CONDITION ASSESSMENT OF RCC STRUCTURES AT

BADARPUR THERMAL POWER STATION

NEW DELHI-110044

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NTPC BADARPUR

CONTENTS

DESCRIPTION		Page No.

Condition Assessment of RCC Structures at Badarpur Thermal Power Station , New Delhi

Introduction

Badarpur Thermal Power Station comprises of 3 Units of 100MW each under Stage-I and two Units of 210MW under Stage-II. The total installed capacity of the station was 720MW. Since January 1990 the 3 Units were de-rated to 95MW reducing the station Generation Capacity to 705 MW.

1 UNIT-I - Commissioned in the year -1973

2. UNIT-II - Commissioned in the year -1974

3. UNIT-III - Commissioned in the year -1975

4. UNIT – IV - Commissioned in the year -1978

5. UNIT –V - Commissioned in the year -1981

As per IBR regulation Act 391(A), the Thermal Power Station are subjected to Residual Life Extension studies after 20 years of service or One lakh hours of operation whichever is earlier.

The structure served the life span of more than 35 years and during this period no assessment was carried. In view of this, NTPC Ltd. Badarpur decided to take up the condition assessment study of RCC Structures of Plant areas .

The Central Power research Institute(CPRI), Thermal Research Centre, Koradi was assigned the job to carry out Condition Assessment of RCC Structures of plant areas. M/s CPRI had conducted the field investigations and submitted the report in six stages as detailed below:

i. Condition Assessment of RCC Structures of Offsite Area at BTPS
ii. Condition Assessment of RCC Structures of Coal Handling Plant at BTPS
iii. Condition Assessment of RCC Structures of Turbine Deck & Auxiliary Foundations (Unit# I, II & III at BTPS
iv. Condition Assessment of RCC Structures of Turbine Deck & its Auxiliary foundations of 200 MW, Unit No. IV&V at BTPS.
v. Condition Assessment of RCC Foundation of Boiler Auxiliaries Unit No- I, II, III & V at BTPS.
vi. Condition Assessment of RCC Foundations of Boiler House & Boiler Auxiliaries of Unit-IV at BTPS.

i) Condition Assessment of RCC Structures of Offsite Area at BTPS

The detailed tests were carried out during 28.02.2009 to 07.03.2009 at BTPS. In addition to the field tests, chemical tests of concrete drilled holes samples were carried out for chemical analysis.

Structures Identified for tests:

The standard tests were carried at random locations for the following structures:

S.No.	Description
1	D.M. Plant Building adjacent to WTP-II
2.	Clarifier 'A'
3	Clarifier 'B'
4	Clarifier behind WTP-II Stage- I
5	Clarifier Stage-I for WTP-1
6.	CT Pump House for Stage-I,II and III
7.	Control Structure Pump House.
8.	TWS Civil Structure
9.	Civil Structure of cooling Tower Stage III
10	Civil Structure of Cooling Tower Stage-II
11	Ash Pump House building and structure.

Inferences:

Following were the inferences drawn based on the physical observations and results of probing tests:

The physical observations were made consequent to detailed inspection of assess the extent of distress in the structure. The condition of structures of offsite area was highly deteriorated and some were in the alarming condition and needed immediate attention for the safety of the structure.

The condition of reinforcement of the above said structures was very poor and in swelling condition due to severe corrosion of re-bars embedded in concrete.

The passivity of the concrete had broken and the concrete was carbonated.

The soundness and density of the concrete was observed to be below the normal range.

Cracks, Honeycombing, de-lamination and spalling of concrete at certain regions. The soundness, density of the concrete was reduced below the normal range as per standard, reinforcement was in corrosion stage, carbonation had taken place.

The strengthening of the foundation was required by providing special treatment for distressed regions as per separate repair/ retrofitting scheme to prevent further deterioration.

Recommendations:

Based on the observations, results of tests and inferences drawn, appropriate recommendations were suggested for distressed members of structures in order to enhance the life span of the structure. The strengthening of the structure was extremely essential for the safety of the structure. The recommended measures of individual structures were carried out as per scheme.

ii) Condition Assessment of RCC Structures of Coal Handling Plant at BTPS

The detailed tests were carried out during the period from 07.11.2008 to 23.11.2008 & 30.06.2009 to 03.07.2009 at BTPS. In addition to the field tests, chemical tests of concrete drilled holes samples were carried out for chemical analysis.

Structures Identified for Tests:

The standard tests were carried at random locations for the following structures:

S.No.	Description
1	Underground Conveyor-1A/B OCHP
2	Underground Conveyor-8 OCHP
3	Underground Conveyor-7 OCHP
4	Underground Conveyor-11 A/B NCHP
5	Discharge Hopper of Wagon Tippler 1 and 2 – OCHP
6	Discharge Hopper of wagon Tippler-3 –NCHP
7	Crusher House RCC Structure – OCHP
8	Crusher House RCC Structure - NCHP
9	Trestle Foundations – OCHP

Conclusions and Overall recommendations:

Following were the inferences drawn based on the physical observations and results of probing tests:

The physical observations were made consequent to detailed inspection to assess the extent of distress in the structure. The condition of structures of Coal Handling Plant was poor and some were in highly deteriorated condition and needed immediate attention for the safety of the structure.

The condition of reinforcement of the above said structures was very poor and in swelling condition due to severe corrosion of rebars embedded in concrete.

The passivity of the concrete was broken and the concrete was carbonated.

The soundness and density of the concrete was observed to be below the normal range.

Cracks, honeycombing de-lamination and spalling of concrete at certain regions was observed.

The soundness/density of the concrete was reduced below the normal range as per standard, reinforcement was in corrosion stage, carbonation had taken place.

Based on the physical observations, analysis of test results and conclusion drawn, it was recommended that the strengthening of the structure was required to prevent further deterioration.

The strengthening of the structure was required to be carried out as per the technical procedure suggested for individual structures.

iii) Condition Assessment of RCC Structures of Turbine Deck & Auxiliary Foundations (Unit# I, II & III at BTPS

The detailed tests were carried out during the shut down period at BTPS as detailed below:

Unit-I : 06.02.2008 to 11.12.2008

Unit-II : 18.11.2009 to 25.11.2009

Unit-III : 17.09.2008 to 27.09.2008

In addition to the field tests, chemical tests of concrete drilled holes samples were carried out for chemical analysis.

Structures identified for Tests:

The following RCC structures were identified for evaluation of standard tests at random locations:

S.N.	Description
1	Main Turbine Deck foundations
2	Main Turbine House Deck supporting columns
3	Boiler Feed Pump Foundations
4	Condenser Foundations
5	Circulation water pump foundations.

3.0 **Conclusions and Overall Recommendations**:

Unit: 1, 2 & 3.

Following were the inferences drawn based on the physical observations and results of probing tests:

The physical observations were made consequent to detailed inspection to assess the extent of distress in the structure.

The RCC Structure of Thermal Power Plant were maintained well. However, due to age effect the condition of structures in some of the areas were poor and in deteriorated condition and needed attention and required to be rectified to enhance the durability of the structure.

In addition to the restoration measures, the periodic maintenance of the structures should be strictly adhered for proper functioning.

The density of concrete was reduced and observed to be below the normal range.

The concrete had lost alkalinity and carbonation of concrete was initiated by reducing pH below 13.

The passivity of the concrete had broken and the potential of the concrete had reduced which confirms the initiation of corrosion steel in concrete.

Spalling, de-lamination Cracks, honeycombing, was observed at certain regions of concrete.

Based on the observations, result of various Non-Destructive and Semi-destructive Test and findings of chemical analysis, appropriate recommended measures were suggested along with the technical procedure for the durability of RCC structures.

It was suggested, that these structures should be subjected to Condition assessment studies once in three years to check the quality of Concrete and Steel of the structures since they are the important Civil Engineering elements of Thermal Power Stations.

iv) **Condition Assessment of RCC Structures of Turbine Deck & its Auxiliary foundations of 200 MW ,Unit No. 4&5 at BTPS**.

The detailed tests were carried out during the period from 10.04.2009 to 13.04.2009 for Unit IV and from 10.11.2008 to 19.11.2008 for Unit V at BTPS. In addition to the field tests, chemical tests of concrete drilled holes samples were carried out for chemical analysis.

STRUCTURES IDENTIFIED FOR TEST

The following RCC Foundations were identified for evaluation tests.

1. Main Turbine Deck Foundations.
2. Main Turbine House Deck Supporting Columns.
3. Boiler Feed Pump Foundations.
4. Condenser Foundations
5. Circulation water pump Foundations.

Conclusion:

Unit 4 and 5

Following were the inferences drawn based on the physical observations and results of probing tests:

The physical observations were made consequent to detailed inspection to assess the extent of distress in the structure.

The condition of Main Turbine Deck foundations, Main Turbine House Deck supporting Columns Boiler Feed Pump Foundations, Condenser Foundation, Circulation Water P:ump Foundations was deteriorated. Honeycombing, de-lamination and spalling of concrete were observed especially in Boiler Feed Pump Foundations.

The soundness/ density of the concrete was reduced, below the normal range as per standard, reinforcement was in corrosion stage, carbonation had taken place.

The condition of structure in BFP areas was poor and highly deteriorated and needed attention to prevent further deterioration.

The structure required strengthening by providing special treatment for distressed regions as per separate repair/ retrofitting scheme.

In addition to the restoration measures, the periodic maintenance of the structures should be strictly adhered for proper functioning.

The density of concrete was reduced and observed to be below the normal range.

The passivity of the concrete was broken and the potential of the concrete was reduced which confirms the initiation of corrosion of steel in concrete. The concrete had lost alkalinity and carbonation of concrete had initiated by reducing pH below 13.

Based on the observations, result of various Non-Destructive and semi-destructive Test and findings of chemical analysis, appropriate recommended measures were suggested along with the technical procedure for the strengthening of the structures.

It was suggested , that these structures should be subjected to Condition assessment studies once in three years to check the quality of Concrete and steel of the structures, since they are the important Civil Engineering elements of Thermal Power Stations.

v) Condition Assessment of RCC Foundation of Boiler Auxiliaries Unit No- I, II, III & V at BTPS.

The detailed tests were carried out during the period from 14.07.2008 to 05.08.2009 at BTPS. In addition to the field tests, chemical tests of concrete drilled holes samples were carried out for chemical analysis.

Structures identified for tests

The following RCC Foundations were identified for evaluation tests:

1. I.D. Fan and Motor
2. FD Fan and Motor
3. PA Fan ad Motor
4. Ball Mill Fan and Motor foundations
5. ESP Foundation and seal air fans
6. Boiler Columns foundations.

Conclusion

Following were the inferences drawn based on the physical observation sand results of probing tests:

The physical observation were made consequent to detailed inspection to assess the extent of distress in the structure. The condition of Ball Mills, I.D. Fans, PA. Fans was extremely poor. Cracks, honeycombing, de-lamination and spalling of concrete were observed. The soundness/ density of the concrete was reduced, below the normal range as per standard, reinforcement was in corrosion stage, carbonation had taken place.

The strengthening of the foundations was required by providing special treatment for distressed regions as per separate repair/retrofitting scheme to prevent further deterioration.

Based on the observations, results of tests and inferences drawn, appropriate recommendations were suggested for distressed members of structures in order to enhance the life span of the structure. The recommended measures of individual structures should be carried out as per separate scheme.

vi) Condition Assessment of RCC Foundations of Boiler House & Boiler Auxiliaries of Unit-IV at BTPS.

The detailed tests were carried out during the period from 14.07.2008 to 05.08.2009 at BTPS. In addition to the field tests, chemical tests of concrete drilled holes samples were carried out for chemical analysis.

Structures identified for tests

The following RCC Foundations were identified for evaluation tests:

1. I.D. Fan and Motor
2. FD Fan and Motor
3. PA Fan ad Motor
4. Ball Mill Fan and Motor foundations
5. ESP Foundation and seal air fans
6. Boiler Columns foundations.

Conclusion:

Following were the inferences drawn based on the physical observations and results of probing tests:

The physical observations were made consequent to detailed inspection to assess the extent of distress the structure. The condition of Ball Mills, ID Fans, PA Fans was extremely poor. Cracks, honeycombing, de-lamination and spalling of concrete was observed at certain regions. The soundness/ density of the concrete was reduced, below the normal range as per standard, reinforcement was in corrosion stage, carbonation had taken place.

The strengthening of the foundations was required by providing special treatment for distressed regions as per separate repair/ retrofitting scheme to prevent further deterioration.

Recommendations:

Based on the observations, results of tests and inferences drawn, appropriate recommendations was suggested for distressed members of structures in order to enhance the life span of the structure. The recommended measures of individual structures should be carried out as per separate scheme.

Probing Tests:

The Condition Assessment is done in two Stages as detailed below:

1. To make a detailed visual inspection/survey on the safely accessible surfaces of RCC structure.
2. To conduct experimental investigation by NDT on the selected accessible locations RCC structures covering:-
    a) Rebound Hammer Test as per IS: 13311-1992 (Part-2)
    b) Ultrasonic Pulse Velocity as per IS: 13311-1992 (Part-1)
    c) Half-cell potential survey as per ASTM C876
    d) Corrosion rate measurement using Resistivity Meter
    e) Core Sampling and testing as per IS: 456-2000 & IS: 516-1959
    f) Linear Polariosation 3 Lp and 4 Lp Test
    g) Carbonation Test
    h) Chemical Analysis

(a)Rebound Hammer Testing (RHT) As Per IS: 13311 (Part 2) – 1992

Rebound hammer testing technique was used for assessing the surface likely compressive strength of concrete. Basic principle of rebound hammer test is given below.

When the plunger of rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such rebound depends upon the surface hardness of concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound is read off along a graduated scale and is designated as the rebound number or rebound index. It is also to be noted that rebound indices are indicative of compressive strength of concrete to a limited depth from the surface. If the concrete in a particular member has internal micro cracking, flaws or heterogeneity across the cross-section, rebound hammer indices will not indicate the same.

IS 13311-1992, part-II states, "*As such, the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in a structure is ±25 percent*." However, the test should only be used as an indication of the probable compressive strength of concrete.

(b)Ultrasonic Pulse Velocity (UPV) Test As per IS: 13311 (Part 1)-1992:

UPV is a non-destructive evaluation method for assessing the quality of concrete homogeneity; changes in the structure of the concrete which may occur with time; presence of cracks, voids and other imperfections; quality of one element of concrete in relation to another etc. Basic principle of UPV method is given below.

In this method, an ultrasonic pulse of longitudinal vibrations is produced by an electro-acoustical transducer which is held in contact with one surface of the concrete member under test. After traversing a known path length in the concrete, the pulse of vibrations is converted into an electric signal by a second electro-acoustical transducer, and an electric timing circuit enables the transit time of the pulse to be measured, from which the pulse velocity is calculated.

The ultrasonic pulse velocity in concrete is mainly related to its density and modulus of elasticity. This in turn depends upon the materials and mix proportions used in making concrete as well as methods of placing, compaction and curing of concrete. If the concrete is not thoroughly compacted, or if there is segregation of concrete during placing or there are internal cracks or flaws, the pulse velocity will be lower, although the same materials and mix proportions are used. The underlying principle of assessing the quality of concrete from ultrasonic pulse velocity method is that, comparatively higher pulse velocities are obtained when the 'quality' of concrete in terms of density, homogeneity and uniformity is good. In case of concrete of poorer quality, lower velocities are obtained. On this basis, guidelines have been evolved for characterizing the quality of concrete in structures in terms of ultrasonic pulse velocity. Such a guideline is given in Table 2, which is reproduced from IS: 13311 (Part I) – 1992.

Table A: Velocity Criterion for Concrete Quality Grading (reproduced from table 2 of IS 13311-1992 (Part-I)

Sl.No.	Pulse Velocity by Cross Probing (Km/Sec)	Concrete Quality Grading
1.	Above 4.5	Excellent
2.	3.5 to 4.5	Good
3.	3.0 to 3.5	Medium
4.	Below 3.0	Doubtful

(c)Half-Cell Potential (HCP) Measurements Test :

The half-cell potential measurement using reference electrode copper, copper sulphate half-cell was carried out to determine extent of corrosion in reinforcing bars of structural points. It is not possible to expose all the reinforcement in the structural element and observe the extent of corrosion. So, this method has been very convenient to assess the condition of the entire length of a member by exposing a portion of the reinforcement at in Suitable location, and measuring the half-cell potential on the entire length, by placing the reference electrode on the wet concrete surface. The test is conducted as per specification given in ASTM C – 876.

The half-cell potential measurement is based on the principal of the corrosion, being an electro-chemical process, induces certain voltage to the reinforcement that is corroding. The wetting of the concrete is required to make the portion between the surface and the reinforcing bar electrolyte.

A criterion for assessment for corrosion of reinforcement steel is given as under.

- If potentials over an area are more positive than -200 mV, there is a greater than 90% probability that no reinforcing steel corrosion is occurring in that area at the time of measurement.
- If potentials over an area are in the range of -200 mV to -350 mV, corrosion activity of the reinforcing steel in that area is uncertain.
- If potentials over an area are more negative than -350 mV, there is a greater than 90% probability that reinforcing steel corrosion is occurring in that area at the time of measurement.

(d)Resistivity Measurement Test (RT)

Working Principle:

Electrical resistivity of concrete is an important parameter which can be related to various other aspects such as strength, porosity, deterioration and others. It is well known that the reinforcing steel embedded in concrete is protected by the concrete cover and that this protection is mainly due to the higher alkalinity and the fairly high electrical resistance of concrete. During any corrosion process, corrosion current has to flow from anode to cathode site through the electrolyte and the resistivity of the concrete has an influence on the flow of this corrosion current.

In case of reinforced concrete structures, the high electrical resistance can impede the flow of such currents. However, resistivity of concrete has been found to vary considerably, depending on the moisture content and soluble salts present in the concrete, the corrosion process can be stifled or accelerated concrete resistivity is generally measured by using the four probe principle.

A known current 'I' is impressed on the outer probes and the resulting potential drop 'V' between the inner probes is measured, resistance 'R' is given by V/I. The equation relating resistivity to measured resistance has been derived from the four probe method.

Resistivity of concrete(p)=$2\pi aR$

Where a = inner electrode distance in cm

R= measured resistance in ohm.

Resistivity Measurements

The electrical resistivity of concrete may be useful for monitoring and inspection of reinforced-concrete structures with regard to reinforcement corrosion. The resistivity of concrete in a given structural element exposed to chloride load gives information about the risk of early corrosion damage, because generally a low concrete resistivity is correlated to more rapid chloride penetration.

In addition, resistivity mapping may show the most porous spots, where chloride penetration is likely to be fastest and future corrosion rates will be highest; preventative measures may be taken accordingly. The resistivity can be measured nondestructively using electrodes placed on the concrete surface. Together with information from half-cell potential mapping or chemical analysis the corrosion risk can be determined.

The tests were conducted by forming grids using "Resi" RESSISTIVITY METER from M/s Proseq, Switzerland as per the guidelines of ASTM 876-91.

(e) Concrete Core Testing:

In this, concrete cores are extracted from the hardened concrete in the structure to compute equivalent compressive strength of cube as per provisions given in IS 456:2000. There are a number of parameters, which influence the measured compressive strengths. Such parameters include size (diameter) of the specimen, length-to-diameter ratio, direction of drilling, method of capping, drilling operations, moisture conditions of cores at the time of testing etc. Many of these parameters have been standardized.

The second set of variables relates to the intrinsic difference that exists between the concrete in structure and in standard laboratory controlled specimens of concrete core representing the former. Such intrinsic differences are due to inherent differences that may occur in mixing constituents, degree of compaction, extent of curing and temperature condition in two cases. The procedure for sampling, preparing, testing and calculating the equivalent compressive strength with corrections are given in IS: 516-1959 (reaffirmed 1999). The net effect of all these parameters is that the strength of concrete cores is in general lower than those of laboratory controlled cube/cylinder specimens. To compute the equivalent compressive strength of cube from the core specimen, guidelines given in Clause no. 17.4.2 & Clause 17.4.3 (page no.30) of IS: 456-2000 (Code of Practice for Plain and Reinforced Concrete) are as followed:

”*Cores shall be prepared and tested as described in IS 516. Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85% of the cube strength of the grade of the concrete specified for the corresponding age and no individual core has a strength less than 75%”*

(f)Linear Polariosation 3 Lp and 4 Lp Test:

This Corrosion tests is conducted for finding the rate of corrosion of reinforcement in concrete. Electrical methods are used to evaluate corrosion activity. Corrosion is an electrochemical process involving flow of charges(electrons and ions) at active sites of bar called anodes, iron atoms lose electron and more into surrounding concrete as ferrous ions. This process is called half cell oxidation reaction or anodic reaction.

$$Fe \rightarrow Fe^{2+} + 2\overline{e}$$

The electron remains in the bar and floats to side called cathode where they combine with water and oxygen that are present in concrete. The reaction at cathode is called half-cell reduction reaction.

$$2H_2O + O_2 + 4\overline{e} \rightarrow 4\,\overline{OH}$$

The Polarization refers to change in open circuit potential as a result of passage of current Rp

$$= \frac{\Delta E}{\Delta i} = \frac{\text{Change in Voltage}}{\text{Change in current.}}$$

Rp = Polarization resistance in ohm/cm^2

B= Constant in volts (0.026 v for steel)

I_{cor} = Corrosion rate $ampere/cm^2$

Linear Polarization method can be used to find Corrosion Current density in $\mu A/cm^2$

$I_{cor} = B/Rp$

Four electrodes linear Polarization.

For uniform distribution of Δi fourth electrode (guard Ring) is added. This controls better path potential is same as of counter electrode. Current flow to the working electrode is confined to the counter electrode. The test was conduced as per the guidelines of ASTM STP-1065

(g)Carbonation Test:

Carbonation is the formation of calcium carbonate (CaCO3) by chemical reactions in concrete, when CO2 penetrates into the hardened concrete. It reacts with portlandite [Portlandite is a mineral formed during the curing of concrete, calcium hydroxide Ca (OH)2] in the presence of moisture forming CaCO3. The rate of carbonation depends mainly on the relative humidity, the concentration of CO2, the penetration pressure and the temperature of the environment where concrete is placed.

As carbon dioxide enters the concrete from the environment, it reacts with calcium hydroxide present in the concrete and depending upon the porosity of concrete it reduces the alkalinity of the pore fluids, depassivating ferric oxide layer on reinforcing bar which in turn initiates the process of corrosion in reinforcement.

To determine the depth of carbonation, concrete is exposed and sprayed with a pH indicator (solutions of 1%phenolphthalein in 70%ethyl alcohol). The demarcation between the region, which turns into magenta (dark pink color) and the region showing no change in colour indicate the carbonation front.

(h)Chemical Analysis:

Chloride Content

Corrosion of reinforcing steel due to chlorides in concrete is one of the most common environmental attacks that lead to deterioration of concrete structures. Whenever there is chloride in concrete there is an increased risk of corrosion of embedded steel. Chloride content is then expressed in kg per cubic meter of concrete and compared with the values of limits of chloride contents in concrete as specified in Table 7 (page no.21) of IS: 456–2000).

Prescribed limit of chloride content of concrete (reproduced from Clause

8.2.5.2 of IS 456:2000

Sl.No.	Type of Use of Concrete	Maximum Total Acid Soluble Chloride Content expressed as Kg/cm^3 of Concrete
1.	Concrete containing metal and steam cured at elevated temperature and pre-stressed concrete.	0.4
2.	Reinforced concrete or plain concrete containing embedded metal	0.6
3.	Concrete not containing embedded metal or any material required protection from chloride.	3.0

pH Value

The pH value of the concrete should be above 11.5 to maintain alkalinity of concrete surrounding the embedded steel. A reduction in the pH value of concrete indicates loss of passive layer around the reinforcement which protects the steel from distress.

For analyzing Chloride content and pH of concrete, concrete powder samples were extracted from 0-20mm, 20-40mm & 40-60mm depths at identified locations and then tested as per IS:14959(Part 2) -2001 (Determination of water soluble and acid soluble Chlorides in Mortar and Concrete – Method of Test).

Sulphate Content

Sulphates are present in most cements and in some aggregates; excessive amounts of water-soluble Sulphate from these or other mix constituents can cause expansion and disruption of concrete. To prevent this, the total water-soluble Sulphate content of the concrete mix, expressed as SO_3, should not exceed 4 percent by mass of the cement in the mix.

Compliances:

The compliance of recommendations of M/s CPRI submitted in their final report for Condition Assessment of RCC Structures in Plant areas at BTPS has been completed at BTPS. Considering the present scenario at BTPS the strengthening of RCC members in Turbine and Boiler areas of Stage- I i.e. for Unit I, Unit II and III has not been considered .

ANNEXURE-I

Typical Technical Procedure:

1. The loose concrete should be chipped out gently without damaging parent concrete up to reinforcement.
2. The chipped should be cleaned with water jet / sand blasting / wire brush.
3. To enhance the strength holes to be drilled 12mm dia 200mm deep at 300 c/c from all sides as well as top. Holes should be drilled near bolts also.
4. Fix nozzles by epoxy patching compound. Honeycombing areas should also be made good with epoxy patching compound.
5. After 24 hours providing and injecting high molecular weight super low viscosity grout till the nipple refuses to take further grout. Follow it up with injection of low viscosity epoxy grout as per procedure.
6. In case of cracks the cracks shall be chiseled and 'V' groove shall be made. Holes to be drilled along the crack at 300 c/c, 12mm dia and 150 to 200 deep. The crack shall be sealed with epoxy patching compound. Low viscosity epoxy grout SLV grade shall be injected at pressure 4 to 5 kg/Cm.Sq.
7. In case of corrosion to reinforcement the reinforcement shall be cleaned by wire brush. Rust converter shall be applied to rebars. An anti corrosive coating to reinforcement bars shall be applied in two coats. In vicinity of corroded bars , concrete corrosion inhibitor shall be applied on entire concrete surface so that it will prevent further corrosion of rebars.
8. Drill holes 12mm dia at 500 c/c and carry out polymer grouting to enhance strength of concrete.
9. Drill holes and fixed shear connectors to fix new reinforcement. Shear connectors shall be of 12mm dia 'L' shaped having dimensions of 150mm x 450mm inserting at least 100 to 125mm inside the concrete. The anchoring shall be done with epoxy grout and the connectors shall be coated with two coats of anti corrosive coating.
10. Carry out jacketing with high strength free flow non shrink micro concrete 200mm thick by fixing shuttering and applying epoxy bond coat or by shotcrete machines if fixing of shuttering is not possible.
11. Apply epoxy bond coat to entire surface for bonding of old to new surface.
12. Carry out shotcrete to entire surface when epoxy bond coat is skilled tacky by adding sifumex and fixing welded mesh.
13. After sufficient curing apply three coats of anti corrosive/ anti carbonation coating developed by CBRI Rurkee.