

JACK ARCH: THE BACK-BONE OF BRITISH COLONIAL RESIDENTIAL BUILDINGS IN INDIA

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ABSTRACT: Till the first half of the nineteenth century the British Colonial Residential Buildings in India suffered lack of an appropriate roofing system. The limitations in materials, technology and technical expertise were main hurdles for any viable solution. The frequent import of steel from England and discarded steel joists from railway during mid of nineteenth century changed the whole scenario and buildings were provided roofs of permanent nature and more secure with reference to fire incidents. Among these options the Jack Arch roofing became the most demanding for all types of buildings and all major departments of the British Indian Empire started to build roofing of their buildings with Jack Arch. It was so feasible and flexible in terms of planning underneath that without any major effort the requirements of any space became possible. In this research it is explored through residential buildings of British India's time that how this structural system remained successful in terms of its application in various building types, construction technology, materials, space requirements, reliability, and climatic aspects. The paper concludes that construction of 'Jack Arch' roofing during British time in India was an economical solution to accommodate the British Colonial space requirements and climatic needs in various building types.

Key words: Jack Arch, Bungalow, Double Headed Rail Joists, Ti Rod, Segmental Arch, Rolled Steel Joists.

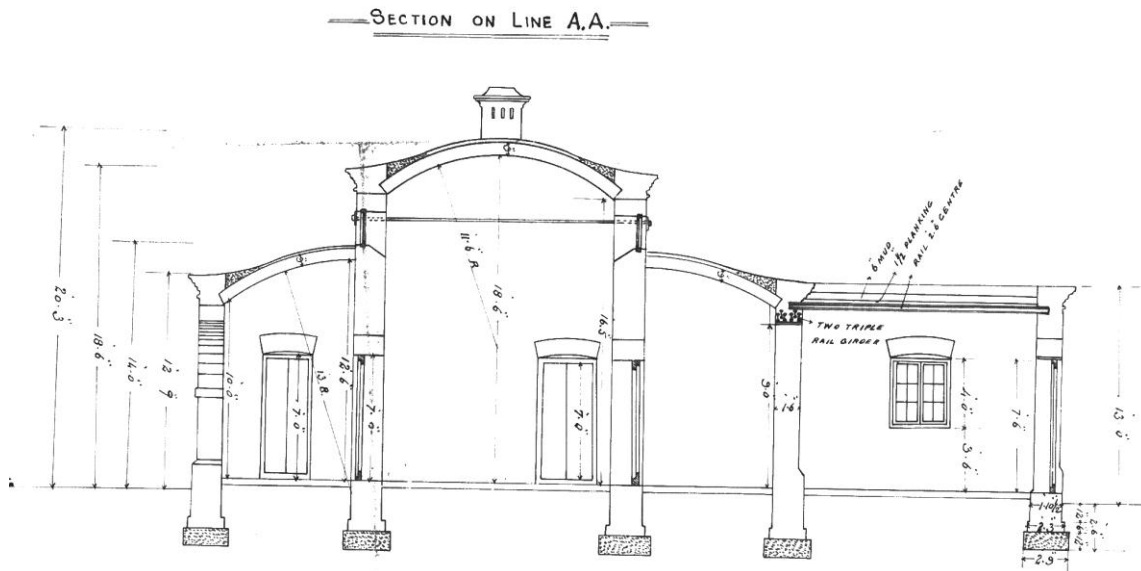
INTRODUCTION

The all major departments of British Indian Empire in India such as the Public Works Department (P.W.D.), Army, Railway, Irrigation and Education had experienced great difficulty in providing appropriate roofing to residential and other buildings during the nineteenth century. At one end the space requirements of European residential and other types of buildings were noticeably different from Indians then on other side the available materials of construction were also limited. For a long time the existing Roofing system of Indian buildings was adopted but their temporary nature, fire catching properties and span limitations were not permitting for further continuation. The spaces of Indian buildings were generally dependent on the span of wooden beams thus these were deficient of accommodating the living, working and life style of European and to support their requirements in Indian colonial culture. The colonial culture was demanding grand, impressive and functional buildings with larger spaces for working, and living. Similarly the climatic conditions of the Plains of India were also demanding for climate friendly roofing for European buildings to provide comfortable indoor thermal conditions during summer. However, under these circumstances it was an important need to find out an appropriate roofing solution for British Colonial buildings in India for various uses

(Arif, 2010). The British Engineers and Architects played a vital role in this direction. The articles written during first decades of twentieth century by those engineers who practically implemented various options of roofing in buildings played a vital role for roofing of future buildings.

A comprehensive article in this regard was published in 1907 on the demand of secretary to the government of India in Public Works Department (P.W.D.) by a British Engineer of Building and Road departments of United Province which summarized the detailed overview of the roofing of Natives and European dwellings in India. The report declared the roofs of nineteenth century as unsuitable for modern buildings on the basis of their temporary nature, involvement of much cost in their renewal, fire catching properties and span limitation. These roofs include; thatch types, brick tiles on wooden trusses, stones tiles resting on wooden joists, burnt clay tiles laid on bamboo framing or round timbering cut from saplings and simply stripped of the bark. Vaulted roof was another option which was constructed with brick masonry with concrete topping (Fig 1). However, the report also explains that the most important step towards an appropriate solution for roof problems in India was Introduction of Jack Arch in European Bungalows because of its suitability in plains of Punjab during summer and spanning over the larger spaces (Wildeblood, 1907).

Fig. 1: Vaulted Roof for a Railway barrack in Station Colony, Lahore, 1896



Source: Design Office Railway Headquarter, Lahore

During the first decade of twentieth century there was rare a significant building in British Punjab built by the British administration where Jack Arch was not used as successful option for roofing. The use of Jack Arch at vast scale led its refinement in its deficient areas and in this regard the Executive Engineer of King Edward Memorial Division, Lahore published an article where better interiors with Jack Arched roof were discussed. This article also provides information on all types of Jack Arch roofs used in India which includes the Flat, Curved and simplest Plain Barrel Arch (Dorman, 1914). Despite various efforts for improvements in Jack Arch the consulting architects to Government of India were not satisfied with the extensive use of this roofing. They wanted change in roofing system and suggested alternates of “hated jack arch” with ‘Kleine’ floor form Europe and America. Besides ‘Kleine’ floor the Reinforced Concrete was also in practice in Europe and America but in India the cost was very high except in the coast towns where the cost of imported cement was at a minimum. Furthermore the skilled labour for this material was not available in India for close supervision required at all stages of the work. (Begg, 1912).

Contrary to ‘Kleine’ and Reinforced Concrete Floors the Jack Arch system was economical for roof construction on the basis of availability of materials and expertise of local Master Builders in different parts of the India. These traditional artists were expert in brick masonry arch construction on the basis of their vast experience. The European engineers having scientific and technological knowledge on structural system of buildings were experts in making scientific calculations

pertaining to designs of structural members resulting cost effeteness and ensuring desire strength of roofs. Furthermore, by establishing standard details for steel joists the system became simpler in execution. However, the combination of European and local expertise resulted “Jack Arch” roofing system as sustainable and economical for colonial buildings in India. (Arif, 2013). The origin of Jack Arch belongs to Europe where first structure was constructed in 1801 and later on it was also spread Eastward and Middle East (Hilton, 1997). In fact the industrial revolution in Europe demanded for large span roofs, which appeared in the form of steel trusses and Jack Arched Roofs (Maheri and Rahmani, 2003).

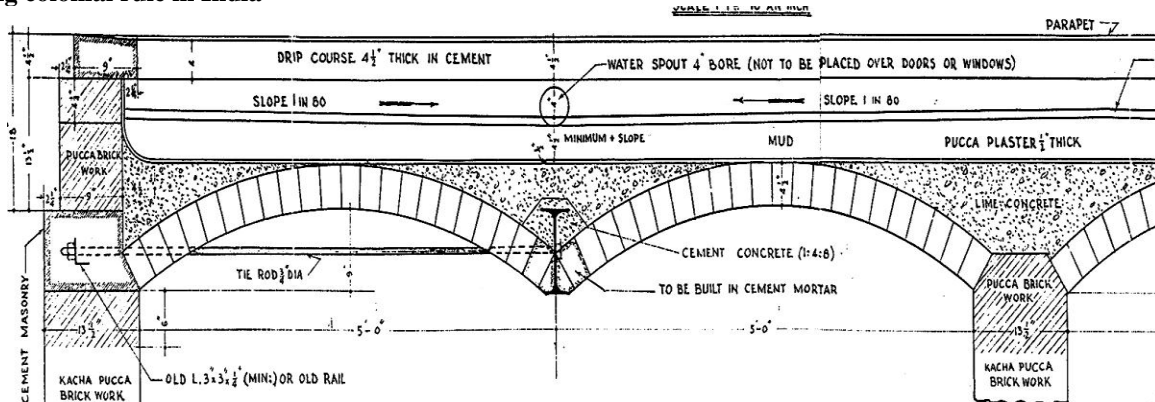
The current study was planned to find out that how Jack Arch became useful to accommodate the European space requirements and indoor climatic comfort in plain areas of the Punjab. The data was collected through physical survey of British Colonial Buildings in Lahore, archival record, old drawings and articles written by British Architects and Engineers during colonial period. The study will be beneficial to provide footings for researchers to work for sustainable solutions in roofing system of buildings giving emphasis on structural form and minimum use of steel.

Jack Arched Roofing: It reveals from archival drawings and existing old buildings that the major components of Jack Arch roofing were Bricks for construction of Segmental Arch, Steel Joists to support arches, Tie Rods at ends arches to keep the arch in its original position and to address the problems of tensile stresses, Wall Plates and Nuts to make the connection of Tie Rods from its

both ends. A Jack Arch roof is usually formed with number of 4.5 inches thick brick masonry segmental arch of 6-9 inches rise from centre for 4 - 6 feet span supported by Rolled Steel Joist (RSJ) spanned over shorter dimension of room from wall to wall. To make

upper surface of roof as flat, the lime or cement concrete was used as filler in gaps. Above that the plaster layer and subsequently the mud layer were usually provided. Atypical detail of Jack Arch is shown in Fig. 2.

Fig. 2: A typical Detail of Jack Arched Roof applied in roofing of Railway Stations, Bungalows and Quarters during colonial rule in India



Source: Design Office Railway Headquarter Lahore

The weight and section of a steel joist was important to define the span limits and in this regard various tables were prepared for reference and were

strictly followed without any deviation. One of the tables which remained in practice in British Railway buildings in Lahore is shown in Fig. 3.

Fig 3: Table for selection of Rolled Steel Beam for Jack Arch Roofing (1934).

Size of Beams	Maximum clear span up to which the beam may be used with a spacing of					Size of Cement Concrete Bed blocks	Remarks
	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"		
5" x 2.5" @9 lbs	8'-8"	8'-3"	7'-10"	7'-5"	7'-1"	9" x 9" x 6"	For intermediate spacing the permissible clear span will vary proportionately
5" x 3" @11 lbs	9'-5"	9'-0"	8'-8"	8'-5"	8'-0"	9" x 9" x 6"	
6" x 3" @12 lbs	11'-0"	10'-6"	10'-1"	9'-7"	9'-2"	9" x 9" x 6"	
7" x 3.5" @15 lbs	13'-4"	12'-9"	12'-4"	11'-10"	11'-5"	9" x 9" x 6"	
7" x 4" @16 lbs	13'-9"	13'-3"	12'-9"	12'-4"	11'-10"	9" x 9" x 6"	
8" x 4" @18 lbs	15'-6"	14'-10"	14'-4"	13'-10"	13'-3"	9" x 9" x 6"	
9" x 4" @21 lbs	17'-8"	17'-0"	16'-4"	15'-10"	15'-1"	9" x 9" x 6"	
10" x 4.5" @25 lbs	20'-1"	19'-4"	18'-7"	18'-0"	17'-5"	12" x 12" x 6"	
10" x 5" @30 lbs	21'-4"	20'-1"	19'-9"	19'-1"	18'-6"	12" x 12" x 6"	
12" x 5" @30 lbs	24'-0"	23'-1"	22'-3"	21'-7"	21'-0"	12" x 12" x 6"	
12" x 5" @32 lbs	24'-8"	23'-8"	22'-10"	22'-1"	21'-5"	12" x 12" x 6"	

Source: Reproduced by the author from original drawing, Design Office Railway Headquarter, Lahore

Fig. 3 reflects that maximum clear span between two joists is 4-6 feet for construction of arches above them. This limitation was important in terms of use of spaces. The Bungalow of the British Colonial Officer was usually comprised of Drawing, Dining, Bedrooms, Office, Bathrooms, Dress Rooms, Store and Lamp room. If a room was 16' from its shorter side then four Jack Arches with 4' wide each were used to provide roofing for that room. In case if it was 18' then three Jack Arches of 6' each were constructed on Steel Joists. This proves that module for Jack Arch in a particular bungalow was

dependent on the space requirements within in the limitations 4-6' but not like Indian house where a space was dependent on wooden beam limitations. According to King the shorter span of Drawing, Dining and Bedroom in British bungalows during early twentieth century was between 18-22 feet (King, 1984).

Besides the roofing of the buildings and giving strength to structure the shape of the Jack Arch was most effective tool for ventilation for low and high roof spaces in bungalows. In almost every bungalow the spaces of low heights such as verandah, stores, bathrooms and lamp

rooms were ventilated with siphon ventilators (4 inches dia 'U' shaped device made of burnt clay) placed on crown of the arches to drag out warm air accumulated under curvature of the arch during hot days of summer

(Fig. 3). The overall thickness of the roof was 11-15 inches which increased in time lag. Jack Arch was also used for constructing Double roof to control indoor thermal condition of the rooms (Fig. 4, 5 and 6).

Fig. 4: Sectional Detail of a bungalow of British Railway Police Officer in Station Colony showing Jack Arched Roofing, Lahore, 1906.

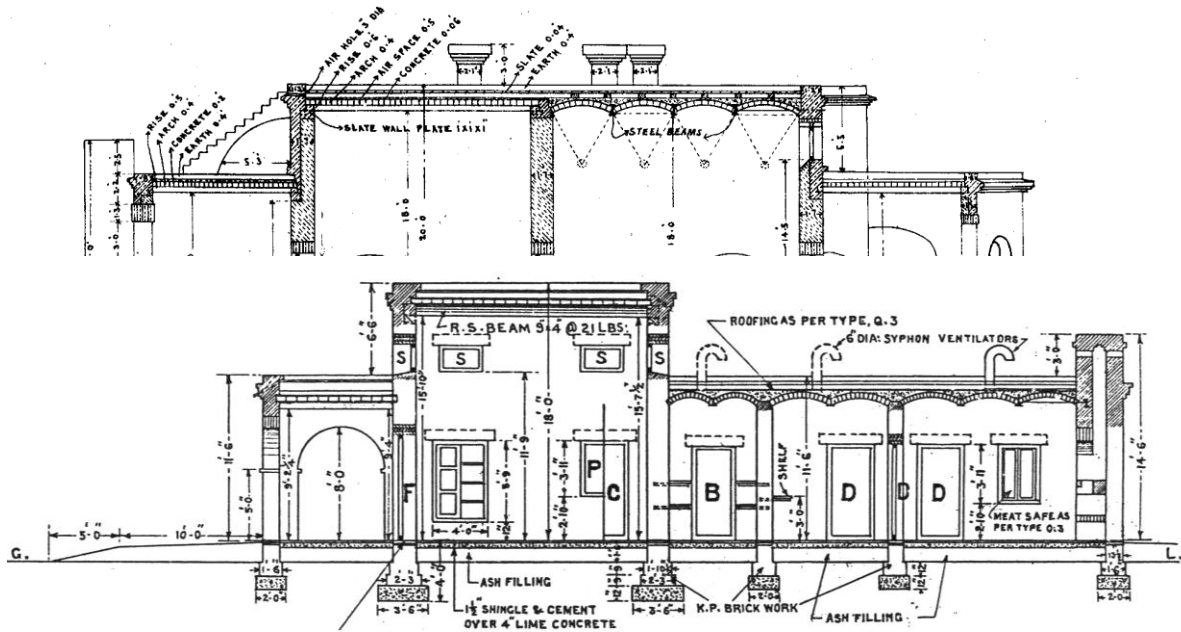


Fig. 5: Sectional Detail of a bungalow of British Officer of Irrigation Department showing Jack Arched Roofing, Amritsar, India, 1908.

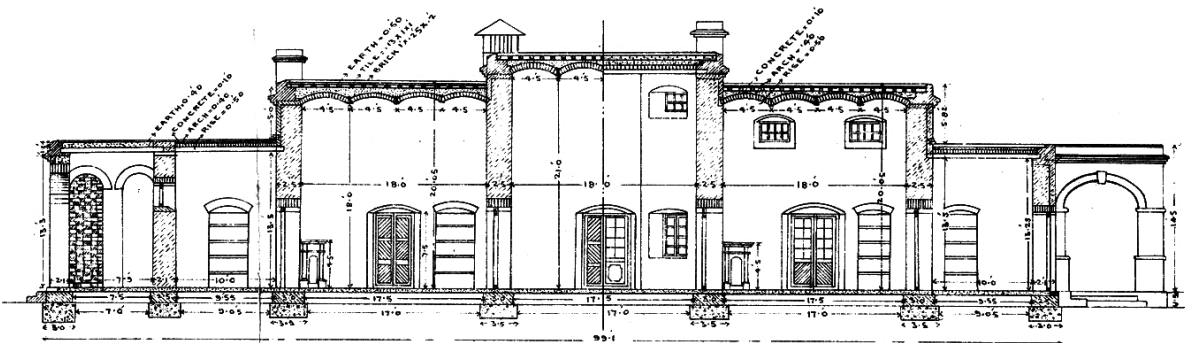


Fig. 6. Sectional Detail of an Irrigation Inspection bungalow showing Jack Arched Roofing, Sargodah, Pakistan, 1902.

RESULTS AND DISCUSSION

Among other roofs the 'Jack Arched' roofing ultimately appeared as sustainable solution for every kind of building in plain areas of India since the mid of nineteenth century. Jack Arch was a roofing system for Industrial Buildings in Europe whose major components

were Steel Girders and Brick Arch. The acceptability of system led its vast application in the buildings of Army, Irrigation, Railway and Public Works Department (Arif, 2013). There were several reasons behind its acceptability at large scale. According to the consulting architect to government India in 1911-12 the Jack Arched roofing was given priority over reinforced concrete because later was prohibitive in price, except in the coast towns where

the cost of imported cement was at a minimum. The report further elaborated that because of non availability of skilled labour and supervisory staff the construction of roofing with reinforced concrete was being discouraged in India and only viable solution was Jack Arched roofing (Begg, 1912).

However, the origin of Jack Arch indicates that it was primarily invented to cater the span requirements of Industrial buildings in England but in British India the system had been interestingly extended to roof construction of every type of building. This practice further increased the demand of steel in India where it was already in use for wide and increasing activity in the construction of bridges, water tanks, railway lines, stations, locomotive and wagons. This enormous consumption of steel on different projects had placed the India as one of the largest consuming center of steel products therefore import of steel from England was a frequent practice to meet the colony's requirement and to safeguard the interest of steel industry in England. In railway the waste steel in the form Double Headed Rail Joists (DHRJ) was an additional provision and incentive to construct Jack Arch roofing for buildings of every nature without any major cost involvement. Furthermore, the railway was also providing all types of plants and equipments to the contractors for erection of girders without any charge. Another reason for the extensive use of Jack Arched roofing was the material and expertise available for construction in India. The major components of this roofing were Steel Girders and Brick Arch therefore it was blend of local (Indian Brick) and imported materials (steel). The Indians were expert in the art of bricks making and its construction whereas the British were capable of knowing structural and other properties of steel. The standard details and information on load bearing capacity of Steel Joists had made the system simple and practical. Under these circumstances the requirement of skilled labour was not as important as it was required in reinforced concrete and other types of roofs (Arif-13).

Conclusion: Since the early days of British colonial period in India there remained a great problem for roofing of new buildings. The problems were generally concerned with availability of materials, climate, expertise in construction and span coverage for the space of various new uses in colonial environment. After having various experiences the ultimate choice came out

in the form of Jack Arch on the basis of simple technique involve in its construction, fast construction, greater structural strength, long life, availability of materials and the most importantly the cost effectiveness. The standard details and information on load bearing capacity of steel joists made the system attractive for any load and span requirement. With the Jack Arch roof it became possible to accommodate the European space requirements in Bungalows and buildings of other uses. The extensive use of Jack Arch in almost every kind of British building in India confirmed the acceptability of the system, flexibility in terms of roofing for buildings of various uses and particularly to cope with the British Colonial space requirements and climatic needs in plain area of the India. On the other side the Jack Arch roofing system was also feasible to safe guard the interest of British steel industry in England and also to consume waste steel from railway lines in India.

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