Verify the functionality of all equipment and their operators, making sure they correspond to specifications. Keep records especially those related to quality control to track the results of inspections, tests and checks [31].

c) Quality control after moulding paving blocks

The following field tests help in ascertaining good quality paving blocks.

- A good paving block should have rectangular plane surface and uniform size. This field check is done through observation.
- A good paving block will have uniform colour throughout. This observation may be made before purchasing the paving block.
- A few blocks may be broken and their cross-section observed. The section should be homogeneous, compact and free from defects like holes and lumps.
- If two paving block are struck with each other they should produce clear ringing sound. The sound should not be dull.
- Make a simple field test by scratching paving block with a nail. If no impression is marked on the surface, the paving block is sufficiently hard.
- The presence of alkalis in paving block is not desirable because they form patches of gray powder by absorbing moisture. [15, 16].

d) Benefits of quality control

- Improved customer satisfaction by delivery of quality products or services that meets customer expectations.
- Minimising waste, rework and defects to reduce costs and improve efficiency.
- Optimising processes and improving efficiency to increase productivity.
- Enhanced reputation is established for delivering quality products or services.
- Compliance is ensured with regulatory requirements and industry standards.

4.5.1. Laboratory test on strength of concrete

The strength of a concrete sample cured and tested under required conditions at a given period depends on the water cement ratio and degree of compaction.

i. Compressive strength of paving blocks

The compressive strength of paving block is the ability to withstand crushing forces. It is one of the important properties of paving blocks and is a measure of its ability to resist cracking under compressive loads. It depends on factors like water-cement ratio, cement strength, properties of concrete material, quality control, etc. The test for compressive strength is performed either on a cube or cylinder. [12, 15, 16, 19, 34]. This test on paving blocks shall consist of a single sample of units in a batch provided from every 1000 m² of units. A batch with a unit area less than 1000 m² may be added to the untested previous batches as the case may be for testing purposes. The number of specimens from each sample shall be eight in number and each of the samples shall be tested to determine their characteristic compressive strength at 28 days [34]. This test makes it possible to judge whether concreting was properly executed, while its strength varies between 30 MPa and 60 MPa but private yards with no traffic, can be ≥25 MPa. Cubic samples 15x15x15 cm are used for crushing after rotating them at 90° to decrease the amount of friction caused by rough finishing. [12, 15, 16, 34].

The concrete for the test prepared with definite proportions which are tempered properly to eliminate voids. After 24 hours moulds are removed and test samples immense in water for curing. The top surface is made even and smooth by putting cement paste and spreading smoothly on whole area. The teste is carried out with a compression testing machine after 7 to 28 days of curing by gradually applying loads at the rate of 14 N/mm² per minute failure. The compressive strength is found by dividing the load at failure by cross sectional area of the sample. [12, 15, 16, 34].

$$\textbf{Compressive Strength } (\sigma_{kc}) = \frac{\text{Load at failure}}{\text{Cross section area}}$$

Table 6: Different grades of paving blocks (IS 15658: 2006)

Grade classification	σ_{kc} of 15 cm cube at 28 days (N/mm²)	Recommendation use of blocks
M25 - M30	25-30	Non-traffic
M30 –M35	30-35	Light traffic
M35 - M40	35-40	Medium traffic
M45 - M59	45-59	Heavy traffic
M60 +	60 +	Very heavy traffic

Note: Test at least three samples for a selected age.

ii. Tensile strength of concrete

The tensile Strength of concrete refers to the maximum stress it can withstand when subjected to a tensile force without failing or cracking. It is the measure of concretes ability to resist pulling or stretching forces. It obtained either by direct methods, or indirect methods [12, 15, 16, 34].

- Direct methods suffer from a number of difficulties related to holding samples properly in the testing machine without introducing stress concentration and to the application of load without eccentricity.

$$\sigma_{st} = 2P/\pi DL$$

Splitting Tensile Strength

P: applied compressive load
D: diameter of sample
L: length of sample

Note: The value recommended according to NF 18-408 varies between 32-35MPa.

4.6. Management of Hygiene and Safety measures

Hygiene and safety measures are crucial during the production of paving blocks to prevent environmental pollution and health related problems. The implementation of these measures is very important because they can create a safe and healthy working environment, by reducing the risk of accidents and injuries and protecting the environment. Therefore the achievements of these measures requires that those participating in the project observe appropriate health and safety requirements. This is to render the site safe and free from any safety and health risk. Furthermore, they have to ensure safe working conditions of everyone present on site, to the extent of controlling equipment and the methods of work and expression of views on the working procedures adopted as they may affect safety and health. As a matter of fact most accidents on the site are due to carelessness, technical faults, inappropriate use of tools, wrong reaction of workers and lack of proper awareness about potential sources of accidents. Knowing the sources of potential and predictable accidents means that they can be prevented. To conveniently handle safety and health hazards, the following key measures to be considered: personal protection equipment, workplace safety, environmental safety, health safety and hygiene safety [43, 44].

Personal protection equipment refers to the equipment and clothing worn by workers to protect themselves from hazards and risk. They are designed to prevent or reduce the risks of injury or illness from physical, chemical, or other hazards. They include helmets for protection against falling objects, safety glasses to protect eyes from flying particles and chemicals splashes, ear protectors to guard against loud noise from equipment, mask when working in a dusty area to avoid inhaling dust and particles, gloves to protect hands from cuts, abrasions and chemical exposure and safety shoes to protect feet from heavy objects and equipment injury [43, 44].

Workplace safety is the practice and procedure adopted to protect employees, contractors and visitors against harm from injury or illness while working on the job. The procedure involves identifying and mitigating hazards, providing training and equipment and promoting a culture of safety within the organization. The main activity include the identification of potential hazards, such as chemical exposure, falling objects or equipment malfunctions and evaluate the likelihood and potential impact of identified hazards, establish procedures for reporting and investigating incidents, keep walkways and the workplace clear of debris and obstacles, ensure adequate lighting around production area and provide a first aid kit as well as a trained first aider on the site [43, 44]. Environmental safety is the procedure of protecting the natural environment and preventing harm to humans, animals and plants from environmental hazards. It consists of identifying and mitigating environmental risks, reducing pollution and promoting sustainable practices. The key elements include reducing air pollution from industrial processes and other sources, protecting water sources, reducing water pollution and promoting water efficient practices, managing waste properly by reducing, reusing and recycling waste to minimize environmental impact [43, 44].

Waste management is the process used to handle, store, transport and dispose of waste in a manner that minimizes harm to humans, animals and the environment. Common type of waste generated on the project sites are solid and liquid waste. The management of the waste can involve the separation of waste into various categories for proper handling and disposal, storage at convenient places on site in such a way to prevent leakage, spillage or other environmental hazards, regular collection to prevent accumulation and environmental harm, transportation to disposal points in a safe and environmental friendly manner and dispose through environmental friendly methods, such as landfilling, incineration or composting [43, 44]. Health and hygiene are essential aspects for maintaining a clean and safe environment, at workplaces. The key aspects of health and hygiene include particularly regular hands washing with water and soap especially after using the toilet, before meals and after blowing one's nostrils, coughing and sneezing, maintaining personal cleanliness, handling and preparing food safely to prevent foodborne diseases and maintaining a clean environment including regular cleaning and disinfection of surfaces, floors and facilities [43, 44].

CONCLUSION

This research has brought to light the origin of concrete interlocking paving blocks in the world and how it later gained recognition overseas. Particular, interest focused on the materials, equipment, labour force, blocks production and production process, while incorporation especially the labour base technology approach a method used to support beneficiaries associated with the concrete paving block project. The research recommends respect of standards and work design and coordinated by a qualified paving engineer. Paving blocks considered as the most convenient for use are those exhibiting very high quality with thickness ranging between 60 mm and 80 mm because of their economical use. However, thicker blocks can only be used with the recommendation of a civil engineer specialised in the domain. In recent years, there is a proliferation of concrete paving block producers and most of them don't possess proven expertise. This study therefore aims at providing more technical information on materials and equipment quality, design options and overall operation leading to the production of paving blocks with desired characteristics thereby bridging the currently existing gap. The labour based technology is used for the development of basic infrastructure while creating employment, generating income, providing technical guidance and capacity building for planning and execution of different types of projects.

The sector can provide several advantages such as natural resource management, infrastructural development, and basic services to improve human capabilities and productivity of labour. It can provide guarantee of employment by ensuring stable employment and providing minimum work wages, with decent working conditions.

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