ALTERNATIVE FOUNDATIONS FOR RESIDENTIAL BUILDINGS

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Abstract— Arches are one of the efficient forms of structural systems. They are widely used in buildings and bridges since ancient times. The behavior of arches depends on the geometric characteristics (i.e. rise, span, thickness and width), materials used for the construction, types of loading and support conditions provided**.** Arches are constructed normally in masonry. Conventionally masonry arches are constructed using Bricks or Stones in cement mortar. Plain cement arches can also be preferred in constructions. This paper presents the effective use of Arches in construction for various purposes which leads to the increase in strength of structures and reduction in the overall cost of construction.

Index Terms—Arch, Crown, style, springing line

I.INTRODUCTION

Arches are known since ancient times and have been used extensively for the construction of bridges. There are several thousand masonry arch road bridges throughout the world, ranging from small span to long multi-span structures. These bridges have given excellent service in terms of strength and durability. In case of buildings arches have also been used to withstand the structural loads above the openings in place of conventional lintels. Now a day's, brick masonry arched panels have been used as roofing elements for low cost buildings to avoid the usage of costly materials like steel and concrete. The use of aches in foundations is very rare even though same has been used extensively for bridges, lintels and roofs. Sarangapani (2002) of Mysore, Nagireddy (2003) of Hyderabad and Pradeep Kumar (2003) of Shimogahave successfully used stone masonry arches in foundations for walls as a replacement to the conventional spread footings. There is around 40 to 50 percent reduction in cost of foundation if arches are used instead of spread footings. Conventionally spread footings are widely used for wall foundations. This type of constructing foundation in India goes back to great antiquity. The modern spread footing consists of stone masonry in 1:6 cement mortars of 5 to 6 courses. Minimum width of the footing at the bottom being 1m.

Arch can also be defined as a beam, which is curved in the lateral direction. Arches are pre-dominantly subjected to compressive stresses. A typical arch with its components are shown in Plate 1. Arches are more economical than the ordinary beams particularly for large spans because the bending moments and shears acting over the cross section of the arches are considerably smaller to that of beams of same span and carrying the same load. The choice of type of arch depends upon the span, the available rise and the architectural effect desired. The semicircular arch gives minimum reaction on the abutments and is used where light abutments are available. The parabolic arch is suitable for uniform loads and elliptical arch is more suited for loads which increase towards the springing as in case of filled spandrel arch. Information available on the behavior of arches is scanty. Arch foundations can be successfully implemented in soils where there are no differential settlementsSome Common Mistakes

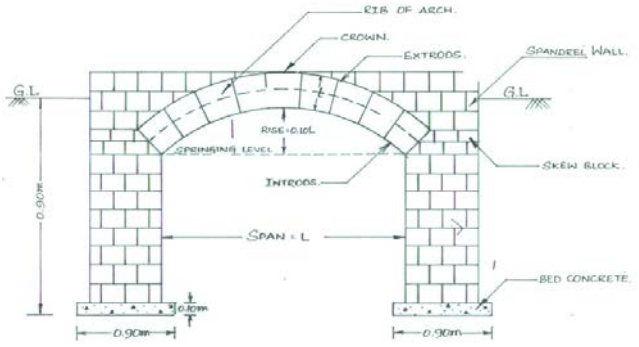

Plate 1. Components of Arch

II.REVIEW OF LITERATURE

The modern study on arches starts from a series of well-known papers by Heyman . In this paper he presented a

complete state of art knowledge on the subject including theoretical and experimental results of the last three centuries. Heyman reviewed many old theories and then presented a mechanism-analysis procedure utilizing the concept of plastic hinges to predict the failure loads of arches.
There have been fairly ancient examples of arch construction i.e. in Egypt and Mesopotamia and many researchers have referred to this. Analysis of the structural behaviour of arches was carried only in the 17th century in spite of the great antiquity of the technique of arch construction.
Non-linear finite element procedure to predict the progressive failure of masonry arch bridges was used by Yew-chaye Loo and Yan Yang . Failure criteria normally used for plain concrete were adopted to define the failure of masonry. The effects of spandrel fill on the arch behavior have also been including in the analysis.

The use of stone masonry arches in foundations was examined by G.Sarangapani and G.S.Suresh . They have concluded that arches in foundations can be effectively used as an alternative to conventional foundation upto two storied buildings located on soils which do not have the tendency of settlements.Table 1 shows the details of masonry arches in foundations that have been used in buildings of Mysore.
G.Sarangapani, Sheshaprakash and GaneshaMogaveera have also made a special study on the load carrying capacity of stone masonry arches. These studies have been made only for a particular span of the segmental arch. The factors such as shape, rise, thickness and size of the abutments, which affect the behaviour of the arches, have not been considered in the studies made. Further the behaviour of arches constructed using materials such as plain concrete, reinforced cement concrete; soil cement blocks etc. have not been studied. Literature reveals that the information available on the experimental investigations conducted on the arches are limited.
V. Srinivaset al has proposed experimental methodologies to be adopted for the evaluation of stone masonry arch bridges. A special instrumentation scheme has also been recommended to measure strains and deflection in the piers and arches. They have conducted some field studies and found the maximum deflection under the dynamic test conditions to be 0.456 mm. This value is well within the permissible limits.

III. ARCH COSTRUCTION PROCEDURE IN FOUNDATIONS

Arches have been used as an economic alternative to the conventional spread footings of walls of residential buildings. The arch can be constructed using masonry, plain cement concrete and reinforced cement concrete. Any shape of the arch can be chosen. Parabolic arches are preferable to other shapes as it is stronger than the circular arches. The study carried out by Deodhar (1992) has shown that the load carrying capacity of parabolic arches is twice that of circular arches. Arches are analysed as two hinged arches subjected to uniformly distributed throughout the span. The uniformly distributed load that gets realised on the arch is due to the brick masonry wall and the slab supported by the wall. The thickness of the arch depends on the magnitude of load acting.
The step by step procedures of constructing arches in foundations are as given below (Refer Plates 2 to 5)
(i) The spans and positions of the arches are fixed suitably based on the positions of walls in building. In general the span varies from 2m to 4.5m.Spans of around 3m are the best.
(ii) Pits of suitable size are excavated for pillars at all junctions of arches. The size of pit depends on the load acting and soil characteristics. A minimum pit size of 1mx1mx1m should be provided.
(iii) Natural ground in between the pits is trimmed to the arch shape so that crown of the arch is at the ground level. The rise of the arch should be as high as feasible to keep the horizontal thrust low. If the crown of the arch is required at higher level than ground level then suitable mud formwork has to be prepared for the arches.
(iv) In the excavated pits, pillars (masonry or cement concrete or reinforced cement concrete) upto springing level are constructed over 1:4:8 cement concrete bed of thickness 100mm.These pillars supports the arches and transfer the loads from arch to the soil. In addition they resist the horizontal thrust of the arch by providing reaction for arch action to take place. If the horizontal thrust is very large, tie rods are provided at the springing level for the end arches.
(v) Arch of designed thickness is constructed. If masonry is used then arch is constructed by placing the masonry units radially on the prepared surface starting from the springing level and proceedings towards the crown.
(vi) Spandrel walls are constructed upto the crown level.

Plate 2. Excavation for Arch foundations

Plate 3. Placing of boulders over cement concrete bed.

Plate 4. Construction of Arches in foundations

Plate 5. Construction of spandrel walls

IV.CASE STUDIES

Table 1 gives the details of arch foundations implemented in various parts of Mysore district for different safe bearing capacity of soil. In some of the buildings arches have been implemented till 5m span successfully.

The load carrying capacity obtained from the tests conducted on laterite block masonry arches in different mortars are presented in table 2.From the results it can be observed that the load carrying capacity of laterite block masonry arches tested varies from 22.24kN/m to 7.85kN/m.For a particular span, rise, thickness and width of the arch, the load carrying capacity is less for arches with lean mortars and is more for arches with rich mortars .The load carrying capacity of arch constructed in 1:3 cement mortar is 22.24kN/m and is maximum compared to all other proportions.

load carrying capacity obtained from the tests conducted on laterite block masonry arches of 3m span, 0.15m thick, and 0.325m width in 1:1:6 cement soil mortar with different rise are presented in Table3. .For a particular span, thickness and width of the arch, the load carrying capacity increases with the increase in rise of the arch

Table1.Details of Mysore buildings with arches in foundations.

	0.6	5	23.54

Table 2 Load carrying capacity laterite block masonry arches in different mortars

Type of mortar	Mortar proportion *C:So:Sa	Mortar strength (MPa)	Failure load (kN/m)
Cement mortar	1:03	16.2	22.24
Cement mortar	1:04	11.1	19.62
Cement mortar	1:0:6	8.92	17.004
Cement soil mortar	1:1:6	7.82	15.83
Cement soil mortar	1:2:9	5.92	12.77
Cement soil mortar	1:5:10	3.62	9.16
Cement soil mortar	1:6:12	2.52	7.85

Table 3 Load carrying capacity of Laterite block masonry arches of different rise

Type of mortar	Rise of arch(m)	Span/Rise	Failure Load(kN/m)
1:1:6 Cement soil mortar	0.15	20	5.23
	0.3	10	15.83
	0.45	6.67	18.31

V.CONCLUSIONS

1. Arches can be effectively used in structural components such as lintels, beams and roofing elements
2. Arches can be used in foundations as an economic alternative to the conventional footings upto 2 to 3 storied buildings.
3. Arches of span varying from 2.5m to 5m can be recommended depending upon the requirements
4. Load carrying capacity of arches are much greater than that of of ordinary beams of same span.
5.Load carrying capacity of arches increases with increase in rise of the arch.

ACKNOWLEDGMENT

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VI. REFERENCES

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Year	User	Location	No.of Stories	SBC (kN/m^2)	Span (m)
1999	Pramoda Devi	A.Nagar	2	250	3.6
1999	Mr.Shashidar	K.Nagar	1	300	3.6
2000	Mr.M.N.Urus	R.K.Nagar	2	350	4.9
2000	Mr.Ramaswamy	Hebbal	1	400	6.0
2000	Mr.Raghavendra	K.Nagar	2	300	4.0
2001	Mr.H.S.Prasanna	J.P.Nagar	2	300	4.9
2003	Dr.G.S.Suresh	C.Puram	2	300	3.6
2003	Mr.GopalKrishna	R.K.Nagar	1	350	3.6
2003	Demonstration Centre,NIE, Mysore	NIE Campus	1	300	3.0

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