# Study the Behavior & Performance of Prestressed Rock Anchors (Encapsulated)

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*Abstract*— **The paper reviews some design rules and quality control associated with Prestressed Rock Anchors (Encapsulated). Design data related to the uplift capacity, rock/grout bond, tendon/grout bond.**

**For comparison, results of some relevant theoretical and experimental investigations are presented between Normal Prestressed Rock anchors & Encapsulated Prestressed Rock Anchors which may tend to contradict the fundamental assumptions of uniform interfacial stress distribution commonly made by designers.**

**On Site quality Control measures are strongly recommended and guidance is provided on permissible drilling tolerances, homing, bonding applications, waterproofing, grouting and final stressing. The project reviews some design rules and quality control associated with Prestressed Rock Anchors (Encapsulated). Design data related to the uplift capacity, rock/grout bond, tendon/grout bond.**

**For comparison, results of some relevant theoretical and experimental investigations are presented between Normal Prestressed Rock anchors & Encapsulated Prestressed Rock Anchors which may tend to contradict the fundamental assumptions of uniform interfacial stress distribution commonly made by designers.**

*Keywords*— **Prestressing, Rock Anchors, Soil Anchors, Rod Anchors, Enacapsulated Anchors, Normal Prestressed Anchors, Vertical Anchors, Inclined Anchors.**

## I. INTRODUCTION

Civil engineering deals with the design, construction and maintenance of physical and naturally built environment, including works like bridges, roads, canals, dams and buildings. It is the oldest and broadest engineering profession. All the engineering specialties have been derived from civil engineering. It is divided into various sub disciplines including environmental engineering, geotechnical engineering, structural engineering, transportation engineering, material engineering, surveying and construction engineering. The principles of all the above engineering aspects are applied to the residential, commercial, industrial and public works projects of all sizes and levels of construction.

Further, anchors were one of first application of stabilization technology. The process of anchoring is decided based on what kind of structure is required to be anchored. If the structure in question is a rather large such as bridge or dam, the preferred method of anchoring is passive / Active Type rock anchoring. Thus it is absolutely important to gauge the size, weight and other factors mention above.

Although rock anchors have been used successfully for many years in connection with the Prestressing of dams, roof strata control, and slope stabilization, in recent years the range of applications has widened considerably. This is due in part to the success achieved by soil / Rock anchors in tying back retaining walls, holding down dock floors, and pile testing. Now, rock anchors are expected to perform without difficulty, even when installed in relatively poor quality, weathered, or laminated, rock. In addition, there is a trend towards higher load capacities for individual and concentrated groups of anchors.

## II. OBJECTIVES

In the present work, it is proposed to Study the Behavior & Performance of Prestressed (Encapsulated Type) Rock Anchors in RCC Structures to determine the optimum benefit through the proposed system. Also the comparative results of some relevant theoretical and experimental investigations are presented between Normal Prestressed Rock anchors & Encapsulated Prestressed Rock Anchors. In the present study, Following objectives are carried out,

1. To analyze and design a different kind of anchoring aspects at different capabilities and locations.
2. To design a Encapsulated Prestressed Rock Anchor with maximum strength, durability and safety factors.
3. To make use of a simple and effective design methodology and construction. The design procedure and methodology adopted is to be in conformance to the present methodology being used in the industry.
4. To analyze the anchor manually with the various loads acting on the it.
5. To meet the requirements of the codal provisions given in the IS, BS and ACI codes, being considered and try to adopt economical sections in the structure.
6. To make detailed drawings indicating the sections used for the various components.
7. To do the comparative Study in terms of its behavior & performances between Normal and Encapsulated Prestressed Anchors.

## III. METHODOLOGY

1. Collection of detail information about analysis and design of Prestressed Anchoring (Encapsulated) as per current practices in the industry.
2. Review of literature and study of examples for the proposed project.
3. Study of IS, BS & ACI codal provisions for the design of Prestressed Rock Anchors.
4. Selection of site and collection of site information from previously completed projects and concerned authorities.
5. Design of Prestressd Rock Anchors Manually from available data.
6. Preparation of detailed design drawings.
7. Result discussions will be prepared based on compared results.

### *A. DESIGN DATA*

- Type of Anchor 1 :- Encapsulated Prestressed Rock Anchor
- Type of Anchor 2 :- Normal Prestressed Rock Anchor

- Inclination Type :- Vertical
- Capacity of Anchor :- 100 MT
- Anchor Hole Diameter :- 150 mm
- HT Strands :- 12.7mm Diameter
- Anchorages :- 12AS13 (Aaditya Make)
- Free Length :- 5000 mm
- Fixed Length :- Calculate from the available data for respective type of anchors
- No. of Strands :- Calculate from the available data for respective type of anchors
- Length of Anchors :- Calculate from the available data for respective type of anchors

*B. METHOD STATEMENT INTRODUCTION:*

Encapsulated Prestressed Rock anchors consists of tendons made of HT Strands 12.7 mm dia.. 7 ply, LRPC, low relaxation unoiled stress relieved strands of class II category. The Encapsulated anchors can take loads from 10T to 500T

**1) Drilling of Hole :**

Drilling of hole with the help of Percussion drilling method. Drilling is to be completed up to required depth. Suitable Diameter hole should be drilled at suitable inclination.

**2) Water Test :**

After cleaning the hole, fix packer in fix length zone and water test is to be conducted. Water loss is to be find out in terms of Lugeons. If the lugeon value is more than 3 then fix length of the hole is to be grouted with the help of neat cement grout with initial mix of 1 : 1 (Cement : Water)

**3) Fabrication of Anchor :**

a) Required number of strands shall be cut to the required length. Cutting of cable is to be derived as - Fix length + Free length + extra 1.0 Mtr. (for stressing purpose.)

b) Strands are cleaned thoroughly and oil on the surface is removed 1st coat of epoxy paint is to be applied immediately with the help of brush. After 24 hour second coat of epoxy paint is to be applied on strands. Quartz sand is to be sprinkled on fix zone of strands when 3rd coat is tacky.

c) Free length of strand is to be cleaned with the help of emery paper. Place the Plain Flexible HDPE Pipe, 2mm Thick on Free Length portion.

d) The pre-stressing strands, greased for the free length portion should be enclosed in HDPE sleeve, 2 mm thick encasing individual strand.

e) Fixed length of the cable is then provided with corrugated HDPE sheathing 2mm thick.

f) Centralizers fabricated from plastic or steel, are provided to ensure min 5 mm grout cover to anchor in fix length.

g) Fabrication :- Fix shoe with the help of brazing at bottom of cable. Then tie spacer at 1.0 mtr. C/C throughout the length of cable.

h) Shifting of cable at site :- Wrap the entire cable with the help of plastic sheet, prepare bundle of suitable diameter so that same can be loaded and off-loaded in truck. Keep all cables above ground levels with the help of wooden sleepers.

**4) Homing & Grouting :**

a) Before lowering of check depth of hole .

b) After checking depth of holder lower fabricated cable into the hole, while lowering ensure that cable is in suspended position be keeping about 300mm from bottom of the hole and of the cable. Cable should be in center of the hole.

c) Grouting of fix length : Prepare neat cement grout of mix 1:0.4 by calculating volume of grout to be poured in fix length zone. If possible dry cement should be sieved to remove any lumps, stone from the cement.

Grout the entire hole (ie. Fix Length + Free Length) with the help of neat cement grout. While grouting the grouting operation should be in one go only. There should not be any stoppage in between and no air in trap in the grout.

**5) Stressing**

Stressing of anchor will be carried out when grout has attained required strength. The stressing will be carried out by using Aaditya make hydraulic jack. After 24 hours of stressing , the extra length of cable above anchor head should be cut by keeping 2” projection above anchor head with the help of grinder.

## IV. RESULT AND DISCUSSION

### *A. Results of Encapsulated Prestressed Rock Anchors*

| Sr. No. | Description | Design Values |
|---|---|---|
| 1 | Design Anchor Load | 100 MT |
| 2 | No. of Strands in Anchor | 8.00 Nos. |
| 3 | Free Length of Anchor | 5.00 Mtr. |
| 4 | Fixed Length of Anchor | 7.50 Mtr. |
| 5 | Dia. Of HT Strands | 12.7mm |
| 6 | Applied Pressure | 310 Kg/Sqcm |
| 7 | Design Elongations | |
| a | Lower Limit | 30.56mm |
| b | Higher Limit | 59.06mm |

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### *B. Results of Normal Prestressed Rock Anchors*

| Sr. No. | Description | Design Values |
|---|---|---|
| 1 | Design Anchor Load | 100 MT |
| 2 | No. of Strands in Anchor | 9.00 Nos. |
| 3 | Free Length of Anchor | 5.00 Mtr. |
| 4 | Fixed Length of Anchor | 8.50 Mtr. |
| 5 | Dia. Of HT Strands | 12.7mm |
| 6 | Applied Pressure | 275 Kg/Sqcm |
| 7 | Design Elongations | |
| a | Lower Limit | 27.26mm |
| b | Higher Limit | 56.23mm |

## V. COMPARATIVE STUDY

| Sr. no. | Desription | Normal Anchor | Encapsulated Anchor No. |
|---|---|---|---|
| 1 | Capacity of Rock Anchor | 100 MT | 100 MT |
| 2 | No. of Strands per Anchor | 9.00 Nos. | 8.00 Nos. |
| 3 | Total Pressure Applied per Stand | 275 Kg/Sqcm | 310 Kg/Sqcm |
| 4 | Total Withstand Load | 67.69% | 80.23% |
| 5 | Fixed length of Anchor | 8.50 Mtr | 7.50 Mtr. |
| 6 | Total Length of Anchor | 13.50 Mtr | 12.50 Mtr |
| 7 | Permiability Test Results in 1st attempt | Failed | Pass |
| 8 | Redrilling Required | Required | Not Required |
| 9 | Permiability Test Results in 2nd attempt | Pass | NA |
| 10 | Total Cemnt Bags requied for Grouting | 16 .00 Nos. | 8.00 Nos. |
| 11 | Total Time required for execution | More Comparative to Encapsulated Anchors | Less comparative to Normal Anchors |
| 12 | Total Expenses required for execution | More Comparative to Encapsulated Anchors | Less comparative to Normal Anchors |
| 13 | Design | These Anchors are designed as per the Indian Standards (IS : 10270-1995 ) | These Anchors are designed as per the International Standards (BS : 8081 - 1989) |
| 14 | Corrosion Protection in Free Length | There are three layers of corrosion protection in free length such as grout, HDPE pipe and then again grout | There are five layers of corrosion protection in free length such as Grease, Individual HDPE pipe, grout, HDPE and then again grout |
| 15 | Corrosion Protection in Fixed Length | There are Two layers of corrosion protection in fixed length such as Epoxy and grout | There are four layers of corrosion protection in fixed length such as Epoxy, grout, Corrugated HDPE pipe and then again grout |
| 16 | Grouting | In Normal Anchors we do Down the hole grouting for fixed portion & for Free length portion we do grouting by air release method. | In Encapsulated Anchors we do Down the hole grouting in one go for fixed & Free length portion. |
| | | Hence there are chances of air pockets entrapped in free length portion. | As the grouting in one go it ensures no air pockets entrapped in anchor hole. |
| 17 | Life | These types of anchors are normally worked as a Temporary Anchors. Life of Anchors are @ 5- 6 years. | These types of anchors are normally worked as a Permanent Anchors. |
| 18 | Restressable | We cannot monitor & restress the anchors in future. | We can monitor & restress the anchors in future if structure permits. |

## VI. CONCLUSION

The following conclusions are drawn from proposed study –

1) Results of analysis indicated that,
   - Since the validity of the Encapsulated anchors are more in terms of life span, performances, and economy, it is recommended that encapsulated anchors should be used in wide ranges whose engineering and geological properties can be fully classified, in order to ascertain as most of its parameters significantly affect anchor performance. In this way it should be possible in due course to provide more reliable and economic design criteria
   - Difference of 1.00 nos. HT Strands more in normal anchors; which lead to the increase in costing. The Nos. of strands require for 100 MT Capacity of Normal Rock anchors and Encapsulated were found out 9.00 Nos. and 8.00 Nos. respectively.
   - Difference of 1.00 mtr. in Fixed length of anchor found more in normal anchors; which lead to the increase in cost & speed of construction. The Total Fixed Length require for 100 MT Capacity of Normal Rock anchors and Encapsulated were found out 8.50 mtrs. and 7.50 mtrs. respectively.
   - Difference of 8.00 Nos. of Cement bags found more in normal anchors; which lead to the increase in cost of construction. The Total Cement Bags require for 100 MT Capacity of Normal Rock anchors and Encapsulated were found out 16.00 nos. and 8.00nos. respectively.
2) Normal Anchor failed at @ 275 Kg/cm² pressure. Whereas Encapsulated Anchor failed at @ 310 Kg/cm² pressure. The Failure occurs due to grout bond failure
3) Normal Anchors withstand for a Maximum load of 67.69% whereas Encapsulated Anchors withstand for a Maximum load of 80.23%
4) From above mentioned results and analysis ; Normal anchors are design to work as Temporary anchors and Encapsulated anchors are design to work for permanent anchors.

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