Value Engineering in Arch Bridge Construction

Nadeel Alam[1], Khushal Chaudhari[2], Lalit Khadayte[3], Dr. D. K. Shinde[4]
[1,2,3]*PG Students*, [4]*Associate Professor,*
Production Department, Veermata Jijabai Technological Institute, Mumbai, Maharashtra, India

***Abstract*– The arches are one of the oldest standing bridge structures. These bridges that were made of stone and brick masonry remain operational after hundreds of years. Arch Bridges made of Brickand Stone masonry have stood the test of time for centuries and they are still operational. Arch Bridges carry only compression forces. In the modern era with growing environmental concern and accumulation of waste and pollutant it becomes necessary to adopt sustainable construction techniques. Arch bridges require high initial cost, precision and due to time consuming construction process, very few arch bridges have been built since the early 1900s. Hence the development of flexi Arch bridge. The Flexi Arches can be installed rapidly, in less than a day rather than months, they prove to be economical than other precast bridges, for length of bridges greater more than 30 meters the economy is more as the high initial cost in machinery is taken care. These Arches have all the characteristics of masonry arches.**

***Keywords*–ARCH bridge; bridge; construction**

I. INTRODUCTION

It is no longer sustainable to construct the masonry arch bridges by conventional methods due to the high cost of the skilled workmanship required to build the accurate centring and to give precise shape to the masonry blocks [1]. The Progress on such type of work is usually weather dependent and slow. During the 1950s and 1960s the prestressed concrete/steel beam and slab systems rose to prominence [2]. Their design lives were 120 years but many of these beams and slab bridges have deteriorated after only 20-30 years. 'fle arch' system is a precast type of arch bridge construction, it is constructed and transported on trailers in the form of a flat pack by using a wire rope to carry itsself-weight during the short lifting phase, but it behaves as a masonry arch once in place. The concrete blocks are pre-cast individually, laid horizontallywith a layer connecting material on top [3]. An insitu layer of concrete, 50mm deep in the case of the 9mspan Bridge in Koregaon, Satara is placed on top and allowed to harden to interconnect the blocks (Figure 1). The arch ring can be castedunto 14 meters or as per the requirement of the design, site conditions and available lifting capacity[2]. While lifting, the gaps closes. The arch unit is then placed on a socket or seating units and the self-weight is then transferred from a single point of contact of concrete to the whole surface.

The attributes of strength, stiffness, durability and minimal maintenance of arch bridges is acknowledged by structural engineers throughout the world. In addition, their aesthetic qualities these type of Arch Bridges have no structural steel and hence the life of the structure is increased. These bridges are already in service in Indian cities like Nagpur and Satara.

II. MANUFACTURE AND INSTALLATION

The Arch ring comprises of various blocks.The blocks are precast individually then they are laid contiguously with the top edge touching, in a horizontal line with a layer of reinforcement material (wire rope) placed on top.These blocks are casted individually in a steel mould. The dimension of the mould is as per the size the blocks desired. The casting is done in controlled conditions. After the final setting time (10 hrs) the blocks are removed from the moulds and checked. These blocks are then placed on a flat levelled surface and continuous curing is done for 28 daysto achieve the desired strength.In-situ screed, typically 40-60mm thick, is placed on top and allowed to harden so that the blocks are interconnected when they are being lifted. The strength of the wire ropes used to support blocks is just enough to lift the arch ring.

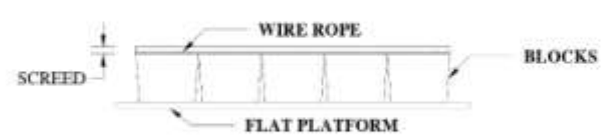


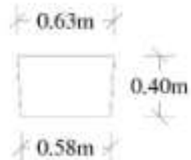
Figure 1: method of Construction of arch unit using pre-cast individual concrete blocks

Usually the width of each arch ring is 1 m but the units can be cast in convenient widths to suit the design requirements, site conditions and available lifting capacity. While lifting these units the gravity helps in closing of the gaps. The tapered shape is given to each block to attain the required shape, less tapered blocks gives flat arches and vice versa.

III. ARCH SYSTEM DETAIL

The 9.21m semi-circular profile arch details are given in Table 1. The 9.21m concrete arch bridge system, as shown in Fig. 2 was backfilled with plum concrete, using granular material and then concrete. The plum concrete was done in three layers. Control samples of concrete from the blocks and screed were tested.Material tests, core cutting test were carried out on samples and the average tensile strength is given in Table 1. The arch was lifted from flat to semicirculararch form by supports at the 6th, 12th and 18th block positions.The blocks used in Korega on Satara project were as per table 1.

Table 1: 9.21m x 4.01m arch details

Block dimensions	
Clear Span	9.21m
Rise	4.01m
Depth of arch ring	0.40m
Width of arch ring:	1.00m
Weight of arch ring:	16.29 tons
Arch ring concrete compressive strength	53N/mm^2
Backfill	Plum concrete to 0.45m above arch extrados

The Concrete Blocks (voussoirs) can be quickly, accurately, and consistently produced with the desired taper in relatively simple shuttering. High quality concrete is to be utilised for the individual precast block units(voussoirs): To enhance the durability of the arch whilst in service. To greatly reduce the variability in the physical properties normally associated with natural stonework. The arch rings are then lifted, transported and placed on precast footings(sockets) at the bridge site and all the self weight is then transferred from tension in the wire ropes to compression in the voussoirs, i.e. it acts in the same way as a conventional masonry arch.

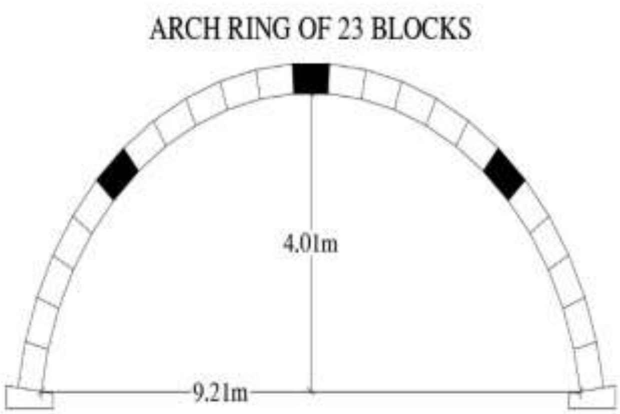


Figure 2:lifting points in arch ring

The fig.2 showing the highlighted blocks(6th,12th,18th) are the lifting points.

Lifting of arch ring

IV. REQUIRED ITEMS FOR SITE AND CASTING YARD

A wide range of equipment are used for construction ranging from bolts to dewatering pump. The essentials are wire ropes, moulds for pier, socket and blocks,channel sections, belts, ratchets, Chain block pulley,polymer slings, drilling machine, pump, blower machine, suitable packing material of wood, steel, safety equipments.

V. PRACTICAL APPLICATIONS

In India 5flexi arch bridges have been constructed so far and over the past fiveyears. The different applications of this system are

- Replacing a bridge that has completed its design life
- widening of existing bridge

VI. BRIDGE WIDENING KOREGAON, SATARA, INDIA

In 2017 the old bridge in the small village of Koregaon, Sarata was to be widened and since the existing bridge was over 124 years old and the need was felt to construct the extension. The bridge is over nilganga river. The construction began in summer as the water level is low, the pcc, foundation was done. As per the site conditions and the design the span of 9.21m and rise of 4.01m was adopted. Each strip weighed 16.29 tons. Each arch ring was placed in 20-25 minutes thus reducing the construction time. The length of this bridge was 45 meters. After placing the Arch Strips grouting is done to ensure that there is surface to surface contact established.

Piers of height 2.5m

Placing of arch strips

The strips are carefully placed on the sockets and the ends of arch ring are adjusted with the help of chain pulleys in order to place the strip horizontally and the surface contact is tried to achieve to avoid the strips from damaging themselves under the self-weight.

Arch strips placed with crane

Brickwork in progress

The brickwork is done to serve as a formwork for plum concrete. It also adds to the aesthetics. The CC brick work can be replaced with precast spandrel walls as per the availability.

Bridge completion

VII. CONCLUSION

- Making the Blocks (voussoirs) with the precise moulds and interconnecting them with wire ropes and screed the arches can be made as per the design with precision without cantering.
- As there is no structural reinforcement thereby reducing the chances of corrosion, the service life of the structure increases
- The lifting time is 20-25 minutes as the speed of placing is far better than precast beams/columns.
- This construction method is faster and simpler, while still achieving the desirable finish of a traditional masonry arch bridge.

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