

## **THE FORGE -WELDED IRON CANNON AT BĀDĀ BURJ OF GOLCONDA FORT RAMPART**

**R. BALASUBRAMANIAM\***, **M. SURENDER\*** AND **S. SANKARAN\***

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The communication deals with the forge-welded iron cannon located at one of the bastions of the Golconda Fort Rampart. An inscription on the cannon provides the date of construction as 1644AD. The iron cannon was manufactured using three layers of pre-fabricated iron rings, hooped and forge-welded over longitudinally placed iron staves. The inside of the barrel of the cannon is rendered smooth by the provision of 21 longitudinal iron staves, which have been flared out in the front end of the cannon. The mastery in forge-welding technique is visible from no gaps between individual rings and the smooth surface. Two unique decorative patterns seen near the front end of the cannon have been described. The excellent atmospheric corrosion resistance of the cannon has been noted and discussed in light of material of construction.

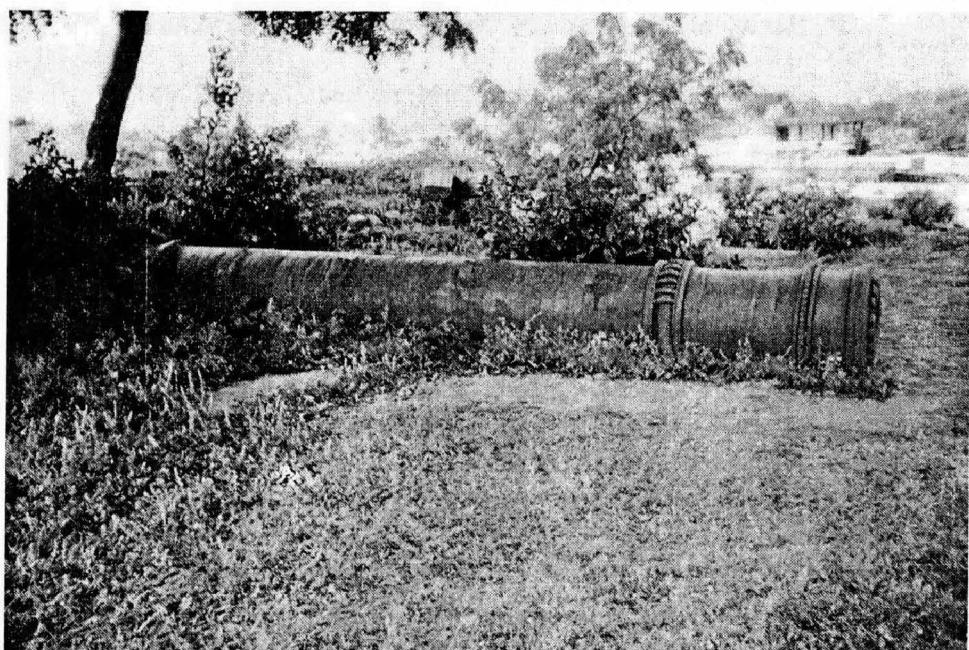
**Key words:** Construction, Corrosion resistance, Design, Forge welding, Iron cannon.

### **INTRODUCTION**

The high status of iron and steel technology in ancient and medieval India is amply reflected in the manufacture and use of numerous large iron objects. Forge welded iron cannons were some of the significant large iron objects manufactured in medieval India. Some notable medieval Indian iron cannons, manufactured by the forge welding technology, have been catalogued<sup>1-3</sup>. These wrought iron cannons, found in different parts of India, were basically manufactured from individual iron rings, which were forge welded together<sup>4,5</sup>. The medieval blacksmiths continued the rich tradition of manufacturing iron objects by the forge welding technique, which was the method practiced and perfected in India to fabricate small and large iron objects.

\*Department of Materials and Metallurgical Engineering, Indian Institute of Technology, Kanpur 208 016, INDIA; author for correspondence: bala@iitk.ac.in

One of the large iron cannons at the Golconda fort at Hyderabad is addressed in this communication. Based on its weight and size, the forge-welded iron cannon (Fig. 1) located at the Baḍā Burj of Golconda Fort outer rampart, must rank among one of the largest in the Indian subcontinent. The cannon formed an important part of the fort defenses. This iron cannon will be addressed in this paper.



**Fig. 1:** One of the forge welded iron cannons at the outer rampart of the Golconda fort. This cannon is located on the Baḍā Burj of the Golconda Fort Rampart.

## HISTORY

The Golconda fort is a majestic monument, which lies on the western outskirts of Hyderabad city in the Indian state of Andhra Pradesh. The present structure is a remnant of a great cultural heritage of more than 400 years<sup>6</sup>. The construction of the fort in its present form by Mohammed Quli Qutub Shah was started around 1525 AD. It stands as the epitome of Nawabi culture and grandeur. Golconda is built on a granite hill 120 m high, and is surrounded by crenulated ramparts constructed of large masonry blocks weighing several tons.

The magnificent architecture of the Golconda fort is manifest in its acoustic system, the structural grandeur of the palaces and ingenious water supply

system. The present state of the buildings and gardens at Golconda remind us about the time when the entire place was replete with sprawling lawns and playing fountains. The design of the ventilation systems of the fort reveals the brilliant planning of the architects. The buildings in the fort were designed to let in a flow of fresh cool breeze, providing respite from the summer heat. In its heyday, the 10 km long road from Golconda to outer Hyderabad was a fabulous market trading for jewels, diamonds, pearls and other gems, which were famous all over the world. The fort was particularly renowned for its diamond trade and the famous 'Kohinoor' diamond originated from here.

Even before the city of Hyderabad was founded, Deccan was ruled from Golconda fort. The fort was founded originally by the Kakatiyas in the 13th century AD. The existing structure was expanded by the Qutub Shahi kings into a massive fort with granite walls and ramparts. The first three Qutub Shahi kings rebuilt Golconda, over a span of 62 years, starting from 1525 AD. It is popularly known in the local Telugu language as *Golla Konda* (Shepherd's Hill) based on a popular story.

The Golconda fort is fortified with two lines of defences. The inner rampart, about 5 km in circumference, protected the palaces and garrison, which were located on the Golconda hill. The outer rampart, surrounding the entire township of Golconda, is about 11 km long, and this was also strongly fortified. The massive gates of the outer rampart were studded with large pointed iron spikes to prevent elephants from battering them down. At regular intervals, the outer fortified wall provided with *burjs* (bastions). At these bastions, iron and bronze cannons were strategically located. The forge welded cannon addressed in this communication is from one of these bastions and this particular bastion is called *Badā Burj* (Big Bastion).

The Golconda fort has seen exciting action. On the fall of Bijapur (12 September, 1686 AD), the Mughal Emperor Aurangazeb reached the vicinity of Golconda. After occupying Hyderabad, the Mughul army laid siege to the fort of Golconda on the 7 February, 1687 AD and finally captured it in 21 September, 1687 AD<sup>6</sup>. After the fort fell into the hands of the Mughals, they located some of their wonderful cast bronze cannons at strategic locations along the outer fort wall. Some of these massive bronze cannons are still located in

the outer rampart of the Golconda fort. One notable cannon is the *Azdhaha Paikar* (Fire of the Dragon). Interestingly, these large bronze cannons are provided with trunions, because they were originally meant to be mobile. It was only later that the Mughals permanently stationed them along the fort ramparts of the Golconda. Therefore, the bronze cannons at Golconda fort are from the time of Mughal occupation, while the iron cannons were present even before the Mughals took over Golconda. The iron cannons are not provided with trunions and therefore, they were meant for stationary application.

Nothing is known from historical sources about the construction of this cannon. However, there is one Persian inscription on the top surface near the front end of the cannon. It reads *Salim Abdullah Shami 1040 Hijri*. Inscriptions on cannon generally provide the name of the cannon construction supervisor and the year of manufacture<sup>7</sup>. This is frequently encountered in medieval Indian cannons. Therefore, the name mentioned in the inscription must be the name of the superintendent who supervised the construction of the cannon. The date 1040 Hijri corresponds to 1644 AD, and this is the year of manufacture of this wonderful cannon.

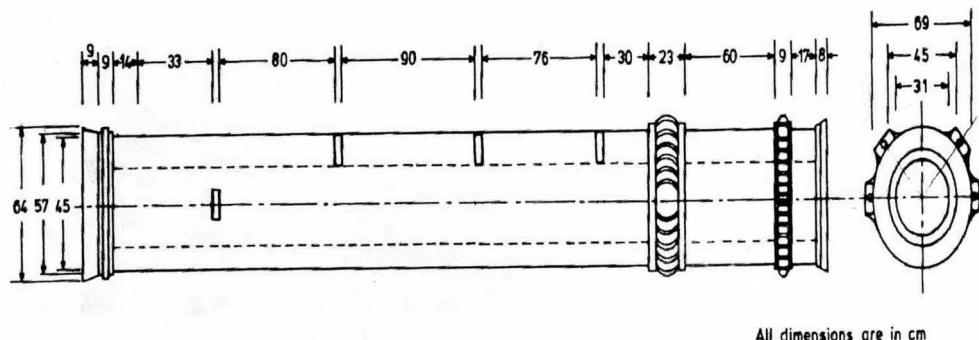
### DESIGN

The forge welded iron cannon is positioned on the top of a big bastion, which projects from the outer fort wall. The cannon faces the east direction. At present, the cannon is lying totally uncared for, in a neglected condition. It is now overgrown with vegetation. It does not rest on any supports but is placed on the ground (Fig 1). The cannon is a muzzle-loading type cannon, in which the gunpowder and the projectile object were loaded from the muzzle (i.e. front end). This is similar to other medieval Indian cannons<sup>4,5</sup>. The various sections of the cannon can be observed in Fig 1.

The dimensions of the iron cannon can be appreciated from the engineering drawing of the cannon, shown in Fig. 2. The total length of cannon, as measured from the front end to the back end of the cannon, is 509 cm. The inner and outer diameters of the cannon are 31 and 69 cm, respectively. However, it must be realized that the cannon's dimensions are closely related to the inch system of measurement, which was the unit of measure in ancient and

medieval India. On conversion to inches, the entire length of the cannon works out to be 200 inches, and the inner and outer diameters of the cannon barrel 12 and 27 inches, respectively.

The fuse hole for igniting the gun powder is located 32 cm from the



**Fig. 2:** Engineering drawing of the cannon showing important dimensions. All dimensions are provided in centimeters.

back end. This is a solid mass of metal, similar to other medieval iron cannons. Therefore, based on the dimensions measured, the conservative weight of the cannon is about 12000 kgs.

The outer appearance of the cannon indicates that individual pre-fabricated iron rings were forged welded in order to create this structure. On the upper surface the cannon, a total of 63 individual rings could be distinguished. The rings also exhibit good continuity and the surface is relatively smooth. All the rings in the external view are almost of same width (3 inches).

These outer rings appear to have been forge welded over two layers of rings. The total number of layers of rings, that make up the thickness of the barrel, cannot be easily distinguished by visual observations alone. This has to be understood by careful non-destructive testing methods. Based on the appearance of the front of the cannon, it appears that the outer ring layer has been forged over at least two layers. It is reasonable to assume that there are three layers of rings, building up the thickness of the barrel, based on the design of other similar forge welded cannons at Thanjavur<sup>4</sup> and Bishnupur<sup>5</sup>. Therefore, as 63 rings were counted on the external surface, there are at least 189 rings that must have been used to manufacture the barrel of the cannon. The skill of the

medieval blacksmith must be appreciated because these rings have been so skillfully forge welded that the entire surface appears almost smooth due to the excellent closure of gaps between the individual iron rings that were forge welded.



**Fig. 3:** Front view of the cannon showing that 20 iron staves that have been folded out on the front face.

The appearance of the cannon from the front is shown in Fig. 3. It can be noted that 20 long strips, each 4.5 cm wide, emanate from the bore and these have been bent over the front face. This provides a pleasing aesthetic appeal to the canon. More importantly, this design aids in firmly gripping the iron strips, which are longitudinally placed along the barrel of the cannon. These strips were provided in medieval Indian cannons to provide a smooth inner surface, in addition to providing the necessary integrity and toughness to the cannon. It is also interesting to note from Fig. 3 that these 20 strips are bridged with an extra metal layer at locations when the strips flare out.

The side view of the cannon, in the front part, is shown in Fig 4. At about 25 cm from the front face, an interesting decorative pattern has been created on the metal surface. A close up view of this pattern is shown in Fig. 5. In this design, three iron bands are placed around the circumference of the

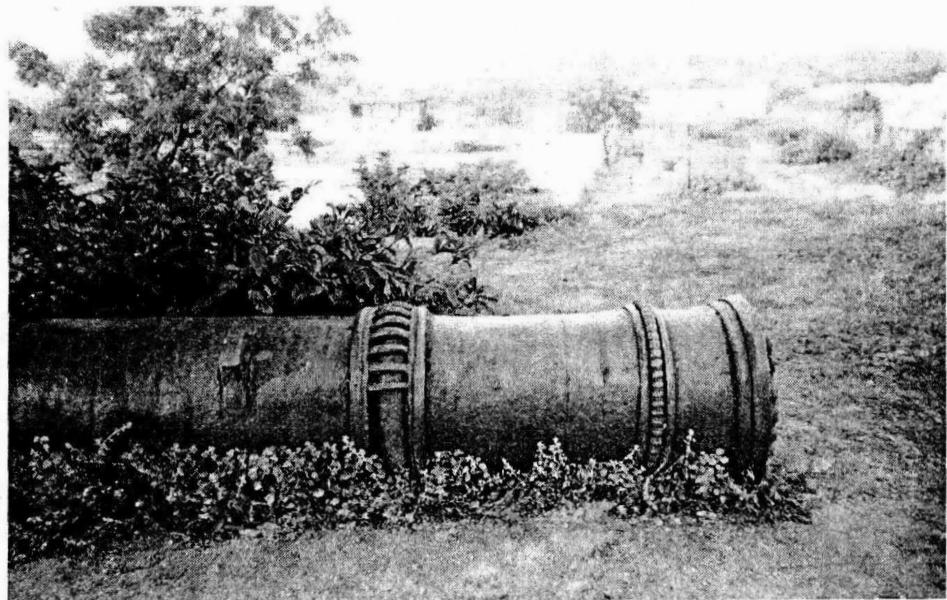


Fig. 4: Side view of the cannon, from close to the front end.

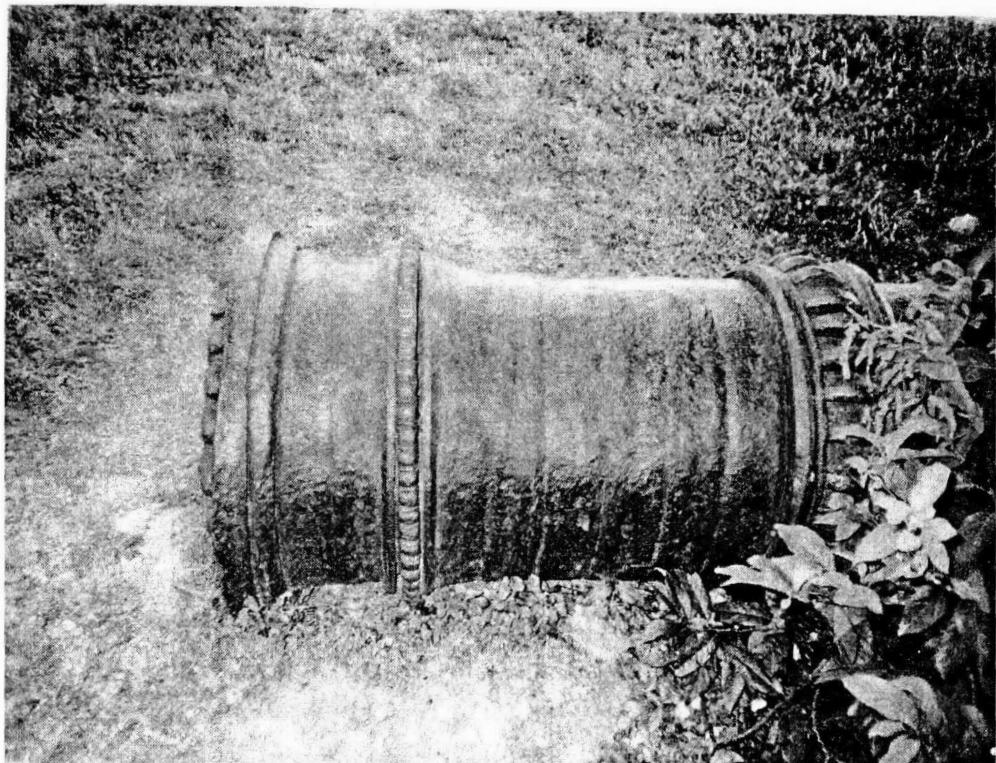


Fig. 5: Close-up view of decorative pattern that appear immediately behind the front face.

cannon, with the inner band being twisted and made of forge-welded iron rods. A decorative design, of bigger size (Fig. 6), appears at a distance of about 1 m from the front end. In this design, two metal rings run along the periphery. Horizontal iron strips have been forge welded on to this rings, to form a band of metallic strip. Owing to its relatively larger size, this design is apparently more clear and attractive when viewed from a longer distance. Although these designs appear to fulfill a decorative purpose, it will also enhance the toughness and strength of the cannon barrel, as they provide additional layers of material.

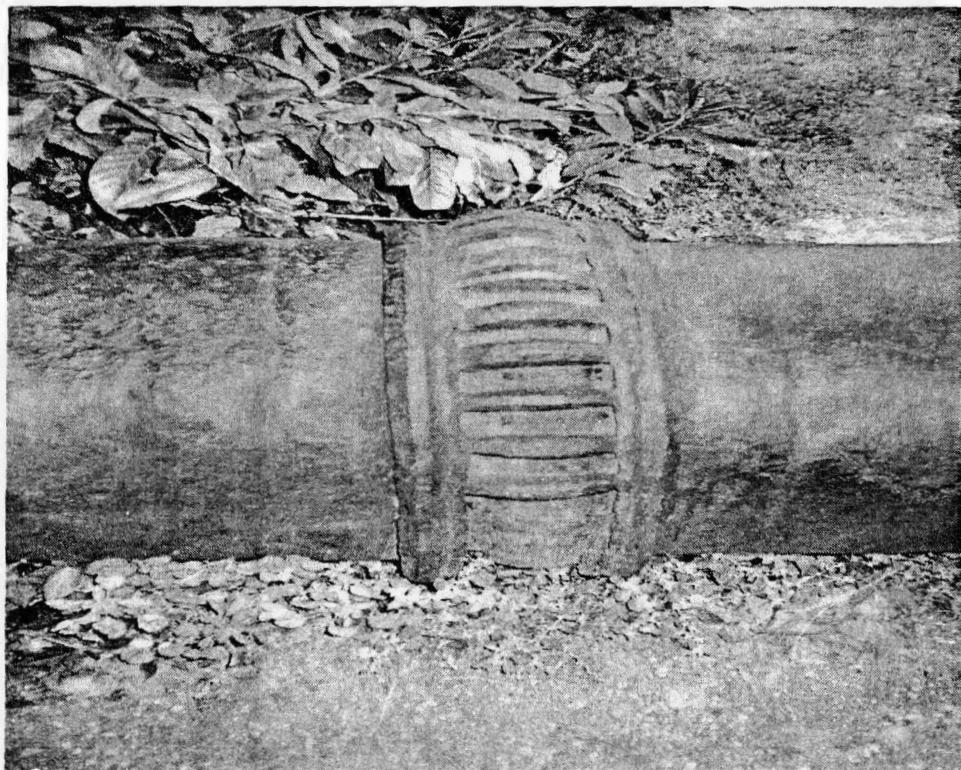


Fig. 6: Close-up view of decorative pattern that appears about one meter from the front face of the cannon.

On moving further down the cannon, a total of 6 metal projections, 3 on each side, are visible at almost equidistant and identical positions (two of them can be seen in Fig 7 behind the decorative pattern). These projections are not located diametrically opposite to each other, but placed nearer to the top surface of the cannon (see also the schematic of Fig. 2). Each projection is provided with a hole of diameter around 3 cm. As the projections are aligned along



Fig. 7: View of the middle portion of the cannon showing projections on the surface. These projections contain central holes.

the length of the cannon (three on each side), it is reasonable to conclude that these projections must have aided handling of the cannon. The handling would not have required large scale movements (i.e. the cannon was not a mobile one), but was rather for adjusting the direction of fire from the cannon.

In addition to these 6 projections, located in the middle of the cannon, 2 more similar projections are located in the rear of the cannon. They also contain a central hole. However, these two projections are not exactly in alignment with the ones that come further ahead in the cannon. This can be observed in Fig.8 where the projection on the left is not in alignment with the other two that come further ahead.

These projections might have been provided for manipulating the cannon's direction, and, also, for possibly aiding its movement and transportation. The actual method by which the gun was moved using these projections is not known. One method by which the cannons were handled was by means of iron rings provided in these holes. Such iron rings can be noted on the large forge-welded cannons at Thanjavur<sup>4</sup>, Murshidabad<sup>7</sup> and Gulbarga<sup>7</sup>. Another

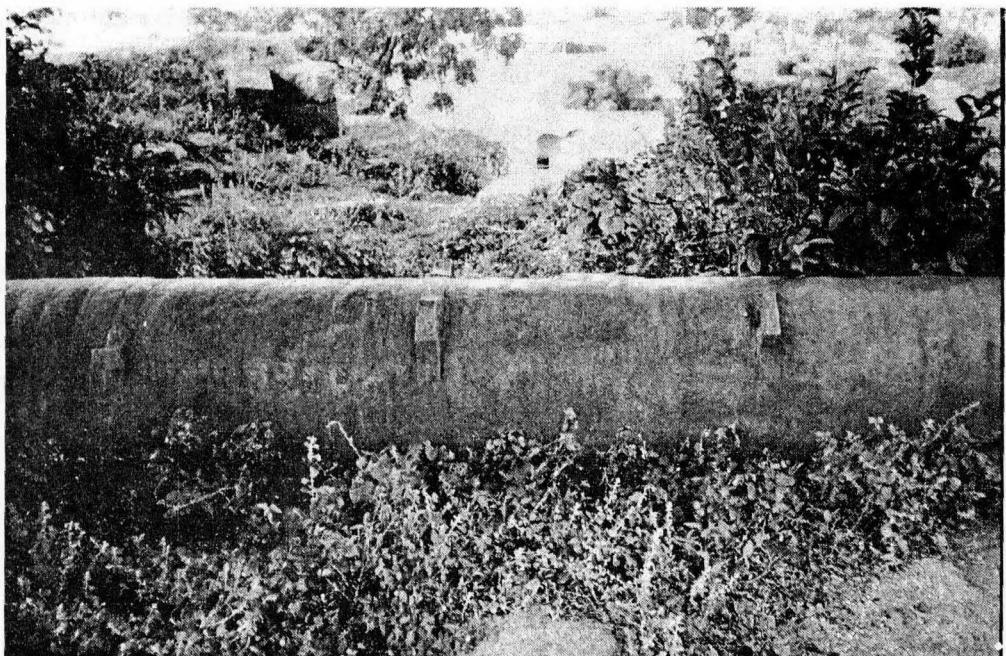


Fig. 8: View of the projections provided on the side of the cannon, in the rear of the cannon.

iron cannon, located in front of the Fateh Burj of the Golconda fort outer rampart, contains large iron rings<sup>8</sup>. Long iron rods or wooden beams, inserted through these clamp rings, would have aided positioning of the cannon during its use. It is worth noting that trunions (i.e. supporting cylindrical projections on the sides of the cannon), like those usually found on smaller sized cannons, are not provided. These trunions were used to house the cannon on wheels, thereby aiding its easy transportation. Therefore, the absence of such a device on the Golconda cannon indicates that this large iron cannon was not meant for mobile use and its function was to be a stationary cannon to protect the rampart of the Golconda fort.

As these are no supports on which the cannon currently rests, it is further reasonable to propose that supports and supporting arrangements for moving the cannon around (i.e. adjusting the firing direction) must have been constructed out of wood. The use of wood provides good damping to the vibrations emitting from the cannon on firing.

On moving further down the length of the cannon, it can be noticed that there is no variation of diameter across the length of the cannon (Fig. 9). This is



Fig. 9: Side view of the back portion of the cannon.

in contrast to what has been observed in the case of the forge welded iron cannon at Bishnupur, called *Dal Mardan*<sup>5</sup>, where the diameter varies across the cross section. However, the design of the Golconda cannon is similar to the Thanjavur iron cannon<sup>4</sup>, where the barrel diameter is constant across the length of the cannon.

The view of the rear end of the cannon is provided in Fig. 10. The fuse hole for igniting the gun powder is located 32 cm from the back end. The appearance of the rear portion indicates that it is a solid mass of metal. The surface of the rear part is relatively flat when compared to the cannons at Thanjavur<sup>4</sup> and Bishnupur<sup>5</sup>. In case of these cannons, the rear end is constructed out of successively smaller diameter rings. It is worth noting that an extra outer ring has been provided at the real end of the Bādā Burj cannon, probably for increasing the impact strength of the canon at this location.

The construction methodology of the cannon, by shrink-fitting of pre-forged iron rings over longitudinally placed iron staves, appears to be similar to that of the Thanjavur cannon. This has been described in great detail elsewhere<sup>4,9</sup>.



**Fig 10:** Rear end of the cannon.

#### ATMOSPHERIC CORROSION RESISTANCE

One of the remarkable observations concerning this forge welded cannon is that it is almost devoid of significance rusting. The surface possesses a reddish golden hue and the surface is also highly reflective, indicating the relatively thin rust layer present on the surface. It must be also noted that no special maintenance procedures are currently applied to this cannon, because it is lying practically away from public view and in a totally uncared condition as the overgrown vegetation on the cannon rightly attests. The overgrown vegetation around the cannon (Fig 1) is a good indication of its current state of preservation. In spite of its gross neglect, the cannon hardly reveals any signs of rusting. This is a truly remarkable observation because, under similar conditions, modern mild steels would have corroded severely in the atmospheric environment.

Considering that the cannon was placed at this location after the capture of Golconda by Aurangzeb (i.e. in 1687), the conservative time of this

cannon at this location is at least 317 years. If the date provided on the cannon is the date of manufacture of cannon (1644 AD), the age of the cannon is 360 years. It is known that corrosion rate of iron in the atmosphere depends upon the environment. For example, rust thickness can be detected from the known atmospheric corrosion rates of iron in several environments<sup>10</sup>, 4-45  $\mu\text{m}/\text{y}$  rural environments, 26-104  $\mu\text{m}/\text{y}$  marine, 23-71  $\mu\text{m}/\text{y}$  urban and 26-175  $\mu\text{m}/\text{y}$  industrial. Assuming the weather at Hyderabad to be rural, the estimated corrosion product layer over a period of 317 years should be between 1268  $\mu\text{m}$  to 14265  $\mu\text{m}$ . When converted to rust, it should have resulted in a rust of thickness between 2536 and 28530  $\mu\text{m}$ . This has certainly not been the case because this particular cannon does not show any evidence for significant rusting (Fig. 1). The actual condition of the material of construction of these cannon indicates that practically no corrosion has taken place. Based on the observed reflectivity of the surface and the known rust thickness on other ancient Indian corrosion resistant irons<sup>11-13</sup>, it can be predicted that the rust on the surface must be in the range of 100-500  $\mu\text{m}$ . Therefore, the remarkable atmospheric corrosion resistance of the cannon has to be appreciated.

Composition analysis of iron from cannon could not be made. However, the relatively high P content of the material of construction (iron) is revealed by its golden brown color. One of the characteristic compositional factors regarding corrosion resistance in ancient Indian iron is their relatively high P content. In fact, Neogi, way back in 1914, attributed high P content as one of the reasons for the excellent atmospheric corrosion resistance of ancient and medieval Indian iron<sup>7</sup>. It is now known that P, even in small amounts of the order of 0.25 wt. %, exerts a very beneficial influence on the atmospheric corrosion of iron<sup>14-16</sup>. This has been attributed to the formation of protective passive film on phosphoric iron. Interestingly, the protective passive film on the phosphoric iron is not protective under complete immersion condition (like soil and solution immersion environments) but only under atmospheric exposure. The protective passive film on phosphoric irons does not form immediately upon atmospheric exposure, but takes some time to develop its protectiveness. It has been shown that the formation of protective passive film on phosphoric iron takes approximately 3 years<sup>11</sup>. There are several stages in the development of protective passive film on phosphoric irons and these have

been described in great detail elsewhere<sup>16</sup>. It is reasonable to propose that the excellent atmospheric corrosion resistance of the iron cannon at Badā Burj of the Golconda fort is due to the formation of a protective passive film on the surface, which results due to the relatively high P content of the cannon iron.

The microstructure of iron from the cannon should contain entrapped slag inclusion and ferritic grains interspersed with coarse cementite/pearlite, as is usually observed in ancient and medieval Indian irons<sup>4,12,13</sup>. The atmospheric rust from the cannon needs to be characterized. There are several modern sophisticated techniques for performing the same<sup>17</sup>. This will help in understanding protective passive film formation on phosphoric irons in general.

### CONCLUSIONS

The massive forge welded iron cannon at the Badā Burj of the Golconda fort rampart has been described. The history of the cannon has been briefly addressed. Special attention was focused on understanding the construction and design of the cannon. The cannon was manufactured by forge welding of pre-forged iron rings over longitudinally placed iron staves. The excellent atmospheric corrosion resistance of the cannon iron has been proposed to be due to the formation of the protective passive film on the surface of phosphoric iron.

### ACKNOWLEDGEMENT

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