# STRUCTURE CONSTRUCTION MATERIALS: CASTING AND STRENGTH OF CONCRETE ARCH PAN

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## ABSTRACT

Nowadays, the methods and the cost of constructions rapidly changes parallel to the current technological development. Due to the increase of the materials cost in the construction, new types of construction methods have been introduced. Permanent formwork is one of the methods that is used to reduce the wastage and construction cost. The advantage of the permanent formwork is where the formwork will become a part of the structure. This research is to determine the optimal height of arch pan under uniformly distributed load from the slab and to achieve the required load of 100kg or 1000N of concrete arch pan without cracking. The construction process is important in order to produce the standard quality with preferable size of the arch pan formwork. Plastic meshes and plastic netting were laid inside along the length of the concrete arch pan which acts as a flexural reinforcement. Based on the arch pan design calculation, it shows that the maximum height of the arch pan is 75mm and the required load for the concrete arch pan has successfully passed without cracking. The strength of concrete arch pan increases with the use of plastic mesh and plastic netting as a reinforcement.

**ABSTRAK**

Pada masa kini, kaedah dan kos pembinaan pesat berubah selari dengan arus pembangunan teknologi. Disebabkan oleh kenaikan kos bahan-bahan dalam pembinaan, kaedah jenis baru telah diperkenalkan. Acuan tetap adalah salah satu kaedah yang digunakan untuk mengurangkan pembaziran dan kos pembinaan. Kelebihan acuan tetap adalah di mana acuan tersebut akan kekal selama-lamanya di dalam struktur tersebut. Dengan itu kos pembinaan dapat dikurang daripada menggunakan perancah dalam pembinaan. Tujuan kajian adalah untuk mengenal pasti ketinggian optimum 'arch pan'dan untuk mencapai bebanan yang diperlukan iaitu 100kg atau 1000N yang mana konkrit 'arch pan' tersebut tidak akan retak. Proses pembinaan adalah penting untuk menghasilkan acuan 'arch pan' yang berkualiti dengan saiz yang telah ditetapkan. Plastik 'mesh' dan plastic 'netting' diletakkan dispanjang arch pan yang mana bertindak sebagai tetulang lenturan. Berdasarkan pengiraan 'arch pan', ketinggian optimum untuk 'arch pan' ialah 75mm dan bebanan yang diperlukan untuk 'arch pan' telah Berjaya dicapai tanpa retak. Kekuatan 'arch pan' juga meningkat dengan penggunaan plastic 'mesh' dan plastic 'netting' sebagai tetulang.

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

In the construction industry, there are always new technologies developed especially in building construction. Nowadays, permanent formwork have emerged and been applied widely rather than using conventional method; temporary formwork which is more expensive and produce a lot of wastage; in term of time and workers. Permanent formwork is a structural element that contains the placed concrete, mould it to the required dimensions and it will remain in place for the lifetime of the structure. In this research, it is focusing on produce standard design of arch pan formwork for the upper floor slab construction.

For the purpose of justifying this arch pan as permanent formwork is applicable used, several tests have been conducted to calculate the ultimate load that can be resisted for the arch pan. Generally, the application of permanent formwork will reduce number of workers and consuming time, thus it literally will cut the construction cost. It will also reduce the construction wastage and working load on-site.

## 1.2 Problem Statement

Due to the globalization era, in the process of nurturing the construction industry towards less labor dependency, Malaysia's government through the collaboration of Construction Industry Development Board (CIDB), encourage to news technologies and ideas towards the construction industry. The news technologies are crucial in order to reduce the cost and wastage of the construction.

In construction industry, small contractors face the problem to construct more than one storey building because they lack of scaffolds in order to construct for the next floor. The problem is they need to allocate a lot of money to rent the scaffolds. Thus, one of the best ways to overcome this problem is through the application of permanent formwork. Basically, the used of permanent formwork will reduce the time consumption, labor and also the construction cost. This is due to the less of worker on site. There's no need to dismantle the formwork as permanent formwork will remain on the structures for the life span of the structures.

## 1.3 Objectives of Study

The objectives of this research are as follows:

- ✓ To determine the optimal height of the arch pan under uniformly distributed loading from the slab.
- ✓ To cast arch pan and that can carry a load of 100kg or 1kN without cracking.
- ✓ To study the effects of introducing meshes laid inside along the length of the arch pan as flexural reinforcements.

## 1.4 Scope of Study

This research will determine the optimum height of arch pan for permanent formwork. Generally, this research comprehends the application of permanent formwork particularly for the upper floor slab of the house structures. Basically, the main focus is on the design procedures of the arch pan formwork to gain the optimum height of concrete arch pan.

To cast the concrete arch pan which can carrying load of 100kg or 1kN without cracking. On the other hand, the tests has been conducted to compares the flexural strength of concrete arch pan and tensile strength of plastic mesh netting that used as the reinforcement structures in the concrete arch pan.

## 1.5 Significance of Study

Generally, permanent formwork has become an essential part of the construction process. The benefits of permanent formwork are; save site labor on-site construction, reduce the falsework and economical. This research is to introduce an alternative ways of formwork construction; instead of conventional/temporary formwork especially to the contractors. Besides that, it can reduce the construction and maintenance cost.

In addition, permanent formwork can also be devised to contribute to the strength of the reinforced concrete structure or provide a high quality surface for it. This research is mainly on producing the standard design of arch pan formwork.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Formwork

Formwork is the surface, support and framing used to define the shape of concrete until the concrete is self-supporting. The assembly of formwork includes; the forms on which the concrete is poured, any bracing added to ensure stability also the support to withstand the loads imposed by the forms and concrete.

The control measures must be implemented in an order of priority and before the work commences. The use of the following systems is not recommended when erecting, altering or dismantling formwork; travel restraint harness systems to prevent a fall and fall arrest harness systems to arrest a fall.

### 2.1.1 Safe Design of Formwork

The building designers, including engineers and architects, must consider the 'buildability' of a structure or building with the objective of producing a design that minimizes the risk of injury during the construction. Formwork designers should consider the work practices necessary to carry the erection and dismantling of the formwork as designed to identify the health and safety risks and controls at the design stage.

The following design measures could be considered to minimize the exposure to risk of injury during the formwork construction; reduce variations in the floor depth – has one consistent depth, reduce the number of columns required and where columns do exist – eliminate capitals and dropdowns, utilize precast columns and beams – reduce the risks associated with fixing reinforcement, erecting and stripping column formwork and pouring on-site and also reduce the cantilevered floor sections.

When specifying the design of the formwork, a formwork designer must allow for all the expected loads applied during three phases of construction; during formwork erecting, during concrete pouring and after concrete pouring is complete until the structure is self-supported.

## 2.2 Factors That Can Affect Concrete Casting Quality

### 2.2.1 Unsteady Weather

Unsteady weather has to be taken in consideration when we execute concrete work.

### 2.2.2 Hot Weather

After the concrete floor work is executed, cover the floor with plastic so the moisture doesn't dry out too fast. If the sun shines very strong on the concrete, then it is in many cases necessary to water under the plastic in simple intervals. We can see on the surface when it is necessary to prevent more from dehydration. Then we will see some white spots who drying to fast. To fast dehydration will lead to cracks in the construction.

### 2.2.3 Cold Weather

When it is very cold weather, it is necessary to prevent the concrete from frost. If the concrete freeze, the hardening process will stop and we will get a weak construction with pores, cracks and corrosion on the reinforcement. To prevent from this risky influence, there are several things to implement:

- ✓ Chemical admixtures in the concrete
- ✓ Hot water in the concrete mixture
- ✓ Covering with winter mat
- ✓ Cover with tents and heating up
- ✓ Heating cables tied to the reinforcement

### 2.2.4 Rainy Weather

Normally it is not a risk to cast concrete in a rainy weather, but to execute concrete floor there is a risk to get a rough surface. That can gives us extra cost considering integrally cast and smoothing out the surface.

## 2.3 The Concept of Arch

Arches are constructed in a variety of forms; straight or curve components. They are used to support roofs and bridge decks and vary in span from a few meters in a roof support system to several hundred meters in bridges. The arches can support compressive and tensile loads, which can be analyzed into 3-pinned arch (statically determinate); two-hinge arch, tied arch, fixed arch and 2-pinned arch (statically indeterminate); three-hinge arch.

This research is focusing on two-pinned symmetrical parabolic arch. Figure 2.0 shows the parabolic arch.

Parabolic Arch Equation;

$$y = kx(L - x)$$

Symmetrical Parabolic Arch Equation;

$$y = \frac{4hx(L - x)}{L^2}$$

Where;

$$x = \frac{4h}{L^2}$$

h = height of arch

L = length of span

x = vertical distance

y = horizontal distance

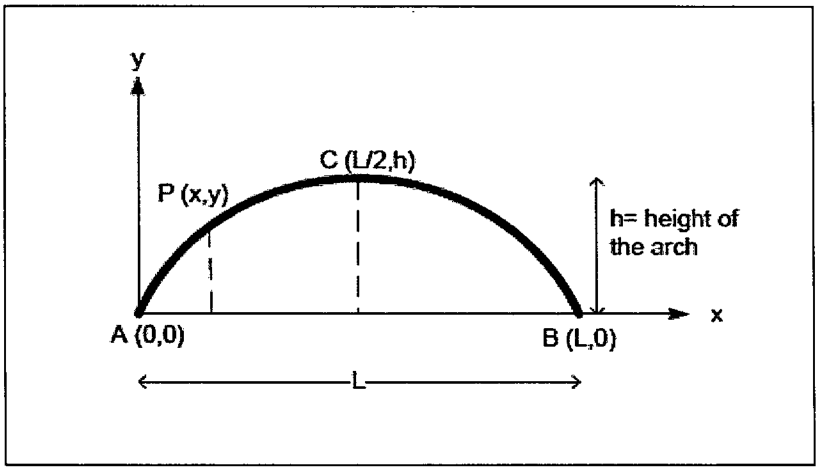


**Figure 2.1**: Parabolic Arch.

## 2.4 The Concept of Arch In Slab Construction

**Figure 2.2** and **2.3**, both illustrate the use of a closely meshed reinforcing agent which proves of great as sistance in constructive work in many cases. With a small mesh material, the concrete dumped directly in upon the previous bent up forms, which is just enough of the concrete passing through the meshes to provide a rough surface for plastering on the ceiling that is formed by the underside of the arch. The ends of bent-up sheets of reinforcing rest upon the flanges of the I-beams in **Figure 2.2** or fastened to the beam reinforcing rods for construction in

**Figure 2.3**. No forms or centering for the arch are necessary in this construction. The arched type floor is used for carrying heavy loads.

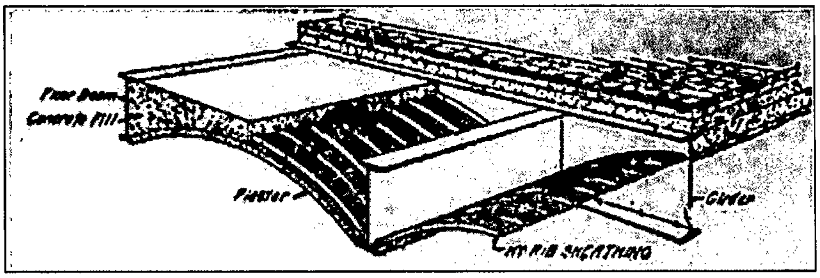

**Figure 2.2**: Arched Floors.

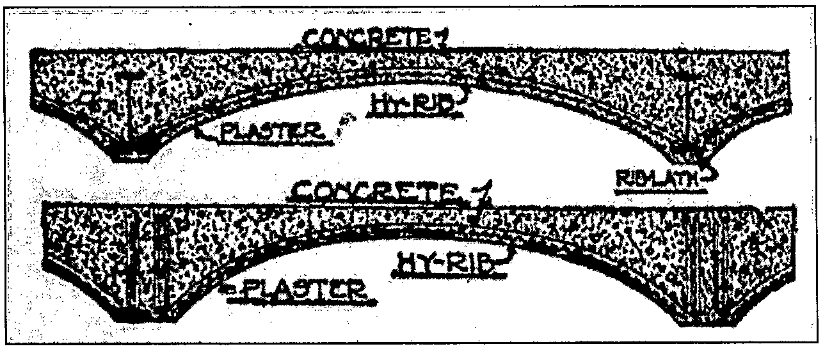


**Figure 2.3**: Arched Slab Floor Construction.

The centers for floor slabs between steel I-Beam are made by suspending joist from the beam flanges and covering them with lagging. Frequently, the joist and lagging are framed together into the panels of suitable size for erecting and carrying. The slab construction is simple in either case; slabs without haunches or plain arches form the filling between the beams. **Figures 2.4** shows an arch slab center; plain hook bolts, with a nut on the lower end, passing through holes in the joists which are commonly employed.

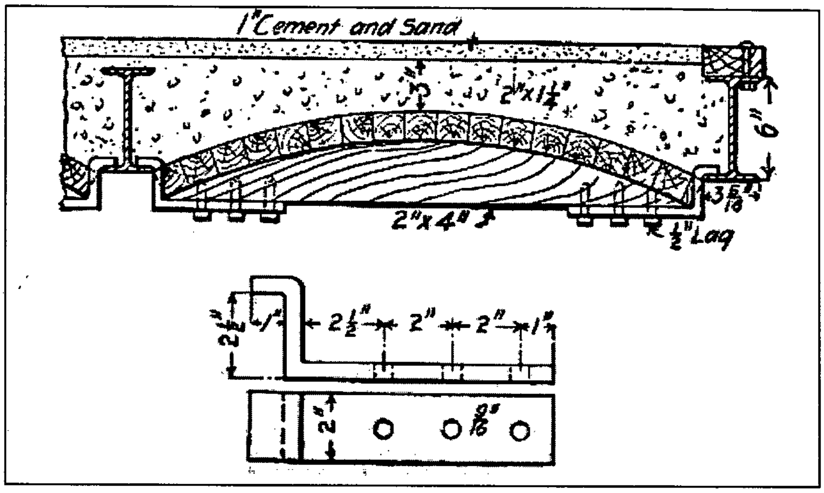


**Figure 2.4:** Form for Arch Slab Between I-Beams.

### 2.4.1 Brick Arched Floor System

The construction of brick arch floor consists of a single arch of unmortar brick, typically only wythe or 4 inches thick and capable of spanning 4 to 8 feet with a center rise of approximately 1/8 of the span. The spring line of the arch was constructed on top of the bottom flange of the supporting beams. Whereas, the space above the arch was filled with concrete that sometimes had wood nailed strips embedded in the top of the slab. Commonly, the tie rod were placed about 1/3 the height of the beam and were spaced from 4 to 6 feet on center. The entire system had to be built on formwork, which supported by brick. This flooring system will weigh about seventy pounds to the foot, and has been practically superseded by the lighter constructions employing terra-cotta arches or concrete.

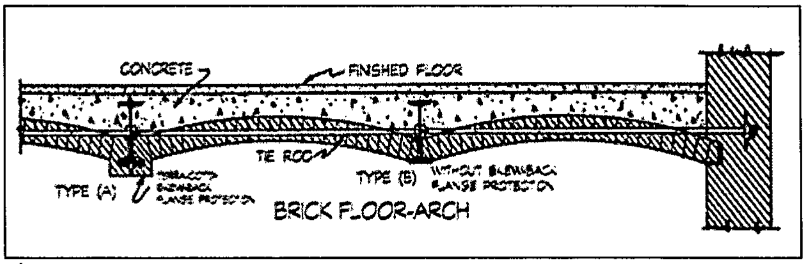


**Figure 2.5:** Brick Arched Floor System.

### 2.4.2 Roebling Arched Floor Systems

The Roebling floor possesses the following advantages; First, a flat ceiling; Second, a continuous air space between the floor arch and the ceiling; Third, ease of adaptation to any building or any load; Fourth, its lightness as compared with the most tile ceilings; Fifth, there are no need for wood centering – the wire arches forming the support for the concrete during the laying. The carrying capacity range between 1000 to 2400 pounds per square feet, on spans of 4 ½ to 5 feet.

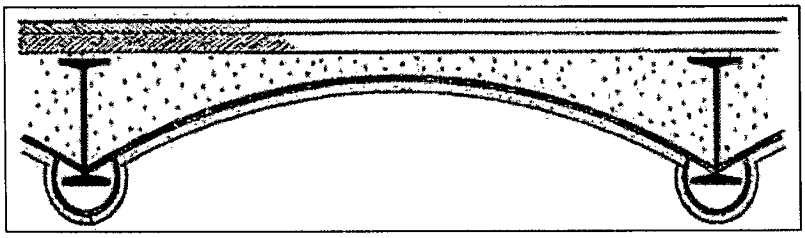

**Figure 2.6(a):** Roebling Floor.

**Figure 2.6(b)** shows the Roebling System is where the concrete is used as an arch and not as a beam in the floor. The first step is to spring between the beams an arch of wire cloth shown at a, stiffened at short intervals by steel rods b, the ends of the arch resting on the lower flanges of the beams. On this base is laid the arched concrete filing shown at c, which, on becoming hard, transmits the loads directly to the beams. The ceiling is held by a similar wire net, fastened to stiffening rods d, that attached to the lower flanges of the beams by clamps also to the arch netting by tie-rods as at g.

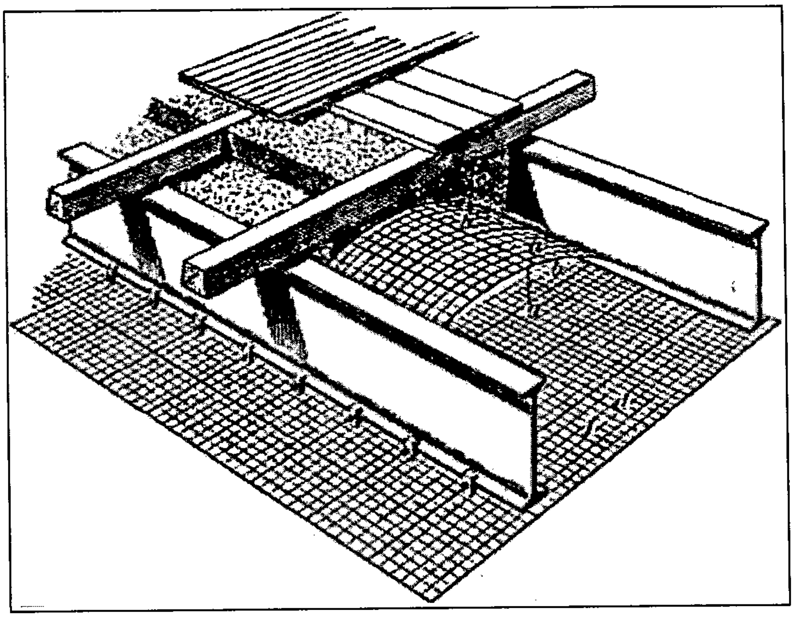

**Figure 2.6(b):** Roebling Construction Method.

### 2.4.3 Clay Tile Arched Floor Systems

Typically, the arches covered with a concrete topping, and often had plaster applied directly to the soffit of the exposed tiles. These types of floor systems were stronger and stiffer than that calculated by the simple analysis of conventional method used. In additional, the clay tiles provide two purposes; by providing the fire protection for the structural steel and transferring loads to the supporting beams.

Basically, there are two types of clay tiles arched floor systems; flat, **Figure 2.7** and segmental, **Figure 2.8**. Both systems were constructed by using hollow clay tiles of varying sizes and shapes with the internal opening cells that similar with today's hollow masonry blocks. During the construction, both of the arches were constructed on the timber formwork platforms to secure the tiles in place.

There are two type of flat clay tiles floor systems; Type I and Type II. For Type I, the load transferred between the beams which are acting as a jack arch with a tapered keystone that is located at the center of the span. The resulting outward horizontal thrust reaction that occurred at the beams was typically resisted through the tie rods that were required both temporarily during the construction of the interior spans and permanently at the end of the spans. For Type II, also referred as the Natco "New York" reinforced flat arch, which is served as a precursor to one and two-way tile joist systems. It is closely spaced by internal reinforcing rods that were embedded between the tiles near the bottom.

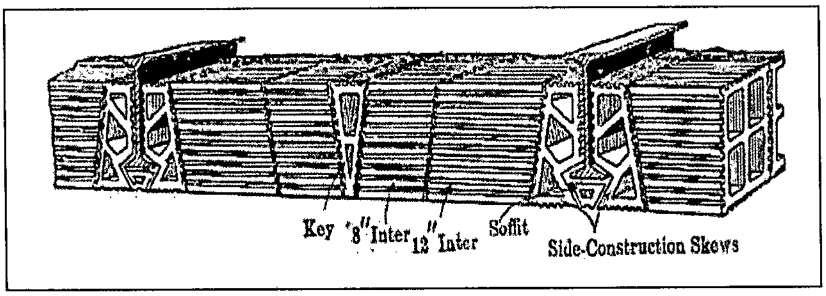


**Figure 2.7(a):** Flat Clay Tile Arched Floor Systems – Type I.

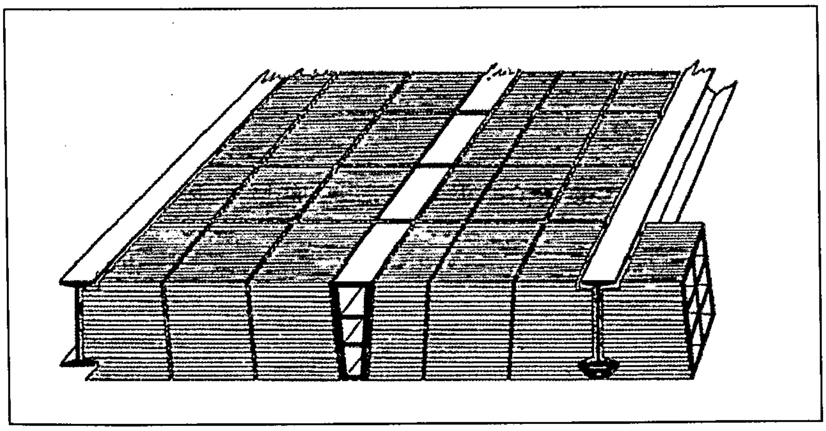

**Figure 2.7(b):** Flat Clay Tile Arched Floor Systems – Type II

Note; Type I = Combination Side and End Construction while Type II = End Construction.

For segmental arch, the clay tiles are arranged in a shallow profile between adjacent parallel beams. Typically, the steel beam were held together with tie rods, which helped to resist the outward thrust that is imposed by the arch on the steel beams, both temporarily during construction and permanently at the end span.

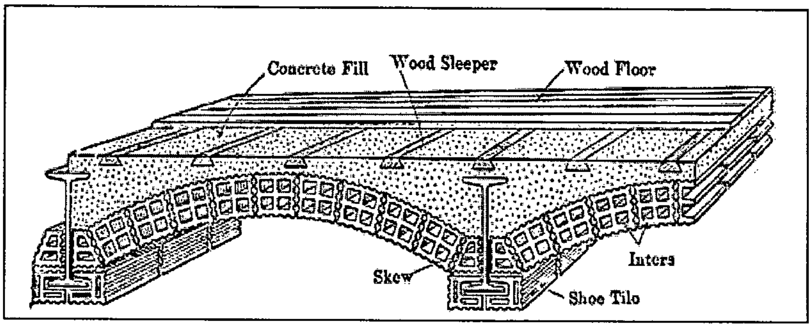


**Figure 2.8:** Segmental Clay Tile Arched Floor Systems.

### 2.4.4 Terra – Cotta Floor Arched Systems

There are two types of terra – cotta floor arches systems; flat, Figure 2.9 and segmental, Figure 3.0. Flat terra – cotta floor arches systems has three method; side method, end method and combination method terra – cotta arch.

For side method arch, the blocks are laid with the webs that parallel to the beams. Usually, side method arches are made of dense terra – cotta and may be obtained of various depth from 6 to 15 inches and should be set with close joints and be thoroughly cemented together. Side method is made to break joints endways, so as to give a bond; and they are usually strong enough for all ordinary floor loads. Generally, the joints in the blocks are made parallel to the sides of the key block, as this gives a uniform pattern which is less expensive than a radial jointing.

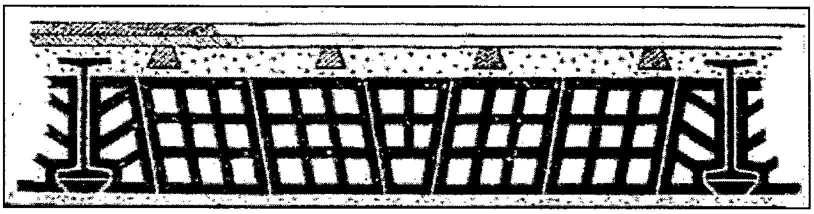

**Figure 2.9(a):** Side Method Terra – Cotta Arch.

For end method, the blocks are usually made of porous terra – cotta and are set end to end, giving greater resistance to the thrust by forming a series of continuous webs from beam to beam. Usually, the blocks are set in continuous lines but not breaking joints.

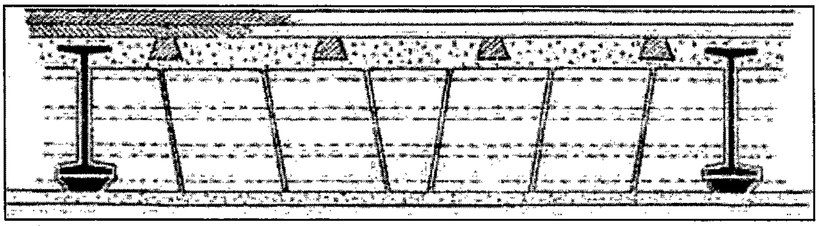

**Figure 2.9(b):** End Method Terra – Cotta Arch.

The combination method is used to gain the extra strength of the end blocks and for the better bearing of the flat skewbacks. So that, the skewbacks are made with many webs and of small sections.

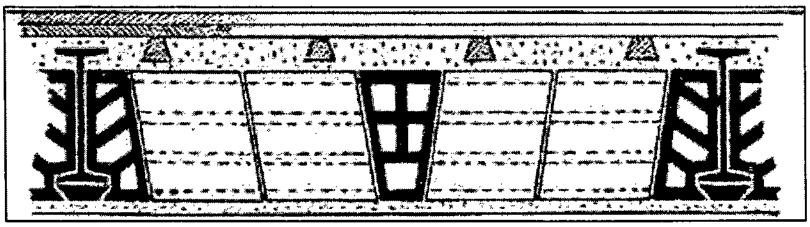

**Figure 2.9(c):** Combination Method Terra – Cotta Arch.