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SHORT-FALLS IN SUB-SURFACE INVESTIGATIONS FOR BRIDGE FOUNDATIONS - A FEW CASE STUDIES ALONGWITH REVIEW OF CODAL PROVISIONS.

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1. SUMMARY

Sub-surface exploration for all Engineering structures ingeneral and bridge foundations in particular is the most important item in the planning of these structures. Investigations by core drilling are discussed in this paper. Importance of core drilling is said to have been realised by the engineers, however, in practice it does not seem to be true. Even in recent past there are a number of projects where there was time and cost over-run basically due to inadequate or improper investigations. At the same time, there are a few projects where considerable economy is achieved with proper investigations. Interpretation is another aspect which is usually neglected. In the investigations what is not obtained from the cores is more important than what is obtained. What is not obtained can be analysed only if very careful observations are made and also recorded during drilling and then the total information collected is interpreted, either by an Engineering Geologist or by a specially trained Engineer, who is well acquainted with the geology of the area as well as the subject proper.

Guidelines are available in various I.S./ I.R.C. codes and P.W.D. Handbook of Maharashtra State. However, experience is that these guidelines are not strictly followed. This is true whether the investgations are carried out by a renowned agency or a local one. Provisions in these specifications which are important but are usually neglected are discussed in this paper. Although very important, core drilling, particularly for bridge or tunnel projects, is done more as a formality and interpretation is either totally neglected or where attempted, give an entirely false picture as they are done by people not qualified for the purpose.

In view of authors' experience in that area, the paper deals with provisions more applicable to Deccan trap area which covers Maharashtra, Madhya Pradesh, Gujarath, Saurashtra, Karnataka and Andhra Pradesh. The paper also suggests some modifications to the codal provisions. Case studies are given which include some success stories of proper investigations and some failure stories.

2. DECCAN TRAP BASALTS - A Few Special Features

In the Deccan Trap two main types of basalts occur : the compact or non-vesicular basalts and the amygdaloidal basalts. The common cavity fillings are zeolites producing white spots. The important difference between them is that the compact basalts are well jointed while the amygdaloidal basalts are unjointed. Jointing in rocks plays a very important role in foundations. Chlorophaeitic basalts (amygaloidal or compact), are also common. Many chlorophaeitic basalts are prone to rapid deterioration on exposure to atmosphere. Hydrothermally altered basalts are often in poor condition. The black and red tachylytic basalts, on exposure to atmosphere, disintegrate into powdery material. Volcanic breccias is another common variety and needs careful consideration. Dykes are also very common in Deccan Traps. These dykes in Deccan Traps are usually harder than surrounding but are very closely jointed. Resting foundations partly on dykes and partly outside is risky (central pier of CBD arm of Konkan Bhavan flyover). Vertical or steeply inclined fractures along which no movement has taken place are common in some parts of the Deccan Trap area. Many of them are quite tight. Water seeping along the crack brings about decomposition of the basalts producing a zone of vertical sheet jointing varying in width from a few centimeters to a meter or more. A number of fractures were met with on Kharpada bridge and were required to be dealt with indivisually.

3. OBSERVATION AND PRECAUTIONS DURING DRILLING

Core drilling is done by two methods : diamond drilling and calyx drilling. Of these diamond drilling is the most efficient process.

3.1 Minimum depth of drilling

There is no uniform practice about depth upto which core drilling is carried out. Practice followed is to drill about 3m in hard rock and 5m in soft rocks. Specifying depth of drilling based on hard rock and soft rock alone is unscientific.

In amygaloidal baslats three types of weaknesses may occur. One is cavities which occur due to escape of gases. These may be varying in size from minute to huge in which even a person can stand (Pune). In second, weathering takes place along various sets of joints. This weathering results in insitu boulders. The thickness of clayey weathered zone in between two insitu boulders may be a couple of meters also (Nagni bridge on Godavari). Third is pot holes which are formed in the Deccan Trap rivers, due to rejuvenation. These pot holes may be couple of meters in diameter (Mula at Mandave). It is necessary that the drill hole as well as the foundation must go beyond these weaknesses.

3.2 Location of Bore Holes

Bore holes as far as practicable, shall be located at the exact foundation location of every foundation. It is Authors' experience that variation of even two meters changes the subsurface geology. At Kharpada bridge on NH-17, drill hole for Pier No. 12 was 4.5 m away from the actual foundation of the Pier. The rock met within the pit was totally different than that met with in the bore. In case of Konkan Bhavan flyover, drill hole for one pier happened to be at correct position where dyke existed. If it was taken 2 - 3 m towards south, picture would have been totally misleading.

3.3 Care During Drilling

To ensure that drilling data are not misinterpreted and also that valuable data are not lost, certain precautions have to be taken during drilling and observations carefully recorded as described in PWD Handbook of Maharashtra. All the water that is fed into the drill comes back to the surface if, the rocks being drilled through, are water tight. If, however, the drill is passing through pervious rocks the water will leak into them and will not return to the surface. This drill water loss may be complete or partial depending on the nature of the rocks. As drill water loss indicates a leaky zone all drill water losses must be carefully recorded during drilling. Observing carefully the colour of drill water is important. Rate of drilling of each run gives in-valuable information. Experience shows that these important requirement are usually neglected. It is always important to know exactly where weak zones occur and what their nature is. But, routine drilling procedures will not provide adequate information on this vital point. In such cases another hole close to previous one is to be drilled in short runs in weak zone. Another alternative is to carry out nearly dry drilling at a very slow rate. Both these methods were adopted on Kharpada bridge on NH-17.

3.4 Length & Number of Pieces of Core

In hard but jointed rock the core recovery may be very good, and consideration of the core recovery alone will lead to the conclusion that the rock is good. This, however, may be wrong, as because of its fragmented condition, the rock will not be good from the engineering point of view.

3.5 Preservation of Core Pieces

The cores of some rocks such as tachylytic basalts (GERU), Volcanic breccias with tachylytic basaltic lava matrix, chlorophaeitic basalts, shales will disintegrate. Therefore, the cores of such rocks must immediately be coated with wax. This was done and was found very useful on Konkan Bhavan flyover and Kharpada bridge.

3.6 Mechanical Fractures

Core would normally break along preexisting divisional planes only. However, due to vibrations during drilling, particularly with a defective machine or defective operation, core may also break even at places where joints do not exists. It is necessary to distinguish between fractures due to jointing and mechanical fractures, which can be done by examining the fracture surfaces.

3.7 Corelogs & Lithologs

All the information gathered during drilling is to be recorded in corelog form. The core log serves as the basic record. A litholog is prepared from the core log to present the information contained in the core log, in a readily intelligible form. Core logging and preparation of lithologs and graphic logs require not only geological expertise of a high order, but also skill in interpreting geological data for engineering purposes and hence these should not be attempted by anyone except an experienced engineering geologist or an Engineer trained in this respect.

3.8 Interpretation

Usually probable founding stratum and its level is not known before drilling. Decision about founding level, SBC and buyoncy can be taken only after proper interpretation of the core log which is usually done later when drilling is terminated. At such time number of alternative types of foundations or alternative levels with different SBCs can be specified and most suited one can be chosen. This was done for 6 to 7 foundation of each of Konkan Bhavan and Chhedanagar flyovers and Kharpada bridge on NH-17. Suitability or otherwise of a particular type of foundation such as open, well or pile can be decided after interpretation of core log. In case of two foundations of Kharpada bridge open foundation was recommanded instead of piles and for three, piles instead of open. Type of foundation need not depend on rock levels only. More precautions are needed for well foundations. Sinking wells through rock is a very costly and time consuming process. It is also risky. Sinking wells through any rock is, therefore, resorted to only when it is unavoidable. In case of pile foundations, further more precautions are necessary. In closely jointed rocks conclusions from normal drilling may, indicate need to go down in rock. Very heavy chiselling will be required for reaching such levels which is costly, time consuming and risky. Where permenent liners are provided, they refuse to go below a certain level and while doing chiselling below the bottom of liner, collapses may occur making piling more and more difficult and complicated and more vulnerable for failure (Kharpada).

Codes need to give better and scientific guide lines upto where drill hole should go. It is felt that the drilling shall be continued at least six meters in rocks giving consistant recovery. Little extra expenditure on extra depth of drilling may result in ease and economy during actual execution.

4. COMMENTS ON SOME CODAL PROVISIONS

4.1 Type of Drilling Equipment

IRC-78/1983 or any other code does not specify type of equipment to be adopted. Three types of equipment are currently available; single tube, double tube and triple tube. Single tube unit is mostly used which needs to be prohibited. Most of the NITS, these days, provide for double tube boring but in practice it is not implemented. Even for very large projects costing crores of Rupees single tube drilling is being adopted. In some regions, triple tube drilling may be needed where weak rocks such as tuff, shale etc. occur. Code needs to specify the type of equipment to be used.

4.2 Depth of Drilling in Rocks

IRC 78/1983 (Cl.704.5.3) provides that "exploratory drill holes may be drilled into the rock to a depth of about 3 meters to distinguish a boulder from a continuous rock formation. A minimum depth of 3 meters in sound rock is recommended. Normally the drill hole shall pass through the upper weathered or otherwise weak zone, well into the rock." Firstly transported boulders need to be distinguished from insitu boulders. As discussed hereinabove, in case of latter, location and thickness of weathered zone will be more important. Secondly, for identifying a boulder, depth need not be a criteria. While saying that a certain depth in sound rock shall be drilled, question is what is a "Sound rock" and who shall decide. At present such decisions are usually left to the driller. Decision where to stop needs to be taken by a trained Engineer or an Engineering Geologist.

4.3 Characteristic Strength of Rock Mass

Cl.704.5.1 of IRC-78 recommends that for arriving at the characteristic strength of the rock mass, reliance be placed more on insitu tests in comparison to laboratory tests. Actually, no insitu test which can give real picture of stratum below is available. Permeability tests will indicate to some extent, nature and material available in joints. Compressive strength, specific gravity and water absorption are the laboratory tests which can be well relied upon if done and interpreted properly.

The clause further states that an Engineering Geologist be associated in the exploration program. In practice it is observed that this is very rarely done. One reason could be ignorance of importance of this requirement. Secondly, probably, such services are not available. It is therefore necessary that all engineers concerned need to be specifically trained in this respect. Such courses need to be designed and implemented on war footing.

4.4 RQD (Rock Quality Designations) Table-5 of Appendix-1 of IRC-78/ 1983.

Firstly the definition needs correction. The correct definition shall be RQD in % = length of the core between joints which are 100 mm and longer devided by length of run. Mechanical fracture of core needs to be properly differentiated from joints. Secondly the concept needs modification. Taking an extreme example of 100% recovery, RQD will be zero if there are 11 No. of pieces between joints of 9.1 cm length whereas it will be 100% if there are 10 number of pieces between joints of 10 cm length. This is ridiculous. It is felt that concept of modified RQD needs to be introduced which can be defined as percentage recovery divided by number of joints rounded to nearest integer and shall be designated as a number. Thus in the former case as above RQD will be 9 and in the latter it will be 10 and will give a more realistic picture.

4.5 Weathering and hardness

Tables 2 and 3 of appendix 1 of IRC 78 give guidelines to decide extent of weathering and hardness. Although extent of weathering and hardness can be decided from these tables, it is difficult for the field Engineer to decide what to do with it. Recommended range of SBCs need to be given in such cases as has been done in table-1.

4.6 Pressures on foundations

Clause 706.2.1 Recommends FOS for rocks : It is felt that the FOS (Factor of Safety) recommended for rocks, particularly for Deccan Traps, can be reduced when investigations and interpretations are properly carried out. While specifying FOS for pressures on foundations, differentiation needs to be made for short and long spans and also for simply supported or continuos spans.

4.7 Scour

No specific provision is made in codes (nor such is possible) for scour in rocks. This is true for both the conditions either when rock is exposed or it is above the calculated scour level considering actual bed material. A provision is always made in NITS that scour shall be considered upto rock. This is very dangerous. The nature and structure of rock so met with needs to be carefully studied and possibility of scour in it is estimated. Foundations levels will then have to be decided based on such estimation. Some guidelines need to be given by codes.

4.8 Depth of Embedment in open foundation

Provision made in cl.705.3.1 of IRC-78/ 1983 is more logical then before since now it defines Hard rock and Soft rock. Still, some more clarification is needed. If foundation has to rest on hard rock and if there is soft rock over it question is whether equivalence of soft rock can be taken while deciding embedment and if so how much. Secondly, minimum depth of rock of required capacity needs to be specified. There are cases where hard rock is overlain by soft rock and in an attempt to provide required embedment, cover of good rock available over soft rock is reduced and the foundation becomes unsafe (Bridges on down stream of Ghod and Chaskaman Dams in Maharashtra).

5. CONCLUSIONS

1) Importance of proper subsurface investigations need to be repeatedly explained and insisted upon all Engineers; from clients, from Consultants or Project Management Consultants and Contractors.

2) Codal provisions need a review and while doing so a proper Engineering Geologist need to be associated with.

3) A special training needs to be imparted to all Engineers concerned so that interpretation of investigations is properly done.

6. ACKNOWLEDGMENT

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7. REFERENCES

i) IRC-78/ 1983.

ii) Maharashtra PWD Handbook of 1980 chapter VI. Preparation of Projects and Engineering Geology.