INTERNATIONAL JOURNAL OF CIVIL AND STRUCTURAL ENGINEERING
Volume 1, No 1, 2010

Research Article ISSN 0976 – 4399

Experimental study on corrosion of transmission line tower foundation and its rehabilitation

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ABSTRACT

In transmission line towers, the tower legs are usually set in concrete which generally provides good protection to the steel. However defects and cracks in the concrete can allow water and salts to penetrate with subsequent corrosion and weakening of the leg.
When ferrous materials oxidized to ferrous oxide (corrosion) its volume is obviously more than original ferrous material hence the chimney concrete will undergo strain resulting in formation of cracks.
The cracks open, draining the water in to chimney concrete enhancing the corrosion process resulting finally in spalling of chimney concrete. This form of corrosion of stub angle just above the muffing or within the muffing is very common in saline areas. If this is not attended at proper time, the tower may collapse under abnormal climatic conditions.
Maintenance and refurbishment of in-service electric power transmission lines require accurate knowledge of components condition in order to develop cost effective programs to extend their useful life.
Degradation of foundation concrete can be best assessed by excavation. This is the most rigorous method since it allows determination of the extent and type of corrosion attack, including possible involvement of microbial induced corrosion.

In this paper, Physical, Chemical and electro chemical parameters, studied on transmission line tower stubs excavated from inland and coastal areas have been presented. A methodology for rehabilitation of transmission tower stubs has been discussed.

Key words: Corrosion, Transmission lines, Galvanizing

1 Introduction

In transmission line towers, the tower legs are usually set in concrete which generally provides good protection to the steel. However defects and cracks in the concrete can allow water and salts to penetrate with subsequent corrosion and weakening of the leg. When ferrous materials oxidized to ferrous oxide (corrosion) its volume is obviously more than original ferrous material hence the chimney concrete will undergo strain resulting in formation of cracks.

The cracks open, draining the water in to chimney concrete enhancing the corrosion process resulting finally in spalling of chimney concrete. This form of corrosion of stub angle just above the muffing or within the muffing is very common in saline areas. If this is not attended at proper time, the tower may collapse under abnormal climatic conditions.

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Maintenance and refurbishment of in-service electric power transmission lines require accurate knowledge of components condition in order to develop cost effective programs to extend their useful life. Degradation of foundations enclosed in concrete or grillage-type can be best assessed by excavation. This is the most rigorous method since it allows determination of the extent and type of corrosion attack, including possible involvement of microbial induced corrosion. To minimize excavation at every footing, tests to indicate the presence of stray current and/or galvanic corrosion can be used. Stray current and galvanic corrosion can be identified by potential surveys of the footings with a Cu/CuSO4 half-cell reference electrode.

1.1 Removal of stub from the field:

As a part of the study, two transmission line tower stubs one in Coimbatore and other in Chennai had been removed by excavation after obtaining permission from the TNEB authorities. The stub of these towers was erected nearly 30 to 35 years ago, and the super structures had been already dismantled for expansion purpose. After excavation by inducting JCB, (Fig. 1-2) the tower stubs were cut removed and transported to Hydro Training Institute, Kuthiraikalmedu for testing purposes.

Fig.1.Removal of stub using JCB
At Coimbatore

Fig.2 .Removal of stub using JCB
at Chennai

1.2 Condition assessment :

The corrosion condition of the actual stubs dismantled from the filed has been experimentally assessed by measuring the corrosion level using half cell potentiometer test. Rebound hammer test also has been conducted for knowing the residual compressive strength of the stub specimens. The tower stubs dismantled as a part of the study are as below.

1) Transmission line tower stub dismantled from inland area: Coimbatore
Othakalmandapam – palladam line: 110 kV line. – Tower No.4 (Fig.3)
Length of stub and size of stub:1.5 m, Top: 25x25 cm, Bottom: 15x15cm
2) Transmission tower stub dismantled from Coastal area: Chennai ETPS to
Manali – 110 kV line. – Tower No.28 (Fig.4)
Length and size of stub:2.2 m, 45x 45 cm

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Fig.3 Stub specimen from inland area

Fig.4. Half cell potentiometer test

Half cell potentiometer test: Half cell potential meter (Fig.5) is used to measure the surface potential differences set up by the electrochemical process of corrosion. Anodic (corroding) and cathodic (passive) areas can be detected in the reinforcement just below the surface. The potential difference between the reinforcement and the half-cell is measured using a high impedance voltmeter. The half cell consists of an electrolyte (i.e. the saturated copper sulphate solution) and the conductor (i.e. the copper rod) which is made into a probe can be held against the concrete surface to determine the probability of corrosion of the reinforcement in the location. Large negative voltages (-350mV) indicate that corrosion may be taking place. Voltages smaller than about -200 mV generally mean corrosion is not taking place. The readings are usually taken on some type of predetermined grid system and equipotential map is drawn as in Fig.6.

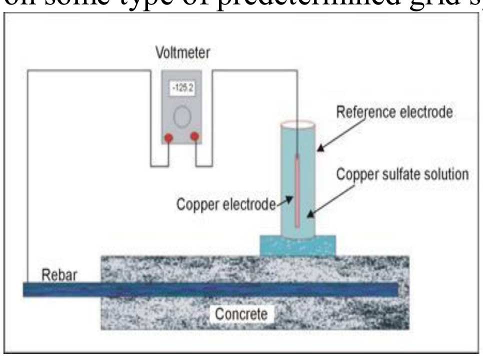

Figure.5 Half-cell measuring circuit

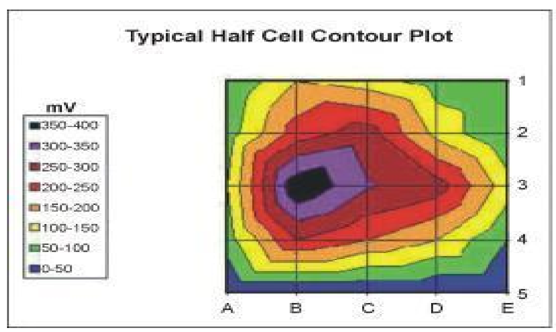

Fig.6. Equipotential map

Rebound hammer test:

Rebound hammer test (Fig.7) is done to find out the compressive strength of concrete by using rebound hammer as per IS: 13311 (Part 2) – 1992. The rebound of an elastic mass depends on the hardness of the surface against which its mass strikes. When the plunger of the rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer. In this study, digital version of the concrete rebound hammer has been used and this hammer automatically shows the compressive strength of concrete.(Fig.8)

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Fig.7 Rebound hammer

Fig.8.Stub specimen tested for compressive strength

Fig.7 a. Spray of phenolphthalein on the specimen

Fig.8.a Breaking of specimen

The stub specimens dismantled in the Inland and coastal area has been checked for carbonation using phenolphthalein test.

2 Results and Discussion:

Half cell potentiometer readings taken on stub 1 and stub 2 are furnished in the table 1& 2. and Fig. 9 & 10 shows the corresponding equipotential map

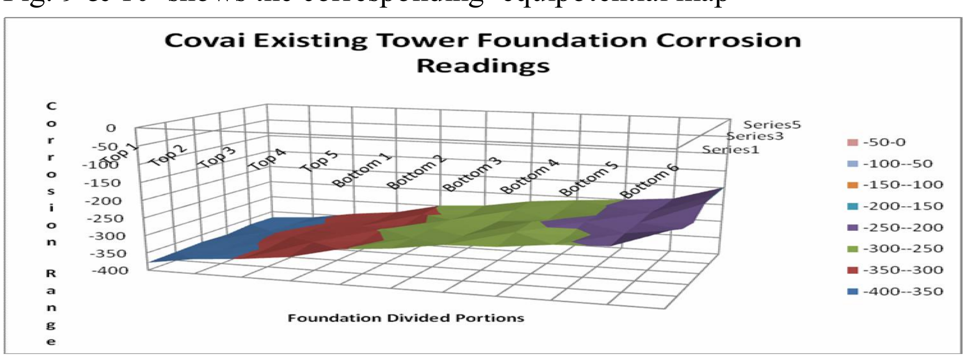

Fig.9. Equipotenial map of the stub excavated in the inland area

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Top1	Top 2	Top 3	Middle 1	Middle2	Middle 3	Bottom 1	Bottom 2	Bottom 3
-735	-698	-671	-590	-550	-487	-421	-323	-256
-738	-722	-653	-621	-535	-489	-423	-301	-249
-745	-713	-655	-609	-521	-467	-398	-286	-254
-737	-701	-653	-598	-511	-441	-385	-278	-246
-734	-697	-672	-612	-520	-449	-389	-289	-247
-731	-720	-667	-603	-537	-444	-391	-281	-230
-740	-711	-659	-599	-515	-437	-387	-271	-239
-731	-699	-661	-601	-529	-462	-401	-298	-251

Table.2. Half cell potentiometer readings taken stub dismantled at coastal area.

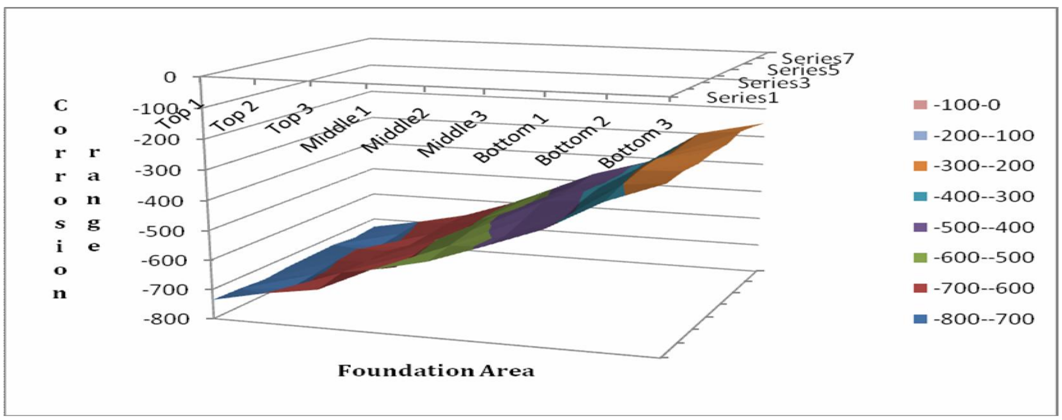

Fig.10 Equipotenial map of the stub excavated in the coastal area

Table 3 & 4 furnishes the compressive strength of the stub specimens and Fig.11 & 12 shows the variation of compressive strength along the length of the specimens.

Table: 3. Compressive strength of stub specimens from inland area

Stub specimen

Top 1(cm)	Top 2(cm)	Mid 1(cm)	Mid 2(cm)	Mid 3(cm)	Bot 1(cm)	Bot 2(cm)
25	23	12	18	20	22	22
20	26	17	22	23	25	24
26	25	15	23	26	20	18
23	21	18	24	25	21	21
21	20	18	18	23	24	21
20	23	15	13	22	24	24
26	20	14	16	23	25	20
27	23	15	15	24	24	20

Fig.11.Variation of compressive strength along the length of the

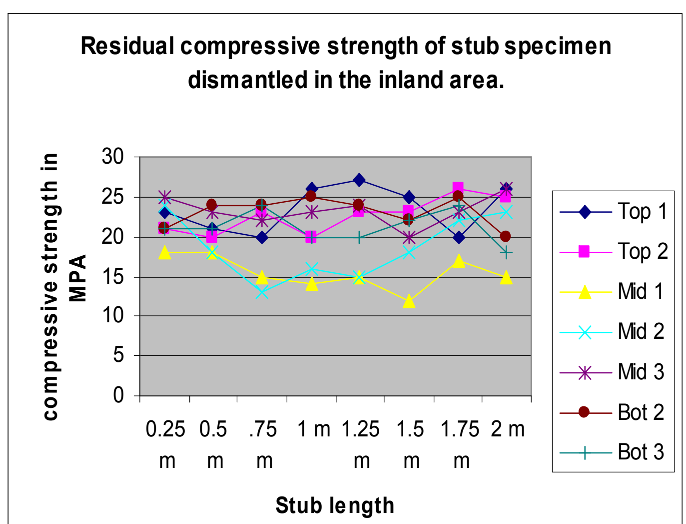

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Table 4.:Compressive strength in MPA of stub specimens from coastal area.

Top 1(cm)	Top 2(cm)	Mid 1(cm)	Mid 2(cm)	Mid 3(cm)	Bot 1(cm)	Bot 2(cm)
11	12	13	9	11	9	9
9	8	12	9	8	8	8
7	8	10	7	9	7	7
8	9	9	10	7	8	6
7	11	10	8	6	5	7
5	10	11	9	5	4	8
4	8	7	8	6	5	6
7	9	10	7	4	4	5

Fig.12. Variation of compressive strength along the length of the stub specimens

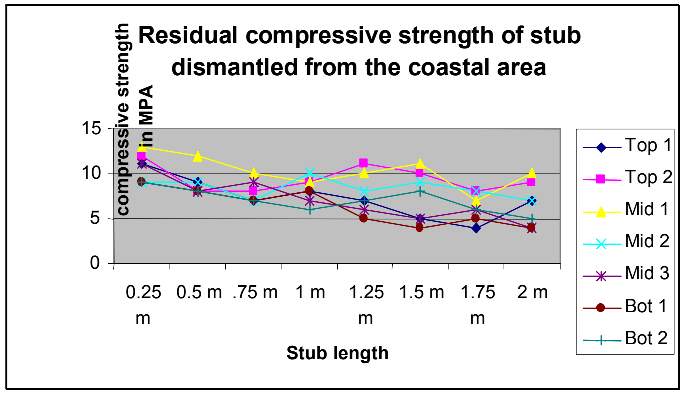

Table.5. Carbonation depth in cm of stub the length specimen From Inland area:

TOP 1(cm)	TOP 2(cm)	MID 1(cm)	MID 2(cm)	MID 3(cm)	BOT 1(cm)	BOT 2(cm)
-8	-9	-2	-1.5	-1.5	-1.5	-1
-9	-10	-2	-1.5	-1.5	-1	-1
-7	-9	-1	-1.5	-1.5	-1	-1
-8	-8	-1.5	-2	-1	-1.5	-1.5
-9	-8	-1.5	-2	-1	-1.5	-1.5
-8	-9	-1	-1.5	-1	-1	-1
-9	-8	-1.5	-2	-1.5	-1	-1.5
-8	-9	-1	-1.5	-1	-1.5	-1

Fig.13 Variation carbonation depth along of the specimens (Inland area)

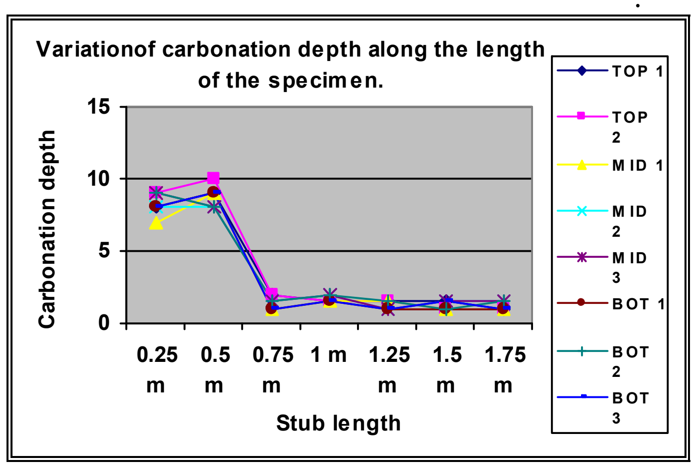

Fig.14 Carbonation depth in the stub specimen dismantled at inland area

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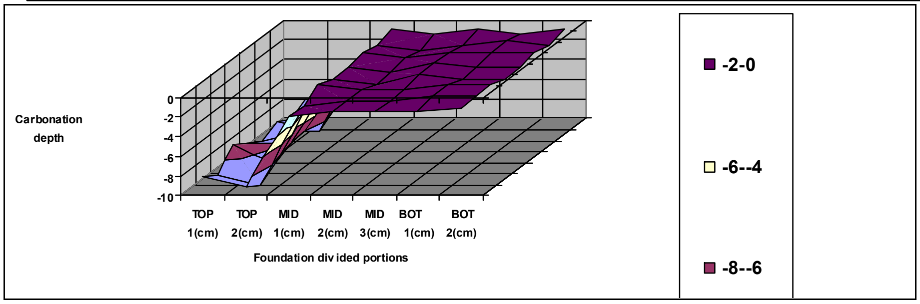


Table: 6.Carbonation depth in cm of stub specimen from coastal area

TOP 1 (cm)	TOP 2(cm)	MID 1(cm)	MID 2(cm)	MID 3(cm)	BOT 1(cm)	BOT 2(cm)
-12	-10	-12	-15	-10	-4	-3
-13	-12	-10	-16	-15	-3	-4
-14	-12	-10	-16	-14	-3	-2
-12	-8	-10	-4	-13	-3	-4
-10	-13	-11	-3	-7	-3	-4
-12	-14	-13	-2	-6	-4	-2
-10	-14	-12	-2	-5	-3	-3
-12	-12	-11	-3	-6	-2	-4

Fig.15 variation carbonation depth along the length of the specimen from the specimen in Coastal area

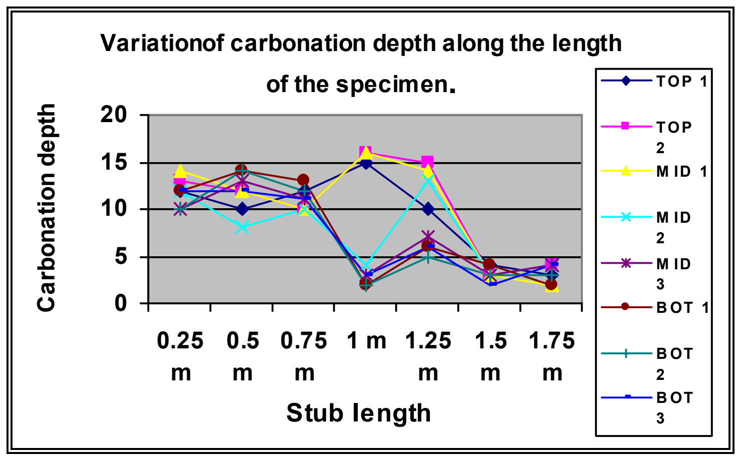
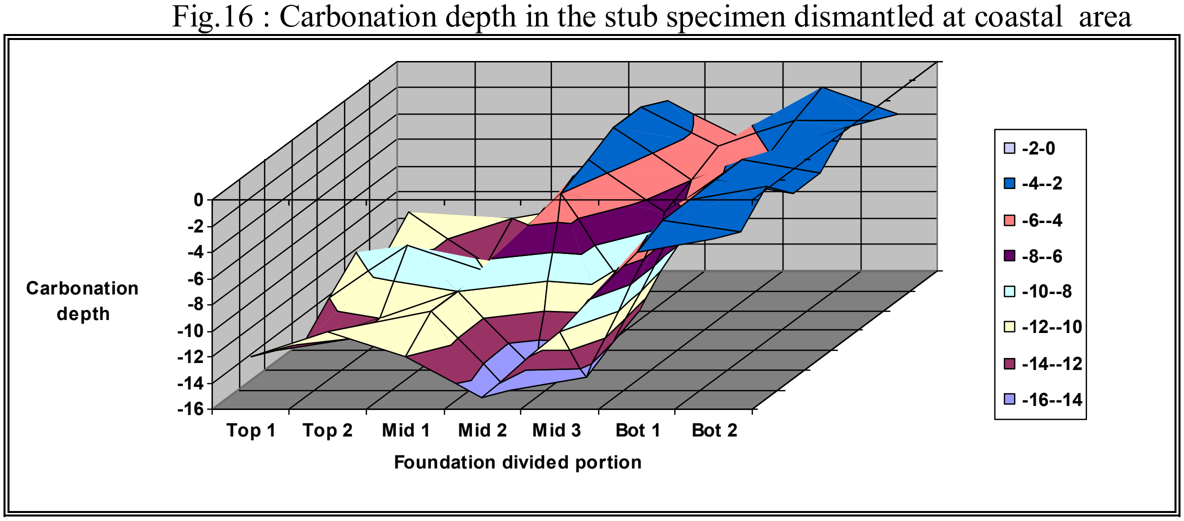


Fig.16 : Carbonation depth in the stub specimen dismantled at coastal area



3 Conclusion:

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From the Condition assessment tests conducted on the actual stub specimens of transmission tower foundations, following observations have been made.

The embedded portion of the stubs in the inland area are almost unaffected by corrosion and the half cell potentiometer readings confirm this.

The rebound hammer test conducted on the stub from inland area indicates the concrete strength above M 20 and this is due to the fact the concrete is not affected by carbonation or chloride ingress.

A kind of Pitting/crevice corrosion noticed in the stub angle /coping interface at the muffing portion of the stub from the inland area is only a local distress.

The stubs tested in the coastal areas shows all the readings above ASTM limit and the corrosion level is alarming also in the embedded portion.

The rebound hammer test conducted on the stub from inland areas indicates lesser than M10 concrete in the major area of embedded portion of the stubs because of carbonation, chloride and other chemicals in such a coastal cum industrial environment.

The phenolphthalein test conducted shows clearly about the extent of carbonation depth. For about 35 cm from the Ground level, the total concrete has been carbonated in the coastal area.

In the Inland specimens, the full carbonation in the coping portion is due to failure of coping due to poor quality and bond.

Based on the observation, a methodology for protecting the concrete stub angle interface is being developed and experimentally studied.

A methodology for protecting the concrete surface and stub angle is also being developed as a part of the study.

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