

NAGARJUNASAGAR DAM

WORLD'S LARGEST MASONRY DAM

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Abstract. This article deals with the design and construction aspects of Nagarjunasagar Dam situated in the province of Andhra Pradesh, India. It is constructed on the river Krishna. The unique aspect of this dam, it is of random rubble masonry in cement mortar which is quite different from most other dams which are of cement concrete construction. There were some portions of the dam constructed in concrete wherever stress and other considerations warranted. The decision of going for masonry was taken after exhaustive tests for strength and other properties of masonry were conducted both in India and also at Bureau of reclamation, Denver, Colorado, USA. Also the availability of plenty of hard granite stone nearby the project site as well as the availability of cheap labour force made the choice more favourable and economic.

1 LOCATION OF THE DAM ON RIVER KRISHNA

The dam is constructed across river Krishna the second largest river in south India (see fig. 1 and 1a). The river Krishna has got a hoary past history. Many civilisations like Satavahana, Ikshvaku, Pallava, Chalukya, Kakatiya and Vijayanagara thrived on its banks. It has its origin in Western Ghats and runs eastwards and joins the Bay of Bengal.

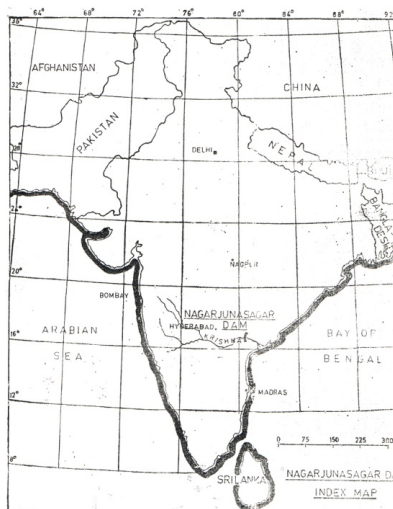


Figure 1: The location map of the dam in India

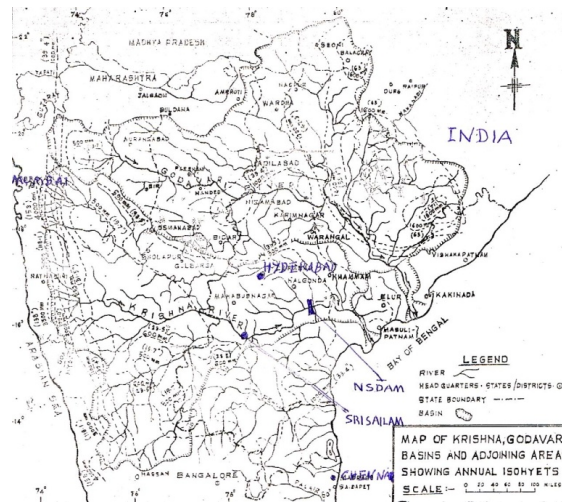


Figure 1a: The location map of the dam in

The Krishna basin with an area of 258,948 sq.km forms 8% of the total geographic area of India. It runs through the states of Maharashtra, Karnataka and Andhra Pradesh with a total length of 1400 kms. It has got several tributaries Koyna, Varuna, Dudhganga, Ghataprabha, Malaprabha, Bhima, Tungabhadra, Dindi, Okachettivagu, Halia, Peddavagu, Musi, Paleru, and Munneru. Nagarjunasagar dam is situated 96 km from Srisailem the famous Hindu pilgrimage town (see fig. 2). The dam is the largest masonry structure in the world for irrigating 1.6 million hectares and with an installed capacity of half a million kilowatts of power. This irrigated area is only next to that of river Ganga which is 3.2 million hectares. This project is an outstanding monument built exclusively by Indian expertise. The project is a symbol of prosperity not only for Andhra Pradesh but also for the entire India.

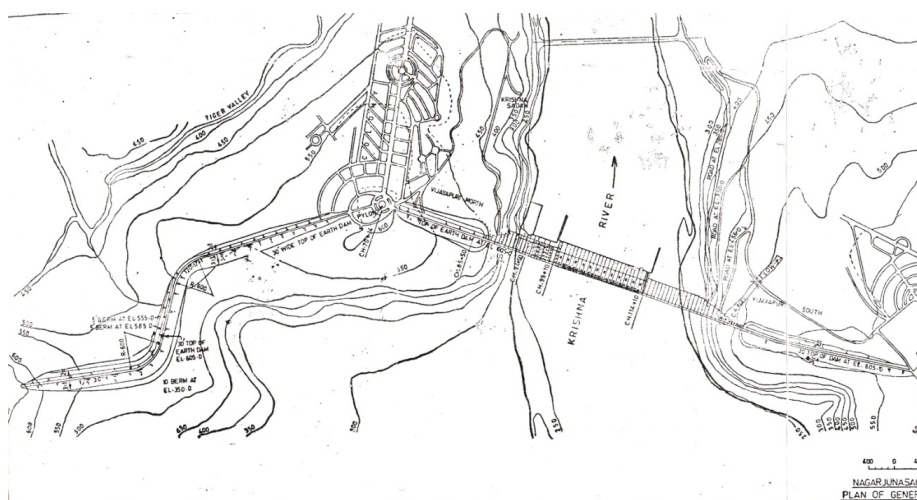


Figure 2: General layout of the dam and the contours

2 HISTORY OF THE PROJECT

The planning commission of India after several deliberations approved the construction of a high dam near Nandikonda village. Accordingly the chief engineers of the Andhra and erstwhile Hyderabad state submitted detailed proposals to the govt of India in 1954.

The central water and power commission scrutinised the proposals and gave the final shape to the project proposals.

The following salient features are incorporated.

1. Dam with FRL at 179.83 m
2. Right canal with sill at 149.0 m level with a capacity of 594.6 cumecs discharge.
3. Left canal with sill at 149.0 m with a capacity of 424.7 cumecs discharge.

Accordingly an investigating division was formed in Dec 1954. The investigation consists of detailed surveys, drawing contours, drilling operations to ascertain the substrata rock profiles, fixing the alignment of the dam and also finalisation of the alignment of both the right and left canals, drawing contours and contour plans.

The investigation was wrought with several practical difficulties since the project area is situated amidst dense forest without any approach to the dam site not even a cart track. The investigating staff were to face wild animals several times and fortunately they did not harm any of the engineers or their staff.

It is really commendable that the investigation was completed in a record time of about one year and the project work was commenced in dec.1955. Pandit Jawaharlal Nehru (the first Prime minister of India after Independence) inaugurated the project. That occasion was a historic one and the Prime minister remarked that the Dam is going to be a temple of modern civilisation. Many dignitaries attended that historic occasion including the Chief minister Dr Sanjeevareddy, Governor Trivedi etc.

Pandit Nehru christened the project after the famous Buddhist saint Nagarjuna who used to preach Buddhism in that valley where the dam is proposed. Also the proposed camps on the north and south sides were named as Vijayapuri north and Vijayapuri south. There are many relics belonging to the saint Nagarjuna and all the relics were relocated at a higher place and a museum was constructed, since the site is going to be inundated the area when the project completes. The Buddhist countries of Srilanka, Burma, Tibet and Indonesia were very much satisfied by our action in relocating the relics of Acharya Nagarjuna and prevented them from submergence. The museum location is Lat. 16° 31' north and Long. 79° 14' minutes east.

3 HISTORY OF SAINT (ACHARVA) NAGARJUNA

It is very appropriate at this juncture to learn a few things about the world renowned Buddhist saint Nagarjuna. According Buddhist historical accounts of Tibet Nagarjuna lived during 13th and 14th centuries at Vijayapuri the present site of the dam. Nagarjuna is the founder of Madhyamika Mahayana Buddhism. He is also an alchemist. His place is a eminent learning place for Buddhists and several teachers from far and near came there to teach: From Kashmir, Gandhara (now Rawalpindi region) Yavana (greek settlements in Kabul) Tamraparnadweepam (Srilanka), Kirata (Tibet), Orissa, Tamilnadu, Bengal etc. Several structures like stupas and chaityas and bathing ghats and auditoriums were constructed to cater to the needs of the inhabitants of Vijayapuri. All these structures were transplanted in a museum named after Nagarjuna at a higher place by the archaeological department of Andhra Pradesh to prevent them from submergence. First photographs were taken of these structures from several angles and then these structures were dismantled and reconstructed most carefully according to the photos taken earlier. This arduous task was carried out eminently by the archaeological department.

4 GEOLOGY OF THE FOUNDATIONS

The general layout of the dam fig. 3 and its cross section showing the various blocks.

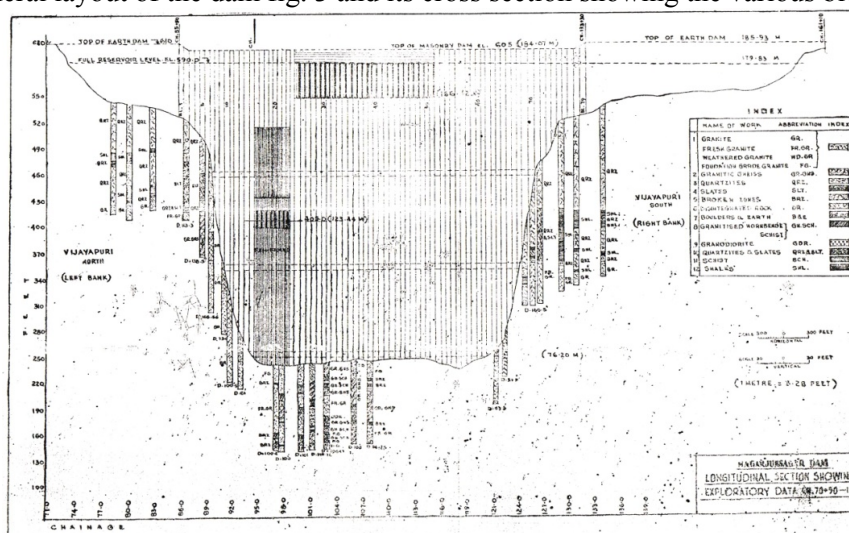


Figure 3: Dam cross section showing the geological strata and the blocks

The nandikonda site which was finally selected was inspected by eminent geologists. They reported that during aeons the river had cut through kniessic knoll overlaid by quartzites. The bed of the river consists of massive and fresh granite kniesses of the peninsular gnessic complex and the flanks are quartzites and shales of the Srisailam stage of the Cuddapah system. The masonry dam was founded on granite rocks from blocks 6 to 69, while blocks 1 to 5 on the left flank and 70 to 79 on the right flank were founded on fresh quartzites. The foundation levels at various chain ages were fixed based on the diamond drill cores ascertain the hard strata availability.

5 PREPARATION OF FOUNDATIONS

The foundations for the dam required very careful treatment to make them percolation proof. First of all the overburden was removed by blasting up to one metre high from the designed foundation level. Then the remaining rock was removed manually by wedging and rodding so that the foundation strata may not get fractured. After getting at the designed level of foundation then consolidation grouting was conducted with cement grout as detailed below. Even in hard rock strata there were some fissures and viens which are to be strengthened by grouting.

- Low pressure grouting: This is for treating the surface layers at shallow depths to provide general consolidation of the surface rock and to fill and seal major seams, joints and crevices.

The holes were driven 9 m deep and at 6 m centres in four rows parallel to the axis of the dam the spacing between rows is about 6m. Grouting pressure was 2.8 to 3.5 kgs per sq cm in quartzite zones and 5.25 to 7.0 kgs per sq.cm in granite zones.

- High pressure grouting: This is carried out in a single row of holes and the line of holes along upstream edge of foundation gallery. This is called curtain grouting which was done at high pressure of 7 to 21 kg per sq cm. Drainage holes were drilled downstream of the curtain holes to release the uplift pressure due to the leakage of water through the curtain. A fault zone was discovered in blocks 7, 8 and 9 and dolerite dyke in blocks 18 to 23. Extra holes were drilled in these places and loose materials removed and refilled with concrete. Grout pressures were controlled so as not to disturb the layers of overlying rock. The drilling operations and low pressure grouting were carried out departmentally. High pressure grouting was entrusted to renowned firms M/s Kilburn & co., and M/s west Bengal coalfields. For grouting Garden Denver pneumatically operated grout pumps were used.

6 GENERAL LAYOUT

The general layout of the dam was given in fig. 2 .Masonry dam was proposed in the river portion and Earth dams on both flanks.

7 AREA CAPACITY CURVE

This was given in fig. 4 which shows the reservoir capacity verses elevation and also the reservoir capacity verses the elevation.

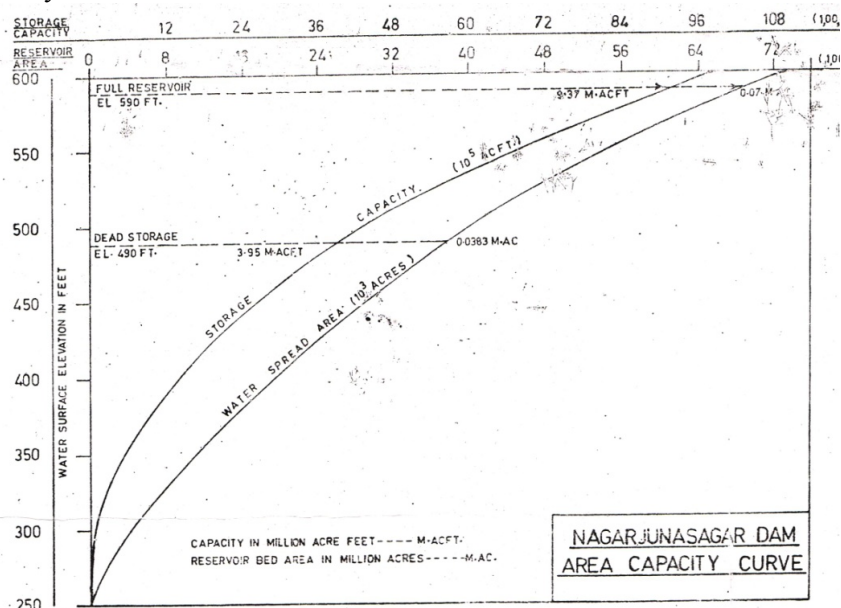


Figure 4: Area Capacity curve

8 CONTROL BOARD

For the project management Nagarjunasagar control board was formed with an administrator and three chief engineer's one for the dam and the other one for the right canal and the other for the left canal.

9 PROCUREMENT OF CONSTRUCTION MATERIALS:

9.1. Cement

Cement was supplied by Macherla cement factory situated at a distance of 22 kms from the dam site. This factory was commissioned mainly to cater to the needs of the construction of the dam and canals and it started supplying cement in April 1959. The maximum daily supply was 1500 tons of cement 1965. A railway line was also constructed from the factory to the dam site to facilitate the supply of cement. The railway siding will come up to Lankamottu about 2.4 km from downstream of dam site on the right bank. At that place Cement was supplied from the factory in specially built bulk cement wagons and these will drop the cement into a hopper wherefrom it is rehandled and reloaded into bulk carrier (Thornycraft make) trucks with pneumatic pumps and transported to the dam site to the batching plants where this cement is pneumatically pumped into the bins in which it is stored till usage.

9.2. Stone

In the initial stages stone was quarried from the quarries in the bed of the river at a distance of 3.2 kms. After the submergence of these quarries other quarries were found 10 kms distance at Bandlakarva and sunkesula and also near Nagarjunakonda on the right bank at a distance of 16 km. The entire stone is transported by Lorries. Blasting with electric detonators and in some cases with gun powder was carried out to quarry the stone. The holes for placing the detonators were drilled with pneumatic jack hammers. The bigger stones were conveyed to the dam by Lorries and the smaller ones are broken into aggregates suitable to be used in concrete. This is done manually as well as by machine operated crushers. Even though most of the construction is in masonry the following places are done in concrete like covering of copper sealing strips, Sides of galleries, Spillway bucket, and rear face of spillway and other special locations.

9.3. Surki

Surki is the fine powder of brick used to be mixed with cement (20 % of cement replaced with Surki) for its puzolonic properties which reduces the heat of hydration and also adds to the long time strength and impermeability of the mortar and concrete. The clay required for the manufacture of bricks for doing surki is found at various locations ranging from 3 to 7 kms. Bricks or balls were manufactured from that clay and they were burnt and then they were powdered in a ball mill to a very fine powder which is the surki.

10 MATERIALS HANDLED

The volume of Nagarjunasagar dam is more than one and a half times in volume of the Hoover dam across Colorado river in US and when compared to Bhakra dam in India. Nagarjunasagar dam is one and a half times bigger and stores 27 % more water. The quantum of masonry and earthwork involved will be sufficient to lay a road of 3 meters wide and 8cm thick around the world. The dam comprises of 1349 meters long and 123 meters high masonry structure flanked by earth dam of 26 meters high on either side. The total length of masonry and the earth dam is 4.8 km. The materials required for the construction were tabulated below.

- Cement:	1.2 million tonnes	24 km from Macherla
- Stone:	5.92 m.cu.m	lead 3.2 to 12.8 km
- Sand:	2.44 m.cu.m	Around 11 kms
- Surki:	0.20 m.tonnes	lead 2.4 to 16 km
- Steel:	60,000 tonnes	1600 kms from steel factories

11. CONSTRUCTION PLANNING

Out of 111 meters of height of the dam above ground level the quantity of masonry for 35 meters height amounts to half. So it was felt that manual lifting of materials up to 35 meters was planned. Scaffolding with country wood material was put up on the rear slope of the dam in a (Z) shape and Jawalis who are specially trained to carry heavy loads were engaged to carry stones. Two jawalis carry a thick bamboo on their shoulders and stones of about 2 to 3 cubic feet were carried with a sling of iron chains tied to the bamboo. This is really a marvellous feat very much appreciated by outside visitors, especially by foreign visitors.

The second stage is planned by machine lifting. Several alternatives were considered like Cable ways, Cranes mounted on steel trestles and belt conveyors. But finally mono tower cranes erected by M/s Larsen and Toubro were worked out to be cheaper and hence were adopted for lifting materials from the ground to the work spot which is higher than 35 meters. The height of the cranes can be increased by extending the tower to suit the height of construction.

The conveyance of materials like stone, rubble sand and surki were done by Lorries to the work site or to the batching plants. Cement was transported by bulk carriers in addition by train direct to the batching plants as described above.

12 BATCHING PLANTS

For mixing of mortar and concrete at the design proportions batching plants were erected. Winget on the left side with a capacity of 3 cu.yards for every mix. Similarly Blawnox plant was erected on the right side with a similar capacity. Individual mixers of one cu.yd capacity were also utilised whenever and wherever required. Lorries come under the batching plants and the plant delivers the mix into the lorry and it takes near the dam and it is manually lifted to the worksite. For higher levels the Lorries carry buckets of 3 cu.yd capacity and the Lorries take the mixes to the dam where they will be lifted by monotower cranes to the work place.

13 SELECTION OF RUBBLE MASONRY FOR CONSTRUCTION

Several masonry dams were constructed the world over but their heights are very small to medium. Some examples are as follows.

Marib dam in south Arabia, Kassorine dam in north Africa, Kaveri dam in south India, Bandi sarj dam in Afghanistan, Raritan dam near new jerky US, Crobois dam in France, Meer alum dam in Hyderabad, India, Masonry anicuts constructed by Sir Arthur Cotton a British engineer across the rivers of Godavari, Krishna, Tungabhadra and Mahanadi, Krishnarajasagar dam and Mettur dam in south India.

Recently in 1911 Roosevelt dam was constructed in US whose height is 86 m and is of masonry.

In 1948 the gigantic Bhakra dam was constructed in India across river Sutlej which is concrete dam.

The Nagarjunasagar Dam is classified as a high dam and it is a historic decision of selecting Rubble Masonry as the medium of construction. This decision is based on several deliberations at high technical level and laboratory tests and stress analysis etc. as noted below and also in consultation with renowned world experts on the subject. The proceedings of the high level committee which had gone into the various aspects of masonry and concrete are as follows.

Strength: Cubes made of masonry of 0.9 m size were tested in United States Bureau of reclamation at Denver Colorado and the results are as follows. The proportion of mortar used in the cubes is indicated below.

Compressive strength (Of cubes) in kgs per sq cm.

- cement mortar	1:3	189 (28 days)	235 (90 days)
- cement mortar	1:4	150	190
- cement motor	1:5	143	160

- With 25 mm concrete mix

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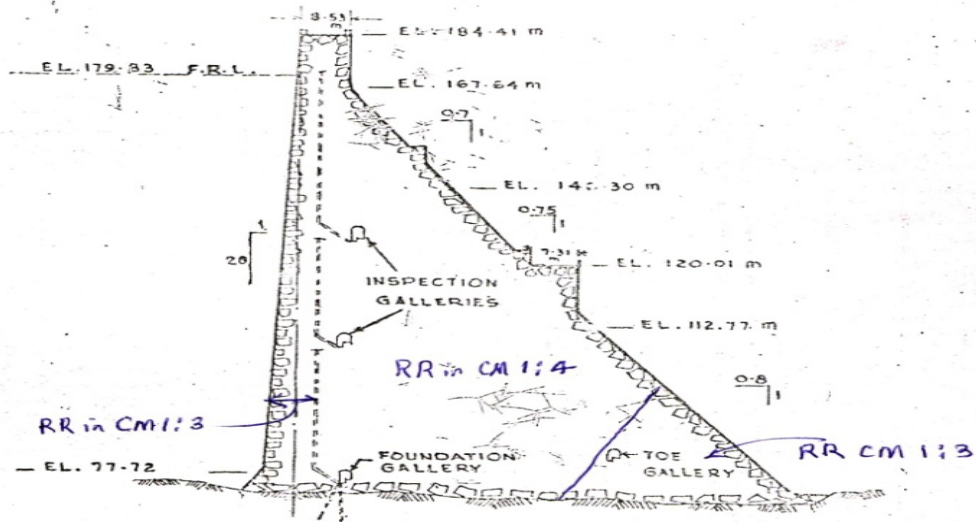
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The same were also tested at an improvised testing equipment at Hirakud dam, India and the above results fairly tally with the above results.

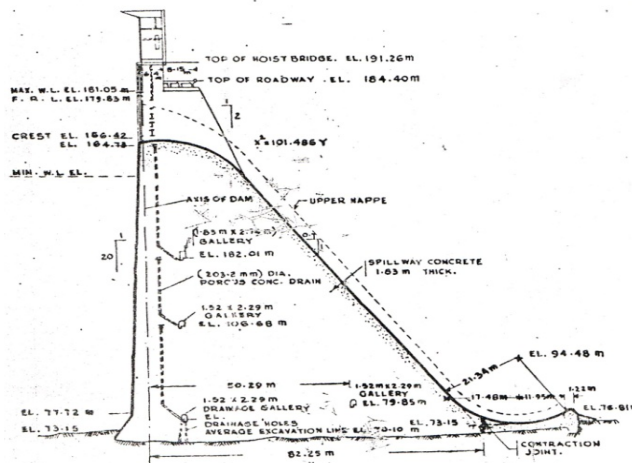
The committee also recommended usage of rich mix of mortar of 1:3 in zones where higher stresses

Occur. The maximum principal stress of 30 kg/sqcm developed in the dam can be safely taken by masonry built with c.m 1:3 with a factor of safety of 7.6 on 90 day strength. Front portion of the dam is also built with c.m 1:3 to make it impermeable. Various zones of masonry were shown in fig. 5 and 6.

Some important advantages of Masonry versus Concrete are given below.



NON-OVER FLOW SECTION



SPILLWAY SECTION

Figure 6: Spillway section

Strength: Masonry has got enough strength.

Cracking: Due to less heat of hydration the possibility of formation of cracks is minimised since the masonry layers are only of 0.3 m.

Seepage: It is observed in the masonry dams constructed previously like Tungabhadra dam and Mettur to be only 2.2 % of the allowable value. The concerned values observed at N.S Dam are also similarly very low as observed in the drainage galleries

Minimum machinery: Much less machinery is required for masonry construction when compared with that of concrete thus saving valuable foreign exchange.

Minimum shuttering: For constructing masonry no much shuttering is required since layers of masonry are laid manually without any shuttering.

Reduction of cement: Cement is a costly commodity and the usage of cement in masonry is only about 50 % when compared to that of concrete of the same strength.

Employment potential: Masonry construction requires four times more labour than that of concrete thus providing employment for several people who depend on manual labour for their sustenance.

Less length of blocks: The coefficient of expansion of Masonry is only 0.3×10^{-5} where as that of concrete is almost double of this. So the length of blocks can be much less when compared to that of concrete dam for limiting the expansion. There by the cost of joints with copper strips etc is reduced so also thereby reducing the joints which are the weak points in the dam.

Cost: The main consideration is the cost. The cost of Masonry with 1:4 red cement mortars is Rs 42 p.cum only whereas that of concrete of the same strength is Rs 50 thus the masonry construction is 30 % cheaper.

Air entraining agent: Aerosine is an air entraining agent manufactured at NSDam laboratories and used in mortar and concrete and by this the workability is increased and thus it is made possible to reduce water cement ratio thereby increasing the strength.

14 MASONRY DAM SECTIONS:

Fig. 5 shows *Non overflow section*. The maximum level i.e. road level is 184.41 m, the FRL is 179.83, the front batter is i in 20 while the rear slope is 0.7 to 1.0, 0.75 to 1.0 and 0.8 to 1.0 at various levels as shown in the figure. There are two ledges on the rear slope of the dam for facilitating conveyance of materials. Drainage/inspection galleries are shown in the figure. The exposed faces were built of dressed stone in cement mortar whereas all the interior portion was constructed with random rubble masonry 1:4 with surki replacing 25 % of cement. The proportion of mortar is changed to a richer one where severe stresses are anticipated such as the toe and the front face where impermeability is required. Zoning of masonry and concrete were shown separately.

Overflow section: fig. 7. Shows the overflow section or the spillway section. The main feature is there is flip bucket with a radius of 21.34 m at the rear toe to deflect the waters down the spillway to a distant place away from the foundations to safeguard the foundations of the dam. The upper nappe is also shown. The face of the spillway is done with reinforced concrete to withstand the kinetic force of the spillway flow.

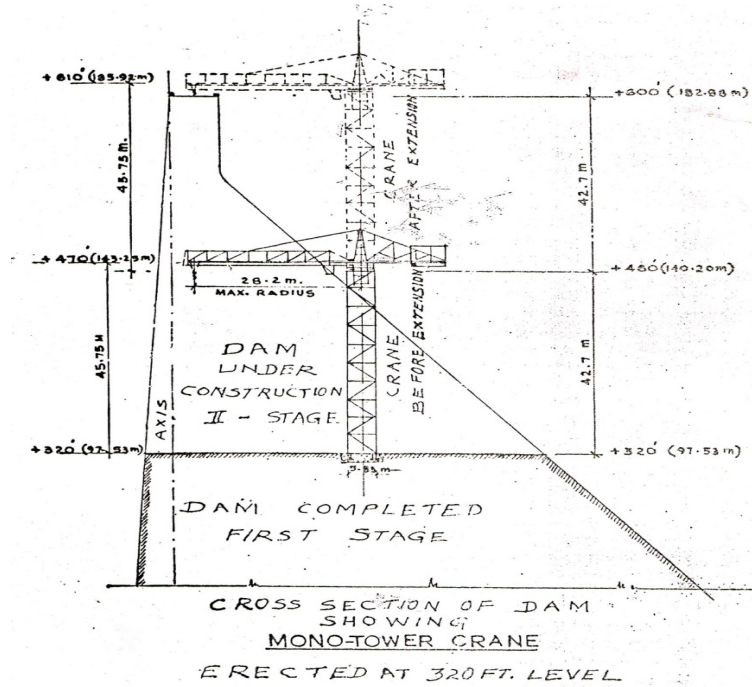


Figure 7: Monotowercranes

The spillway course is designed as a parabolic curve $X^2=101.486Y$. The drainage/ inspection galleries and the air vents are also shown.

Powerdam section: fig. 8. For the development of waterpower penstocks of 4.88m dia are provided to lead the water from the reservoir to the generator turbines. Trash rack, Bulk head gates can also be seen.

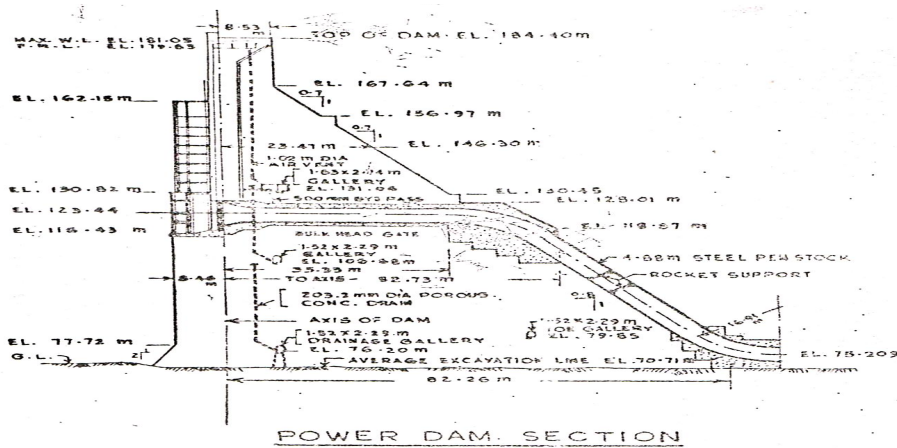


Figure 8: Powerdam section

Also seen that the penstocks were embedded in concrete and at the toe of the dam an anchor block is constructed to stabilise the penstock against the centrifugal forces developed due to change in direction of waterflow. The other details are common. The details of the power development are as follows.

Right canal: There are two generators of Kaplan turbines of 30 mw each totalling to 60 mw with 100 % power factor and voltage of 11 Kv. This is seasonal power.

Left canal: There are two generators of Kaplan turbines each of 25 mw totalling to 50 mw with 100 % power factor and 11 kV voltage. This is also seasonal power.

Powerdam: Blocks 16 to 23 and 71 and 72 constitute the power dam. Eight numbers of 50 mw each Francis turbines were provided for development of 400 mw. The water from the dam will feed the generators though the penstocks embedded in the dam **Earthdam sections:** Fig.

9. *Left Earthdam*: The top of the dam is 9.14 m wide. The dam is composed of impervious core with a casing of semi pervious material. There is a cutoff trench at the bottom of the front toe. Dumped rip rap is on the front face laid over a filter. Rock toes are provided at both the front and rear toes. *Right earthdam*: This is a smaller section with the impervious core overlaid with semipervious core and both the front and rear slopes are filled with excavated materials from the right canal. Rock fill toes are provided at both the toes. The earth is conveyed from approved quarries and conveyed by Lorries and scrappers. The earth is formed in layers of about 10 inches and consolidated with road rollers and sheepsfoot rollers and it is consolidated to 0.9 proctors density. The optimum moisture content as determined in the laboratory is also checked for all layers.

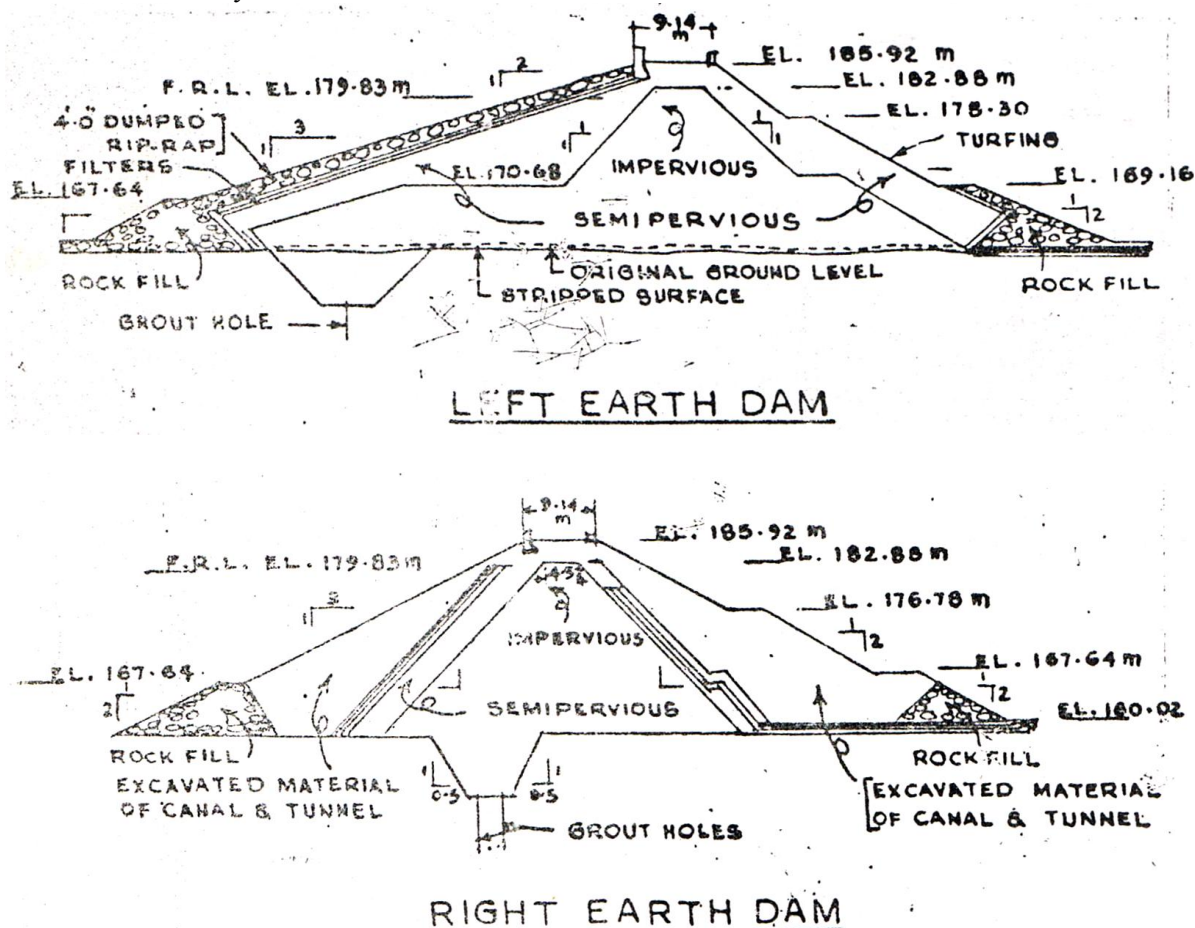


Figure 9: Earthdam sections

15 METHOD OF MASONRY CONSTRUCTION

Since masonry is the main construction material it is necessary to give a brief description of the method of construction. Heavy stones called jeddy stones (Undressed) of about one to two cubic feet in size were carried by jawalies on the scaffoldings from the ground to the work spot. For higher levels the stone is lifted by monotowers. The stone is dumped at the work place along with smaller stones and mortar (which is conveyed there by the above methods) is dumped over the stones and smaller stones and chips are placed in the mortar dump and the entire thing is vibrated with a crow bar so that the cement cream surfaces. The same procedure is continued on the hearting of the dam. But in the front and rear faces dressed stone is used for construction. Quality control staff were constantly supervising the consolidation by vibration.

16 QUALITY CONTROL AND LABORATORY CIRCLE

There is a very strong and effective quality control and inspection team to ensure good quality of work. On every block there are always QC staff in addition to the construction staff to see that the construction is done as per specifications. Every morning the area is to be passed by the QC staff to ensure the cleanness of the surface before starting work. The same has to be cleaned by using airwater jets to clean the debris collected due to dust and other factors. The quality of stone and mortar were also inspected and to be passed by the QC staff. The Copper strip joints which is a very important to make the joints impervious are also inspected and passed before concrete is laid. Concreting is also effectively supervised. The consolidation by proper vibration with electrical vibrators is ensured. Wherever mass concrete is involved cooling pipes are embedded and cold water circulated to reduce the heat of hydration thereby eliminating the chances of cracking. Cubes and cylinders are cast with the mortar and concrete which are used on the dam and the same are tested after 28 and 90 days at the laboratory to ascertain that design strength is obtained. In the earthdam the QC staff tested the quality of the earth conveyed and for every layer of the earth dam the density is checked and it is ensured that it conforms to 0.9 of proctors density at optimum moisture content and it is seen that proper consolidation is done with road rollers and sheepsfoot rollers etc.

17 LABORATORY

There was a full fledged testing laboratory with universal testing machines and soil testing machines and chemical examination kits etc. The test samples cast at the site and at the batching plants were taken to the lab and cured and tested at 28 and 90 days and if the strength falls below the design values the field staff is alerted .Also the stone samples from quarries and the surki samples from the factory and earth samples from quarries were tested and their suitability examined and the field staff are informed.

Design of mixes, Tests of the earth samples and stone samples are conducted and their suitability examined and necessary advises are given to the field staff. Cement which is a very important ingredient is tested thoroughly and it is tested for is fineness, soundness, vicat test, for setting time, tensile strength and compressive strength.

18 INSTRUMENTATION

Carlson type of instruments for measuring stress strain and deflection were installed by the laboratory staff in strategic places in the dam.

19 RESEARCH WORK

The QC wing conducted research in the Engineering research laboratories at Hyderabad (India).The following aspects had been studied in the model studies at the laboratories.

- The ogee curve of the spillway.

- The diameter of the flip bucket at the rear toe of the spillway.

- Invented a new type of air entraining agent called Aerosine which is successfully used in the mortar and concrete mixes in the construction of the dam. The air entrainment will increase the workability of the mix for a lower water cement ratio and hence increasing the strength. This is manufactured in the laboratory by mixing Rosin resin with Caustic soda.

20 CONTROL OF RIVER WATER

The river water is controlled though the following arrangements.

- . Diversion tunnel: The tunnel enables to let out water to the riparian ayacut under the Prakasam Barrage at Vijayawada in addition diverting water during the construction phase.

- Penstocks: There are penstocks on both right and left sides through which water is let down for power production.
 - Chute sluices: These are high level sluices through which water can be released in emergent cases.
 - Canal regulators both right and left: These are for releasing water for the commandable ayacut under the dam.
 - Spillway: For discharging the maximum flood in the river.
- See details from the salient features.

21 COST OF THE DAM

The cost of the dam as per 1971 estimates is Rs 730 million against Rs 364 Million as per the 1954 estimates. The increase in cost is mainly due to the escalation of the cost of construction materials since 1954.

22 AYACUT DEVELOPMENT

The right canal (Jawahar canal) with a discharge of 594 cumecs is having a distributary system of 33,000 km and irrigates an ayacut of 0.475 million hectares in addition to stabilising 48,000 hectares of Krishna delta under Prakasam Barrage at Vijayawada.

The left canal (Lal bahadur canal) with a discharge of 311 cumecs is having a distributary system of 15000 kms irrigating an area o 0.397 million hectares.

Cropping pattern: As per the limited availability of water with respect to the irrigable area and also the nature of soils available wet and dry crops are fixed in a ratio of 1:2. The general layout and the canal system were shown in fig. 11.

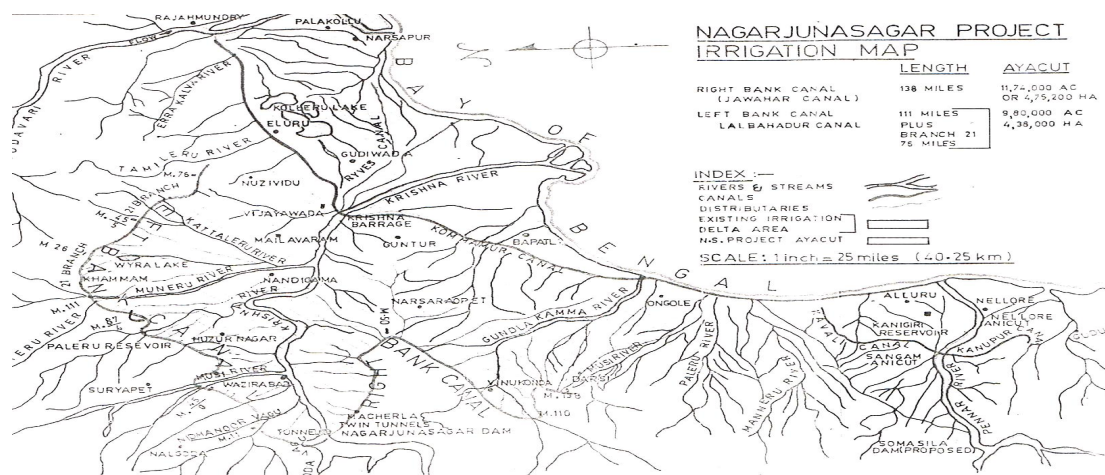


Figure 11: Layout of irrigation canals and ayacut

The area proposed under irrigation under this project is virgin land and hence the farmers needed some training and monetary encouragement by means of incentives which were provided by the revenue department.

23 SALIENT FEATURES

The salient features of the dam are as follows:

Masonry dam

- Catchment area at dam site 83,087 sq. miles

- Average Annual rainfall	35 inc(889) mm
- Maximum discharge observed at site	11.70 lakh cusecs (33,100 cumecs)
- Maximum Design flood As assessed from discharge data	15.4 lakh cusecs (43,600 cumecs)
- As assessed from extended data	19.00 lakh cusecs (53,800 cumecs)
- Full reservoir level	590.00 ft. for the design flood of 15.4 lakh cusecs or 43,600cumecs
- Gross storage capacity	9.37 m.a. ft (11,557 m. cum.)
- Dead storage capacity	4.86 m.a.ft. (5,994 m. cum.)
- Live storage capacity	4.51 m.a. ft. (5,563 m.cum.)
- Total length	4,756 ft. (1,450 m.)
- Spillway	1,545 ft (471 m.)
- Non-overflow including power dam	3,211 ft. (980 m.)
- Maximum height of the dam	409 ft. (124.5 m.)
- Bottom base width	320.0 ft. (97.4 m.)
- Top width	30.50 ft. (9.20 m.)
- Top of dam	605.0ft. (184.50 m.)
- Spillway crests elevation	546.0 ft. (166.5 m.)

24 CIVIC AMENITIES

Medicare: A 100 bed hospital was constructed with qualified doctors to cater to the need of the working staff.

Quarters: All the working staff were provided with quarters of various categories depending on their position in the dam hierarchy. EE type, AE type, A type, B type, C type, D type etc.

Tourist attraction and Rest houses: Since there is a lot of importance as a tourist centre for this project and for the museum where the relics of Nagarjuna were preserved, deluxe accommodation for tourists was constructed. Vijayavihar for VIPs and Project house for others on the left flank. On the right flank there are Riverview guest house, Lake View guest house, are also there for the visitors. The main attractions for the tourist us is the Nagarjunakonda where the relics of Lord Buddha were carefully preserved in the newly constructed museum after being retrieved from the underground. There is a rest house near Nagarjunakonda where visitors can stay. There is a boat plying between the dam site and Nagarjunakonda. It is a pleasure to travel in this boat through the bluish green waters of the reservoir with very pleasant scenic beauty.

Ethipothala waterfalls: There is a waterfall d/s of the dam about 20kms from the dam site which also is a famous tourist attraction.

25 CONCLUSIONS

As observed by Jawaharlal Nehru the first Prime Minster of Minter of free India this enormous project is a modern temple of humanity. The people of India in general and those of AndhraPradesh in particular are the beneficiaries of this project and the ayacut area of this project has become a big granary.

Under this famous construction there lies a sad story of those who lost their lives while performing their duties during the construction of the dam. I offer my humble tribute to all of them.