UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

4/2/84

To: B. D. Liaw

Fm: G. Lear

Subject: Corrosion Effect on Re Bar

Attached are four (4) documents that relate to the subject. Waterford NPP basemat cracks and water seepage have made the potential corrosion and its effect upon rebar performance an issue for staff resolution.

Please review the attached documents and advise me of your assessment of any possible rebar performance degradation and control measures if needed at Waterford. The recent schedule for our re-evaluation of the basemat requires that your input be available, to be published, no later than April 13, 1984.

George Lear

Encl: as
cc: Ma

FOIA-84-455

E/B.14

REFERENCES

1. "8.0 Corrosion Potential" is an excerpt from Harstead Engineering Associates, Inc. Report NO. 8304-1, Sept. 19, 1983 "WATERFORD III SES ANALYSIS OF CRACKS AND WATER SEEPAGE IN FOUNDATION MAT" for Louisana Power & Light Co..

2. "IDENTIFICATION OF LEACHATE" is a report by Twin City Testing and Engineering Laboratory, Inc. which is an attachment to the Harstead report referenced above.

3. Question 32 was given to the licensee as a part of 3/26/84 meeting agenda between the NRC and licensee and its consultants

4. Affidavit of William F. Gundaker of Ebasco

REFERENCE 1

8.0 Corrósion Potential

8.1 Passivation Mechanism in Reinforced Concrete

In order to assess the potential for corrosion in the reinforcing steel of the NPIS basemat, several references concerning corrosion of steel in concrete were reviewed (References 14-18).

As noted in Reference 14, "the corrosion resistance of steel in Portland cement concrete has been recognized for more than a century. The protective mechanism, not described until recent years, is due to a passivating film of gamma ferric oxide which is formed and maintained in the alkaline environment produced by cement hydration".

As noted in Reference 15, "Iron and steel are not thermodynamically stable in water. Either acid or neutral water corrodes iron and forms a ferrous solution. This solution, in contact with oxygen, oxidizes to form hydrated ferric oxide -- a major constituent of rust. If the water is sufficiently alkaline, at pH 8 to 14 for example, the Fe_2O_3 and Fe_3O_4 which form are relatively insoluble and deposit a protective film on the metal surface. The metal is then said to be passivated".

The passivating mechanism, therefore, requires an alkaline environment (pH of about 12.5) and an absence of oxygen in order to form a protective film on the surface of the reinforcing steel.

The alkalinity of the water derives from the hydration of the cement, which generates calcium hydroxide.

A relatively oxygen-free environment is generally insured by careful control of the concrete mix and its subsequent placement. Depth of concrete cover is also a factor.

As noted in Reference 16, "In addition, concrete of low water-cement ratio and well cured has a low permeability which minimizes penetration of corrosion inducing factors -- oxygen, chloride ion, carbon dioxide, and water."

8.2 Job Specifications

Section I, Paragraph 7.3 of the Ebasco Concrete Masonry specification (Reference 19) stipulates that: "The aggregate, sand and water combined in the same amounts as in the concrete mix shall not contain a total soluble chloride ion content of more than 250 ppm water when water is extracted from the combination after being thoroughly mixed, unless the Engineer allows a deviation in writing...".

Section I, Paragraph 9.7 of that specification further requires that: "No admixture containing chlorides to an extent that the requirements of Paragraph 7.3, with the admixture mixed with the water, are exceeded shall be acceptable unless the Engineer allows a deviation in writing...".

Section II, Paragraph 8.4 of that specification also stipulates that: "Calcium Chloride shall not be used for accelerating the set of the cement in any concrete containing reinforcement or embedded metal parts".

The limitation on the maximum allowable soluble chloride contained in the concrete mix defined in the Reference 19 specification is subsequently verified by the sampling and testing procedures mandated by that specification.

8.3 Laboratory Testing

In order to deduce any evidence of corrosion in the basemat reinforcing steel, several water samples and a solid (leachate) sample were subjected to laboratory analysis.

The three water samples subjected to laboratory analysis were obtained at the following locations:

a) Water rising in Conduit No. 33074, which rises near the West Temporary Electrical Pit, runs to the southeast for approximately 90 feet, and again rises above the basemat. At the south end, no water was rising, indicating a blockage to the flow of water. The conduit is located approximately 3 feet below the top of the basemat.

b) Ground water flowing through conduits which extend from the side of the mat to the East Temporary Electrical Pit.

c) Water collecting at a crack in the Waste Gas Tank Compressor B room.

The solid sample was collected along the top surface of a crack located along an east-west axis between column lines R and Q_1, and straddling column line 1_M.

The laboratory report summarizing the results of the analyses performed on these samples is contained as Appendix M.

As noted under 'Testing Methods and Results' each of the three liquid samples were subjected to analysis for pH, chloride, alkalinity, iron, calcium and sodium. The results of these analyses are subsequently tabulated on page 2 (note that samples designated '1', '2' and '3' accord with the order in which the sample locations are defined herein).

The value of the pH obtained for sample 1, 12.5, accords with the pH of concrete, as previously noted. The pH of 7.5 obtained for samples 2 and 3 is due to the carbonation process which normally occurs at the surface of concrete exposed to open air.

As noted in Reference 14, "Free carbon dioxide reduces pH by carbonation, but only to a depth of a few millimeters in sound concrete".

The report results indicate the virtual absence of iron in the three liquid samples, a clear indicator that the chemical constituents of rust are not present. The ppm of chloride are also well within the maximum allowable 250 ppm mandated in the Ebasco Concrete Masonry specification (Reference 19), as previously noted.

The solid (leachate) sample was subjected to spectrographic and X-ray diffraction techniques. Iron and Calcium are identified as the two major chemical constituents contained in the solid sample.

As noted in the appended laboratory report under 'Remarks', the calcium hydroxide liberated during the hydration of Portland cement will form calcium carbonate in the presence of carbon dioxide; the iron content contained in the solid sample is identified as magnetite.

The results of the testing of the water samples and leachate are consistent with the process of corrosion protection of the steel reinforcing bars embedded in the concrete. As a matter of interest, it should be noted that the reinforcing bars are large. In general, the top reinforcing bar diameter is 1-3/8 inches while the bottom reinforcing bar diameter is 2-1/4 inches.

These properties accord with the properties of the iron compound which (under properly controlled conditions) forms a passivating film on the surface of the reinforcing steel (see the initial extract from Reference 15).

It is interesting to note that this deposition mechanism also occurs in boilers, and is succinctly stated in Section 6, page 129 of Mark's Standard Handbook for Mechanical Engineers (Seventh Edition):

> "At saturation temperatures above moderately low pressures, a second mechanism predominates, in which iron removes oxygen from water or steam, forming iron oxide and releasing hydrogen:
>
> $$3\ Fe + 4H_2O \longrightarrow Fe_3O_4 + 8H$$
>
> It is noteworthy that this mechanism does not require the intervention of dissolved gaseous oxygen in the water, which is often the rate-limiting factor in the electrochemical corrosion discussed earlier in this subsection.
>
> The stable oxide at boiler temperatures in a non-oxidizing environment is magnetite, Fe_3O_4 (ferrous ferrite). A normal protective skin of magnetite is formed from the underlying steel".

On the basis of the foregoing evaluation, it is therefore concluded that there is no evidence to infer the existence of basemat rebar corrosion in the vicinity of a crack.

8.4 Steel Containment Corrosion

As noted in HEA Trip Report No. 6 (Reference 5), an inspection of the annular area between the Containment Vessel and the Shield Building revealed some surface corrosion at the base of the Containment Vessel, which might be due to the presence of water generated by construction activity.

As soon as this area can be adequately controlled with respect to the presence of such construction-related water, it is the recommendation of HEA that a program be implemented to clean and field paint the base of the Containment Vessel to insure that the corrosion process has been eliminated in this area.

REFERENCES

1. HEA Trip Report No. 1, W3-HE-LP-001, July 15, 1983.
2. HEA Trip Report No. 2, W3-HE-LP-002, August 1, 1983.
3. HEA Trip Report No. 3, W3-HE-LP-003, August 22, 1983.
4. HEA Trip Reports Nos. 4 & 5, W3-HE-LP-004, August 24, 1983.
5. HEA Trip Report No. 6, W3-HE-LP-006, September 6, 1983.
6. Foundation Design of the Waterford Nuclear Plant, by J. L. Ehasz and E. Radin, December, 1973.
7. Review of Site Settlements, by M. Pavone and J. L. Ehasz, September, 1978.
8. RCB Foundation Crack Map, Ebasco Drawing No. SK 1564-4.1-G-28, August 17, 1977.
9. Ebasco Letter Doc: CH-039-77, File: 6Q-R-4, July 27, 1977.
10. Ebasco Nonconformance Report W3NCR-16143, May 27, 1983.
11. WSES-FSAR-UNIT-3, Section 11.2, Liquid Waste Management System.
12. Compatibility of Large Mat Design to Foundation Conditions, by J. L. Ehasz and P.-C. Liu
13. Ebasco Calculation OFS No. 1352.063, Steel Containment Stability, Rev. 1, July 28, 1983.
14. Steel Corrosion in Concrete, by D. A. Hausmann, Materials Protection, November, 1967, pp. 19-23.
15. The Mechanism of Steel Corrosion in Concrete Structures, by C. T. Ishikawa and B. Bresler, Materials Protection, March, 1968, pp. 45-47.

16. Mechanisms of Corrosion of Steel in Concrete, by G. J. Verbeck, ACI Publication SP-49, June, 1975, pp. 21-38.

17. Criteria for Cathodic Protection of Steel in Concrete Structures, by D. A. Hansmann, Materials Protection, October, 1969, pp. 23-25.

18. Cathodic Protection of Steel in Concrete, by R. C. Robinson, ACI Publication SP-49, June, 1975, pp. 83-93.

19. Ebasco Specification Concrete Masonry, Project Identification No. LOU-1564.472, Issue Date: December 31, 1971.

4-2-84
Plowday

John Ma — 6, 1, 2 - Concrete Mix AA-1

AA-1 - Barrow Agee

One mix

AA-1A
-2A AA-3A
-3B1A

1. What was AA-1 mean ✓
memo calls for 14A-6

2. Was not trial mix
Trial mix was from -

— Where is trial mix for actual concrete used for 1, 2, 6, ?

John Ma — 202-492-8473

FOIA-84-455
E/B.15

RECEPTACLE

1975 DEC -2 PM 6: 42

FOIA-84-455
E/8.16

Q/A CORPORATION

READY MIX CONCRETE DELIVERY TICKET
A SUBSIDIARY OF TEXAS INDUSTRIES, INC.
8100 CARPENTER FREEWAY • DALLAS, TEXAS
PHONE (214) 637-3100

CUSTOMER'S COPY # 1

X
CUSTOMER SIGNATURE

DELIVERY OF THESE MATERIALS IS MADE SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF.

BATCHMAN SIGNATURE

SOLD TO:

EBASCO SES, 499-S01-6
AA-1 517 PDA
AA14A6

DELIVER TO: (JOB LOCATION)

4-3-84

Note! The original copy of the batch plant ticket will not copy on a photocopy machine. The data on this report was copied from the original batch plant ticket. Thomas Scott

JOB NAME

LOCATION

SPECIAL INSTRUCTIONS

PLANT NUMBER	BATCH NUMBER	JOB NUMBER	DESIGN NUMBER	SLUMP ADJUST	MOIST. %	TRUCK YARDS	YARDS ORDERED	YARDS DELIVERED
439	123	14	14	-2.1	3.8	9.00	902.0000	1098.000

AGG. ZERO	CMT. ZERO	WTR. ZERO	SAND BIN	ADMIX % ADJUST 1ST	ADMIX % ADJUST 2ND	ADMIX % ADJUST 3RD	ICE
15	16	3	3	100	100	100	0

1ST AGG. WEIGHT	BIN	2ND AGG. WEIGHT	BIN	3RD AGG. WEIGHT	BIN	CEMENT WEIGHT	SILO	WATER WEIGHT	NBR.	1ST ADMIX AMOUNT	TYPE	2ND ADMIX AMOUNT	TYPE	3RD ADMIX AMOUNT	TYPE
9752	1	6502	5	12312	3	4659	1	1492	1	18	1	0	0	189	3

DATE AND TIME	MIXER WATER	TRUCK NUMBER	TOTAL WATER PER YARD
12/02/75 18:14:00	0.0	105	215

WATER ADDED TO SLUMP GAL.

WATER ADDED CUSTOMER REQUEST GAL.

3.5 gals per yard

TIME POURED OUT

TEST CYLINDER TAKEN YES ☐ NO ☐

TIME AT PLANT

NO. 001116

FORM NO. 948

ADDITIONAL STRUCTURAL QUESTIONS 4/3/84
J.M.

1. Concrete mix to be used for Waterford 3 base mat was specified in a memorandum from R.F. Vine/A.H. Wer to J.O. Booth of Ebasco, dated November 24, 1975 (Attache the NRC was told on March 26, 1984 that the actual concrete went into the first three blocks of the mat was designated as AA-1 by Barrow-Agee Laboratories (Attachr The report of summary of mix design by Barrow-Agee provided to the NRC by LP&L contains AA-1a instead of AA-1. Therefore, it is assumed that the concrete mix AA-1a was actually used for the first three blocks of the mat. The ingredients, such as aggregate size, and the ratios of ingredients of mix AA-1a are different from that of basic mix specified in the Ebasco memorandum. Explain the discrepancy and provide the try mix data for mix AA-1a, as the were done in the Ebasco memorandum.

2. Provide current loads and ~~their~~ magnitudes and locations on the top of the mat, and the additional loads and their magnitudes, and locations that will be added on in the future.

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E/B. 17

J. Ma   Question on 4/4/84

Provide shear capacity and design shear stress in the mat in two regions:

A. Bounded by column line 12M and 7FH in N-S direction and T2 and R in E-W direction. This shear stress and shear capacity is measured along the 45° line from R column line toward column 12M.

B. Bounded by column line 12 M and 7FH in N-S direction and column line RP. This shear capacity and stress should be E-W direction.

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E/B.18

4/5/84

COMMON FOUNDATION BASEMAT

LIMITING CONDITION FOR OPERATION

3.7.14 The Structural Integrity of the Nuclear Plant Island Structure (NPIS) Common Foundation Basemat shall be OPERABLE.

APPLICABILITY: At all times

ACTION:

With the NPIS Common Foundation Basemat inoperable, perform an engineering evaluation to determine the effects of the condition on the structural integrity of the NPIS Common Foundation Basemat; prepare and submit a Special Report to the Commission within 14 days pursuant to Specification 6.9.2, 1) Detailing the results of the engineering evaluation, and 2) Justifying the acceptability of continued operation, otherwise be in at least HOT STANDBY within the next 6 hours and in COLD SHUTDOWN within the following 30 hours.

SURVEILLANCE REQUIREMENTS

4.7.14 The NPIS Common Foundation Basemat shall be demonstrated OPERABLE:

a) At least once per 92 days by verifying that the measured differential settlement of the Common Foundation Basemat does not exceed 1/2 inch and the total differential settlement does not exceed 1 inch.

b) At least once per 92 days by analyzing a sample of groundwater obtained in proximity to the NPIS Common Foundation Basemat and verifying that the Chloride content does not exceed 250 ppm.

c) At least once per 18 months during shutdown by verifying that no cracking exists with a width in excess of 40 mils at the lowest levels of each of the buildings on the NPIS Common Foundation Basemat.

FOIA-84-455

E/B.19

3/4.7.14 NPIS COMMON FOUNDATION BASEMAT

The OPERABILITY of the Nuclear Plant Island Structure (NPIS) Common Foundation Basemat will ensure that the structural integrity of the plant foundation will remain functional during normal operations and in the event of a safe shutdown earthquake. The limitation on the foundation basemat differential and total settlement is conservative with respect to the Final Safety Analysis Report Section 2.5.4.13.3.

The limitation on chlorides in groundwater in proximity to the NPIS is consistent with concrete design specifications for Waterford 3 and is well below the threshold for breakdown of the passivating film on structural rebar which is taken as 710 ppm in the presence of free oxygen and up to 3550 ppm when free oxygen is not present.

In the event that the chloride limitation is reached, the effects of seepage of groundwater into minute cracks in the foundation basemat will be evaluated and mitigative measures defined as necessary and reported to the Commission.

The limitation on crack width assures protection of rebar against corrosion as discussed in the Commentary to ACI 318-71 Section 10.6.

G. Lear
J. Ma
J. Chen
L. Heller } Pls review the LP&L's draft proposal passed to me during 4/4/82 mtg in New York ... 4/5/82

PLANT SYSTEMS

COMMON FOUNDATION BASEMAT

LIMITING CONDITION FOR OPERATION

3.7.13 The Structural Integrity of the Nuclear Plant Island Structure (NPIS) Common Foundation Basemat shall be OPERABLE.

APPLICABILITY: At All Times

ACTION:

With the NPIS Common Foundation Basemat inoperable, perform an engineering evaluation to determine the effects of the condition on the structural integrity of the NPIS Common Foundation Basemat; prepare and submit a Special Report to the Commission within 30 days pursuant to Specification 6.9.2, 1) Relating the results of the engineering evaluation, and 2) Justifying the acceptability of continued operation, otherwise be in at least HOT STANDBY within the next 5 hours and in COLD SHUTDOWN within the following 30 hours.

SURVEILLANCE REQUIREMENTS

4.7.13 The NPIS Common Foundation Basemat shall be demonstrated OPERABLE:

a) At least once per 92 days by verifying that the differential settlement does not change by more than 1" as determined by Table 4.7-2.

b) At least once per 92 days by analyzing a sample of groundwater obtained in proximity to the NPIS Common Foundation Basemat and verifying that the Chloride content does not exceed 250 PPM.

c) At least once per 18 months by verifying that no visible cracking exists with a width in excess of 15 mils on the accessible areas of the basemat.

3/4.7.13 NPIS COMMON FOUNDATION BASEMAT

The OPERABILITY of the Nuclear Plant Island Structure (NPIS) Common Foundation Basemat will ensure that the structural integrity of the plant foundation will remain functional during normal operations and in the event of a safe shutdown earthquake. The limitation on the foundation basemat differential settlement ensures that the structural integrity of the foundation basemat will be maintained comparable to the original design standards. The limitation on chlorides in groundwater in proximity to the NPIS is consistent with concrete design specifications for Waterford 3 and is well below the threshold for breakdown of the passivating film on structural rebar which is taken as 710 ppm in the presence of free oxygen and up to 3550 ppm when free oxygen is not present. The limitation on crack width identifies any significant cracks that would require an engineering evaluation to determine the structural integrity of the foundation basemat. In the event that any of the limitations is reached, the effects on the foundation basemat will be evaluated and mitigative measures defined as necessary and reported to the Commission.

TABLE 4.7-2

FOUNDATION BASEMAT DIFFERENTIAL SETTLEMENT MONITORING

BASELINE*			CURRENT*			ACCEPTANCE CRITERION
ELEV.	AVG. ELEV.	DIFF. SETTLEMENT	ELEV.	AVG. ELEV.	DIFF. SETTLEMENT	
1))			1))			
2))	X		2))	X_1		
3))			3))			
4))		$\lvert(X-Y)\rvert$	4))		$\lvert(X_1-Y_1)\rvert$	$\lvert(X_1-Y_1)\rvert = \lvert(X-Y)\rvert \pm 1''$
5))			5))			
6))	Y		6))	Y_1		
7))			7))			
8))			8))			

* Baseline is the differential settlement as of September 1, 1983

** Current is the differential settlement as determined in accordance with surveillance requirement 4.7.13.a.

3/26/84

BNL
JC - Chen
JM - Ma
ST - Turk

JT(IV) - Tapia
DJ - Jeng

QUESTIONS ON WATERFORD 3 BASEMAT
3/26 MEETING IN BETHESDA

Allegations recently reported in a GAMBIT newspaper article and in staff investigations concerning the GAMBIT article have lead to the assignment of additional reviewers to evaluate the base mat adequacy. This transmittal is a composite set of Questions from the reviewers, and is intended to faciliate LP&L's preparation for the meeting on March 26, 1984 in Bethesda.

RIV
1. How many nonconformance reports were issued on the basemat? How many relate to poor concrete placement practices? What were corrective actions taken? Provide justification to substantiate your position that these practices could not have led to the development of cracks or localized porous zones which may be the cause of water intrusion.

2. Where was water table when 1977 cracks were discovered?

3. Is there any evidence of convex curvature due to ring wall loading?

4. Provide X-Section maps of mat flexure over time period zero to present.

√JC
5. Provide complete documentation of groundwater control and foundation heave from the start of dewatering until the present time. Include the history of soil excavation and backfill beneath the mat. Added Qs

6. Provide the foundation loading history under each block during construction of the mat and walls. This should include the distribution of pressure under each block. Include the location and history of loads due to backfilling adjacent to foundation blocks.

7. Provide complete settlement history for each block from initial pouring until the present time. Dwyer/J. Ma.

8. Analyse and discuss the relationship of the above variables (Qs 5-7 above) on the history of all observed mat cracks and leaks.

√ S Turk
9. What basis is there for accepting the adequacy of construction of the first 3 blocks?

10. If engineering judgement was involved in accepting those blocks, what was the basis for that judgement? Where is it documented?

11. What corrective actins were necessary for the first 3 blocks? What corrective actions were taken, and provide specifics for each pour? Where are these actions documented?

12. Were any cracks discovered in 1977 outside of the ringwall? Provide documenttation. If none were discovered outside ringwall why not infer that these three blocks were poorly constructed?

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E/B. 12

13. Did Kominsky recopy illegible cadweld records? Under whose direction? Why? What happened to the original records?

14. Provide summary of actions taken following Hill's presentation of QA deficiencies. Provide detailed report on document review undertaken and all results.

15. Provide LP&L's evaluation of adequacy of Harstead's third report. Does LP&L assert that it represents their views as well?

ST 16. Provide specific basis for Harstead's conclusion that the doucmentation problems do not affect their prior conclusion as to basemat's strength. What documents did Hartstead review? What did he look at? Did he see the Phearson-Brigg memo? Hill's NCR's? Other NCR's?

BNL √ 17. Provide differential settlement contours for 6 month periods, starting from early 1977 to present.

18. According to the settlement contours shown in figure 2.5.118, the curvature is concave downward in both directions. This implies cracks on the top surface in both directions which would not penetrate all the way through.

In view of the above why did the water seep thru? Why dosen't the crack pattern match the given differential settlement?

It is possible that there are localized convex surfaces on the mat which are not shown in the figure (the grid is quite rough)?

19. Please provide all soil properties (re. results of soil tests, reports confirmed compression test results, boring records, shear modulus etc).

20. Provide all concrete property data, rebar data, placement data (ie also detailed as built drawings of mats).

BNL 21. Provide any revised calculations that include settlement effects.

√ 22. Is the Phearson memo accurate? What kind of actions has LP&L taken to respond to and resolve his allegations?

JM

23. Memos of inspectors Hill and Davis, as reported in GAMBIT, stated that they found a broad range of deficiencies in virtually every record package examined and the situation demanded a complete review of all civil/structural records. What is your response to this allegation?

24. GAMBIT reported that there was falsification on cadweld splices of reinforcing bars. What is LP&L's response to this allegation?

25. What were the problems in the seven NCR's on QA deficiencies in concrete, as mentioned in the last column on page 28 of GAMBIT, and how were they disposed of?

JM

26. What were the problems of soils, waterstops, cadweld splices, and the placement of concrete, as mentioned in the third column on page 22 of Gambit, and how were they resolved?

DJ

27. Do the allegations described in Phearson's memo and the Gambit article reflect generally what happened during the construction of the mat? If yes, how would these non-conformance of QA/QC requirements affect the structural integrity of the mat? If not, identify those allegation which are unfounded and the basis thereof.

Tomorrow 3/27

28. In light of the allegations, documented NCRs, and QA/QC deficiencies, what has LP&L done or what does LP&L intend to do in order to resolve the allegations and deficiencies?

?

29. Does maintain that the mat possesses adequate capability to resist the design loads and confirm to the criteria commited to in the FSAR despite all the deficiencies and allegations listed? If yes, provide the supporting technical basis. If not, propose specific means to resolve them and thus render the mat acceptable to the staff.

In any case, the "as-built-mat" should be shown by the applicant, if feasible, to maintain adequate safety margins to perform its safety function and maintain its structural integrity.

A quantitative demonstration of the "as-built" mat capacity, including adoption of test, monitoring and strengthening programs, if needed, should be provided for staff review.

30. What is LP&L's technical rationale for explaning what has happened (including, water seepage, potential through-thickness cracks, predominently one-way cracks within containment region, uneven settlements, etc) to the mat? What monitoring program(s) has been implemented is underway? What are the results of these programs? Did the monitoring data show that both the cracking and water seepage problems have stabilized and there is no sign of continued degration? What improvements, could be applied to the on-going programs?

31. Are there any known voids of some significant size to affect the mat structural integrity? If yes, what are the sizes (best estimates) and extent of these voids? What is LP&L's suggested diposition to the issue of voids. If no disposition is needed, what is the technical basis?

DJ

32. Conservatively assuming the existence of extensive through-cracks of the mat, assess the impact of the presence of water on the long-term stuctural integrity of rebars and mat capacity. Also assess the same impacts due to other potential corrosive elements.

BNL

WATERFORD III BASE MAT

2-D FINITE ELEMENT MODEL

- 1042 NODES
- 300 PLANE STRESS ELEMENTS (t = 288 in)
  60 ELEMENTS WITH REBARS.
- 61 SOIL SPRINGS
- 1961 APPLIED LOADS
- 123 BOUNDARY CONSTRAINTS
- MODELS WITH AND WITHOUT VOIDS

  VOIDS WITH 5, 10 AND 15 PERCENT
  RANDOM DISTRIBUTION

APPLIED LOADS

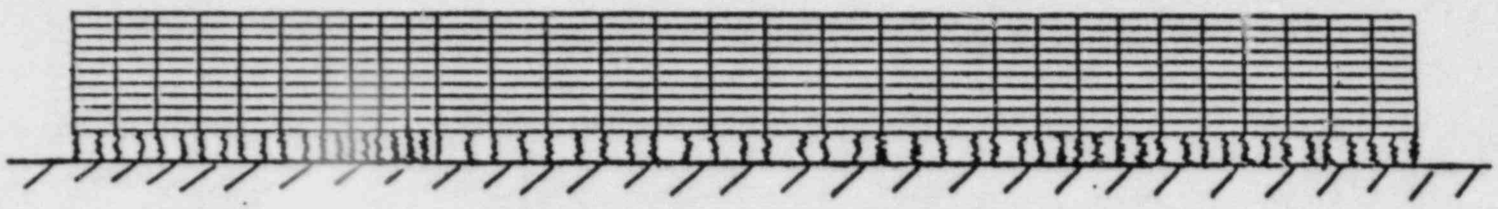
1. OBTAIN X_2- DISPLACEMENTS AND X_1- ROTATIONS AT VARIOUS NODES ON THE STRIP.

2. INTERPOLATE DISPLACEMENTS AND ROTATIONS FOR INTERMEDIATE NODES.

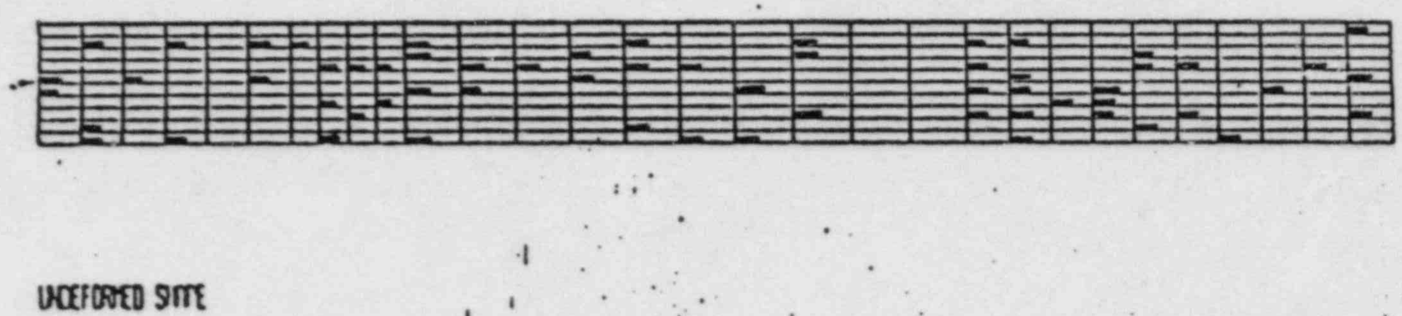
3. ASSEMBLE THE GLOBAL STIFFNESS MATIRX K FOR THE 2-D MODEL.

4. OBTAIN GLOBAL NODAL FORCES AS

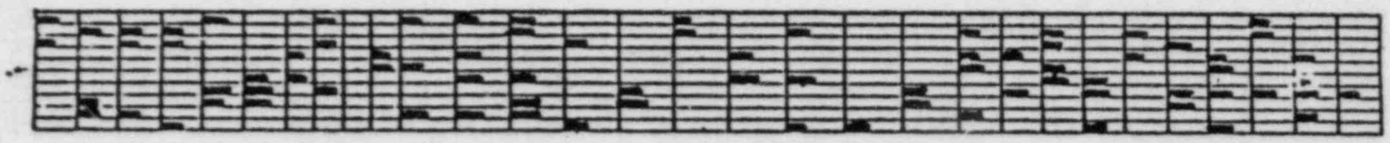
$$\{F\} = [k]\{U\}$$



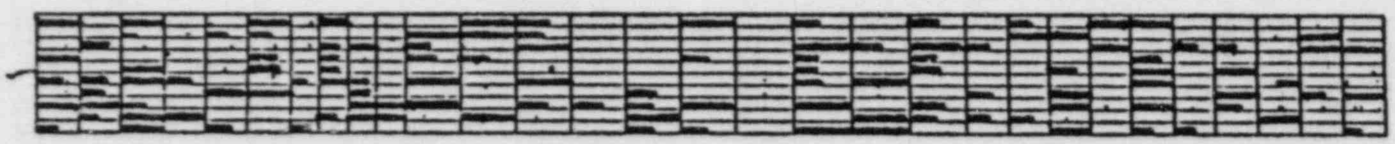
UNDEFORMED SHAPE



5 PERCENT VOIDS


UNDEFORMED SHAPE

10 PERCENT RANDOM VOIDS



UNDEFORMED SHAPE

15 PERCENT VOIDS

Element no	Ny	My
251	-6.67	+18.02
253	-138.4	-118.2
256	-138.8	-239.2
479	-11.99	-772.1
477	-11.45	-561.0
414	-122.3	-496.5
417	-119.9	-429.4

Element 477 (EBASCO)

σ_{yy} = 0.578 N_y ± 0.289 M_x

= 0.578 × (11.45) + 0.289 × 561

= 6.61 + 162.32 = 168.93 psi

Stress in element (285) (2-D model)

σ_{yy} = 208 psi

Element 253 (EBASCO)

σ_{yy} = \0.578 (+138.4) + 0.289 × 118.2

= 79.99 + 34.15 ≃ -114 psi

Element 272 (2-D model)

σ_{yy} = 78 psi

Element 414 (EBASCO)

σ_{yy} = 0.578 × 122.3 + 0.289 × 496.5

= 70.69 + 143.48

= 214.17

Element 297 (2-3)

σ_{yy} = 60 psi

MAT UNDER REACTOR BLDG

FOIA-84-455
E/B.1

EBASCO SERVICES INCORPORATED

NEW YORK

BY HK DATE MAR 11 SHEET 91 OF

CHKD. BY GH DATE 5-16-72 OFS NO. DEPT. NO.

CLIENT LOUISIANA POWER & LIGHT COMPANY

PROJECT WATERFORD STEAM ELECTRIC STATION - UNIT No. 3

SUBJECT FLOATING RAFT FDN

MAX M UNDER REACTOR BLDG

TOTAL WEIGHT OF REACTOR BLDG = 162,000^{k}

$A = \pi \cdot \overline{77}^2 = 18{,}700\ FT^2$

$\bar{p} = \frac{162\,000}{18\,700} = 8.7$ KSF ↓

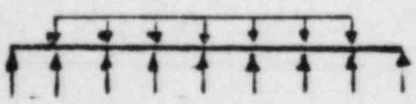
FROM P. 58, NORMAL OPERATING COND.

BEARING PRESSURE UNDER THE WHOLE MAT

$p_b = \left(\frac{7.02 + 6.50}{2}\right) = 6.76$ KSF ↑ {INCLUDING LOAD FACTOR = 1.5

FROM ROARK (FLAT PLATES, CASE #11)

SUPPORTED BY UNIFORM PRESSURE OVER ENTIRE AREA, UNIFORM LOAD OVER CONCENTRIC CIRCULAR AREA.



$m = \frac{1}{\text{POISSON'S RATIO}}$

LOAD FACT. ↗

AT CENTER: $S = -\frac{1.5 \cdot 3W}{2\pi m t^2}\left[(m+1)\log\frac{a}{r_0} + \frac{1}{4}(m-1)\left(1 - \frac{r_0^2}{a^2}\right)\right]$

$= \frac{1.5 \times 3 \cdot 162{,}000}{2\pi \cdot \frac{1}{0.17} \cdot t^2}\left[\left(\frac{1}{0.17}+1\right)\log\frac{101}{77} + \frac{1}{4}\left(\frac{1}{0.17}-1\right)\left(1 - \frac{\overline{77}^2}{101^2}\right)\right]$ ($r_0 + 2t$)

$= \frac{1.5 \cdot 13{,}149}{t^2}\left[6.882 \log 1.312 + 1.220(.419)\right]$

$(6.882 \cdot 0.27155 + 1.220(.419))$

$S = 1.5 \times \frac{13{,}149}{t^2} \cdot (1.8688 + 0.511)$

$S = 46{,}940 / t^2$ $S = \frac{6M}{t^2}$ $M = \frac{46940}{6} \times \frac{t^2}{t^2} = 7824^{1k}/'$

F01A-84-455 E/B.2

MAT UNDER REACTOR BLDG (CON'T)

ALSO FROM ROARK, FLAT PLTS CASE 1
EDGES SUPPORTED UNIFORM LOAD OVER ENTIRE SURFACE

$$S = \frac{3W}{8\pi m t^2}(3m+1)$$

Where $W = (1.5 \cdot 8.7 - 6.76)\pi a^2 = 6.29\pi a^2$

$$= \frac{3(6.29\pi \cdot \overline{77}^2)}{8\pi \cdot \frac{1}{0.17} t^2}\left(3 \cdot \frac{1}{0.17} + 1\right)$$

$$S = \frac{44300}{t^2} \qquad s = 6M/t^2$$

$$S_{edge} = \frac{3W}{4\pi t^2} = \frac{3 \times 6.29\pi(77)^2}{4\pi t^2} = \frac{6M}{t^2}$$

AT CENTER:

$$M = 44300/6 = 7380 \text{ 'k/'}$$

$$\therefore M_{edge} = \frac{3 \times 6.29 \times 77 \times 77}{4 \times 6} = 4662 \text{ 'k/'}$$
$+ 2717$
$= 7379$ 'k/'

O.K. By J.ma

CASE #6 EDGES FIXED

AT CENTER

$$S = \frac{3W(m+1)}{8\pi m t^2}$$

$$= \frac{3(6.29\pi \cdot \overline{77}^2)(1/0.17 + 1)}{8\pi m t^2}$$

FLAT PLATE WITH FIXED ENDS

$$S = \frac{16300}{t^2} \qquad s = 6M/t^2$$

$$M = 16300/6 = 2717 \text{ 'k/'}$$ AT CENTER, BOTT. FACE IN TENS.

CONCR. BLOCK UNDER THE REACTOR BLDG WILL ADD TO THE RIGIDITY ∴ INSTEAD OF CASE # 11 (on p. 91) USE CASE #1 M VALUE ON THIS PAGE.

FOIA-84-455
E/B.1

UNDER REACTOR BLDG
MOMENT IN E-W DIRECTION (CON'T)

MOMENT AT CENTER:

EDGES SUPPORTED : M = 7380 'k/'

EDGES FIXED : M = 2717 'k/'

CONSERVATIVELY ASSUME 20% FIXITY & BY LINEAR INTERPOLATION

$$M = 7380 - 0.20(7380 - 2717) = 6447 \text{ 'k/'}$$

d = 136"
F = 18.5 $K_u = 6447/18.5 = 348$
$a_u = 4.23$

$$A_s = \frac{6447}{4.23 \times 136} = 11.2 \text{ in}^2$$

USE 2 LAYERS OF #18 @ 8

$A_s = 12 \text{ in}^2$ MOMENT CAPACITY = 6940 'k/'

FOIA-84-455
E/B.1

EBASCO SERVICES INCORPORATED
NEW YORK

BY C R W DATE 4/8/81 SHEET 93a OF ____
CHKD. BY JCY DATE 4/8/81 OFS NO. ____ DEPT. NO. ____
CLIENT ____
PROJECT WATERFORD #3
SUBJECT FLOATING RAFT FDN

MAT UNDER REACTOR BLDG (CONT.)

EDGES FIXED

AT EDGE $S = \frac{3W}{4\pi t^2} = \frac{3(6.29\pi \times 77^2)}{4\pi t^2}$

$= \frac{27970}{t^2}$

$M = \frac{St^2}{6} = \frac{27970}{6} = 4661$ 'K/'

EDGES SUPPORTED $M = 0$.

Assume 50% Fixity $M = 2330$ 'K/'

$A_s = \frac{2330}{4.23 \times 136} = 4.05$ in².

E-W #11 @ 6 + #11 @ 12 Provided on Top Reinf

$A_s = 4.68$ □" > 4.05 □"

ok

N-S — #11 @ 6"

FOIA-84-455

E/B.1

FORM 561 REV 7-71

BARROW-AGEE Laboratories
INCORPORATED

CHEMISTS ENGINEERS

EBASCO SERVICES, INC
RECEIVED
FEB 3 1975
WATERFORD 3 FIELD

LITTLE ROCK, ARKANSAS

JANUARY 9, 1975

REPORT OF SUMMARY OF MIX DESIGN

OR EBASCO SERVICES, INC., P.O. BOX 70, KILLONA, LOUISIANA 70066

OB WATERFORD THREE, STEAM ELECTRIC STATION, TAFT, LOUISIANA

AMPLE FROM BATCH PLANT BY BARROW-AGEE LABORATORIES, INC.,

OURCE OF MATERIAL LOUISIANA INDUSTRIES - PRICE PIT DEPOSIT AGGREGATES

IX:	W3-AA-1a 4000 PSI PLAIN		W3-AA-2a 4000 PSI EXTRA CEMENT	W3-B-1a 3000 PSI PLAIN	W3-AA-3a 4000 PSI ADMIX
ement, TXI, Type II, lbs.	587	5283	687	517	564
ater, gallons	33	297	33	33	31
ine aggregate, lbs.	1269	11421	1235	1295	1277
/4" aggregate, lbs.	586	5274	570	598	589
" aggregate, lbs.	1155	10395	1124	1179	1162
A, oz.	3.9		4.6	3.4	2.5
A, oz.	0		0	0	24
ump, In.	3		3	4.25	3.5
r Content, %	3.5		4.8	5.25	6.25
it Wt. fresh, pcf (onotube Avg.)	142.6		144.8	144.0	142.4

FOIA-84-456 E/B.2

X:	W3-AA-4a 4000 PSI ADMIX EXTRA-CEMENT	W3-B-2a 3000 PSI ADMIX	W3-AA-5a 4000 PSI ADMIX RED. AIR	W3-AA-6a 4000 PSI PLAIN NO AIR
ment, TXI, Type, lbs.	664	494	564	600
ter, gallons	31	31	32	36
ne aggregate, lbs.	1260	1319	1304	1387
4" aggregate, lbs.	582	608	601	566
" aggregate, lbs.	1147	1200	1187	1117
A, oz.	1.5	1.0	0.0	0.0
A, oz.	28	21	24	0
ump, in.	3.75	2.5	3.25	5.75
r Content, %	4.5	4.9	3.75	2.25
it Wt. fresh, pcf (onotube Avg.)	147.9	144.0	146.0	148.2

EMARKS:

Cement Type II test results reported on Barrow-Agee report No. LR-83819. Price Pit Deposit fine aggregate test results reported on Barrow-Agee report No. LR-83912. Price Pit Deposit coarse aggregate test results reported on Barrow-Agee report No. LR-83911.

OPIES TO: 6-ABOVE

REVIEWED BY C. Satterfield
EBASCO Q/C. CIVIL

John M. Woodard
Barrow-Agee Laboratories, Inc.

ABORATORY NO. LR-83818

BARROW-AGEE Laboratories INCORPORATED

CHEMISTS ENGINEERS

LITTLE ROCK, ARKANSAS

JANUARY 9, 1975

REPORT OF SUMMARY OF MIX DESIGN

FOR EBASCO SERVICES, INC., P.O. BOX 70, KILLONA, LOUISIANA 70066

JOB WATERFORD THREE, STEAM ELECTRIC STATION, TAFT, LOUISIANA

SAMPLE FROM BATCH PLANT BY BARROW-AGEE LABORATORIES, INC.

SOURCE OF MATERIAL LOUISIANA INDUSTRIES - PRICE PIT DEPOSIT AGGREGATES

COMPRESSIVE STRENGTH, PSI

MIX:	W3-AA-1a	W3-AA-2a	W3-B-1a	W3-AA-3a
24 Hours	-	-	-	1290 1330 1380
3 Days	-	-	-	3150 3180 3270
7 Days	4075 4050	4330 4490	3450 3500	4780 4530 4420
28 Days	6370 5980	6150 6900	5940 6010	6190 6490 6830

Unit Weight, pcf (Sonotube Average)

3 Days	140.93	143.32	142.40	141.14
7 Days	140.53	142.95	141.82	140.79
14 Days	140.53	142.99	141.73	140.66
28 Days	140.53	143.00	141.75	140.65

REMARKS: Cement Type II test results reported on Barrow-Agee report No. LR-83819. Price Pit Deposit fine aggregate test results reported on Barrow-Agee report No. LR-83912. Price Pit Deposit coarse aggregate test results reported on Barrow-Agee report No. LR-83911.

COPIES TO: Same

REVIEWED BY
[signature]
EBASCO Q/C. CIVIL

John M. Woodard
Barrow-Agee Laboratories, Inc.

LABORATORY NO. LR-83818

jlw

Satterfield

BARROW-AGEE Laboratories
INCORPORATED

CHEMISTS ENGINEERS

EBASCO SERVICES, INC. RECEIVED

LITTLE ROCK, ARKANSAS

MARCH 12, 1975

REPORT OF SUMMARY OF MIX DESIGN (CONT.)

FOR EBASCO SERVICES, INC., P.O. BOX 70, KILLONA, LOUISIANA 70066

JOB WATERFORD THREE, STEAM ELECTRIC STATION, TAFT, LOUISIANA

SAMPLE FROM BATCH PLANT BY BARROW-AGEE LABORATORIES, INC.,

SOURCE OF MATERIAL LOUISIANA INDUSTRIES - PRICE PIT DEPOSIT AGGREGATE

COMPRESSIVE STRENGTH, PSI

MIX	W3-AA-1a	W3-AA-2a	W3-B-1a	W3-AA-3a
90 Days	7870 7430	7750 7960	7250 7690	7960 8530 7780

UNIT WEIGHT, PCF (SONOTUBE AVERAGE)

60 Days	140.60	143.25	141.87	140.65
90 Days	140.96	143.25	141.86	140.77

COMPRESSIVE STRENGTH, PSI

MIX	W3-AA-4a	W3-B-2a	W3-AA-5a	W3-AA-6a
90 Days	9340 8880 8840	6970 6720 6970	7530 8140	7250 7320

UNIT WEIGHT, PCF (SONOTUBE AVERAGE)

60 Days	146.65	143.00	144.47	146.49
90 Days	146.80	143.05	144.43	146.13

REMARKS:

REVIEWED BY C Satterfield EBASCO Q. C. CIVIL

COPIES TO: 4-ABOVE

John M. Woodard

LABORATORY NO. LR-83818-A jlw

Barrow-Agee Laboratories, Inc.

BARROW-AGEE Laboratories
INCORPORATED

CHEMISTS ENGINEERS

LITTLE ROCK, ARKANSAS

JANUARY 9, 1975

REPORT OF SUMMARY OF MIX DESIGN

FOR EBASCO SERVICES, INC., P.O. BOX 70, KILLONA, LOUISIANA 70066

JOB WATERFORD THREE, STEAM ELECTRIC STATION, TAFT, LOUISIANA

SAMPLE FROM BATCH PLANT BY BARROW-AGEE LABORATORIES, INC.

SOURCE OF MATERIAL LOUISIANA INDUSTRIES, - PRICE PIT DEPOSIT AGGREGATES

COMPRESSIVE STRENGTH, PSI

MIX:	W3-AA-4a	W3-B-2a	W3-AA-5a	W3-AA-6a
24 Hours	1340	1430	-	-
	1560	1420		
	1610	1360		
3 Days	3930	2920	-	-
	3960	2940		
	3940	3180		
7 Days	5750	3500	4510	3570
	5390	3290	4950	3840
	5610	4140		
28 Days	7710	5840	6900	6720
	7500	5850	5940	6370
	7610	6010	5940	

Unit Weight, pcf (Sonotube Average)

	W3-AA-4a	W3-B-2a	W3-AA-5a	W3-AA-6a
3 Days	146.87	143.71	144.99	146.89
7 Days	146.59	143.20	144.60	146.60
14 Days	146.45	142.87	144.43	146.27
28 Days	146.61	142.89	144.46	146.37

REMARKS: Cement Type II test results reported on Barrow-Agee report No. LR-83819. Price Pit Deposit fine aggregate test results reported on Barrow-Agee report No. LR-83912. Price Pit Deposit coarse aggregate test results reported on Barrow-Agee report No. LR-83911.

COPIES TO: Same

REVIEWED BY John M. Woodard

LABORATORY NO.

R

M E M O R A N D U M

November 24, 1975
4.0

TO: J. O. Booth

FROM: R. F. Vine/A. H. Wern

SUBJECT: LOUISIANA POWER AND LIGHT COMPANY
WATERFORD STEAM ELECTRIC STATION
1980 - 1165 MW INSTALLATION - UNIT NO. 3
CONCRETE DESIGN MIX

The following concrete mix is to be used for concrete in the Combination Structure Mat.

Master Design Mix - 14A6: (Quantities per cubic yard Aggregates SSD)

Cement	517 lbs.
Water	232 lbs.
Fine Aggregate	1316 lbs.
½" Aggregate	707 lbs.
1" Aggregate	1074 lbs.
AEA: Protex	2.0 oz.
WRA: Protex PDA 25 Type D	21 oz. (4.0 oz. per cwt)
W/C Ratio	0.45

The water cement ratio used may be lower than the above mix provided adequate workability is achieved and it may vary up to a maximum of 0.50. This will provide for variations in the workability of the concrete and to tailor the workability for the specific location where it is being placed. This criteria is based upon the following design/trial mixes.

Mix 14A9 utilizing the same ratios of ingredients as 14A6 with the exception of water which was 238 lbs. resulting in a W/C ratio of 0.46.

Mix 14A10 utilizing the same ratios of ingredients as 14A6 with the exception of water which was 231 lbs. resulting in a W/C ratio of 0.45.

FOIA-84-455
E/B.3

Mix 14A11 utilizing the same ratios of ingredients as 14A6 with the exception of water which was 258 lbs. resulting in a W/C ration of 0.50.

Mix 14A12 utilizing the same ratios of ingredients as 14A6 with the exception of water which was 243 lbs. resulting in a W/C ratio of 0.47.

This mix and the allowed variations thereon are approved based upon tests showing the following properties:

Mix	14A6	14A9	14A10	14A11	14A12
Air Content	5.0	4.8	4.0	4.8	4.6
Slump	4-½"	2-3/4"	1-3/4"	7-3/4"	7-½"
Wet Weight	145.7pcf	146.1	148.4	143.7	144.8
Strength 24 hr.	1473psi	1603	1928	1210	1150
3 day	3637	3831	4498	2446	2258
7 day	4456	4728	5318	3219	3607
28 day	(6037)	(6406)	(7205)	(4361)	(4887)

Test data for 28 day strength will be available prior to first concrete placement. Data from similar concrete placed for the barge dock and concrete weights indicates that the 7 day strength averages 73.8% of the 28 day strength; the 28 day strengths are extrapolated based upon that data. The 28 day strengths for the barge dock and concrete weights averaged 6103 psi with a range from 5509 psi to 6516 psi.

Specification requirements for laboratory trial mixes are a specific weight between 133 pcf and 147 pcf with an average of 138 pcf and a 28 day concrete compressive strength of 4600 psi. The dry specific weights have in previous tests on similar concrete been approximately 3 pcf less than the wet weights. Therefore all of the mixes are expected to meet specification requirements.

It is expected that the master design mix (14A6) and mixes 14A9, 14A10 and 14A12 actual 28 day strengths will meet or exceed the specification requirements for trial mixes. Mix 14A11 may be marginal in meeting this strength. All of the mixes are expected to meet the requirements for compressive strength for Class AA (4000 psi) production concrete which are:

a - No individual strength test results falls more than 500 psi below the required class strength at 28 days.

b - The averages of all sets of three consecutive strength test results equal or exceed the required class strength at 28 days.

The mat placement may be considered as a reinforced footing, a slab and, in portions, unreinforced heavy mass construction. As such the 10 batch average slump can be between 4 inches and 1 inch and the single batch slump can be between 5 inches and 1 inch depending upon the portion of the mat being placed and the workability desired. For the mat the first paragraph of Part 10.9 of Section I of the concrete masonry specification shall be the guide namely: "Concrete shall be a consistency and workability suitable for the conditions of the job".

RFV/lls

Attachments:

1 - Design Mixes Lab Test Summary Sheets
2 - Production Concrete Summary Sheets
3 - Trial Mix Testing Schedule (Mixes 6 through 9)
4 - Strength vs. Time Chart

cc: J. M. Brooks
R. K. Stampley
W. L. Sheehan
P. C. Liu
J. W. Seaver
D. N. Galligan

cc: 12-4-75
C. R. Satterfield (2)
R. W. Zaist
B. D. Fowler
R. A. Hartnett
W. C. Griggs

August 5, 1977
COR-LW3-77-55M

To: P Grossman

From: A W Peabody/M D Oliveira

Subject: LOUISIANA POWER & LIGHT COMPANY
WATERFORD SES UNIT 3
CORROSION OF REINFORCING STEEL AND
STEEL CONTAINMENT VESSEL PLATES IN CONTACT WITH WATER

In accordance with your telephone request, we have analysed a possible situation in the common mat where supposedly ground water weeping from concrete cracks found on the surface of the mat could corrode the reinforcing steel and the outside bottom plates of the Steel Containment Vessel.

It is a proven fact that concrete by its alkaline nature passivates carbon steel embedded in it.

It is also known that water in contact with concrete becomes alkaline and consequently its corrosivity to steel decreases considerably.

In addition to these factors, assuming that ground water is left inside the crack network to a certain extent, this water will be near stagnant and without replenishment of oxygen. Consequently, the rate of corrosion under the above circumstances, if any, will be negligible. This applies to the reinforcing rebars as well as to the outside of the vessel bottom plates, in case the repairs presently being conducted do not fully prevent the water from reaching the vessel.

MDO/hn
cc: R K Stampley
J O Booth/B D Fowler
D N Galligan
L Skoblar
W F Gundaker

FOIA-84-455

E/8.5