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STABILITY AND STRESS ANALYSES OF BRANDON ROAD DAM, ILLINOIS WATERWAY

by

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Final Report

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An investigation was conducted to analyze the tainter-gate, sluice-gate, ice-chute, and head-gate monoliths of Brandon Road Dam to determine if they meet present-day stability requirements. In general, the stability analyses for these monoliths were performed for the following case loadings: (a) normal operation, (b) normal operation plus ice, (c) normal operation plus earthquake, and (d) flood condition.

In the analyses of the tainter-gate, sluice-gate, and (Continued)

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ice-chute monoliths, the total monolith for each was analyzed and determined to be adequate in stability. However, due to overstress between the main body and the downstream apron of the structures, the aprons of each were considered ineffective and therefore, were eliminated from the analyses.

The shear stresses in the keys that connect the pier and spillway sections of the tainter-gate monoliths were calculated and found to be less than the allowable $1.1\sqrt{f'_c}$. Therefore, the pier and spillway are considered to act monolithically.

In the stability analyses of the tainter-gate, sluice-gate, ice-chute, and head-gate monoliths, the results showed the monoliths to be inadequate against overturning stability for all case loadings. The head-gate monoliths were also inadequate for resistance against sliding. To correct these deficiencies, prestressing was recommended and the details are presented for each of the monoliths. The monoliths were reanalyzed to include the recommended prestressing and were determined to be adequate in stability for all case loadings.

A 3D finite-element analysis program (SAP V) was used to compute the net stresses in the structure and foundation of the tainter-gate monolith after prestressing for the case loadings. The results showed no overstress in the monolith but did show tensile stresses existing in the spillway crest and heel areas of the monolith. Although such tensile stresses are not allowed in most areas, these do not exceed $0.01f'_c$ and therefore are considered small and acceptable.

A finite-element, axisymmetric analysis was also used as a part of the stress analysis of the tainter-gate foundation and grout anchor. The results showed no overstress in either the foundation or the grout anchor due to the prestressing.

The sluice-gate, ice-chute, and head-gate monoliths are not overstressed after prestressing.

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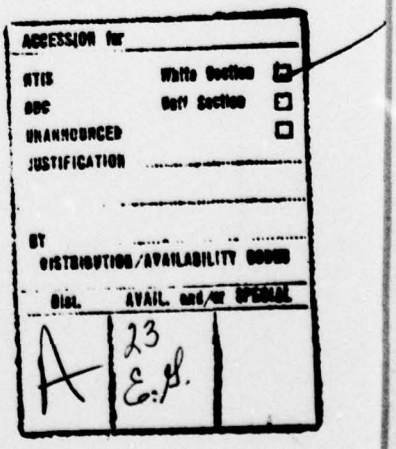

PREFACE

A stability analysis of Brandon Road Dam was performed for the U. S. Army Engineer District, Chicago, by the Concrete Laboratory (CL) of the U. S. Army Engineer Waterways Experiment Station (WES).

The work was monitored by Messrs. Ignas Juzenas and George Sanborn of the Chicago District. Their interest and help was greatly appreciated.

The study was performed under the direction of Messrs. B. Mather, J. M. Scanlon, R. L. Stowe, and J. E. McDonald, CL. The structural analysis was performed by Dr. C. E. Pace, Messrs. R. L. Campbell and E. F. O'Neil, and SP5 John Z. Oak. The material properties were obtained by Mr. Stowe and the Soils and Pavements Laboratory, WES. This report was prepared by Dr. Pace and Mr. Campbell.

The Commander and Director of the WES during the conduct of the test program and the presentation and publication of this report was COL J. L. Cannon, CE. Mr. F. R. Brown was Technical Director.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.40000	millimetres
feet	0.3048	metres
pounds (mass)	0.4535924	kilograms
pounds (force)	4.448222	newtons
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (force) per square inch	6894.757	pascals
tons (force) per square foot	95.76052	kilopascals

STABILITY AND STRESS ANALYSES OF BRANDON ROAD DAM ILLINOIS WATERWAY

PART I: INTRODUCTION

Background

1. The results of previous studies of Brandon Road Dam have been published, and the overall view and sections of the dam are presented in References 1-3 and the material properties of the concrete, foundation rock, and silt are given in Reference 4.

2. Even though such structures have been in service for a long time, it is important that they be examined in view of present-day criteria to assure continued structural adequacy. If the structural design or the state of deterioration causes the structure to fail to satisfy current criteria, thereby producing unsafe or doubtful conditions of safety, the structure must be modified to conform to good engineering standards.

3. One of the main considerations for structural adequacy of a dam is the stability of the various monoliths when subjected to possible loading conditions. The stability study reported herein involved analyzing selected monoliths to determine if they had adequate resistance against overturning, sliding, and base pressures. Only one monolith of each configuration was analyzed; the conclusions based on these analyses are adequate for an evaluation of all monoliths.

4. The adequacy of the structure to resist overturning can be judged by the location of the resultant of applied loads with respect to the base of the section where stability is being considered (within the dam, at the base-foundation interface or at a plane or combination of planes below the base). In general, the gravity sections where stability against overturning is being considered are required to have the resultant of applied loads fall within the kern of the base of the section being analyzed. For operating conditions with earthquake, the

resultant only has to fall within the base, but the allowable foundation stresses should not be exceeded.

5. The percent effective base (percent of the base which is in compression) is a good way to present where the resultant falls in a rectangular base section. It is a good guide for representing overturning resistance for any shape base. An example for a rectangular base is shown below:

Percent Effective Base	Resultant Location Within Base
100	Within middle 1/3 or in kern area
75	At 1/4 points of base
50	At 1/6 points of base

6. Sliding resistance of a monolith is calculated by choosing a trial failure plane or combination of planes and calculating the resistance along this path. The resistance may be composed of several types. The sliding resistance due to friction and cohesion on the surface between the monolith and its foundation is calculated by the shear-friction formula given in ETL 1110-2-184.[5] These formulas are inadequate for evaluating structural sliding on inclined planes. The sliding resistance due to all or any part of the failure plane extending through either the concrete monolith or the foundation is calculated from the shearing strength of the material acting over the length in which shearing occurs.

7. In general, a shear-friction safety factor of 4 is required for all conditions of loading where earthquake is not considered and is 2-2/3 for loading conditions considering earthquake. In discussions with the Office, Chief of Engineers, it was concluded that the following safety factors for sliding would be adequate.

Condition	Minimum Value for Safety Factor
a. Use angle of internal friction corresponding to the shear strength at interface between concrete and rock (lower bound parameter), reliable strut resistance, no key resistance, and no cohesion.	1.5

(Continued)

Condition	Minimum Value for Safety Factor
b. Condition a plus earthquake.	1.15
c. Use angle of internal friction associated with the shear resistance at clay-filled partings which are considered conservatively to be the least probable parameter close to the concrete foundation interface, plus key resistance, plus cohesion, and plus reliable strut resistance.	4
d. Condition c plus earthquake	2-2/3

From the above, the criteria using safety factors of 1.5 and 1.15 will be considered as limiting conditions only if the criteria using safety factors of 4 and 2-2/3 are exceeded.

8. The base pressures are the sum of the contact and uplift pressures on the concrete-foundation interface.

9. A three-dimensional stress analysis must be performed to determine if there is any overstress in the concrete monolith or foundation due to correcting overturning deficiency by prestressing the monolith to the foundation.

Objective

10. The objective of this study was to analyze the monolith of the dam to see if they meet present-day stability requirements. If present-day criteria were not met, corrective measures were to be recommended.

PART II: STABILITY ANALYSIS

Tainter-Gate Monolith

11. The typical geometry of the tainter-gate monolith at Brandon Road Dam is shown in Appendix A, Figure A1. The piers are inset into the tainter-gate monoliths to el 526.69* with side keys projecting into the overflow sections.

12. A stability analysis for a typical tainter-gate monolith was performed for the following case loadings.

a. Normal operation.

b. Normal operation plus ice.

c. Flood condition.

d. Normal operation plus earthquake.

13. Surcharge water (flood pool upstream and normal pool downstream) was found to be less critical than flood condition as discussed later. The material properties used in this analysis were determined from laboratory tests of core samples.[4] The pressure on the dam monoliths caused by the silt was determined by using the method developed by Mononbe and Okabe as described by Seed and Whitman.[6] The water pressure used to assure adequate design against earthquake was obtained as described in Engineer Manual 1110-2-2200 (Westergaard Theory).[7]

14. The main concerns were adequacy against overturning, sliding, and base pressures at any elevation in the monolith or at the monolith-foundation interface.

15. The first concern for this monolith was the stability of the piers which were constructed and keyed into the overflow section of the dam monolith. The stability analysis of the piers (key resistance neglected) showed that they were stable under normal operating conditions but were unstable for normal operating plus ice loading. The analysis of pier stability for normal operation was to show the results

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* Elevations cited herein are in feet referenced to mean sea level (ft msl). A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

uunder the most frequent loading and for normal operation plus ice to determine the stability of the pier for the most critical load case.

16. The piers could be prestressed into the main body of the tainter-gate monolith or into the foundation. The most logical and structurally sound prestressing would be symmetrically across the monolith joint. Many uncertainties would be presented if the piers were symmetrically prestressed across the construction joints which would in effect tie the total dam together.

17. The stability analysis for the pier did not consider any key resistance; it may be that the stress in the keys is low and they can be depended upon to be effective in resisting overturning for the normal operation plus ice loading. A simple but indicative stress analysis as presented in Appendix A (beginning with Figure A2) determined shear stress in the keys under applicable loadings. The resultant force was transferred to the centroid of the key areas. The stress due to force and unbalance moment transfer was found not to be excessive in relation to the allowable $1.1\sqrt{f'_c}$.

18. Since the ice condition at Brandon Road Dam has never been a problem and the keys are not stressed excessively in shear, the stability of the piers is considered adequate. If river conditions begin to change in the future and allow more ice to form, the problem will be restudied at that time.

19. The case loadings for the tainter-gate monoliths were first considered with the stilling basin slab, overflow section, and piers acting as a unit. The much thinner, nonreinforced stilling basin slab was then checked to see if it was overstressed.

20. The presentation herein of the results of the stability analysis for the tainter-gate monoliths is as follows:

a. Summary of stability analysis (Tables 1-3).

b. General presentation of prestressing (Figure 1).

c. Plan view locating prestressing (Figure 6).

d. Base plate design (Figure 6).

e. Detail stability computations (Figures A2-A9).
(1) Pier stability (Figure A2).

(2) Stability, total monolith (Figures A3-A5).
(3) Stability, overstressed apron eliminated (Figures A6-A9).

21. The stability of the tainter-gate monolith during normal operation showing that the apron is overstressed is presented in Figure A3. Since there are 21 tainter-gate monoliths and a considerable amount of prestressing is needed to assure their stability, the computation for all load cases is presented for both the total monolith and for the monolith with the overstressed apron eliminated.

22. The problem with the total monolith is not instability but is the high tensile stress in the apron. Since Corps of Engineers' requirements do not allow any tensile stress in the apron it is necessary to consider the apron as cracked and ineffective. The calculation for the stability of the tainter-gate monolith considering the overstressed apron eliminated is presented in Figures A6-A9.

23. The critical section for stability of the tainter-gate monolith (monolith's overstressed apron eliminated) is at the base foundation interface. A plot of overturning moment versus tailwater elevation shows that the overturning moment under surcharge water pressure is less critical than the overturning moment for flood condition. The overturning moment is at a maximum at a tailwater elevation of about 506 for the total monolith and at about el 510 for the portion of the monolith excluding the overstressed apron.

24. It is apparent that the base pressures, especially when the prestress forces are added, are below maximum allowable; therefore, they are not critical. The factor of safety against sliding is above the minimum criterion if the downstream end of the apron is in bearing contact with the rock. The main contributor to developing adequate sliding resistance is obtained from the rock at the downstream end of the apron. This makes it very important to assure the adequacy of strut resistance downstream of the apron. If key resistance, cohesion, and strut action are not considered, the factor of safety against sliding is less than one, even after prestressing the monoliths to the foundation. It is not advisable to place a high degree of dependence on an

unreinforced concrete element which is susceptible to cracking due to stress concentrations, as is the key, or on cohesion which can relax under sustained loading; therefore, the strut action at the toe of the apron is essential.

25. The apron is highly overstressed in tension and when the overstressed apron is eliminated and overturning computations are made, it is found that the normal operation plus ice condition governs the needed prestress and a prestress force of 1567 kips is required per tainter-gate monolith. Full uplift was applied to the portions of the base not in compression. With the uplift force adjusted, the percentage of base in compression ranged from 0 to 27.52 percent. Although the base becomes 100 percent effective after prestressing, the uplift condition is not changed. The reason for this is that, after part of the monolith base has not been in compression, silt or other sediment could get under the monolith and continue to allow free access of water to that part of the base.

26. The tainter-gate monolith should be anchored to the foundation using prestressing cables grouted into the foundation. Portland-cement base grout is recommended for anchorages. The holes must be clean. The flow and pressure of water into the boreholes should be below allowable limits or the holes should be sealed. It is recommended that the cable within the concrete monolith be bonded (after prestressing has been completed) to prevent corrosion. The details are presented in Figure 1.

27. The maximum prestress load required is 1567 kips/tainter-gate monolith. The prestress cables are of the sort made by VSL Corporation, Los Gatos, California. Using a 16-strand cable (VSL catalog No. ERS-16) with a maximum working load of 396.5 kips, four holes are required per monolith.

28. The layout of the prestress holes in relation to the tainter-gate geometry is presented in Figure 6.

29. A three-dimensional stress analysis was performed to assure that the prestressing does not overstress the concrete of the foundation. A 20-ft embedment length was used in the three-dimensional stress analysis even though a 25-ft length was recommended in the field (see

Part III). To assure that the depth of prestress embedment (25 ft) is adequate, a conventional analysis was performed. It is recommended that a grout giving a 3-day compressive strength of 5000 psi be used.* A conservative bond strength for design purposes is 5 percent of the compressive strength (or a maximum of 200 psi, Reference 8) which establishes the anchorage length as approximately

$$\frac{(396{,}500 \text{ lb})}{(200 \text{ psi})(8\text{-in. circumference})\ (12 \text{ in./ft})} = 20.7 \text{ ft}$$

The 20-ft anchorage is probably adequate but a 25-ft length should be used to be conservative. The tendons can be tensioned after 3 days. The space around the tendons inside the concrete monolith should be filled with grout to prevent corrosion. This should be done only after there is a negligible loss of prestressing with time. The prestressing base plate design and its dimensions are given in Figure 6.

Sluice-Gate Monolith

30. The geometry of the sluice-gate monolith is shown in Figure A10. The entire structure contains six bays that are identical to the one shown. Since the gate bays are similar, a three-dimensional stability analysis was conducted on one bay.

31. The monolith was analyzed for overturning, sliding, and base pressures for four cases of loading. They were:

a. Normal operation.

b. Normal operation plus ice.

c. Flood condition.

d. Normal operation plus earthquake.

32. Before the analysis was undertaken, a stress analysis of the cross section of the monolith at the junction of the monolith and the downstream sill was performed, similar to that for the tainter-gate

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* Such grouts are available as a prepacked mixture from a large number of companies or can be batched from readily available material.

monolith. It was found that the concrete at this section was heavily overstressed in tension; therefore, no analysis was conducted on the sluice gate with the toe section intact.

33. The analyses of the four load cases with the overstressed tow eliminated are shown in Figures A11-A13. The presentation of the results of the stability analyses for the sluice-gate monolith is as follows:

a. Summary of stability analysis (Tables 4 and 5).

b. General presentation of prestressing (Figure 2).

c. Plan view locating prestressing (Figure 7).

d. Base plate design (Figure 7).

e. Detail stability computations (Figures A11-A13).

34. Again, as in the analysis of the tainter-gate monolith, the percentage of the base in compression is less than 100, which requires that full uplift be applied to the portion of the base that is not in compression and the calculations adjusted to reflect such uplift. With the uplift force adjusted, the percentages of base in compression ranged from 0 to 15.56 percent. These percentages resulted in calculated base pressures as high as infinity.

35. All the case loadings require prestressing to bring the base back into full compression. The largest prestress force to bring the resultant to the third point of the base was 286 kips per 13-ft bay for the normal operation plus ice condition. Before the prestress force, the bay had infinite base pressures and with prestress the maximum base pressure will be approximately 3 kips/ft^2.

36. The factors of safety against sliding are above the minimum required for stability if the resistance of the foundation downstream of the monolith is included in the calculations. If the key resistance, cohesion, and the strut action are neglected, the sliding safety factors are reduced to values much lower than 1.

37. Soundings show that much of the downstream part of the sluice-gate monolith (especially at sluice gates 4 and 6) has been eroded. This is a very critical situation and repair of the eroded areas should be accomplished as soon as possible. The following

analysis assumes that this remedial work is going to be completed as soon as possible.

38. A maximum prestress force of 286 kips is required per sluice-gate monolith for the normal operation plus ice condition. The prestress cables are assumed to be similar to catalog No. ER5-6 of the VSL Corporation, Los Gatos, California, using such six-strand cable with a maximum working load of 148.7 kips; two holes are required per monolith.

39. The layout of the prestress holes in relation to the sluice-gate geometry is presented in Figure 7. The prestress force is such that each bay can be prestressed by two six-strand tendons, one on each side of the gate slot.

Ice-Chute Monolith

40. The geometry of the ice-chute monolith is shown in Figure A14. This monolith has the same cross section along its entire length, therefore it was analyzed as a two-dimensional plane structure.

41. The monolith was analyzed for stability of overturning, sliding, and base pressure for four load cases. The load cases analyzed are:

a. Normal operations.

b. Normal operations plus ice condition (gate in raised position).

c. Normal operation plus ice condition (gate in lowered position).

d. Flood condition.

The analysis of these four load cases is shown in Figures A15-A21. It is seen that the base is full compression (100 percent) and the base pressures are well within the allowable maximum of 200 kips/ft^2 when the total monolith is analyzed for stability.

42. This total monolith, like the typical tainter-gate monolith, was stable. It was, however, overstressed in tension at the minimum cross section between the spillway and the apron downstream. This is shown by the analysis given in Figure A15, sheets 4 and 5. It was then necessary to reanalyze the monolith with the overstressed section

assumed to be cracked and ineffective.

43. The four load cases applied to the uncracked monolith were applied to the monolith with the overstressed toe eliminated. Normal operation plus earthquake forces were added to the load cases for this situation. The two conditions of normal operation plus ice (with gate raised and also with gate lowered) were necessary because the position of the gate during ice conditions changes the summation of forces on the monolith.

44. The presentation herein of the results of the stability analysis for the ice-chute monolith is as follows:

a. Summary of stability analysis (Tables 6-8).

b. General presentation of prestressing (Figure 3).

c. Plan view locating prestressing (Figure 8).

d. Base plate design (Figure 8).

e. Detailed stability computations (Figures A15-A21).

45. The calculations showed that the flood condition was the most critical loading case.

46. With full uplift applied to the portion of the base which is not in compression the percentages of base in compression ranged from 17.21 to 43.77 percent. The results of the analysis can be seen in Tables 6-8.

47. Since the flood condition is critical with respect to overturning, it will require the greatest prestress force to bring the resultant vertical force back into the middle third of the base. The calculated force necessary to prestress the ice-chute monolith is 22.32 kips/ft^2 or 670 kips for the entire monolith. This force will put the entire base of the monolith with the overstressed toe eliminated in compression and produce a maximum base pressure of 6.67 kips/ft^2 at the location of the crack.

48. The factor of safety against sliding is greater than the minimum required, provided resistance from the foundation material downstream of the monolith is included. If this resistance is neglected, then even with the prestress force applied the factor of safety is less than approximately 2.5. If strut resistance, cohesion, and key

resistance are neglected, the safety factor is less than 1. This means that strut resistance downstream of the monolith is necessary.

49. The same comments that applied to the tainter-gate monolith regarding prestressing cables, grouting types, and corrosion protection apply here. Using a 7-strand cable (VSL catalog No. ER5-9) with a maximum working load of 173.5 kips, four holes are required per monolith.

Head-Gate Monolith

50. The head-gate structure consists of eight similar 41-ft monoliths with two bays per monolith. A three-dimensional analysis was performed for one 41-ft monolith. Each of these monoliths is symmetrical about its centerline. The head-gate monolith's geometry is shown in Figure A22 with the cross-sectional geometry of one bay shown.

51. The load cases analyzed for this monolith were:

a. Normal operation.

b. Extreme maintenance with both bays dewatered.

c. Normal operation plus ice.

d. Flood condition.

e. Normal operation plus earthquake.

f. Induced surcharge.

52. The induced surcharge condition was with a headwater elevation of 541.0 (flood level) and a tailwater elevation of 503.6 (normal-operation level). The extreme maintenance with both bays dewatered was included because of recommendations made in Appendix E of Reference 2 to dewater both bays of a gate when under a maintenance situation such that high transverse stresses would not be applied to the intermediate pier of the monolith.

53. The stability analysis of these six loading cases is shown in Figures A23-A28. The percentages of base in compression from overturning calculations ranged from 48.12 percent for the normal operation case to 0.0 percent for both the normal operation plus ice case and the extreme maintenance case.

54. In the sliding analysis the strut resistance was set equal to zero based on results of soundings made at the toe area of the head-gate

structure by the Chicago District (Reference 4). Without any reliable strut resistance the factor of safety against sliding for all cases failed to meet allowables as defined in paragraph 7.

55. The base pressures at the toe of the monolith also exceed the allowable (200 ksf) for all cases.

56. The monolith must be prestressed in order to bring the resultant of the vertical forces back to the middle third of the monolith and to meet sliding criteria. The extreme maintenance case controlled the magnitude of the prestress for meeting sliding criteria. The required prestress for this case is 3538 kips per monolith or 221 kips per hole per monolith. The normal operation plus ice case controlled the location of prestressing for meeting overturning criteria. A plan view locating prestressing is shown in Figure 9.

57. It was decided to prestress through the floor of the two bays in the monolith rather than through the piers to avoid prestressing through the slender pier sections and to avoid the heavy reinforcing contained in these piers. The vertical holes were located inside the upstream face of the monolith behind the needle beams to provide greater overturning resistance. The downstream holes are to be drilled at an angle of 40 deg from the vertical to provide greater sliding resistance. The prestressing was designed to resist sliding with a factor of safety of 4 and also to have the total base in compression for all load cases except for the normal operation plus earthquake case. A general layout of the prestressing is shown in Figure 4.

58. In the stability analysis of the monolith after prestress, the monolith meets all stability criteria for overturning, sliding, and base pressures. A summary of the stability analysis is presented in Tables 9 and 10.

59. The prestress details are the same as previously described. A 9-strand cable (VSL catalog No. 1R5-9) with a maximum working load of 223 kips with 16 holes per monolith is required. The base plate design for the prestressing is given in Figure 9. If a safety factor somewhat less than 4 is allowed or if strut resistance is established downstream of the headgate monoliths the prestressing can be reduced.

PART III: STRESS ANALYSIS

Finite-Element Analysis Program

Introduction

60. A finite-element analysis program called "SAP V" was used to compute the stresses in the structure and foundation. This program was designed and programmed to be an effective and efficient computer program for analyzing very large complex three-dimensional structural systems with no loss of efficiency in the solution of small problems. Twelve structural element types were included to increase the usability and flexibility of the program.

61. The capacity of the program is controlled by an "A" array containing 10,000 double precision words of storage. The size of this array can be changed to increase the capacity of the program by increasing the value of "MTOT1" in a routine labeled SAP V of the program.

Input

62. Each node in the system is described by a location and a set of boundary conditions. The location is input as either cartesian (x, y, z) or cylindrical (r, z, θ) coordinates. The boundary conditions are defined by three translations and three rotations.

63. Each element in the system is described by a set of nodes and a material type. Other element inputs include material properties such as Young's modulus of elasticity, weight density, coefficient of thermal expansion, cross-sectional area, Poisson's ratio, shear area, strain area, and shear modulus.

64. Undeformed or deformed finite-element grids can be obtained directly from SAP V; at present, capabilities do not exist to directly plot stress by SAP V. If stress plots are desired, a way to plot them must be devised and the maximum and minimum stresses will have to be calculated as well as plotted.

65. Structural loadings are input as nodal and element loads. The nodal loads are applied as forces and moments. The element loads include thermal, gravity, and hydrostatic loadings.

Output

66. The solution output includes displacements and rotations for unrestrained node and normal and shearing stresses at selected points for each element. The output units are the same as the input units.

Results of Finite-Element Stress Analysis

67. In the three-dimensional finite-element analysis of the tainter-gate monolith and foundation, prestressing was applied for each of the following load cases.

a. Normal operation.

b. Normal operation plus ice.

c. Flood condition.

The finite-element grid for this analysis is presented in Appendix B, Figures B1-B11.

68. The three-dimensional stress results show tensile stresses in the spillway crest and heel areas of the monolith. Although such stresses are not allowed in most areas where these occur, they do not exceed $0.01f'_c$ and therefore are considered small and acceptable. The shear stress in these areas was found to be less than $1.1\sqrt{f'_c}$ and, therefore, acceptable. These stresses are included in the principal stress tables for areas A and C, Tables B1-B15. Element locations for these areas are presented in Figures B6-B11.

69. The three-dimensional results of the prestressing in the foundation show no overstress and are included in the principal stress tables for area B, Tables B1-B15. In the axisymmetric analysis of the foundation under prestress loading only (Figure B12) the stresses decrease rapidly with depth. In this two-dimensional analysis the stress is approximately 4.0 psi in tension at a depth of 10 ft below the monolith key and 2.3 psi in tension at a depth of 20 ft. Both analyses indicate that a 25-ft foundation depth is adequate for the applied prestressing.

70. The other monoliths (sluice gate, ice chute, and headgate) require equal or less prestress force per location than that applied to

the tainter-gate monoliths; therefore, with prestressing as proposed, no overstress will be created in the monolith or foundation.

REFERENCES

1. "Stability Analysis - Locks and Dams, Illinois Waterway, Brandon Road Lock and Dam; Stability Investigation of Existing Brandon Road Lock and Dam, Illinois Waterway," Department of the Army, Chicago District, CE, Everett McKinley Dirksen Building, Chicago, Ill., Feb 1973.

2. "Stability Analysis - Locks and Dams, Illinois Waterway, Brandon Road Lock and Dam; Appendix E, Stability Analysis of Dam Masonry," Department of the Army, Chicago District, CE, Everett McKinley Dirksen Building, Chicago, Ill., Feb 1973.

3. "Illinois Waterway, Illinois, Brandon Road Lock and Dam," Periodic Inspection Report No. 2, June 1973, Department of the Army, Chicago District, CE, Everett McKinley Dirksen Building, Chicago, Ill.

4. Stowe, R. L., "Concrete and Rock Tests, Rehabilitation Work, Brandon Road Dam, Illinois Waterway, Chicago District," Miscellaneous Paper C-78-4, May 1978, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

5. "Engineering and Design, Gravity Dam Design Stability," ETL 1110-2-184, 25 Feb 1974.

6. Seed, H. B. and Whitman, R. V., "Design of Earth Retaining Structures for Dynamic Load," *ASCE Specialty Conference on Lateral Stresses in the Ground and Design of Earth Retaining Structures* Cornell University, 1970.

7. "Engineering and Design, Gravity Dam Design," EM 1110-2-2200, 25 Sep 1958.

8. Littlejohn, G. S. and Bruce, D. A., "Rock Anchors - Design and Quality Control," 16th Symposium on Rock Mechanics, University of Minnesota, 22-24 Sep 1975.

SUBJECT: TABLE I - SUMMARY OF STABILITY ANALYSIS - TAINTER GATE MONOLITH - TOTAL MONOLITH

COMPUTED BY: | DATE:

CHECKED BY: | DATE:

TAINTER-GATE MONOLITH CASE LOADINGS	EVALUATING CONDITION	EFFECTIVE BASE (PERCENT)	SLIDING SAFETY FACTOR* CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	FOUNDATION PRESSURE KIPS/FT^2
TOTAL MONOLITH								
NORMAL OPERATION	ALLOWABLE	100	4	—	—	1.5	—	200
	ACTUAL	100	9.97	2.12	0.84	8.27	0.41	3.95
NORMAL OPERATION + ICE	ALLOWABLE	100	4	—	—	1.5	—	200
	ACTUAL	100	9.34	1.98	0.79	7.74	0.39	3.29
FLOOD CONDITION	ALLOWABLE	100	4	—	—	1.5	—	200
	ACTUAL	100	9.24	1.93	0.74	7.67	0.36	3.59

* CASE 1 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION, KEY AND STRUT RESISTANCE
CASE 2 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION AND KEY RESISTANCE
CASE 3 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION RESISTANCE
CASE 4 - LOWER BOUND PARAMETERS - FRICTION AND STRUT RESISTANCE
CASE 5 - LOWER BOUND PARAMETERS - FRICTION RESISTANCE

WES FORM NO. 1253A
DECEMBER 1964

SUBJECT: TABLE 2 – SUMMARY OF STABILITY ANALYSIS – TAINTER GATE MONOLITH – OVERSTRESSED TOE ELIMINATED WIHOUT PRESTRESS

COMPUTED BY: DATE:

CHECKED BY: DATE:

TAINTER-GATE MONOLITH CASE LOADINGS (WITHOUT PRESTRESS)	EVALUATING CONDITION	EFFECTIVE BASE (PERCENT)	SLIDING SAFETY FACTOR * CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	FOUNDATION PRESSURE KIPS/FT²
MONOLITH WITH OVERSTRESSED TOE ELIMINATED								
NORMAL OPERATION	ALLOWABLE	100	4	–	–	1.5	–	200
	ACTUAL	27.52	9.65	1.79	0.52	8.11	0.25	535
NORMAL OPERATION + ICE	ALLOWABLE	100	4	–	–	1.5	–	200
	ACTUAL	0	9.00	1.63	0.44	7.58	0.21	∞
FLOOD CONDITION	ALLOWABLE	100	4	–	–	1.5	–	200
	ACTUAL	0	9.07	1.61	0.40	7.66	0.19	∞
NORMAL OPERATION + EARTHQUAKE	ALLOWABLE	0	2⅔	–	–	1.15	–	200
	ACTUAL	Resultant Outside Base	8.35	1.55	0.45	7.02	0.22	∞

* CASE 1 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION, KEY AND STRUT RESISTANCE
CASE 2 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION AND KEY RESISTANCE
CASE 3 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION RESISTANCE
CASE 4 - LOWER BOUND PARAMETERS - FRICTION AND STRUT RESISTANCE
CASE 5 - LOWER BOUND PARAMETERS - FRICTION RESISTANCE

WES FORM NO. DECEMBER 1964 1253A

SUBJECT: TABLE 3 - SUMMARY OF STABILITY ANALYSIS - TAINTER GATE MONOLITH - OVERSTRESSED TOE ELIMINATED, WITH PRESTRESS

COMPUTED BY: DATE:

CHECKED BY: DATE:

TAINTER-GATE MONOLITH CASE LOADINGS (WITH PRESTRESS)	EVALUATING CONDITION	EFFECTIVE BASE (PERCENT)	SLIDING SAFETY FACTOR * CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	FOUNDATION PRESSURE KIPS/FT²
MONOLITH WITH OVERSTRESSED TOE ELIMINATED								
NORMAL OPERATION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	10.05	2.19	0.92	8.31	0.45	5.35
NORMAL OPERATION + ICE	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	9.37	2.01	0.82	7.76	0.40	7.48
FLOOD CONDITION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	9.45	1.99	0.78	7.84	0.38	6.60
NORMAL OPERATION + EARTHQUAKE	ALLOWABLE	0	2 2/3	-	-	1.15	-	200
	ACTUAL	43.37	8.70	1.90	0.79	7.19	0.39	9.24

* CASE 1 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION, KEY AND STRUT RESISTANCE
CASE 2 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION AND KEY RESISTANCE
CASE 3 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION RESISTANCE
CASE 4 - LOWER BOUND PARAMETERS - FRICTION AND STRUT RESISTANCE
CASE 5 - LOWER BOUND PARAMETERS - FRICTION RESISTANCE

WES FORM NO. 1253A
DECEMBER 1964

SUBJECT: TABLE 4 - SUMMARY OF STABILITY ANALYSIS
SLUICE - GATE MONOLITH - OVERSTRESSED TOE ELIMINATED
WITHOUT PRESTRESS

COMPUTED BY: DATE:

CHECKED BY: DATE:

SLUICE - GATE MONOLITH CASE LOADINGS (WITHOUT PRESTRESS)	EVALUATING CONDITION	EFFECTIVE BASE (PERCENT)	SLIDING SAFETY FACTOR *					FOUNDATION PRESSURE KIPS/FT²
			CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	
OVERSTRESSED TOE ELIMINATED								
NORMAL OPERATION	ALLOWABLE ACTUAL	100 15.56	4 11.83	- 1.77	- 0.36	1.5 10.23	- 0.18	200 130
NORMAL OPERATION + ICE	ALLOWABLE ACTUAL	100 0	4 10.80	- 1.55	- 0.25	1.5 9.37	- 0.12	200 ∞
FLOOD CONDITION	ALLOWABLE ACTUAL	100 0	4 10.92	- 1.56	- 0.25	1.5 9.48	- 0.12	200 ∞
NORMAL OPERATION + EARTHQUAKE	ALLOWABLE ACTUAL	0 Resultant Outside Base	2 1/3 10.45	- 1.57	- 0.32	1.15 9.04	- 0.16	200 ∞

* CASE 1 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION, KEY AND STRUT RESISTANCE
CASE 2 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION AND KEY RESISTANCE
CASE 3 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION RESISTANCE
CASE 4 - LOWER BOUND PARAMETERS - FRICTION AND STRUT RESISTANCE
CASE 5 - LOWER BOUND PARAMETERS - FRICTION RESISTANCE

WES FORM NO. DECEMBER 1964 1253A

SUBJECT: TABLE 5 - SUMMARY OF STABILITY ANALYSIS
SLUICE-GATE MONOLITH - OVERSTRESSED TOE ELIMINATED WITH PRESTRESS

COMPUTED BY: DATE:

CHECKED BY: DATE:

SLUICE-GATE MONOLITH CASE LOADINGS (WITH PRESTRESS)	EVALUATING CONDITION	EFFECTIVE BASE (PERCENT)	SLIDING SAFETY FACTOR * CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	FOUNDATION PRESSURE KIPS/FT²
OVERSTRESSED TOE ELIMINATED								
NORMAL OPERATION	ALLOWABLE ACTUAL	100 100	4 12.21	– 2.16	– 0.74	1.5 10.42	– 0.36	200 3.75
NORMAL OPERATION + ICE	ALLOWABLE ACTUAL	100 100	4 11.15	– 1.90	– 0.60	1.5 9.54	– 0.29	200 3.12
FLOOD CONDITION	ALLOWABLE ACTUAL	100 100	4 11.27	– 1.92	– 0.60	1.5 9.65	– 0.30	200 3.25
NORMAL OPERATION + EARTHQUAKE	ALLOWABLE ACTUAL	100 100	2⅔ 10.79	– 1.90	– 0.66	1.15 9.20	– 0.32	200 3.28

* CASE 1 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION, KEY AND STRUT RESISTANCE
CASE 2 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION AND KEY RESISTANCE
CASE 3 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION RESISTANCE
CASE 4 - LOWER BOUND PARAMETERS - FRICTION AND STRUT RESISTANCE
CASE 5 - LOWER BOUND PARAMETERS - FRICTION RESISTANCE

WES FORM NO. DECEMBER 1964 1253A

SUBJECT: TABLE 6 - SUMMARY OF STABILITY ANALYSIS
ICE-CHUTE MONOLITH - TOTAL MONOLITH

COMPUTED BY: DATE:

CHECKED BY: DATE:

ICE-CHUTE MONOLITH CASE LOADINGS	EVALUATING CONDITION	EFFECTIVE BASE (PERCENT)	SLIDING SAFETY FACTOR * CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	FOUNDATION PRESSURE KIPS/FT²
TOTAL MONOLITH								
NORMAL OPERATION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	11.75	2.59	1.18	9.74	0.58	4.65
NORMAL OPERATION + ICE (GATE RAISED)	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	-	-	-	-	-	23:58
NORMAL OPERATION +ICE (GATE LOWERED)	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	-	-	-	-	-	24.91
FLOOD CONDITION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	-	-	-	-	-	20.33

* CASE 1 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION, KEY AND STRUT RESISTANCE
CASE 2 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION AND KEY RESISTANCE
CASE 3 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION RESISTANCE
CASE 4 - LOWER BOUND PARAMETERS - FRICTION AND STRUT RESISTANCE
CASE 5 - LOWER BOUND PARAMETERS - FRICTION RESISTANCE

WES FORM NO. DECEMBER 1964 1253A

SUBJECT: TABLE 7 - SUMMARY OF STABILITY ANALYSIS
ICE - CHUTE MONOLITH - OVERSTRESSED TOE ELIMINATED WIHOUT PRESTRESS

COMPUTED BY: | DATE:

CHECKED BY: | DATE:

ICE - CHUTE MONOLITH CASE LOADINGS (BEFORE PRESTRESS)	EVALUATING CONDITION	EFFECTIVE BASE (PERCENT)	SLIDING SAFETY FACTOR * CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	FOUNDATION PRESSURE KIPS/FT²
MONOLITH WITH OVERSTRESSED TOE ELIMINATED								
NORMAL OPERATION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	43.77	11.27	2.22	0.83	9.45	0.40	8.45
NORMAL OPERATION + ICE GATE RAISED	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	36.22	10.93	2.14	0.80	9.18	0.39	9.85
NORMAL OPERATION + ICE GATE LOWERED	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	40.62	11.37	2.20	0.80	9.55	0.39	8.68
FLOOD CONDITION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	17.21	10.39	1.94	0.64	8.76	0.31	16.51
NORMAL OPERATION + EARTHQUAKE	ALLOWABLE	0	2⅔	-	-	1.15	-	200
	ACTUAL	17.84	9.58	1.89	0.70	8.04	0.34	18.57

* CASE 1 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION, KEY AND STRUT RESISTANCE
CASE 2 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION AND KEY RESISTANCE
CASE 3 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION RESISTANCE
CASE 4 - LOWER BOUND PARAMETERS - FRICTION AND STRUT RESISTANCE
CASE 5 - LOWER BOUND PARAMETERS - FRICTION RESISTANCE

SUBJECT: TABLE 8 - SUMMARY OF STABILITY ANALYSIS
ICE - CHUTE MONOLITH - OVERSTRESSED TOE ELIMINATED WITH PRESTRESS

COMPUTED BY: DATE:

CHECKED BY: DATE:

ICE - CHUTE MONOLITH CASE LOADINGS (AFTER PRESTRESS)	EVALUATING CONDITION	EFFECTIVE BASE (PERCENT)	SLIDING SAFETY FACTOR * CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	FOUNDATION PRESSURE KIPS/FT²
MONOLITH WITH OVERSTRESSED TOE ELIMINATED								
NORMAL OPERATION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	11.61	2.57	1.18	9.62	0.57	5.49
NORMAL OPERATION + ICE GATE RAISED	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	11.27	2.48	1.13	9.34	0.55	5.76
NORMAL OPERATION + ICE GATE LOWERED	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	11.72	2.56	1.15	9.72	0.56	5.41
FLOOD CONDITION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	10.71	2.26	0.96	8.92	0.47	5.95
NORMAL OPERATION + EARTHQUAKE	ALLOWABLE	0	2 2/3	-	-	1.15	-	200
	ACTUAL	90.60	9.88	2.18	1.00	8.19	0.49	6.67

* CASE 1 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION, KEY AND STRUT RESISTANCE
CASE 2 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION AND KEY RESISTANCE
CASE 3 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION RESISTANCE
CASE 4 - LOWER BOUND PARAMETERS - FRICTION AND STRUT RESISTANCE
CASE 5 - LOWER BOUND PARAMETERS - FRICTION RESISTANCE

SUBJECT: TABLE 9 - SUMMARY OF STABILITY ANALYSIS
HEAD-GATE MONOLITH - WITHOUT PRESTRESS

COMPUTED BY: DATE:

CHECKED BY: DATE:

HEAD GATE MONOLITH CASE LOADINGS (BEFORE PRESTRESS)	EVALUATING CONDITION	EFFECTIVE BASE (PERCENT)	SLIDING SAFETY FACTOR* CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	FOUNDATION PRESSURE KIPS/FT²
NORMAL OPERATION	ALLOWABLE ACTUAL	100 48.12	4 2.80	- 2.80	- 1.45	1.5 0.71	- 0.71	200 430
NORMAL OPERATION + ICE	ALLOWABLE ACTUAL	100 21.56	4 2.41	- 2.41	- 1.17	1.5 0.57	- 0.57	200 848
FLOOD CONDITION	ALLOWABLE ACTUAL	100 29.87	4 2.43	- 2.43	- 1.17	1.5 0.57	- 0.57	200 607
NORMAL OPERATION + EARTHQUAKE	ALLOWABLE ACTUAL	0 26.03	2 2/3 2.35	- 2.35	- 1.22	1.15 0.59	- 0.59	200 795
INDUCED SURCHARGE CONDITION	ALLOWABLE ACTUAL	100 29.52	4 2.41	- 2.41	- 1.17	1.5 0.57	- 0.57	200 622
EXTREME MAINTENANCE CONDITION WITH BOTH BAYS DEWATERED	ALLOWABLE ACTUAL	100 0	4 1.99	- 1.99	- 0.64	1.5 0.31	- 0.31	200 ∞

*CASE 1 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION, KEY AND STRUT RESISTANCE
CASE 2 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION AND KEY RESISTANCE
CASE 3 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION RESISTANCE
CASE 4 - LOWER BOUND PARAMETERS - FRICTION AND STRUT RESISTANCE
CASE 5 - LOWER BOUND PARAMETERS - FRICTION RESISTANCE

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SUBJECT: TABLE 10 - SUMMARY OF STABILITY ANALYSIS HEAD-GATE MONOLITH - WITH PRESTRESS

COMPUTED BY: DATE:

CHECKED BY: DATE:

HEAD-GATE MONOLITH CASE LOADINGS (AFTER PRESTRESS)	EVALUATING CONDITION	EFFECTIVE BASE (PERCENT)	SLIDING SAFETY FACTOR * CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	FOUNDATION PRESSURE KIPS/FT²
NORMAL OPERATION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	4.81	4.81	3.46	2.07	2.07	8.35
NORMAL OPERATION + ICE	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	4.26	4.26	3.02	1.82	1.82	8.64
FLOOD CONDITION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	4.29	4.29	3.04	1.83	1.83	8.41
NORMAL OPERATION + EARTHQUAKE	ALLOWABLE	0	2 2/3	-	-	1.15	-	200
	ACTUAL	100	4.04	4.04	2.90	1.73	1.73	9.47
INDUCED SURCHARGE CONDITION	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	4.25	4.25	3.01	1.82	1.82	8.31
EXTREME MAINTENANCE CONDITION WITH BOTH BAYS DEWATERED	ALLOWABLE	100	4	-	-	1.5	-	200
	ACTUAL	100	4	4	2.65	1.67	1.67	6.50

* CASE 1 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION, KEY AND STRUT RESISTANCE
CASE 2 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION, COHESION AND KEY RESISTANCE
CASE 3 - LEAST PROBABLE EXISTING PARAMETERS - FRICTION RESISTANCE
CASE 4 - LOWER BOUND PARAMETERS - FRICTION AND STRUT RESISTANCE
CASE 5 - LOWER BOUND PARAMETERS - FRICTION RESISTANCE

WES FORM NO. DECEMBER 1253A

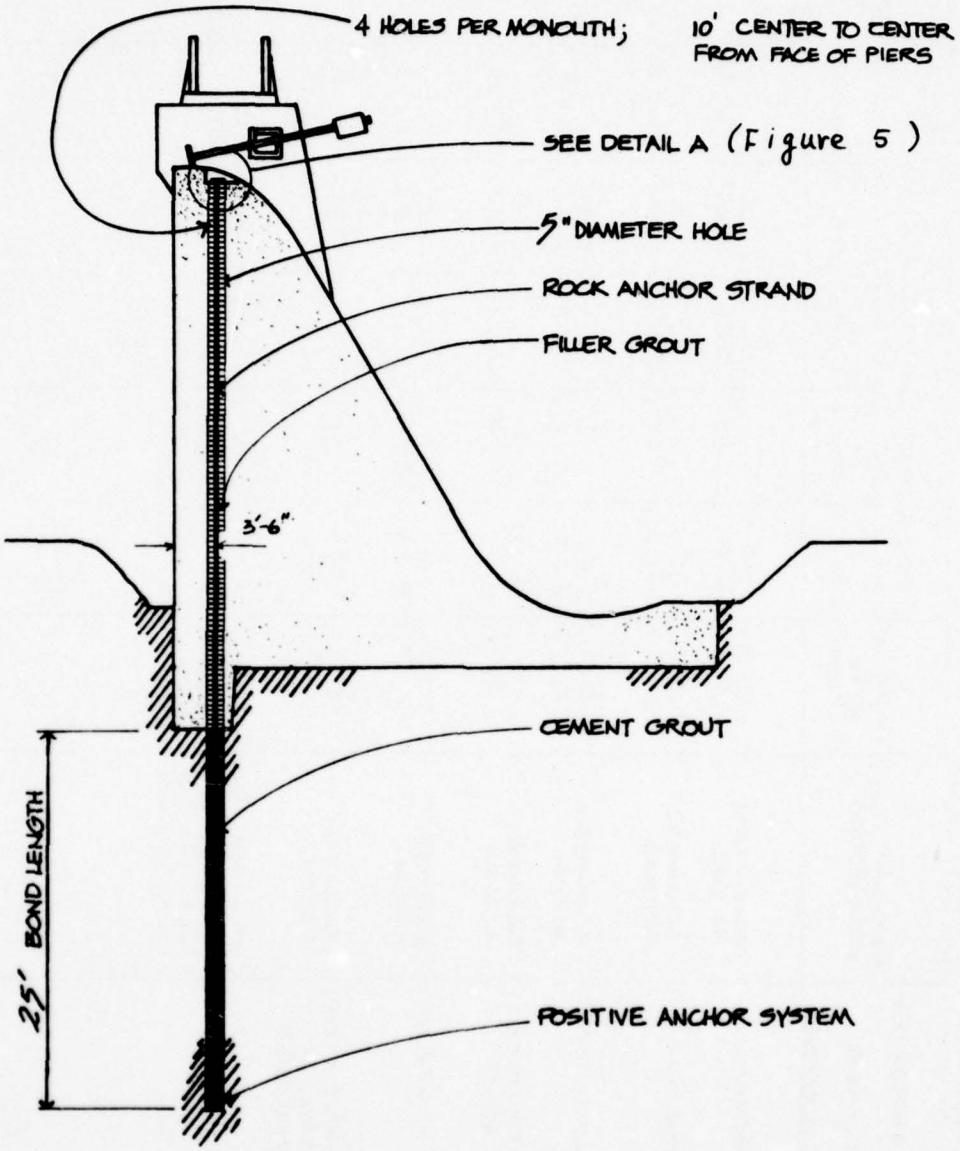


Figure 1. General layout of prestressing for tainter-gate monolith

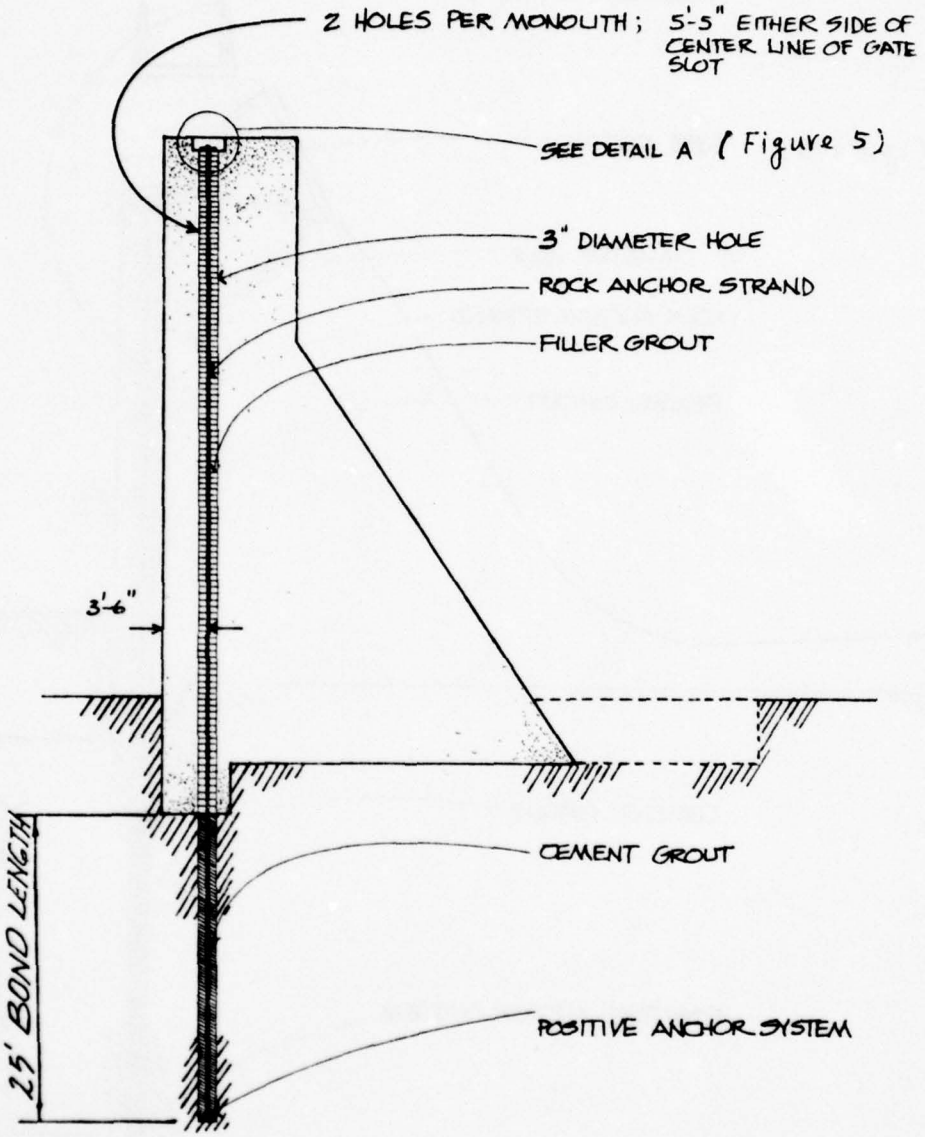


Figure 2. General layout of prestressing for sluice-gate monolith

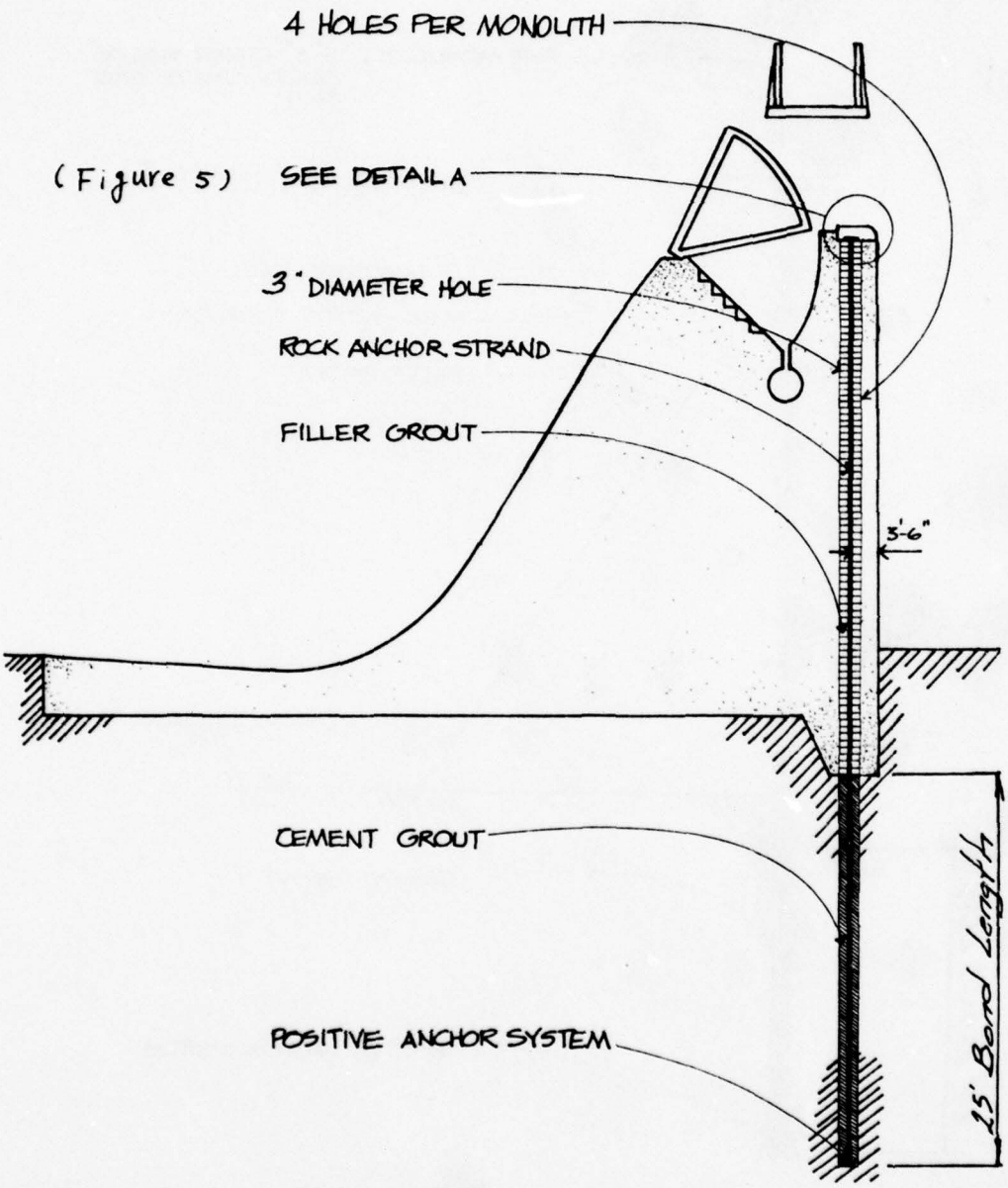


Figure 3. General layout of prestressing for ice-chute monolith

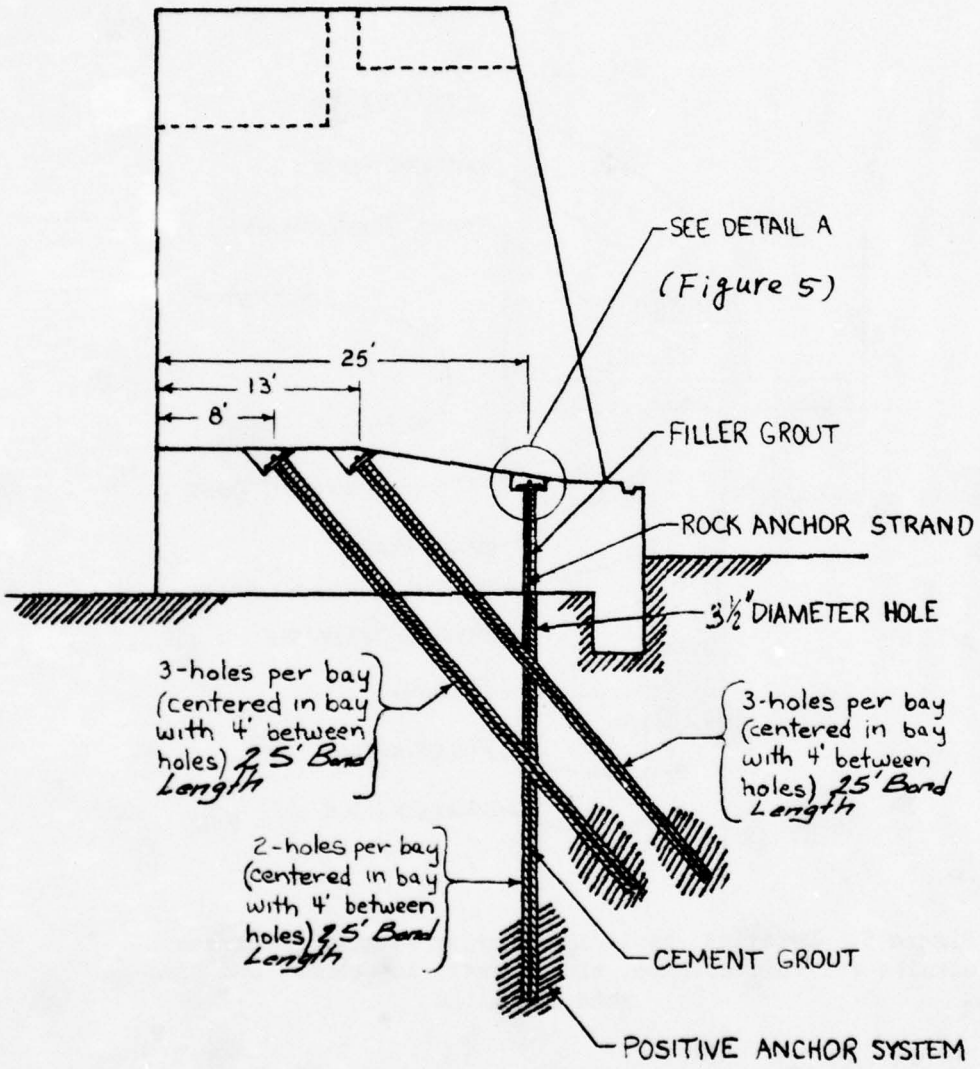


Figure 4. General layout of prestressing for head-gate monolith

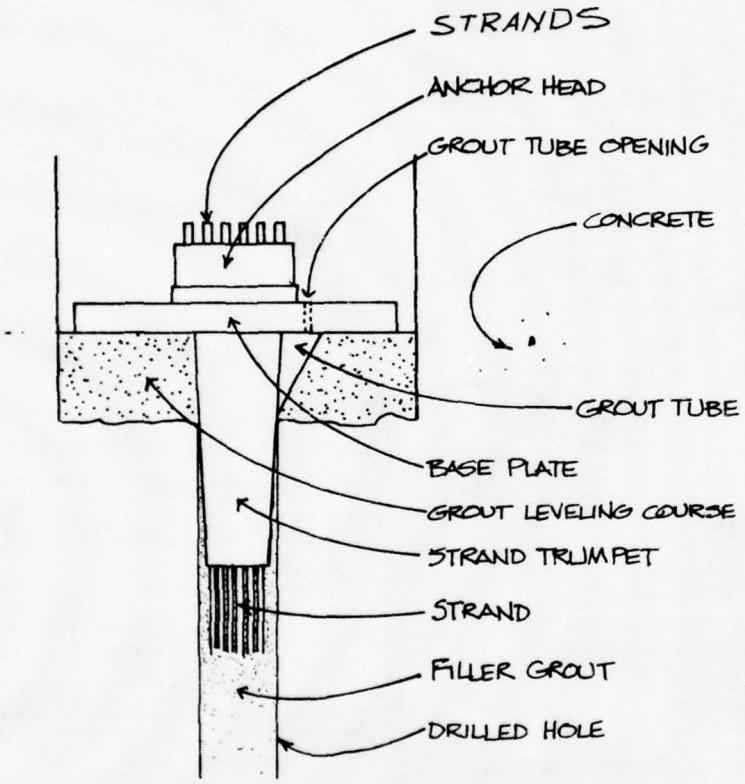
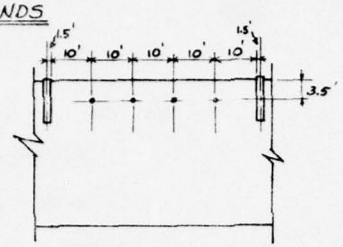


Figure 5. Detail A, typical anchoring system; prestress details for tainter-gate, sluice-gate, ice-chute, and head-gate monoliths

LOCATION OF PRESTRESSING STRANDS



PLAN VIEW

BASE PLATE DESIGN

average compressive strength from lab tests of cores taken from the monolith (at approximate depth of anchor plate) = f_{avg} = 4310 psi

allowable bearing = .375 f_{avg}

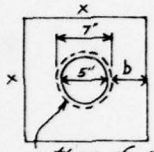
= 375 (4310)

= 1,616 psi

= 1.616 KSI

working force applied to each tendon = 392 kips

required area of each base plate = $\frac{392}{1.616}$ = 243 in^2



outline of post tension anchor head

$x^2 - \frac{\pi}{4}(5)^2 = 243$

$x = \sqrt{243 + \frac{\pi}{4}(5)^2}$

= 16.21" use 16¼ in

plate thickness

$thickness = \sqrt{\frac{(3)(F_p)(b)^2}{F_b}}$

$= \sqrt{\frac{(3)(1.616)(4.625)^2}{27}}$

= 1.96 in use 2.0"

$b = \frac{16.25 - 7}{2} = 4.625$

F_b = 27 KSI

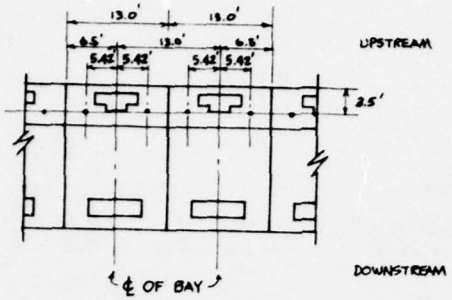
F_p = allowable bearing

plate dimensions

16¼" x 16¼" x 2"

Figure 6. Prestress details, tainter-gate monolith

LOCATION OF PRESTRESSING STRANDS



BASE PLATE DESIGN

average compressive strength from lab tests of cores taken, from monolith (at approximate depth of anchor plate) = 4340 psi

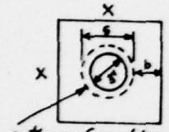
allowable bearing = $.375\, f'_{arg}$

$= .375(4340)$

$= 1627$ psi $= 1.627$ KSI

force applied to each tendon = 139.9 Kips

required area of each base plate = $\frac{143^{K}}{1.627\ KSI} = 87.84\ in^2$



outline of post tension anchor head

$x^2 - \frac{\pi}{4}(8)^2 = 87.84$

$x = \sqrt{87.84 + \frac{\pi}{4}(8)^2}$

$= 9.74"$ use $9\frac{3}{4}"$

thickness $= \sqrt{\frac{3 F_p b^2}{F_b}}$

$= \sqrt{\frac{(3)(1.627)(2.375)^2}{27}}$

$= 1.01"$ use 1"

$b = \frac{x - s}{2} = 2.375$

$F_b = 27$ KSI

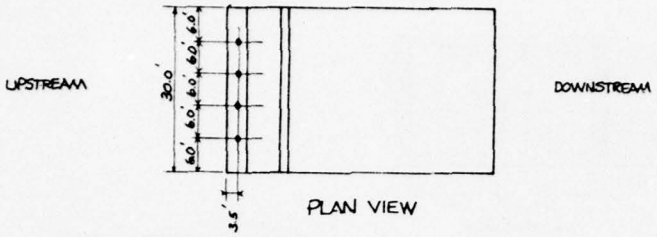
F_p = Allowable bearing

base plate dimensions

$9\frac{3}{4}" \times 9\frac{3}{4}" \times 1"$

Figure 7. Prestress details, sluice-gate monolith

LOCATION OF PRESTRESSING STRANDS



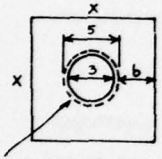
BASE PLATE DESIGN

average compressive strength from 186 tests of cores taken from monolith adjacent to the ice chute = f'_{avg} = 4310 psi

allowable bearing = $.375\, f'_{avg}$ = $.375(4310)$ = 1616 psi = 1.616 KSI

working force applied to each tendon = 168 Kips

required area of each base plate = $\frac{168}{1.616}$ = 104 in^2



outline of post tension anchor head

$X^2 - \frac{\pi}{4}(3)^2 = 104$

$X = \sqrt{104 + \frac{\pi}{4}(3)^2}$

$= 10.54$ in use $10\frac{3}{4}$ in.

plate thickness

$$\text{thickness} = \sqrt{\frac{(3)\, F_p\, b^2}{F_b}}$$

$$= \sqrt{\frac{(3)(1.616)(2.875)^2}{27}}$$

= 1.22 in.
use $1\frac{1}{4}$"

$b = \frac{10.75 - 5}{2}$

= 2.875 in.

F_b = 27 KSI

F_p = Allowable bearing

bearing plate dimensions
$10\frac{3}{4}$" x $10\frac{3}{4}$" x $1\frac{1}{4}$"

Figure 8. Prestress detail, ice-chute monolith

BASE PLATE DESIGN

average compressive strength from lab tests of cores taken from the monolith = f'_{cm} = 5120 psi

allowable bearing = .375 f'_{cm}

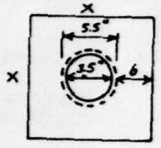
= .375(5120)

= 1920 psi = 1.920 KSI

working force applied to each tendon:

for overturning prestress = 221 KIPS

required area for each base plate = $\frac{221}{1.92}$ = 115.10 in^2



$x^2 - \frac{\pi}{4}(3.5)^2 = 115.10\ in^2$

$x = \sqrt{115.10 + \frac{\pi}{4}(3.5)^2}$

= 11.17 in use $11\frac{1}{4}$ in.

THICKNESS $b = \frac{11.25 - 5.5}{2} = 2.875$ in.

for overturning tendons

thickness = $\sqrt{\frac{(3)(1.920)(2.875)^2}{27}}$

= 1.33 in use $1\frac{1}{2}$ in.

BEARING PLATE DIMENSIONS

$11\frac{1}{4}$" x $11\frac{1}{4}$" x $1\frac{1}{2}$"

PLAN VIEW OF BAYS SHOWING PRESTRESS LOCATION

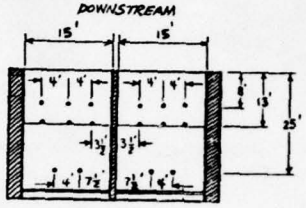


Figure 9. Prestress details, head-gate monolith

APPENDIX A: STABILITY OF TAINTER GATE, SLUICE-GATE, ICE-CHUTE, AND HEAD-GATE MONOLITHS

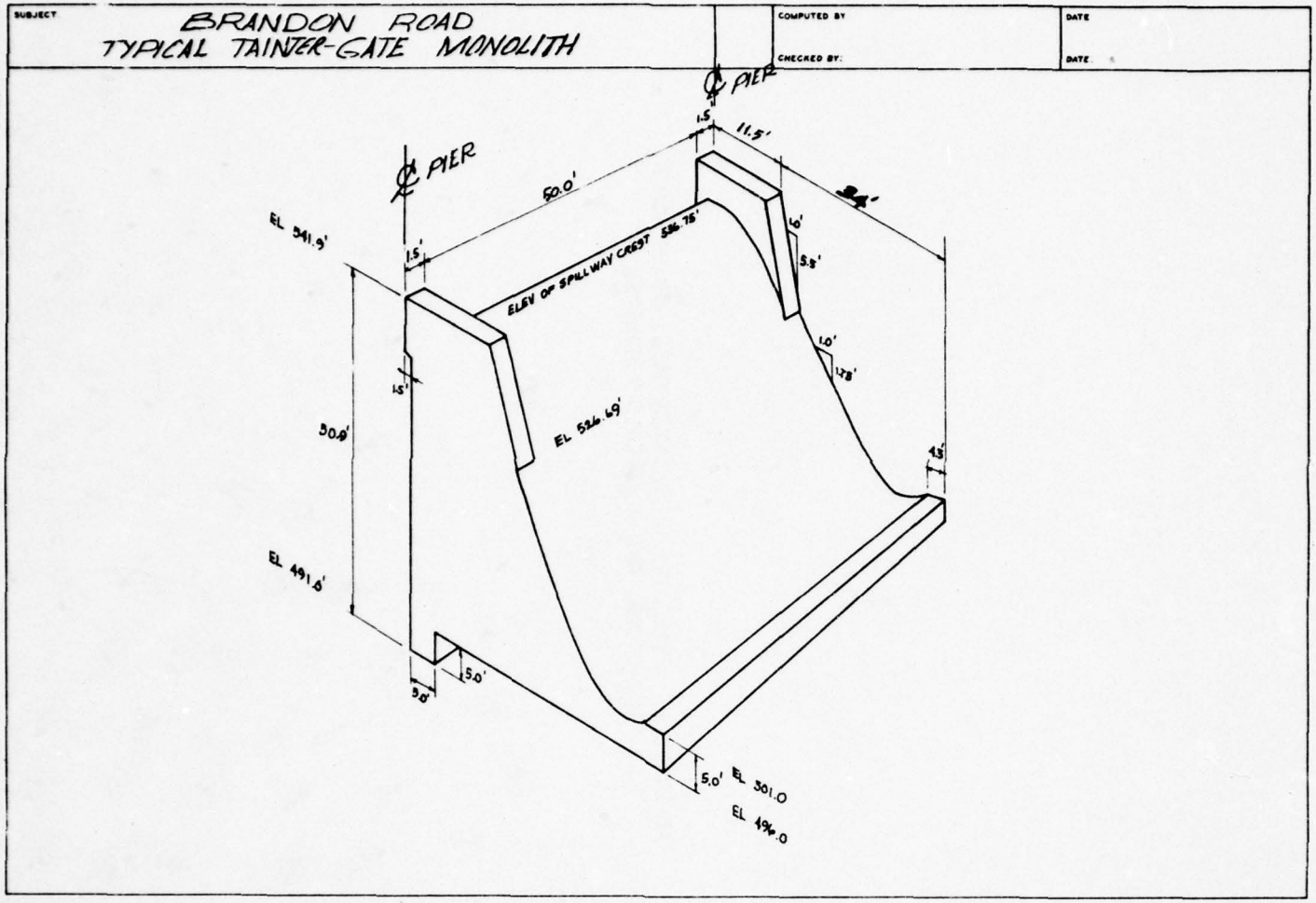
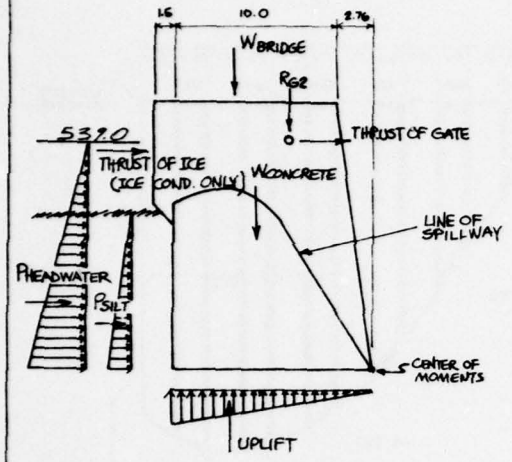


Figure A1. Typical tainter-gate monolith

SUBJECT: BRANDON ROAD
PIER STABILITY - TAINTER-GATE MONOLITH

COMPUTED BY: DATE:
CHECKED BY: DATE:



	ITEM	FACTORS	FV	FH	ARM	MOMENT
	WCONCRETE	[.1515][(10)(541.9-526.69)(3) + (1.5)(541.9-536.11)(3) + (½)(1.5)²(3) + (1½)(2.76)(541.9-526.69)(3)]	88.13		7.39	614.33
	WBRIDGE	VALUE TAKEN FROM APPENDIX E, STABILITY ANALYSIS BRANDON ROAD	11.00		8.27	90.97
	RG2	VALUE SAME AS IN PRESENT STABILITY ANALYSIS FOR NORMAL OPERATION	11.28		5.10	57.38
541.9	UPLIFT	[.0625][(539.0-526.69)(½)(.5)(12.76)(3)]	-7.36		8.51	-62.63
	PHEADWATER	[.0625](½)(539-526.69)²(3)		-14.21	4.10	-58.26
	PSILT	[.0203](½)(535-526.69)²(.5)(3)		-1.05	2.77	-2.91
536.11	THRUST OF GATE	VALUE SAME AS IN PRESENT STABILITY ANALYSIS FOR NORMAL OPERATION		-7.91	12.06	-95.39
			98.05	-23.17		543.49

NORMAL OPER. RESULTANT ARM = $\frac{543.49}{98.05}$ = 5.54' > 4.25' in middle third of base O.K.

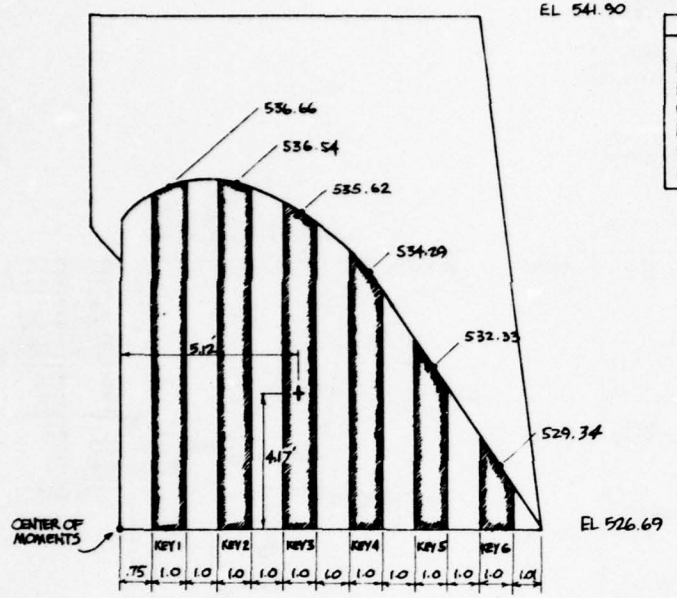
526.69	ITEM	FACTORS	FV	FH	ARM	MOMENT
	WCONCRETE	[.1515][(10)(541.9-526.69)(3) + (1.5)(541.9-536.11)(3) + (½)(1.5)²(3) + (1½)(2.76)(541.9-526.69)(3)]	88.13		7.39	614.33
	WBRIDGE	VALUE TAKEN FROM APPENDIX E, STABILITY ANALYSIS BRANDON ROAD	11.00		8.27	90.97
	RG2	VALUE SAME AS IN PRESENT STABILITY ANALYSIS FOR NORMAL OPERATION PLUS ICE	0.25		5.10	1.27
	UPLIFT	[.0625][(539.0-526.69)(½)(.5)(12.76)(3)]	-7.36		8.51	-62.63
	PHEADWATER	[.0625](½)(539-526.69)²(3)		-14.21	4.10	-58.26
	PSILT	[.0203](½)(535-526.69)²(.5)(3)		-1.05	2.77	-2.91
	THRUST OF ICE ON PIER	[5](3)(1)		-15.00	11.81	-177.15
	THRUST OF GATE	VALUE SAME AS IN PRESENT STABILITY ANALYSIS FOR NORMAL OPERATION PLUS ICE		-257.91	12.06	-3110.39
			87.02	-288.17		-2704.77

NORMAL OPER. + ICE RESULTANT ARM = $\frac{-2704.77}{87.02}$ = -31.08' UNSTABLE

Figure A2. Shear stress in keys between pier and spillway, tainter-gate monolith (Sheet 1 of 10)

SUBJECT: BRANDON ROAD PIER STABILITY - TAINTER-GATE MONOLITH	COMPUTED BY: CHECKED BY:	DATE: DATE:

DETERMINING AN INDICATION OF MAXIMUM SHEAR STRESS IN KEYS BETWEEN PIER AND SPILLWAY



CENTROID OF KEY GROUP
(MOMENTS TAKEN ABOUT JOINT AT UPSTREAM FACE AT ELEV 526.69)

ITEM	AREA	X-ARM	Y-ARM	MOM.x	MOMy
KEY 1	(536.66-526.69)(1) = 9.97	1.25	4.985	12.46	49.70
KEY 2	(536.54-526.69)(1) = 9.85	3.25	4.925	32.01	48.51
KEY 3	(535.32-526.69)(1) = 8.93	5.25	4.465	46.88	39.87
KEY 4	(534.29-526.69)(1) = 7.60	7.25	3.800	55.10	28.88
KEY 5	(532.33-526.69)(1) = 5.64	9.25	2.820	52.17	15.90
KEY 6	(529.34-526.69)(1) = 2.65	11.25	1.325	29.81	3.51
	44.64			228.43	186.37

RESULTANT HORIZONTAL ARM = $\frac{228.43}{44.64}$ = 5.12'

RESULTANT VERTICAL ARM = $\frac{186.37}{44.64}$ = 4.17'

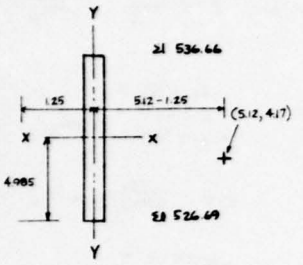
A4

Figure A2. (Sheet 2 of 10)

SUBJECT	COMPUTED BY:	DATE:
BRANDON ROAD PIER STABILITY - TAINTER-GATE MONOLITH	CHECKED BY:	DATE:

POLAR MOMENT OF INERTIA OF EACH KEY TRANSLATED TO THE CENTROID OF THE GROUP

KEY 1



$I_{xx} = \frac{(1)(9.97)^3}{12} = 82.59 \text{ ft}^4$

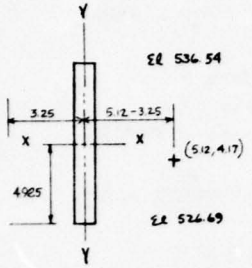
$I_{xx_{centroid}} = I_{xx} + A\bar{Y}^2$
$= 82.59 + (9.97)(4.985 - 4.17)^2$
$= 89.21 \text{ ft}^4$

$I_{yy} = \frac{(1)^3(9.97)}{12} = 0.83 \text{ ft}^4$

$I_{yy\,centroid} = I_{yy} + A\bar{x}^2$
$= 0.83 + (9.97)(5.12 - 1.25)^2$
$= 221.15 \text{ ft}^4$

$I_{key\,1} = I_{xx_{centroid}} + I_{yy\,centroid}$
$= 89.21 + 221.15$
$= 310.36 \text{ ft}^4$

KEY 2



$I_{xx} = \frac{(1)(9.85)^3}{12} = 79.64 \text{ ft}^4$

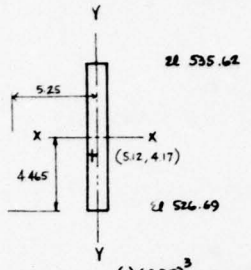
$I_{xx_{centroid}} = I_{xx} + A\bar{Y}^2$
$= 79.64 + (9.85)(4.925 - 4.17)^2$
$= 85.25 \text{ ft}^4$

$I_{yy} = \frac{(1)^3(9.85)}{12} = 0.82$

$I_{yy\,centroid} = I_{yy} + A\bar{x}^2$
$= 0.82 + (9.85)(5.12 - 3.25)^2$
$= 35.26 \text{ ft}^4$

$I_{key\,2} = I_{xx\,centroid} + I_{yy\,centroid}$
$= 85.25 + 35.26$
$= 120.51 \text{ ft}^4$

KEY 3



$I_{xx} = \frac{(1)(8.93)^3}{12} = 59.34 \text{ ft}^4$

$I_{xx_{centroid}} = I_{xx} + A\bar{Y}^2$
$= 59.34 + (8.93)(4.465 - 4.17)^2$
$= 60.12 \text{ ft}^4$

$I_{yy} = \frac{(1)^3(8.93)}{12} = 0.74 \text{ ft}^4$

$I_{yy\,centroid} = I_{yy} + A\bar{x}^2$
$= 0.74 + (8.93)(5.25 - 5.12)^2$
$= 0.89 \text{ ft}^4$

$I_{key\,3} = I_{xx\,centroid} + I_{yy\,centroid}$
$= 60.12 + 0.89$
$= 61.01 \text{ ft}^4$

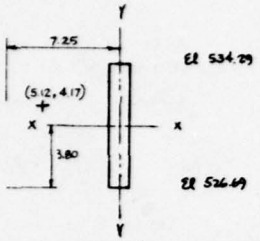
Figure A2. (Sheet 3 of 10)

SUBJECT: BRANDON ROAD
PIER STABILITY - TAINTER-GATE MONOLITH

COMPUTED BY: DATE
CHECKED BY: DATE

POLAR MOMENT OF INERTIA OF EACH KEY TRANSLATED TO THE CENTROID OF THE GROUP

KEY 4



$I_{xx} = \frac{(1)(7.60)^3}{12} = 36.58\ ft^4$

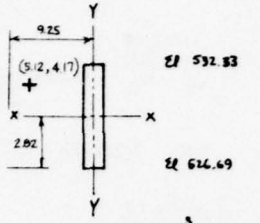
$I_{xx_{centroid}} = I_{xx} + A\bar{y}^2$
$= 36.58 + (7.60)(4.17 - 3.8)^2$
$= 37.62\ ft^4$

$I_{yy} = \frac{(1)^3(7.60)}{12} = 0.63$

$I_{yy_{centroid}} = I_{yy} + A\bar{x}^2$
$= 0.63 + (7.60)(7.25 - 5.12)^2$
$= 35.11\ ft^4$

$I_{key\ 4} = I_{xx_{centroid}} + I_{yy_{centroid}}$
$= 37.62 + 35.11$
$= 72.73\ ft^4$

KEY 5



$I_{xx} = \frac{(1)(5.64)^3}{12} = 14.95\ ft^4$

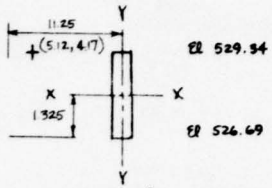
$I_{xx_{centroid}} = I_{xx} + A\bar{y}^2$
$= 14.95 + (5.64)(4.17 - 2.82)^2$
$= 25.23\ ft^4$

$I_{yy} = \frac{(1)^3(5.64)}{12} = 0.47$

$I_{yy_{centroid}} = I_{yy} + A\bar{x}^2$
$= 0.47 + (5.64)(9.25 - 5.12)^2$
$= 96.67\ ft^4$

$I_{key\ 5} = I_{xx_{centroid}} + I_{yy_{centroid}}$
$= 25.23 + 96.67$
$= 121.90\ ft^4$

KEY 6



$I_{xx} = \frac{(1)(2.65)^3}{12} = 1.55\ ft^4$

$I_{xx_{centroid}} = I_{xx} + A\bar{y}^2$
$= 1.55 + (2.65)(4.17 - 1.325)^2$
$= 22.99$

$I_{yy} = \frac{(1)^3(2.65)}{12} = 0.22$

$I_{yy_{centroid}} = I_{yy} + A\bar{x}^2$
$= 0.22 + (2.65)(11.25 - 5.12)^2$
$= 99.80\ ft^4$

$I_{key\ 6} = I_{xx_{centroid}} + I_{yy_{centroid}}$
$= 22.99 + 99.80$
$= 122.79\ ft^4$

TOTAL POLAR MOMENT = $\sum_{i=1}^{6} I_{key\ i}$

$I_{TOTAL} =$ 310.36 + 120.51 + 61.01 + 72.73 + 121.90 + 122.79 = $809.30\ ft^4$

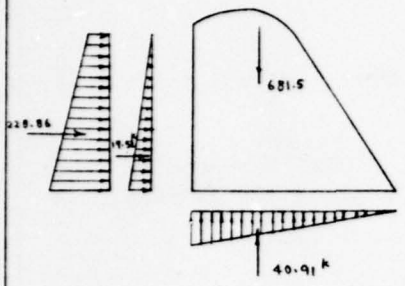
Since there are keys on both sides of the pier I_{TOTAL} should be multiplied by 2

$I = 2\ I_{TOTAL}$
$= (2)(809.3)$
$= 1618.6\ ft^4$

Figure A2. (Sheet 4 of 10)

SUBJECT: BRANDON ROAD
PIER STABILITY - TAINTER-GATE MONOLITH

COMPUTED BY:
CHECKED BY:
DATE
DATE:



ITEM	FACTORS	F_V	F_H	ARM	MOMENT
WT_{CONC}	$(83.13 - 42.24)(^{9}/_{8})$	681.5		6.47	4409.31
$P_{HEAD\ WTR}$	$(.0625)(539 - 536.95)(536.75 - 526.69)(50) + (.5)(.0625)(536.75 - 526.69)^2(50)$		-228.86	3.87	-886.05
P_{SILT}	$(.5)(.0203)(535 - 526.69)(.5)$		-19.52	2.79	-48.54
UPLIFT	$(.0625)[(539.0 - 526.69)(1/2)(.5)(12.76)\frac{20}{2}]$	-40.91		8.51	-348.10
SUB TOTAL		640.59	-246.38		3126.62
WT_{GATE}	NORMAL OPERATION	1.44		10.76	15.49
$SUM_{N.O.}$		642.03	-246.38		3142.11
WT_{GATE}	NORMAL OPERATION WITH ICE	12.48		10.76	134.28
$SUM_{N.O.+ICE}$		653.09	-246.38		3260.9

$$C_{N.O.} = \frac{3142.11}{642.03} = 4.89 \quad , \quad C_{N.O.+ICE} = \frac{3260.9}{653.09} = 4.99$$

LET:

ΔV = SHEAR IN KEYS (KIPS)

ΔM = TORQUE TRANSFERRED BY KEYS (FT-KIPS)

ARM = MOMENT ARM OF ΔV ABOUT CENTER OF GRAVITY OF BASE (FT)

SHEAR FORCE AND MOMENT IN KEYS

ASSUME KEYS DO NOT SHEAR AND THE PIER AND SPILLWAY ACT AS A UNIT RESULTING IN NO DIFFERENTIAL SETTLEMENT BETWEEN THEM. THIS WILL CAUSE THE STRAIN UNDER THE PIER AND SPILLWAY TO BE EQUAL AT A COMMON POINT BETWEEN THEM

FOR COMMON POINTS

$$\epsilon_{PIER} = \epsilon_{SPILLWAY}$$

$$E_{PIER} = E_{SPILLWAY}$$

Figure A2. (Sheet 5 of 10)

SUBJECT: BRANDON ROAD
PIER STABILITY - TAINTER GATE MONOLITH

COMPUTED BY:
CHECKED BY:
DATE:
DATE:

THEREFORE, THE STRESSES AT COMMON POINTS ARE EQUAL

$$P_{PIER} = \epsilon_{PIER} E_{PIER} \quad (1)$$

$$P_{SPILLWAY} = \epsilon_{SPILLWAY} E_{SPILLWAY} \quad (2)$$

SINCE THE RIGHT SIDES OF EQUATIONS (1) AND (2) ARE EQUAL

$$P_{PIER} = P_{SPILLWAY}$$

FOR COMMON POINTS.

THEREFORE, $P_{P\text{-}AVE} = P_{S\text{-}AVE}$

SHEAR FORCE TRANSFERRED BY KEY (NORMAL OPERATION)

$$\frac{F_{VP} - \Delta V}{A_P} = \frac{F_{VS} + \Delta V}{A_S}$$

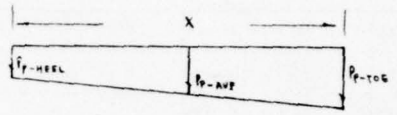
$$\Delta V = \frac{F_{VP} A_S - F_{VS} A_P}{A_P + A_S} = \frac{(98.05)(638) - (642.03)(38.28)}{38.28 + 638.00}$$

$$= \frac{3799.99}{676.28} = 56.16$$

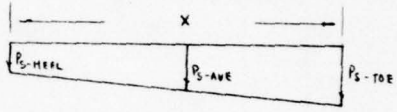
TORQUE TRANSFERRED BY KEY (NORMAL OPERATION)

$$P_{P\text{-}TOE} = \frac{98.05 - 56.16}{38.28} + \frac{[98.05(12.76/2 - 5.54) - \Delta M](6.38)}{\frac{(3)(12.76)^3}{12}}$$

$$= 1.0943 + 1.0117 - \Delta M\,(0.012284)$$



BASE PRESSURE DIAGRAM - PIER



BASE PRESSURE DIAGRAM - SPILLWAY

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Figure A2. (Sheet 6 of 10)

SUBJECT: BRANDON ROAD PIER STABILITY - TAINTER-GATE MONOLITH	COMPUTED BY: CHECKED BY:	DATE: DATE:

$$P_{S-TOE} = \frac{642.03 + 56.24}{638} + \frac{[642.03\,(12.96/2 - 4.891) + \Delta M]\,6.38}{\frac{50(12.96)^3}{12}}$$

$$= 1.0945 + 0.7050 + \Delta M\,(0.000737)$$

$$P_{P-TOE} = P_{S-TOE}$$

$$1.0943 + 1.0117 - \Delta M\,(0.012284) - 1.0945 - 0.7050 - \Delta M\,(0.000737) = 0$$

$$-\Delta M\,(0.013021) = -0.3065$$

$$\Delta M = \frac{0.3065}{0.013021} = 23.54^{k'}$$

$$ARM = \frac{23.54}{56.16} = 0.42'\ \text{(ABOUT CENTROID OF BASE)}$$

Figure A2. (Sheet 7 of 10)

SUBJECT: BRANDON ROAD PIER STABILITY - TAINTER-GATE MONOLITH	COMPUTED BY: CHECKED BY:	DATE: DATE:

SHEAR STRESS TRANSFERRED BY KEYS (NORMAL OPERATION)

c = DISTANCE TO EXTREME OUTER FIBER OF KEYS (FT)

J = POLAR MOMENT OF INERTIA OF KEYS (FT^4)

τ = AVERAGE MAXIMUM SHEAR STRESS IN KEYS (PSI)

$$\tau = \frac{\Delta V}{A_{KEY}} + \frac{\Delta V * (ARM + 1.26) * c}{J}$$

$$\tau = \left[\frac{56.16^{k}}{44.64} + \frac{(34.87)(0.4[+1.26)}{1618.6} \right]$$

τ = 1.28 ksf = 8.96 psi

A10

Figure A2. (Sheet 8 of 10)

SUBJECT: BRANDON ROAD
PIER STABILITY - TAINTER-GATE MONOLITH

COMPUTED BY: DATE:
CHECKED BY: DATE:

SHEAR FORCE TRANSFERRED BY KEY (NORMAL OPERATION WITH ICE)

$$\frac{F_{vp} - \Delta V}{A_p} = \frac{F_{vs} + \Delta V}{A_s}$$

$$\Delta V = \frac{F_{vp} A_s - F_{vs} A_p}{A_p + A_s} = \frac{(89.02)(638) - (653.07)(38.28)}{38.28 + 638.00}$$

$$= 45.13$$

TORQUE TRANSFERRED BY KEY (NORMAL OPERATION WITH ICE)

$$P_{p\text{-}TOE} = \frac{87.02 - 56.16}{38.28} + \frac{[87.02(12.76/2 + 31.08) - \Delta M](6.38)}{\frac{3(12.76)^2}{12}}$$

$$= 0.8062 + 40.04 - \Delta M(0.01228)$$

$$P_{s\text{-}TOE} = \frac{653.07 + 56.26}{638} + \frac{[653.07(12.76/2 - 4.89) + \Delta M](6.38)}{\frac{50(12.76)^3}{12}}$$

$$= 1.112 + 0.7172 + \Delta M(0.000737)$$

$$P_{p\text{-}TOE} = P_{s\text{-}TOE}$$

$$0.8062 + 40.04 - \Delta M(0.01228) - 1.112 - 0.7172 - \Delta M(0.000737) = 0$$

$$-\Delta M(0.013017) = -39.017$$

$$\Delta M = 2997.39 \text{ k'}$$

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Figure A2. (Sheet 9 of 10)

SUBJECT	COMPUTED BY	DATE
BRANDON ROAD PIER STABILITY - TAINTER-GATE MONOLITH	CHECKED BY	DATE

SHEAR STRESS TRANSFERRED BY KEYS (NORMAL OPERATION WITH ICE)

C = DISTANCE TO EXTREME OUTER FIBER OF KEYS (FT)

J = POLAR MOMENT OF INERTIA OF KEYS (FT^4)

τ = AVERAGE MAXIMUM SHEAR STRESS IN KEYS (PSI)

$$\tau = \frac{\Delta V}{A_{KEY}} + \frac{\Delta V * (ARM + 1.26) * C}{J}$$

$$ARM = \frac{2997.39}{45.13} = 66.42$$

$$\tau = \frac{45.13}{44.64} + \frac{45.13\,(66.42 + 1.26)}{1618.6}$$

$$\tau = 1.01 + 1.89 = 2.90 \text{ KSF} = 20.1 \text{ PSI}$$

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Figure A4. (Sheet 10 of 10)

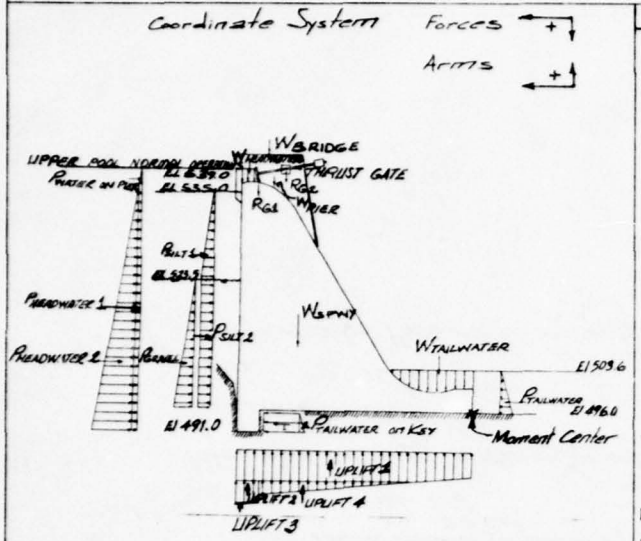
SUBJECT: Brandon Road - Tainter-Gate
Normal Operation - Total Monolith

COMPUTED BY:

CHECKED BY:

DATE

DATE



ITEM	FACTORS	Fv	FH	ARM	MOMENTS
W SPWY	[.1515][45114.72] } VOLUMES CALCULATED BY	6834.88		31.46	215025.32
W PIER	[.1515][278.81] } GRAPHICAL MEANS	42.24		38.02	1604.96
W HEADWATER	[.0625](539 - 536.75)(2)(50)	14.06		43.00	604.69
W TAILWATER	[.0625][2527.04] VOLUME CALCULATED BY GRAPHICAL MEANS	157.94		8.12	1282.47
W BRIDGE	}	11.00		39.51	434.61
R_{G_1}	} VALUES VERIFIED AND TAKEN FROM APPENDIX E, BRANDON ROAD LOCK AND DAM STABILITY ANALYSIS OF DAM MASONRY	1.44		42.00	60.48
R_{G_2}	}	11.28		36.34	409.92
UPLIFT 1	(0.48)(44)(53)	-1119.36		22.00	-24625.92
UPLIFT 2	[3.00 - ((539 - 503.6)/49)(.0625)(5) - 0.48](5)(53)	-607.97		41.50	-25230.85
UPLIFT 3	(3.00 - 2.77)(5)(0.5)(53)	- 31.80		42.33	- 1346.09
UPLIFT 4	[3.00 - ((539 - 503.6)/49)(.0625)(10) - (5)(0625) - 0.48](39)(0.5)(53)	-1814.79		26.00	-47184.65
PHEADWTR 1	(.0625)(2.25)(536.75 - 491)(53)		-340.98	17.88	- 6096.72
PHEADWTR 2	(.0625)(45.75)(45.75)(0.5)(53)		-3466.63	10.25	-35532.96
PGRAVEL	(.0775)(27.50)(27.50)(0.5)(0.45)(53)		-698.92	9.17	- 6409.10
PSILT 1	(.0203)(11.50)(11.50)(0.5)(0.5)(53)		- 35.57	31.33	- 1114.41
PSILT 2	(.0203)(11.50)(523.50 - 496)(0.5)(53)		-170.13	13.75	- 2339.24
THRUST GATE	(.0625)(2.25)(2.25)(0.5)(50)		- 7.91	42.75	- 338.15
PTAILWATER	(.0625)(7.60)(7.60)(0.5)(53)(.6)		57.40	2.53	145.23
PTAILWATER 1 ON KEY	(2.24)(5)(53)		593.60	- 2.50	- 1484.00
PTAILWATER 2 ON KEY	(2.76 - 2.24)(5)(0.5)(53)		68.90	- 3.33	- 229.44
PWATER ON PIERS	(.0625)(2.25)(2.25)(0.5)(3)		- 0.47	41.50	- 19.51
		+3498.92	-4000.71		+67616.64

OVERTURNING

Resultant Location From Moment Center = $\frac{67616.64^{K'}}{3498.92^{K}} = 19.33'$

1/3 Base Width = $\frac{44'}{3} = 14.67'$

100% Effective Base

Figure A3. Stability analysis, tainter-gate monolith, total monolith, normal operation (Sheet 1 of 6)

SUBJECT:	COMPUTED BY:	DATE:
Brandon Road - Tainter Gate Normal Operation - Total Monolith	CHECKED BY:	DATE:

PERTINENT DATA

$1.1\sqrt{f'_c}$ = Allowable shear strength (assumed)

5880 psi = Average f'_c lower portion of tainter gate monolith

$0.15\,f'_c$ = Maximum shear strength of concrete (assumed)

58 T/ft² = Cross-bed shear strength of foundation rock (from tests)

For Sliding at or near the concrete-foundation interface

(a) Least probable parameters (Clay-filled parting failure)

$c = 0.43$ tsf

$\phi = 45°$

(b) Lower bound parameters (precut, concrete-on-rock failure)

$c = 0.0$ tsf

$\phi = 26°$

Allowable Bearing Pressure (Concrete Governs) $= \frac{(5280\ \#/in^2)(144)}{4(1000)} \approx 200$ T/ft²

$\gamma_{concrete} = 151.5\ \#/ft^3$

$\gamma_{Rock} = 164.4\ \#/ft^3$

Silt (Horizontal Pressure Coefficient) = 0.5

Figure A3. (Sheet 2 of 6)

SUBJECT	COMPUTED BY:	DATE
Brandon Road - Tainter - Gate Normal Operation - Total Monolith	CHECKED BY:	DATE

Buckling of the apron is possible only in an upward direction. Slenderness can be checked in a conservative manner by considering the slab as a column and check to see if it can be neglected (ACI Standard 318-71). Plate theory could be used but it is unnessary if this check is adequate.

$$\frac{k\,l_u}{r} < 34 - 12\,\frac{M_1}{M_2}$$

Where

k = effective length factor
l_u = unsupported length
r = radius of gyration
M_1 = smaller design end moment on compression member
M_2 = larger design end moment on compression member

$k = 1$
$l_u = 13.7'$
$r = 0.30(5) = 1.5$

Even if $\frac{M_1}{M_2}$ is assumed to be a maximum value of 1 the following results are obtained

$$\frac{(1)(13.7)}{1.5} = 9.1 < 22$$

Buckling of the apron is not a problem

The ultimate shear strength of concrete can be taken as 15% of the uncanfined compressive strength. The maximum strut resistance to produce shear through the concrete apron and not through the rock at the end of the apron is as follows:

Maximum Strut Resistance Through Concrete Apron
= (maximum shear stress)(Minimum length over which we get a 45° shear)(Width of section to shear)

$= (0.15)(5830\,psi)\left(\frac{144}{1000}\right)\left(\frac{4.67'}{\sin 45°}\right)(53')$
$= 44,079^{k}$

The shear resistance of the rock strut (From EM 1110-2-189)

$= 2sDW = (2)(58)(5)(53)$
$= 30,740^{k}$

The rock strut governs

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Figure A3. (Sheet 3 of 6)

SUBJECT	COMPUTED BY	DATE
Brandon Road - Tainter-Gate Normal Operation - Total Monolith	CHECKED BY:	DATE:

SLIDING

Under Conditions Using Least Probable Existing Parameters

Resistance to Sliding = key Resistance + V tan 45° + CA + Strut Resistance

$= 1.1\sqrt{f'_c}\,A_{rea} + [3498.92 - \text{Weight key}]\tan 45° + (0.86\,^{k}/_{\square'})\,Area + \text{Strut Resistance}$

$= 1.1\sqrt{3880}\,\frac{(144)(6)(53)}{1000} + [3498.92 - (5)(6)(53)(0.1515)]\tan 45° + (0.86\,^{k}/_{\square'})(39)(53)$

$+ (53)(2)(58)(5)$

$= 3205^{k} + 8298^{k} + 1778^{k} + 30,740^{k}$

$= 39,021^{k}$

Shear Friction Safety Factor $(S_{s\text{-}f}) = \frac{39021^{k}}{3912^{k}} = 9.97 > 4$ O.K.

Without {Strut Resistance} $S_{s\text{-}f} = \frac{8281}{3912^{k}} = 2.12$

Without {Strut Resistance, Cohesion, key Resistance} $S_{s\text{-}f} = \frac{3298^{k}}{3912^{k}} = 0.84$

Due to uncertainties concerning the dependability of cohesion and key resistance, the strut resistance downstream of the tainter-gate monoliths is essential.

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan 26° + Strut Resistance

$= (3298)(0.488) + 30,740^{k}$

$= 32,349^{k}$

$S_{s\text{-}f} = \frac{32,349^{k}}{3912^{k}} = 8.27 > 1.5$

Without Strut Resistance

$S_{s\text{-}f} = \frac{1609^{k}}{3912^{k}} = 0.41$

As Stated Previously Strut Resistance Downstream of the Tainter-Gate Monoliths is Essential.

BASE PRESSURES

$f = \frac{P}{A} \pm \frac{Mc}{I}$

The maximum base pressure is the sum of the intergranular and uplift pressures.

Intergranular Pressure

$f_I = \frac{3498.92}{(44)(63)} \pm \frac{(3498.92)(22 - 19.33)22}{\frac{(63)(44)^3}{12}}$

$= 1.50 \pm 0.55 = 0.95\,^{k}/_{\square'}$ heel
$2.05\,^{k}/_{\square'}$ toe

Uplift

Heel $f_{u_h} = (539 - 491)(0.0625) = 3\,^{k}/_{\square'}$

Toe $f_{u_t} = (503.6 - 496)(0.0625) = 0.48\,^{k}/_{\square'}$

Total

$f_{heel} = 0.95\,^{k}/_{\square'} + 3\,^{k}/_{\square'} = 3.95\,^{k}/_{\square'}$

$f_{toe} = 2.05\,^{k}/_{\square'} + 0.48\,^{k}/_{\square'} = 2.53\,^{k}/_{\square'}$

$< 200\,^{k}/_{\square'}$ O.K.

Figure A3. (Sheet 4 of 6)

SUBJECT: Brandon Road - Stress Computations at Critical Section of Apron for 1' of Tainter Gate Monolith

COMPUTED BY: | DATE

CHECKED BY: | DATE

SHEAR FORCE, V

$F_V = 29.97^k$

SHEAR STRESS, T

$T = \frac{V}{A} = \frac{29.97}{(1)(5)} = 5.99 \frac{k}{ft}$ or 41.6 psi

FRICTION FORCE

$(f_f) = V \tan\phi$
$= 29.97 \tan 26°$
$= 14.62^k$

AXIAL FORCE, A_x

$F_x = f_f + F_H$
$= 14.62 + 1.59 = 16.21^k$

MOMENT, M, ABOUT C.G. OF SECTION

$M = 202.16^{k'}$

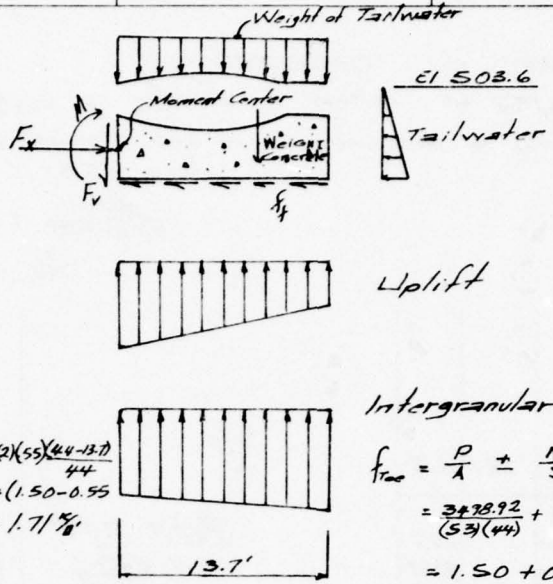
MAXIMUM STRESS ON SECTION

$\sigma_{MAX} = \frac{F_x}{A} + \frac{M}{S}$
$= \frac{16.21}{(5)(1)} + \frac{202.15}{(1)(5)^2/6}$
$= 3.24 + 48.52$
$= 51.76 \frac{k}{ft}$ or 359 psi (Compression)

MINIMUM STRESS ON SECTION

$\sigma_{MIN} = 3.24 - 48.52 = -45.2 \frac{k}{ft}$ or -314 psi (Tension)

OVERSTRESSED
No TENSION ALLOWED



Intergranular Pressure

$f_{toe} = \frac{P}{A} \pm \frac{M}{S}$
$= \frac{3478.92}{(53)(44)} + \frac{3478.92\left(\frac{44}{2} - 13.53\right)}{(53)\frac{(44)^2}{6}}$
$= 1.50 + 0.55$
$= 2.05 \frac{k}{ft}$

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Figure A3. (Sheet 5 of 6)

SUBJECT: Brandon Road - Stress Computations at Critical Section of Apron for 1' of Tainter Gate Monolith

COMPUTED BY:

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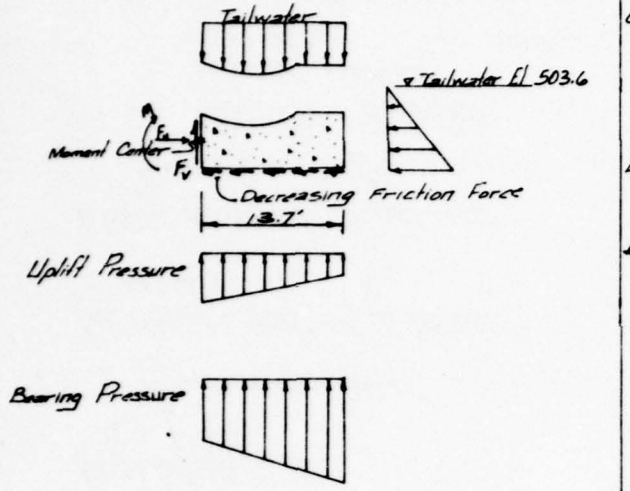
DATE:

DATE:



ITEM	FACTORS	F_V	F_H	ARM	MOMENTS
Tailwater	$\frac{1}{2}(0.0625)[(503.6-501)+(503.6-496)]5$ obtained graphically	2.57	1.59	0.033 -6.44	-16.55
Concrete Weight	obtained graphically	3.97		-6.93	- 27.5
Uplift	$(.0625)[503.6-496](13.7)(1)$	-6.51		-6.85	44.6
	$(.0625)\frac{(587-503.6)}{49}(13.7)^2/2$	-4.24		-4.57	19.38
Bearing	$(1.71)(13.7)(1)$	-23.43		- 6.85	160.50
	$(2.05-1.71)(\frac{13.7}{2})$	-2.33		- 9.13	21.27
		-29.97	1.59		202.16

$$\sigma = \frac{P}{A} \pm \frac{Mc}{I}$$

$$= \frac{1.81}{5} \pm \frac{(202.17)(2.5)}{\frac{(1)(5)^3}{12}}$$

$= 0.36 \pm 48.52$

$= 48.88$ KSF or 339 psi Compression in Top

$= -48.16$ KSF or 334 psi Tension in Bottom

1 OVERSTRESSED. NO TENSION ALLOWED

Figure A3. (Sheet 6 of 6)

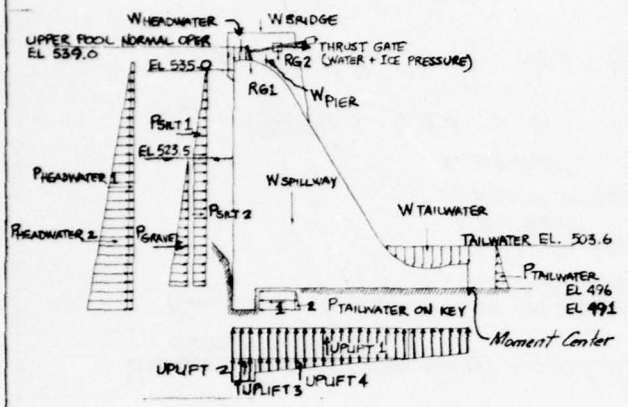
SUBJECT: Brandon Road - Tainter-Gate
Normal Operation + Ice - Total Monolith

COMPUTED BY:

CHECKED BY:

DATE:

DATE:



ITEM	FACTORS	Fv	FH	ARM	MOMENTS
W SPWY	[.1515](45114.72) } VOLUMES CALCULATED BY	6834.83		31.46	215025.32
W PIER	[.1515](278.81) } GRAPHICAL MEANS	42.24		38.02	1604.96
W HEADWATER	[.0625](539 - 536.75)(2)(50)	14.06		43.00	604.69
W TAILWATER	[.0625](2527.04) VOLUME CALCULATED BY GRAPHICAL MEANS	157.94		8.12	1282.47
W BRIDGE	}	11.00		39.51	434.61
RG1	} VALUES VERIFIED AND TAKEN FROM APPENDIX E, BRANDON ROAD LOCK AND DAM STABILITY ANALYSIS OF DAM MASONRY	12.48		42.00	524.16
RG2	}	0.25		36.34	9.08
UPLIFT 1	(0.48)(44)(53)	-1119.36		22.00	- 24625.92
UPLIFT 2	[3.00 - ((539 - 503.6)/49)(.0625)(5) - 0.48](5)(53)	-607.97		41.50	- 25230.85
UPLIFT 3	(3.00 - 2.77)(5)(0.5)(53)	- 31.80		42.33	- 1346.09
UPLIFT 4	[3.00 - ((539 - 503.6)/49)(.0625)(10) - (5)(.0625) - 0.48](39)(0.5)(53)	-1814.79		26.00	- 47184.65
PHEADWTR 1	(.0625)(2.25)(536.75 - 491)(53)		-340.98	17.88	- 6096.72
PHEADWTR 2	(.0625)(45.75)(45.75)(0.5)(53)		-3466.63	10.25	- 35532.96
PGRAVEL	(.0775)(27.50)(27.50)(0.5)(0.45)(53)		-698.92	9.17	- 6409.10
PSILT 1	(.0203)(11.50)(11.50)(0.5)(0.5)(53)		- 35.57	31.33	- 1114.41
PSILT 2	(.0203)(11.50)(523.50 - 491)(0.5)(53)		-170.13	13.75	- 2339.24
THRUST GATE	[(.0625)(2.25)(2.25)(0.5) + 5](50)		-257.91	42.75	-11025.65
PTAILWATER	(.0625)(7.60)(7.60)(0.5)(53)(.6)		+ 57.40	2.53	+ 145.23
PTAILWATER 1 ON KEY	(2.24)(5)(53)		+593.60	- 2.50	- 1484.00
PTAILWATER 2 ON KEY	(2.76 - 2.24)(5)(0.5)(53)		+ 68.90	- 3.33	- 229.44
PWATER ON PIERS	(.0625)(2.25)(2.25)(0.5)(3)		- 0.47	41.50	- 19.51
THRUST ICE ON PIER	(5)(10)(3)		- 15.00	42.50	- 637.50
		+3498.93	-4269.71		+56354.48

Figure A4. Stability analysis, tainter-gate monolith, total monolith, normal operation plus ice (Sheet 1 of 2)

SUBJECT	COMPUTED BY:	DATE
Brandon Road - Tainter - Gate Normal Operation + Ice - Total Monolith	CHECKED BY:	DATE:

OVERTURNING

Resultant Location from Moment Center

$$= \frac{56354.48}{3498.93} = 16.11'$$

⅓ Base Width = 14.67'

100% Effective Base

SLIDING

The basic data for the tainter-gate monolilths are given on Sheet 1.

Under Conditions Using Least Probable Existing Parameters

Resistance to sliding = key resistance + V tan 45° + cA + Strut resistance

$$= 3205^k + (3498.92 - 200.74)\tan 45° + 1778^k + 30,740^k$$

$$= 3205^k + 3298^k + 1778^k + 30,740^k$$

$$= 39,021^k$$

$$S_{s\text{-}F} = \frac{39,021^k}{4177^k} = 9.34 > 4$$

Without {Strut Resistance} $S_{s\text{-}F} = \frac{8281^k}{4177^k} = 1.98$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s\text{-}F} = \frac{3298^k}{4177^k} = 0.79$

Under Conditions Using Lower Bound Parameters

Sliding Resistance = V tan 26° + Strut Resistance

$$= 32,349^k$$

$$S_{s\text{-}F} = \frac{32,349^k}{4177^k} = 7.74 > 1.5$$

Without {Strut Resistance} $S_{s\text{-}F} = \frac{1609^k}{4177^k} = 0.39$

BASE PRESSURE

Interganular Pressure

$$f_1 = \frac{3498.93}{44 \times 53} \pm \frac{(3498.93)(22 - 16.11)22}{\frac{(53)(44)^3}{12}}$$

$$= 1.50 \pm 1.21$$

$= 2.71$ ⁵⁄₀' Toe

0.29 ⁵⁄₀' Heel

Uplift

$f_{toe} = 0.48$ ⁵⁄₀'

$f_{heel} = 3$ ⁵⁄₀'

Total

$f_{toe} = 2.71 + 0.48 = 3.19$ ⁵⁄₀'

$f_{heel} = 0.29 + 3 = 3.29$ ⁵⁄₀'

Figure A4. (Sheet 2 of 2)

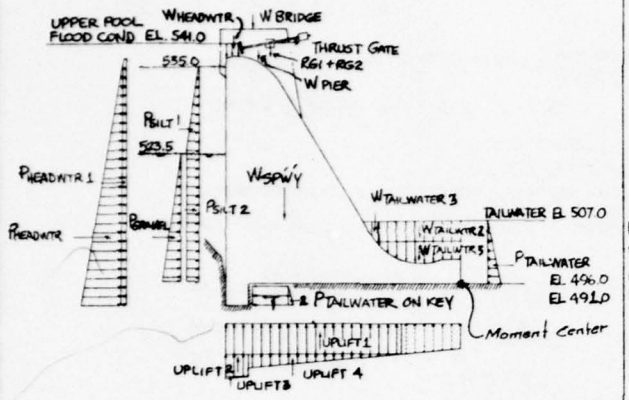
SUBJECT: Brandon Road - Tainter-Gate Flood Condition - Total Monolith

COMPUTED BY:

CHECKED BY:

DATE:

DATE:



ITEM	FACTORS	F_V	F_H	ARM	MOMENTS
W_{SPWY}	[1515](4511.4.72) } VOLUMES CALCULATED	+6834.88		31.46	+215025.32
W_{PIER}	[1515](278.81) } BY GRAPHICAL MEANS	+ 42.24		38.02	+ 1604.96
$W_{HEADWATER}$	[.0625](541-536.75)(20)(50)	+ 26.56		43.00	+ 1142.02
$W_{TAILWATER\,1}$	[.0625](2527.04) VOLUME CALCULATED BY GRAPHICAL MEANS	+ 157.94		8.12	+ 1282.47
$W_{TAILWATER\,2}$	[.0625](507-503.6)(17.67)(53)	+ 199.01		8.84	+ 1759.23
$W_{TAILWATER\,3}$	[.0625](507-503.6)(1.94)(5)(53)	+ 10.92		18.32	+ 200.14
W_{BRIDGE}	} VALUES VERIFIED AND TAKEN FROM AP-	+ 11.00		39.51	+ 434.61
RG_1+RG_2	} PENDIX E, BRANDON RD. LOCK AND DAM STABILITY ANALYSIS OF DAM MASONRY	+ 12.73		36.34	+ 462.61
UPLIFT 1	(0.69)(44)(53)	-1609.08		22.00	- 35399.76
UPLIFT 2	[3.13 - ((541-507)/49)(.0625)(5) - 0.69](5)(53)	- 589.14		41.50	- 24,449.24
UPLIFT 3	(3.13-2.91)(5)(5)(53)	- 29.15		42.33	- 1234.02
UPLIFT 4	[3.13 - ((541-507)/49)(.0625)(10) - (5)(.0625) - 0.69](39)(5)(53)	-1746.62		26.00	-45411.99
$P_{HEADWTR\ 1}$	[.0625](541-536.75)(536.75-491)(53)		-644.01	17.88	- 11514.90
$P_{HEADWTR\ 2}$	[.0625](536.75-491)^2(0.5)(53)		-3466.63	10.25	- 35532.96
P_{GRAVEL}	[.0775](523.5-496)^2(.5)(.45)(53)		- 698.92	9.17	- 6409.10
$P_{SILT\ 1}$	[.0203](535-523.5)^2(.5)(.50)(53)		- 35.57	31.33	- 1114.41
$P_{SILT\ 2}$	[.0203](535-523.5)(523.5-496)(.5)(53)		- 170.13	13.75	- 2339.24
GATE THRUST	VALUES VERIFIED AND TAKEN FROM APPENDIX E BRANDON RD. STABILITY ANALYSIS OF DAM MASONRY		- 7.91	42.75	- 338.15
$P_{TAILWATER}$	[.0625](507-493)^2(0.5)(53)(0.6)		+ 120.25	3.67	+ 441.32
$P_{TAILWATER\ 1\ ON\ KEY}$	(2.38)(5)(53)		+ 630.70	- 2.50	- 1576.75
$P_{TAILWATER\ 2\ ON\ KEY}$	(2.91-2.38)(5)(5)(53)		+ 70.23	- 3.33	- 233.87
$P_{WATER\ ON\ PIERS}$	[.0625](541-536.75)^2(5)(3)		- 1.69	42.17	- 71.26
		+3321.29	-4203.68		+56727.03

Figure A5. Stability analysis, tainter-gate monolith, total monolith, flood condition (Sheet 1 of 2)

SUBJECT:	COMPUTED BY:	DATE:
Brandon Road - Tainter-Gate Flood Condition - Total Monolith	CHECKED BY:	DATE:

OVERTURNING

Resultant Location from Moment Center = $\frac{56727.03}{3321.29}$ = 17.08'

⅓ Base Width = 14.67'

100% Effective Base

SLIDING

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance
= 3,205^k + 3120^k + 1778^k + 30,740^k
= 38,843^k

$S_{S\cdot F} = \frac{38,843^k}{4204^k} = 9.24 > 4$

Without {Strut Resistance} $S_{S\cdot F} = \frac{8103^k}{4204^k} = 1.93$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{S\cdot F} = \frac{3120^k}{4204^k} = 0.74$

Under Conditions Using Least Probable Parameters

Resistance to Sliding = V tan 26° + Strut Resistance
= 3120 tan 26° + 30,740
= 32,262^k

$S_{S\cdot F} = \frac{32,262^k}{4204^k} = 7.67 > 1.5$

Without Strut Resistance = $\frac{1522^k}{4204^k} = 0.36$

BASE PRESSURES

Intergranular Pressure

$f_x = \frac{3321.29}{44 \times 53} \pm \frac{(3321.29)(22 - 17.08)\,22}{\frac{53(44)^3}{12}} = 1.42 \pm 0.96 = 2.38$ % Toe
0.46 % Heel

Uplift

$f_{u\,heel} = (50)(0.0625) = 3.13$ %

$f_{u\,toe} = (11)(0.0625) = 0.69$ %

Total

$f_{heel} = 3.13 + 0.46 = 3.59$ %

$f_{toe} = 0.69 + 2.38 = 3.07$ %

STRESS AT CRITICAL SECTION OF APRON

TENSION OVERSTRESS HAS ALREADY BEEN ESTABLISHED

Figure A5. (Sheet 2 of 2)

SUBJECT: Brandon Road - Tainter-Gate Monolith
Normal Operation - Overstressed Apron Eliminated

COMPUTED BY:

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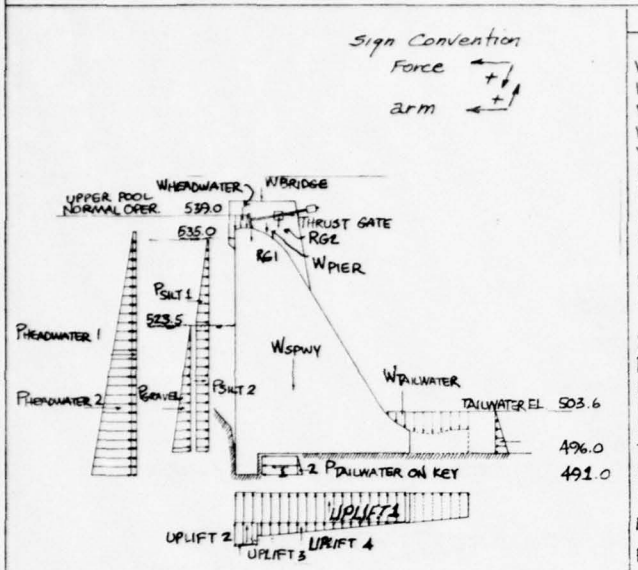

ITEM	FACTORS	Fv	FH	ARM	MOMENTS
W SPWY	[.1515](41838.20) } VOLUMES CALCULATED BY	+6338.49		19.71	+124931.50
W PIER	[.1515](278.81) } GRAPHICAL MEANS	+ 42.24		24.32	+ 1027.28
W HEADWATER	[.0625](539-536.75)(2)(50)	+ 14.06		29.30	+ 411.96
W TAILWATER	[.0625](2.4)(3.9)(0.5)(53)	+ 16.79		1.30	+ 21.83
W BRIDGE	} VALUES VERIFIED AND TAKEN FROM AP-	+ 11.00		25.81	+ 283.91
R_{G1}	} PENDIX E, BRANDON ROAD LOCK AND DAM	+ 1.44		28.30	+ 40.75
R_{G2}	} STABILITY ANALYSIS OF DAM MASONRY	+ 11.28		22.64	+ 255.38
UPLIFT 1	(1.09)(30.3)(53)	-1750.43		15.15	- 26519.03
UPLIFT 2	[3.00-((539-503.6)/49)(.0625)(5)-1.09](5)(53)	- 445.20		27.80	- 12376.56
UPLIFT 3	(3.00-2.77)(5.0)(0.5)(53)	- 30.48		28.63	- 872.50
UPLIFT 4	[3.00-((539-503.6)/49)(.0625)(10)-(5)(.0625)-1.09](25.3)(.5)(53)	- 771.02		16.87	-13007.07
P HEADWTR 1	(.0625)(2.25)(536.75-491)(53)		-340.98	17.88	- 6096.72
P HEADWTR 2	(.0625)(45.75)(45.75)(0.5)(53)		-3466.63	10.25	-35532.96
P GRAVEL	(.0775)(27.50)(27.50)(0.5)(0.45)(53)		- 698.92	9.17	- 6409.10
P SILT 1	(.0203)(11.50)(11.50)(0.5)(0.5)(53)		-35.57	31.33	- 1114.41
P SILT 2	(.0203)(11.50)(523.50-496)(0.5)(53)		-170.13	13.75	- 2339.24
THRUST GATE	(.0625)(2.25)(2.25)(0.5)(50)		- 7.91	42.75	- 338.15
P TAILWATER	(.0625)(7.60)(7.60)(0.5)(53)(.6)		+57.40	2.53	+ 145.23
P TAILWATER 1 ON KEY	(2.24)(5)(53)		+593.60	- 2.50	- 1484.00
P TAILWATER 2 ON KEY	(2.77-2.24)(5)(0.5)(53)		+ 70.22	- 3.33	- 233.84
P WATER ON PIERS	(.0625)(2.25)(2.25)(0.5)(3)		- 0.47	41.50	- 19.51
		+3438.17	-3999.39		+20774.75

FIRST TRIAL SOLUTION DETERMINING IF PART OF THE BASE IS NOT IN COMPRESSION. FULL UPLIFT MUST BE APPLIED UNDER NON COMPRESSIVE AREAS

OVERTURNING

Resultant Location from Moment Center = $\frac{20,774.75}{3438.17}$ = 6.04'

Base width = 30.3'

% Effective Base = $\frac{(3)(6.04)}{30.3}$ = 60%

Figure A6. Stability analysis, tainter-gate monolith, normal operation (Sheet 1 of 5)

SUBJECT	COMPUTED BY:	DATE:
Brandon Road - Tainter-Gate Monolith Normal Operation - Overstressed Apron Eliminated	CHECKED BY:	DATE:

PORTION OF BASE IN COMPRESSION DETERMINED BY TRIAL AND ERROR

OVERTURNING

$$\% \text{ EFFECTIVE BASE} = \frac{(3)(27.8)}{30.3} = 27.52\%$$

Prestress Needed (Full uplift under non-compressive part of base)

$$(60.1 - 27.8)(2222) = \text{Prestress}(16.7)$$

$$\text{Prestress} = \frac{(2222)(723)}{16.7} = 962 \text{ Kips}$$

Vertical Applied Load(V) = Total Vertical Loads - Actual Uplift (Assuming Full Uplift Under Non-Compressive Area of Base).

$$= 6435 - 0.0625(539-491)(5)(53) - (0.0625)(539-496)(25.3-8.34)(53) - \left[\frac{(0.0625)(539-496)(18.5)}{2}\right](8.34)(53)$$

$$= 6435 - 4213 \approx 2222^{K}$$

A24

Figure A6. (Sheet 2 of 5)

SUBJECT: Brandon Road - Tainter Gate Monolith
Normal Operation - Overstressed Apron Eliminated

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

OVERTURNING (Without Prestress)

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

% Effective Base = 27.52%

Prestress = 962 kips

Shear Friction Safety Factor (S_{S-F}) $= \frac{37{,}744^k}{3{,}910^k} = 9.65 > 4$

Without {Strut Resistance} $S_{S-F} = \frac{7{,}004^k}{3{,}910^k} = 1.79$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{S-F} = \frac{1{,}021^k}{3{,}910^k} = 0.52$

SLIDING (Without Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 3205^k + (2222 - 201)\tan 45° + 1778^k + 30{,}740^k$

$= 3205^k + 2021^k + 1778^k + 30{,}740^k$

$= 37{,}744^k$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan 26° + Strut Resistance

$= (2222 - 201)\tan 26° + 30{,}740^k$

$= 986^k + 30{,}740^k$

$= 31{,}726^k$

$S_{S-F} = \frac{31{,}726^k}{3{,}910^k} = 8.11 < 1.5$

Without {Strut Resistance} $= \frac{986^k}{3{,}910^k} = 0.25$

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} - P_{TAILWTR\ ON\ KEY}$

$= 3999.39 - (0.0625)\left[539 - \frac{491 + 496}{2}\right](53) + \left[593.60 + 70.28\right]$

$= 3999.39 - 753.59 + 663.82$

≈ 3910

Figure A6. (Sheet 3 of 5)

SUBJECT: Brandon Road - Tainter-Gate Monolith
Normal Operation - Overstressed Apron Eliminated

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

Shear Friction Safety Factor ($S_{s\text{-}f}$) = $\frac{39,311^k}{3,910^k}$ = 10.05 > 4

Without {Strut Resistance} = $\frac{8,571^k}{3,910^k}$ = 1.19

Without {Strut Resistance, Cohesion, Key Resistance} = $\frac{3,588^k}{3,910^k}$ = 0.92

SLIDING (With Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

= Key Resistance + (2222 - 201 + Max. Prestress) tan 45°

+ 1778^k + 30,740^k

= 3,205^k + 3,588^k + 1,778^k + 30,740^k

= 39,311^k

Driving Force = 3,910^k

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan 26° + Strut Resistance

= 3,588 tan 26° + 30,740^k

= 1750^k + 30,740^k

= 32,490^k

$S_{s\text{-}f}$ = $\frac{32,490^k}{3,910^k}$ = 8.31 > 1.5

Without {Strut Resistance} = $\frac{1,750^k}{3,910^k}$ = 0.45

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Figure A6. (Sheet 4 of 5)

SUBJECT	COMPUTED BY:	DATE
Brandon Road - Tainter Gate Monolith Normal Operation - Overstressed Apron Eliminated	CHECKED BY:	DATE

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

IOE $f_{Total} = \frac{2}{3}\frac{P_t}{x} + Uplift$

$= \frac{2}{3}\left(\frac{2222}{2.78}\right) + \frac{13.7}{8.34+13.7}\left[0.0625(539-496) - 0.0625(503.6-496)\right] + 0.0625(503.6-496)$

$= 532.9 + 1.9 = 534.8 \frac{k}{ft^2} > 200 \frac{k}{ft^2}$

HEEL $f_{Total} = 0 + 0.0625[539-491] = 3 \text{ ksf} < 200 \text{ ksf}$

With Prestress

Intergranular

$f = \frac{P}{A} \pm \frac{Mc}{I} = \frac{(2222+1567)}{(30.3)(53)} \pm \frac{\left[2222\left(\frac{30.3}{2}-2.78\right) - 1567\left(\frac{30.3}{2}-3.5\right)\right](15.15)}{\frac{(53)(30.3)^3}{12}}$

$= 2.36 \pm 1.14$

IOE $f = 3.50 \text{ ksf}$

HEEL $f = 1.22 \text{ ksf}$

IOE $f_{Total} = Intergranular + Uplift$

$= 3.50 + 1.85 = 5.35 \text{ ksf}$

HEEL $f_{Total} = 1.22 + 3.0 = 4.22 \text{ ksf}$

$< 200 \text{ ksf}$

Figure A6. (Sheet 5 of 5)

SUBJECT: Brandon Road - Tainter-Gate Monolith
Normal Operation + Ice - Overstressed Apron Eliminated

COMPUTED BY:
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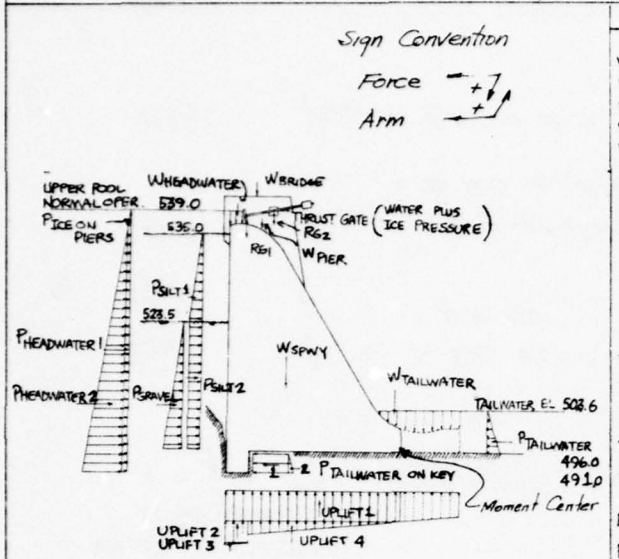
DATE:
DATE:



ITEM	FACTORS	Fv	FH	ARM	MOMENTS
WSPWY	[.1515](41838.20) } VOLUMES CALCULATED BY	+6338.49		14.71	+12493.50
WPIER	[.1515](278.81) } GRAPHICAL MEANS	+ 42.24		24.32	+ 1027.28
WHEADWATER	[.0625](539-536.75)(2)(50)	+ 14.06		29.30	+ 411.96
WTAILWATER	[.0625](2.6)(3.9)(0.5)(53)	+ 16.79		1.30	+ 21.83
WBRIDGE	} VALUES VERIFIED AND TAKEN FROM AP-	+ 11.00		25.81	+ 283.91
RG1	PENDIX E, BRANDON ROAD LOCK AND DAM	+ 12.48		28.30	+ 353.18
RG2	STABILITY ANALYSIS OF DAM MASONRY	+ 0.25		22.64	+ 5.66
UPLIFT 1	(1.09)(30.3)(53)	-1750.43		15.15	- 26519.03
UPLIFT 2	[3.00-((539-503.6)/49)(.0625)(5)-1.09](5)(53)	-445.20		27.80	- 12376.56
UPLIFT 3	(3.00-2.77)(5.0)(0.5)(53)	- 30.48		28.63	- 872.50
UPLIFT 4	[3.00-((539-503.6)/49)(.0625)(10)-(5)(0.0625)-1.09](25.3)(.5)(53)	-771.02		16.87	-13007.07
PHEADWTR 1	(.0625)(2.25)(536.75-491)(53)		-340.98	17.88	- 6096.72
PHEADWTR 2	(.0625)(45.75)(45.75)(0.5)(53)		-3466.63	10.25	-35532.96
PGRAVEL	(.0775)(27.50)(27.50)(0.5)(0.45)(53)		-698.92	9.17	- 6409.10
PSILT 1	(.0203)(11.50)(11.50)(0.5)(0.5)(53)		-35.57	31.33	- 1114.41
PSILT 2	(.0203)(11.50)(523.50-496)(0.5)(53)		-170.13	13.75	-2339.24
THRUST GATE	[(.0625)(2.25)(2.25)(0.5)+5.0](50)		-257.91	42.75	- 11025.65
PTAILWATER	(.0625)(7.60)(7.60)(0.5)(53)(.6)		+57.40	2.53	+ 145.23
PTAILWATER 1 ON KEY	(2.24)(5)(53)		+593.60	- 2.50	- 1484.00
PTAILWATER 2 ON KEY	(2.77-2.24)(5)(0.5)(53)		+ 70.22	- 3.33	- 233.84
PWATER ON PIERS	(.0625)(2.25)(2.25)(0.5)(3)		- 0.47	41.50	- 19.51
PICE ON PIERS	(5)(1.0)(3)		-15.00	42.50	- 637.50
		+3438.18	-4264.39		+9512.46

Figure A7. Stability analysis, tainter-gate monolith, normal operation plus ice (Sheet 1 of 5)

SUBJECT	COMPUTED BY:	DATE
Brandon Road - Tainter-Gate Monolith Normal Operation + Ice Overstressed Apron Eliminated	CHECKED BY:	DATE

FIRST TRIAL SOLUTION DETERMINING IF PART OF THE BASE IS NOT IN COMPRESSION. FULL UPLIFT MUST BE APPLIED UNDER NON-COMPRESSIVE AREAS.

OVERTURNING

Resultant Location from Moment Center = $\frac{3512.46}{3438.18}$ = 2.77'

Base Width = 30.3'

% Effective Base = $\frac{(3)(2.77)}{30.3}$ = 27 %

Full Uplift Under Non-Compressive Area of Base

Resultant Location from Moment Center = $\frac{-4174.61}{2,036.63}$ = -2.75'

0% Effective Base

The Above Was Determined by Trial & Error

Check on Total Vertical Applied Load Under Full Uplift Criteria

Vertical Applied Load(V) = Total Vertical Load - Actual Uplift (Assuming Full Uplift Under Non-Compressive Area of Base)

= 6435 - (0.0625)(539-491)(5)(53)
-(0.0625)(539-496)(25.3)(53)

= 6435 - 4399 = 2037*

Figure A7. (Sheet 2 of 5)

SUBJECT: Brandon Road - Tainter Gate Monolith
Normal Operation + Ice - Overstressed Apron Eliminated

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

% Effective Base = 0%

Prestress Needed

$(101 + 2.75)(2037) = \text{Prestress}(303-101-39)$

$\text{Prestress} = \frac{(12.85)(2037)}{16.7} = 1567 \text{ kips}$

Shear Friction Safety Factor $(S_{s\text{-}f}) = \frac{37559^{k}}{4,175^{k}} = 9.00 > 4$

Without {Strut Resistance} $S_{sf} = \frac{6,819^{k}}{4,175^{k}} = 1.63$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{sf} = \frac{1836^{k}}{4,175^{k}} = 0.44$

SLIDING (Without Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 3,205^{k} + (2,037-201)\tan 45° + 1,778^{k} + 30,740^{k}$

$= 3,205^{k} + 1,836^{k} + 1,778^{k} + 30,740^{k}$

$= 37,559^{k}$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan 26° + Strut Resistance

$= 1,836 \tan 26° + 30,740^{k}$

$= 895^{k} + 30,740^{k}$

$= 31,635^{k}$

$S_{s\text{-}F} = \frac{31,635^{k}}{4,175^{k}} = 7.58 > 1.5$

Without {Strut Resistance} $S_{s\text{-}F} = \frac{895^{k}}{4,175^{k}} = 0.21$

Driving Force = $F_H - P_{\text{HEADWTR ON KEY}} + P_{(\text{WTR FROM DIRECTION OF TAILWATER})}$

$= 4264.39 - 753.59 + 663.82$

$= 4,174.62^{k}$

Figure A7. (Sheet 3 of 5)

SUBJECT: Brandon Road - Tainter-Gate Monolith
Normal Operation + Ice - Overstressed Apron Eliminated

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

Shear Friction Safety Factor ($S_{s\text{-}f}$) $= \frac{39{,}126^{k}}{4{,}175^{k}} = 9.37 > 4$

Without {Strut Resistance} $S_{s\text{-}f} = \frac{8{,}386^{k}}{4{,}175^{k}} = 2.01$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s\text{-}f} = \frac{3{,}403^{k}}{4{,}175^{k}} = 0.82$

SLIDING (With Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 3{,}205^{k} + (2{,}037 - 201 + 1{,}561)\tan 45° + 1{,}778^{k} + 30{,}740^{k}$

$= 3{,}205^{k} + 3{,}403^{k} + 1{,}778^{k} + 30{,}740^{k}$

$= 39{,}126^{k}$

Driving Force = $4{,}174.62^{k}$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan 26° + Strut Resistance

$= 3{,}403 \tan 26° + 30{,}740^{k}$

$= 1{,}660^{k} + 30{,}740^{k}$

$= 32{,}400^{k}$

$S_{s\text{-}f} = \frac{32{,}400^{k}}{4{,}175^{k}} = 7.76$

Without {Strut Resistance} $S_{s\text{-}f} = \frac{1{,}660^{k}}{4{,}175^{k}} = 0.40$

Figure A7. (Sheet 4 of 5)

SUBJECT: Brandon Road - Tainter Gate Monolith
Normal Operation + Ice - Overstressed Apron Eliminated

COMPUTED BY: DATE:
CHECKED BY: DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

TOE $f_{Total} = \frac{2}{3}\frac{P_y}{x} + Uplift$

$= \frac{2}{3}\frac{2037}{0} + Uplift = \infty$

HEEL $f_{Total} = 0 + (0.0625)[539 - 491] = 3$ KSF

With Prestress

Intergranular Pressure

$$f = \frac{2037 + 1567}{(30.3)(53)} \pm \frac{(3,604)(5.05)(15.15)}{\frac{(53)(30.3)^3}{12}}$$

$= 2.24 \pm 2.24$

$= 4.48$ K/□' Toe

0 K/□' Heel

Uplift

$f_{U_t} = (48)(0.0625) = 3$ K/□'

$f_{U_h} = (43)(0.0625) = 2.69$ K/□'

Total

$f_{Toe} = 4.48 + 3 = 7.48$ K/□'

$f_{Heel} = 0 + 2.69 = 2.69$ K/□'

Figure A7. (Sheet 5 of 5)

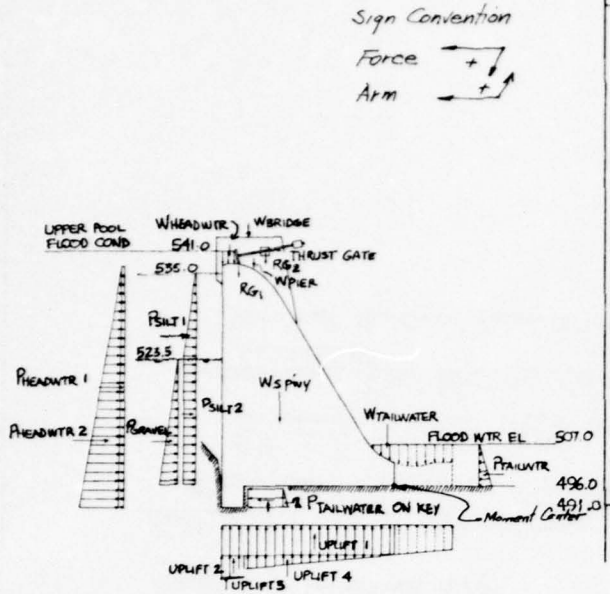
SUBJECT: Brandon Road - Tainter-Gate Monolith
Flood Condition - Overstressed Apron Eliminated

COMPUTED BY:

CHECKED BY:

DATE:

DATE:



ITEM	FACTORS	F_V	F_H	ARM	MOMENTS
W_{SPWY}	[.1515](41838.2) } VOLUMES CALCULATED	+6338.49		19.71	+124931.50
W PIER	[.1515](278.81) } BY GRAPHICAL MEANS	+ 42.24		24.32	+ 1027.28
W HEADWATER	[.0625](541 - 536.75)(2.0)(50)	+ 26.56		29.30	+ 778.21
W TAILWATER	[.0625](6)(63)(.5)(53)	+ 62.61		2.10	+ 131.48
W BRIDGE	} VALUES VERIFIED AND TAKEN FROM APPENDIX E, BRANDON RD. LOCK AND DAM STABILITY ANALYSIS OF DAM MASONRY	+ 11.00		25.81	+ 283.91
$R_{G1} + R_{G2}$		+ 12.75		22.64	+ 288.21
UPLIFT 1	(1.28)(30.3)(53)	-2055.55		15.15	- 31141.61
UPLIFT 2	[3.13 - ((541 - 507)/49)(.0625)(5) - 1.28](5)(53)	- 431.95		27.80	- 12008.21
UPLIFT 3	(3.13 - 2.91)(5)(0.5)(53)	- 28.49		28.63	- 815.60
UPLIFT 4	[3.13 - ((541 - 507)/49)(.0625)(10) - (5)(.0625) - 1.28](25.3)(0.5)(53)	- 737.50		16.87	- 12441.54
$P_{HEADWTR\ 1}$	[.0625](541 - 536.75)(536.75 - 491)(53)		- 644.01	17.88	- 11514.90
$P_{HEADWTR\ 2}$	[.0625](536.75 - 491)^2(0.5)(53)		-3466.63	10.25	- 35532.96
P_{GRAVEL}	[.0775](523.5 - 496)^2(0.5)(0.45)(53)		- 698.92	9.17	- 6409.10
$P_{SILT\ 1}$	[.0203](535 - 523.5)^2(0.5)(0.5)(53)		- 35.57	31.33	- 1114.41
$P_{SILT\ 2}$	[.0203](535 - 523.5)(523.5 - 496)(.5)(53)		- 170.13	13.75	- 2339.24
GATE THRUST	VALUES VERIFIED AND TAKEN FROM APPENDIX E, BRANDON RD. STABILITY ANALYSIS OF DAM MASONRY		- 7.91	42.75	- 338.15
$P_{TAILWATER}$	[.0625](507 - 495)^2(0.5)(53)(0.6)		+120.25	3.67	+ 441.32
$P_{TAILWATER\ 1\ ON\ KEY}$	(2.38)(5)(53)		+630.7	- 2.50	- 1576.75
$P_{TAILWATER\ 2\ ON\ KEY}$	(2.91 - 2.38)(5)(.5)(53)		+140.45	- 3.33	- 467.70
$P_{WATER\ ON\ PIERS}$	[.0625](541 - 536.75)^2(.5)(3)		- 1.69	42.17	- 71.26
		+3187.02	-4133.46		+12109.33

Figure A8. Stability analysis, tainter-gate monolith, flood condition (Sheet 1 of 5)

SUBJECT	COMPUTED BY	DATE
Brandon Road - Tainter-Gate Monolith Flood Condition - Overstressed Apron Eliminated	CHECKED BY:	DATE:

FIRST TRIAL SOLUTION DETERMINING IF PART OF THE BASE IS Not In Compression Full Uplift Must be Applied Under Non-Compressive Area of Base

OVERTURNING

Resultant Location from Moment Center = $\frac{12109.35}{3187.02} = 3.80$

Base Width = 30.3'

% Effective base = $\frac{(3)(3.8)}{30.3} = 37.6\%$

normal operations + ice governs the necessary prestress force

Full Uplift Under Non-Compressive Area of Base

Resultant Location from Moment Center = $\frac{-3,176.05}{1,835.89} = -1.19'$

0% Effective Base
Determined by Trial & Error

Check on Total Vertical Applied Load Under Full Uplift Criteria

Vertical Applied Load (V) = Total Verlical Load - Actual Uplift (Assuming Full Uplift Under Non-Compressive Area of Base)

$= 6435 - (3.125)(5)(53) - (0.0625)(541-496)(25.3)(53)$

$= 6435 - 4599 = 1836^{k}$

Figure A8. (Sheet 2 of 5)

SUBJECT: Brandon Road - Tainter Gate Monolith
Flood Condition - Overstressed Apron Eliminated

COMPUTED BY: DATE:
CHECKED BY: DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

% Effective Base = 0%

Prestress Needed

$(10.1 + 1.19)(1,835.9) = \text{Prestress}(30.3 - 10.1 - 3.5)$

$\text{Prestress} = \frac{(11.29)(1835.9)}{16.7} = 1241^{k}$

Normal Operation + Ice Governs

SLIDING (Without Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 3205^{k} + (1836 - 201)\tan 45° + 1778^{k} + 30,740^{k}$

$= 3,205^{k} + 1,635^{k} + 1,778 + 30,740^{k}$

$= 37,358^{k}$

Shear Friction Safety Factor (S_{s-f}) $= \frac{37358^{k}}{4,118^{k}} = 9.07$ 74

Without {Strut Resistance} $S_{s-f} = \frac{6618^{k}}{4,118^{k}} = 1.61$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s-f} = \frac{1635^{k}}{4,118^{k}} = 0.40$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan 26° + Strut Resistance

$= (1836 - 201)\tan 26° + 30,740^{k}$

$= 797^{k} + 30,740^{k}$

$= 31,537^{k}$

$S_{s-f} = \frac{31,537^{k}}{4,118^{k}} = 7.66$

Without {Strut Resistance} $S_{s-f} = \frac{797^{k}}{4118^{k}} = 0.19$

Driving Force = $F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{(WTR FROM DIRECTION OF TAILWATER)}}$

$= 4133.46 - 0.0625\left[541 - \frac{491 + 496}{2}\right](5 \times 53) + [630.7 + 140.45]$

$= 4133.46 - 786.72 + 771.15 = 4117.89^{k}$

Figure A8. (Sheet 3 of 5)

SUBJECT: Brandon Road - Tainter-Gate Monolith
Flood Condition - Overstressed Apron Eliminated

COMPUTED BY: DATE:
CHECKED BY: DATE:

Shear Friction Safety Factor ($S_{s\text{-}f}$) $= \frac{38,925^{\#}}{4,118^{\#}} = 9.457$

Without {Strut Resistance} $S_{s\text{-}f} = \frac{8,185^{\#}}{4,118^{\#}} = 1.99$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s\text{-}f} = \frac{3,202^{\#}}{4,118^{\#}} = 0.78$

SLIDING (With Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 3,205^{\#} + (1,836 - 201 + 1567) \tan 45° + 1,778^{\#} + 30,740^{\#}$

$= 3,205^{\#} + 3,202^{\#} + 1,778^{\#} + 30,740^{\#}$

$= 38,925^{\#}$.

Driving Force = $4117.89^{\#}$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan 26° + Strut Resistance

$= (1836 - 201 + 1567) \tan 26° + 30,740^{\#}$

$= 32,302^{\#}$

$S_{s\text{-}F} = \frac{32,302^{\#}}{4,118^{\#}} = 7.84 > 1.5$

Without {Strut Resistance} $S_{s\text{-}F} = \frac{1562^{\#}}{4,118^{\#}} = 0.38$

Figure A8. (Sheet 4 of 5)

SUBJECT: Brandon Road - Tainter Gate Monolith
Flood Condition - Overstressed Apron Eliminated

COMPUTED BY:

CHECKED BY:

DATE:

DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

Toe $f_{Total} = \infty$

Heel $f_{TOTAL} = 0 + 0.0625[541 - 491] = 3.13^{k}/_{ft^2}$

With Prestress

Intergranular Pressure

$$f = \frac{(1836)(1567)}{(30.3)(53)} \pm \frac{\left[1836\left(\frac{30.3}{2}+0.77\right) - 1567\left(\frac{30.3}{2} - 3.5\right)\right] 15.15}{\frac{(53)(30.3)^3}{12}}$$

$= 2.12^{k} \pm 1.35^{k}$

$= 3.47^{k}/_{ft^2}$ Toe

$= -\cancel{1.1}^{0}{}^{k}/_{ft^2}$ Heel

Uplift

$f_{U_{HEEL}} = (50)(0.0625) = 3.13^{k}/_{ft^2}$

$f_{U_{TOE}} = (45)(0.0625) = 2.81^{k}/_{ft^2}$

Total

$f_{TOE} = 3.47 + 3.13 = 6.60^{k}/_{ft^2}$

$f_{HEEL} = 2.81^{k}/_{ft^2}$

Figure A8. (Sheet 5 of 5)

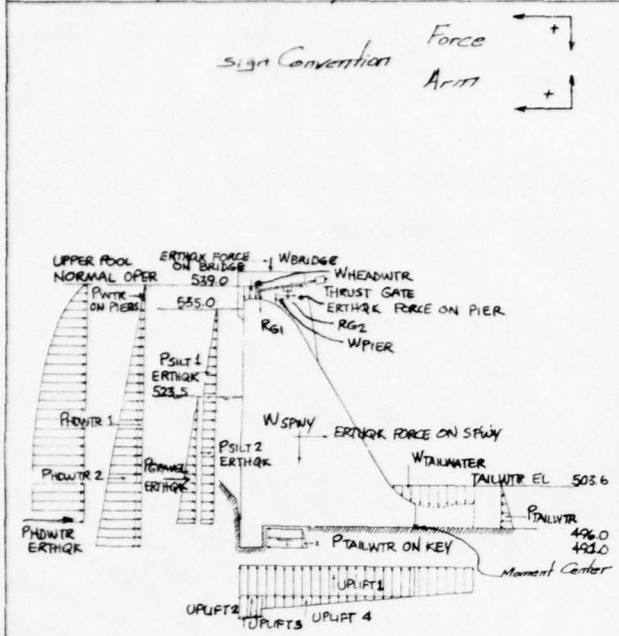
SUBJECT: Brandon Road - Tainter Gate Monolith
Normal Operation + Earthquake - Overstressed Toe Eliminated

COMPUTED BY:

CHECKED BY:

DATE:

DATE:



ITEM		F_v	F_H	ARM	MOMENTS
W_{SPWY}	[.1515] (45114.72) } VOLUMES CALCULATED	+6338.49		19.71	+ 124931.5
W_{PIER}	[.1515] (278.81) } BY GRAPHICAL MEANS	+ 42.74		24.32	+ 1027.28
$W_{HEADWATER}$	[.0625] (539 - 536.75)(2)(50)	+ 14.06		29.30	+ 411.96
$W_{TAILWATER}$	[.0625] (503.6 - 501)(3.9)(.5)(53)	+ 16.79		1.30	+ 21.83
W_{BRIDGE}	} VALUES VERIFIED AND TAKEN FROM AP-	+ 11.00		25.81	+ 283.91
RG_1	PENDIX E, BRANDON RD LOCK AND DAM STA-	+ 1.44		28.3	+ 40.75
RG_2	BILITY ANALYSIS OF DAM MASONRY	+ 11.29		22.64	+ 255.61
UPLIFT 1	(1.09)(30.3)(53)	-1750.43		15.15	- 26519.03
UPLIFT 2	[3.00 - ((539 - 503.6)/49)(.0625)(5) - 1.09] (5)(53)	- 445.2		27.80	- 12376.56
UPLIFT 3	(3.00 - 2.77)(5)(.5)(53)	- 30.48		28.63	- 872.50
UPLIFT 4	[3.00 - ((539 - 503.6)/49)(.0625)(10) - (5)(.0625) - 1.09](25.3)(.5)(53)	- 771.02		16.87	- 13007.07
$P_{HEADWATER\ 1}$	[.0625](2.25)(536.75 - 491)(53)		- 340.98	17.88	- 6096.72
$P_{HEADWATER\ 2}$	[.0625](45.75)(45.75)(0.5)(53)		3466.63	10.25	- 35532.96
$P_{TAILWATER}$	[.0625](2.6)(3.9)(0.5)(53)		+ 16.79	1.30	+ 21.83
$P_{TAILWATER\ 1\ ON\ KEY}$	(2.24)(5)(53)		+ 593.60	- 2.50	- 1484.00
$P_{TAILWATER\ 2\ ON\ KEY}$	(2.77 - 2.24)(5)(0.5)(53)		+ 70.22	- 3.33	- 233.84
GATE THRUST	VALUES VERIFIED AND TAKEN FROM APPENDIX E BRANDON ROAD STABILITY ANALYSIS OF DAM MASONRY		- 7.91	42.75	- 338.15
$P_{WATER\ ON\ PIER}$	[.0625](2.25)(2.25)(.5)(3)		- 0.47	41.50	- 19.51
	EARTHQUAKE FORCES				
HORIZ. FORCE OF PIER	[.05](42.24)		- 2.11	42.81	- 90.41
HORIZ. FORCE OF SPWY	[.05](6338.49)		-316.92	15.11	- 4788.73
$P_{WATER\ EARTHQUAKE}$	$\left[\left(\frac{7}{8}\right)(51)(.05)(38)\sqrt{(38)(38)}\right]\frac{53}{1000(1)}$		- 130.12	20.20	- 2628.32
$P_{SILT\ 1\ EARTHQUAKE}$	[.0203](11.5)^2(.5)(.54)(53)		- 38.41	31.78	- 1220.99
$P_{SILT\ 2\ EARTHQUAKE}$	[.0203](11.5)(27.5)(.5)(53)		- 170.13	13.75	- 2339.24
$P_{GRAVEL\ EARTHQUAKE}$	[.0775](27.5)^2(.5)(.55)(53)		- 854.23	10.24	- 8747.33
HORIZ. FORCE OF BRIDGE	[.05](11)		- 0.55	45.90	- 25.25
		3438.17	-4607.27		- 10797.46

Figure A9. Stability analysis, tainter-gate monolith, normal operation with earthquake (Sheet 1 of 5)

SUBJECT: Brandon Road - Tainter-Gate Monolith Normal Operation + Earthquake - Overstressed Toe Eliminated	COMPUTED BY: CHECKED BY:	DATE: DATE:

First Trial Solution Determining if Part of the Base is Not in Compression. Full Uplift Must be Applied Under Non-Compressive Area of Base

OVERTURNING

Resultant Location from Moment Center = $\frac{-10,792.46}{3,438.17} = -3.14'$

0% Effective Base

Apply Full Uplift Under Non-Compressive Area of Base

Vertical Applied Load (V) = 2222^{k} (From Normal Operation)

Figure A9. (Sheet 2 of 5)

SUBJECT: Brandon Road - Tainter-Gate Monolith
Normal Operation + Earthquake - Overstressed Toe Eliminated

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

OVERTURNING (Uplift for Normal Operation Used)

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

Resultant location From Moment Center = $\frac{-25,400.87}{2227.66} = -11.43'$

0% Effective Base

Prestress Needed

$(30.3 - 3.5)(\text{Prestress}) = (2222)(11.43)$

$\text{Prestress} = \frac{25,394^k}{26.8} = 948^k$

Normal Operation + Ice Governs

SLIDING (Without Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 3,205^k + (2222 - 201)\tan 45° + 1,778^k + 30,740^k$

$= 37,744^k$

Driving Force = 460.27 − 753.59 + 663.82

= 4517.50^k

Shear Friction Safety Factor (S_{s-f}) $= \frac{37,744^k}{4,518^k} = 8.35$ 7.26 7

Without {Strut Resistance} $S_{s-f} = \frac{7004^k}{4,518^k} = 1.55$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s-f} = \frac{2021^k}{4,518^k} = 0.45$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan 26° + Strut Resistance

$= (2222 - 201)\tan 26° + 30,740^k$

$= 986^k + 30,740^k$

$= 31,726^k$

$S_{s-f} = \frac{31,726^k}{4,518^k} = 7.02$ 7 1.15

Without {Strut Resistance} $S_{s-f} = \frac{986^k}{4,518^k} = 0.22$

Figure A9. (Sheet 3 of 5)

SUBJECT: Brandon Road - Tainter-Gate Monolith
Normal Operation + Earthquake - Overstressed Toe Eliminated

COMPUTED BY:

CHECKED BY:

DATE:

DATE:

Shear Friction Safety Factor (S_{s-f}) $= \frac{39,311^k}{4,518^k} = 8.70 \gtrless 2.67$

Without {Strut Resistance} $S_{s-f} = \frac{8,571^k}{4,518^k} = 1.90$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s-f} = \frac{3,588^k}{4,518^k} = 0.79$

SLIDING (With Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 3,205^k + (2222 - 201 + 1567) \tan 45° + 1,778^k + 30,740^k$

$= 39,311^k$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan 26° + Strut Resistance

$= (2222 - 201 + 1567) \tan 26° + 30,740^k$

$= 32,480^k$

$S_{s-f} = \frac{32,480^k}{4,518^k} = 7.19 \gtrless 1.15$

Without {Strut Resistance} $S_{s-f} = \frac{1740^k}{4,518^k} = 0.39$

Driving Force = 4607.27 - 753.59 + 663.82

$= 4,517.50^k$

A1-1

Figure A9. (Sheet 4 of 5)

SUBJECT: Brandon Road - Tainter Gate Monolith
Normal Operation + Earthquake - Overstressed Toe Eliminated

COMPUTED BY:

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DATE:

DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

Toe $f_{total} = \infty$

Heel $f_{total} = 0 + 0.0625(539 - 491) = 3$ k/ft²

With Prestress

$$f = \frac{(2222 + 1567)}{(303)(53)} \pm \frac{\left[2222\left(15.15 + 11.43\right) - 1567\left(\frac{303}{2} - 3.5\right)\right] 15.15}{\frac{(53)(30.3)^3}{12}}$$

$= 2.36 \pm 5.03$

$= 7.39$ k/ft² Toe

0 k/ft² Heel

Uplift

$f_{U_{HEEL}} = (48)(0.0625) = 3$ k/ft²

$$f_{U_{TOE}} = \frac{13.7}{3(2.78) + 13.7}\left[0.0625(539 - 496) - 0.0625\left[503.6 - 496\right] + 0.0625\left[503.6 - 496\right]\right] = 1.85 \text{ k/ft}^2$$

Total

$f_{TOE} = 7.39 + 1.85 = 9.24$ k/ft²

$f_{HEEL} = 3$ k/ft²

< 200 k/ft²

Figure A9. (Sheet 5 of 5)

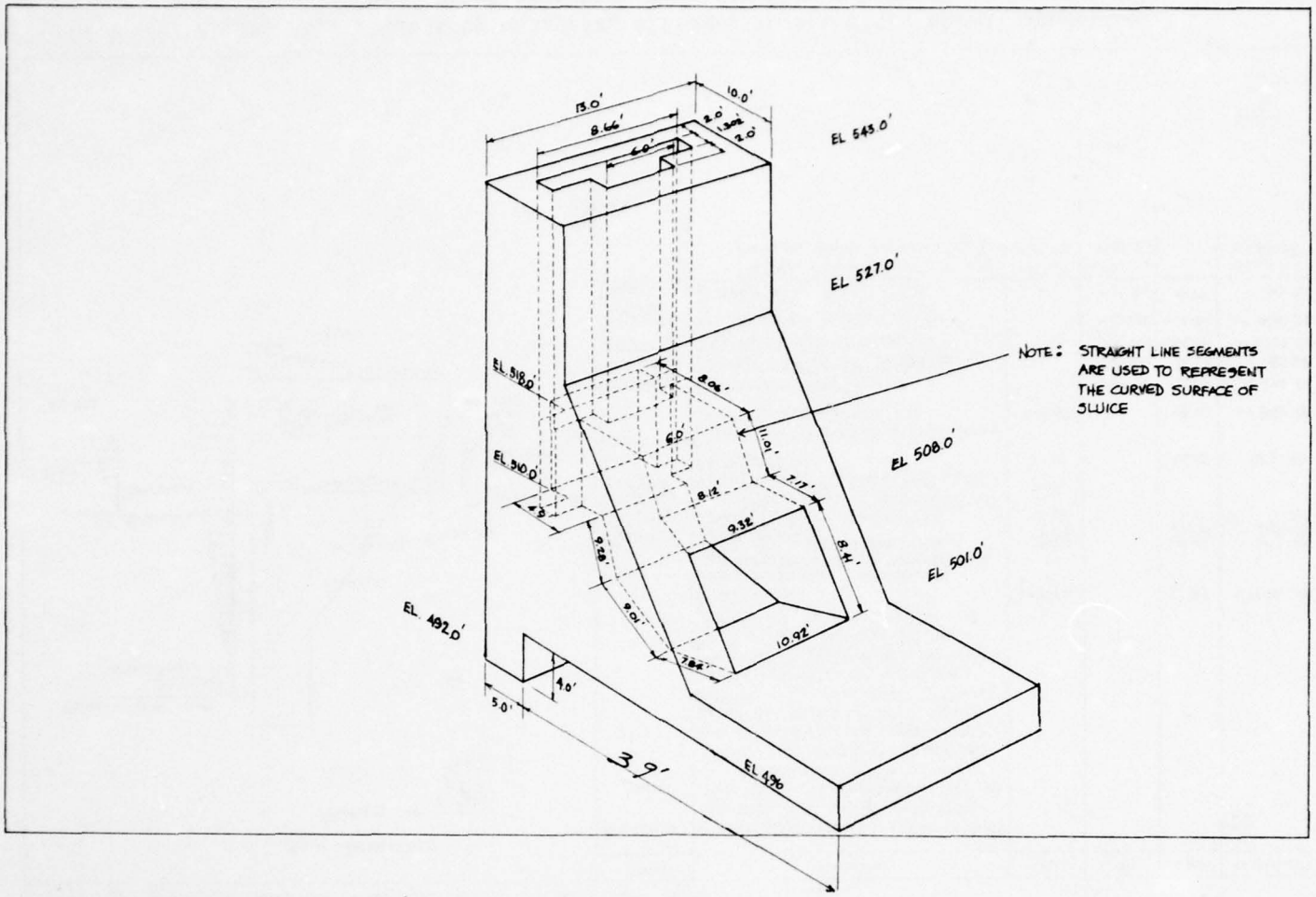


Figure A10. Typical sluice-gate monolith

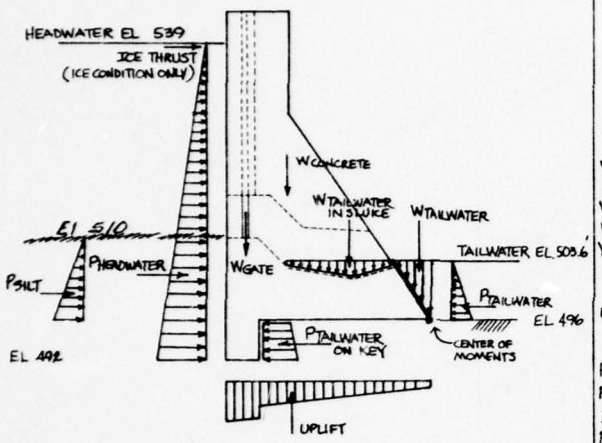
SUBJECT: Brandon Road Sluice-Gate Monolith
Normal Operation and Normal Operation + ice conditions

COMPUTED BY:

CHECKED BY:

DATE:

DATE:



ITEM	FACTORS	F_V	F_H	ARM	MOMENTS
W CONCRETE	$[.1536]\left[(10)(16)+(\tfrac{1}{2})(8)(1)+(8)(9)+(\tfrac{1}{2})(8.67)(8)+(\tfrac{1}{2})(6.67)(10)+(2)(10)+(\tfrac{1}{2})(6.43)(8)+(\tfrac{1}{2})(6.43)(1)+(5)(4)+(27.35)(4)+(\tfrac{1}{2})(3.33)(5)+(10)(4.9)+(\tfrac{1}{2})(6.1)(7)+(6.1)(3)+(\tfrac{1}{2})(3)(8.5)+(\tfrac{1}{2})(1)(7.83)\right](13)-(8.66)(1.302)(25)-(6)(2)(25)+(\tfrac{1}{2})(1)(8)(3.5)(2)+(7)(8)(3.5)(2)+(7)(6.6)(\tfrac{1}{2})(2)\left(\tfrac{3.5+3.44}{2}\right)+(\tfrac{1}{2})(6)(7)(2)\left(\tfrac{3.5+2.44}{2}\right)+(2)(3.6)(7)\left(\tfrac{2.58+3.07}{2}\right)+(2)(3)(8.5)(.5)\left(\tfrac{3.07+2.09}{2}\right)+(2)(5)(8.06)\left(\tfrac{1.89+2.58}{2}\right)+(\tfrac{1}{2})(8.06)(1)\left(\tfrac{1.89+2.58}{2}\right)+(2)(7)(4.67)(\tfrac{1}{2})\left(\tfrac{1.04+1.89}{2}\right)+(2)(7.83)(1)(\tfrac{1}{2})\left(\tfrac{1.04+2.09}{2}\right)+(3.16)(2)(2)\left(\tfrac{1.89+2.09}{2}\right)-(2)(1.33)(1.302)(8)$	1275.22		21.33	27196.12
W GATE	VALUE TAKEN FROM APPENDIX E, BRANDON RD. STABILITY ANALYSIS DAM MASONRY, GATE + MISC. STEEL =	5.00		28.32	141.60
W HEADWATER	$[.0625]\left[(6)(2.34)(6)\right]$	7.02		29.49	207.02
W TAILWATER	$[.0625]\left[(\tfrac{1}{2})(503.6-496)(3.33)(13)\right]$	10.28		1.11	11.42
W TAILWATER IN SLUICE	$[.0625]\left[(8)(2.34)(6)+(\tfrac{1}{2})(8.5)(3.6)\left(\tfrac{8.85+6.7}{2}\right)+(\tfrac{1}{2})(7.83)(3.6)\left(\tfrac{10.92+8.85}{2}\right)+(\tfrac{1}{2})(2.6)(6.1)\left(\tfrac{10.92+8.85}{2}\right)\right]$	31.17		16.15	503.40
UPLIFT	$[(\tfrac{1}{2})(5)(2.938)+(\tfrac{1}{2})(5)(2.619)+(\tfrac{1}{2})(25.66)(2.114)+(\tfrac{1}{2})(25.66)(0.475)][13]$	-612.42		19.28	-11980.98
P HEADWATER	$[.0625](539-492)^2(\tfrac{1}{2})(13)$		-897.56	11.67	-10474.53
P TAILWATER	$[.0625](503.6-496)^2(\tfrac{1}{2})(13)(0.6)$		14.08	2.53	35.62
ICE THRUST	$[5](1)(13)$ (ICE CONDITION ONLY)		-65.00	42.50	-2762.50
P TAILWATER ON KEY	$[(2.114)(\tfrac{1}{2})(4)+(2.619)(\tfrac{1}{2})(4)][13]$		123.05	-2.06	-254.23
P SILT	$[.0203](\tfrac{1}{2})(510-496)^2(5)(13)$		-12.93	4.67	-60.38
	NORMAL OPERATION (WITHOUT ICE)	716.27	-773.36		5325.05
	NORMAL OPERATION (WITH ICE)	716.27	-838.36		2562.55

Figure A11. Stability analysis, sluice-gate monolith, normal operation and normal operation plus ice (Sheet 1 of 8)

SUBJECT: Brandon Road Sluice-Gate Monolith Normal Operation	COMPUTED BY: CHECKED BY:	DATE: DATE:

FIRST TRIAL SOLUTION TO DETERMINE IF PART OF THE BASE IS NOT IN COMPRESSION. IF SO, THEN FULL UPLIFT MUST BE APPLIED UNDER NON-COMPRESSIVE AREAS

OVERTURNING (FIRST TRIAL SOLUTION)

Resultant location from Moment center

Normal Operations:

$$\frac{5325.05}{716.27} = 7.43'$$

Normal Operations + ice:

$$\frac{2562.55}{716.27} = 3.58'$$

Base width = 30.66'

% Effective Base

Normal Operation $= \frac{(3)(7.43)}{30.66} = 72.70\ \%$

Normal Operation + ice $= \frac{(3)(3.58)}{30.66} = 35.03\ \%$

Figure A11. (Sheet 2 of 8)

SUBJECT: Brandon Road - Sluice-Gate Monolith
Normal Operation

COMPUTED BY: DATE:
CHECKED BY: DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(1.59)}{30.66} = 15.56\ \%$$

Prestress Needed

$$\frac{309.85\left(\frac{30.66}{3} - 1.59\right)}{30.66 - 10.22 - 3.5} = 158 \text{ Kips}$$

Shear Friction Safety Factor $(S_{s\text{-}f}) = \frac{8871}{750} = 11.83 > 4.0$

Without {Strut Resistance} $= \frac{1331}{750} = 1.77$

Without {Strut Resistance, Cohesion, Key Resistance} $= \frac{271}{750} = 0.36$

Strut Resistance Downstream of the Sluice-Gate Monolith is Essential

SLIDING (Before Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$$= 1.1\sqrt{f_c'}\,A_{KEY} + [F_V - \text{Wt of Key}]\tan 45^\circ + c\,A_{BASE} + 2sdw$$

$$= 1.1\sqrt{5630}\,(5)(13)\left(\frac{144}{1000}\right) + [309.85 - 0.15(5)(4)(13)]\,(1) + 0.86\,(25.66)\,(13) + (2)(58)(5)\,(13)$$

$$= 773 + 271 + 287 + 7540 = 8871 \text{ Kips}$$

Driving Force = $F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$

$$= 773.36 - 0.0625\left[539 - \frac{492 + 496}{2}\right](4)(13) + 123.05$$

$$= 750.16 \text{ Kips}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance

$$= 271 \tan 26^\circ + 7540$$

$$= 7672 \text{ Kips}$$

$$S_{s\text{-}f} = \frac{7672}{750} = 10.23 > 1.5$$

Without {Strut Resistance} $= \frac{132}{750} = 0.18$

Strut Resistance Downstream of the Sluice-Gate Monolith is Essential

Figure A11. (Sheet 3 of 8)

SUBJECT: Brandon Road - Sluice-Gate Monolith
Normal Operation

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

Shear Friction Safety Factor ($S_{s\cdot f}$) = $\frac{9157}{750}$ = 12.21 > 4.0

Without {Strut Resistance} = $\frac{1617}{750}$ = 2.16

Without {Strut Resistance, Cohesion, Key Resistance} = $\frac{557}{750}$ = 0.74

Full Uplift Applied Under non-Compressive Area of Base.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 1.1\sqrt{f_c'}\,A_{KEY} + [F_V + PS\text{-}WH \text{ of } Key]\tan 45° + c\,A_{BASE} + 2sdw$

$= 1.1\sqrt{5630}\,(5)(13)\left(\frac{144}{1000}\right) + [309.85 + 286 - 0.15(5)(4)(13)](1) + 0.86\,(25.66)(13) + 2(58)(5)(13)$

$= 773 + 557 + 287 + 7540 = 9157$ Kips

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 773.36 - 0.0625\left[539 - \frac{492+496}{2}\right](4)(13) + 123.05$

$= 750.16$ Kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance

$= 557 \tan 26° + 7540$

$= 7812$ Kips

$S_{s\cdot f} = \frac{7812}{750} = 10.42 > 1.5$

Without {Strut Resistance} = $\frac{272}{750}$ = 0.36

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Figure A11. (Sheet 4 of 8)

SUBJECT	COMPUTED BY:	DATE
Brandon Road - Sluice-Gate Monolith Normal Operation	CHECKED BY:	DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{Uplift}$$

$= 0 + 0.0625[539 - 496] = 0. + 2.69 = 2.69$ KSF Heel

$= \frac{2(309.85)}{3(1.59)} + 0.0625[503.6 - 496] = 129.9 + 0.48 = 130.38$ KSF Toe

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{Uplift}$$

$$= \frac{309.85 + 286}{(30.66)(13)} \pm \frac{309.85\left(\frac{30.66}{2} - 1.59\right) - 286\left(\frac{30.66}{2} - 3.5\right)}{(13)(30.66)^2/6} + \text{Uplift}$$

$= 1.49 - 0.43 + 2.69 = 1.06 + 2.69 = 3.75$ KSF Heel

$= 1.49 + 0.43 + 0.48 = 1.92 + 0.48 = 2.40$ KSF Toe

Figure A11. (Sheet 5 of 8)

SUBJECT: Brandon Road - Sluice - Gate Monolith
Normal Operation + Ice

COMPUTED BY: DATE:
CHECKED BY: DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(-9.86)}{30.66} \rightarrow 0.\%$$

Prestress Needed

$$\frac{241.26\left(\frac{30.66}{3} + 9.86\right)}{30.66 - 10.22 - 3.5} = 286 \text{ Kips}$$

Shear Friction Safety Factor $(S_{s\text{-}f}) = \frac{8802}{815} = 10.80 > 4.0$

Without {Strut Resistance} $= \frac{1262}{815} = 1.55$

Without {Strut Resistance, Cohesion, Key Resistance} $= \frac{202}{815} = 0.25$

SLIDING (Before Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + $V \tan 45° + cA$ + Strut Resistance

$$= 1.1\sqrt{f_c'}\,A_{KEY} + \left[F_V - \text{UH of Key}\right]\tan 45° + cA_{BASE} + 2sdw$$

$$= 1.1\sqrt{5630}\,(5)(13)\left(\frac{144}{1000}\right) + \left[241.26 - 0.15(5)(4)(13)\right](1) + 0.86(25.66)(13) + 2(58)(5)(13)$$

$$= 773 + 202 + 287 + 7540 = 8802 \text{ Kips}$$

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$$= 838.36 - 0.0625\left[539 - \frac{492 + 496}{2}\right](4)(13) + 123.05$$

$$= 815.16 \text{ Kips}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = $V \tan \phi$ + Strut Resistance

$$= 202 \tan 26° + 7540$$

$$= 7639 \text{ Kips}$$

$$S_{s\text{-}F} = \frac{7639}{815} = 9.37 > 1.5$$

Without {Strut Resistance} $= \frac{98.5}{815} = 0.12$

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Figure A11. (Sheet 6 of 8)

SUBJECT	COMPUTED BY:	DATE
Brandon Road - Sluice-Gate Monolith Normal Operation + Ice	CHECKED BY:	DATE

Shear Friction Safety Factor ($S_{s\cdot f}$) = $\frac{9088}{815}$ = 11.15 > 4.0

Without {Strut Resistance} = $\frac{1548}{815}$ = 1.90

Without {Strut Resistance, Cohesion, Key Resistance} = $\frac{488}{815}$ = 0.60

Full Uplift Applied Under non-Compressive Area of Base.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance

$= 1.1\sqrt{f'_c}\,A_{key} + [F_V + PS - \text{Wt of Key}]\tan 45° + CA_{BASE} + 2sdw$

$= 1.1\sqrt{5630}\,(5)(13)\left(\frac{144}{1000}\right) + [24126 + 286 - 0.15(5)(4)(13)](1) + 0.86(25.66)(13) + 2(58)(5)(13)$

$= 773 + 488 + 287 + 7540 = 9088$ Kips

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 838.36 - 0.0625\left[539 - \frac{492 + 496}{2}\right](4)(13) + 123.05$

$= 815.16$ Kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance

$= 488 \tan 26° + 7540$

$= 7778$ Kips

$S_{s\cdot f} = \frac{7778}{815} = 9.54 > 1.5$

Without {Strut Resistance} = $\frac{239}{815}$ = 0.29

Figure A11. (Sheet 7 of 8)

SUBJECT	COMPUTED BY	DATE
Brandon Road - Sluice - Gate Monolith Normal Operation + Ice	CHECKED BY	DATE

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{Uplift}$$

$$= 0. + 0.0625\left[539 - 496\right] = 0. + 2.69 = 2.69 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= \frac{2(241.26)}{3(0)} + 0.0625\left[503.6 - 496\right] = \infty + 0.48 = \infty \text{ KSF} \quad \underline{\text{Toe}}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{Uplift}$$

$$= \frac{241 + 286}{(13)(30.66)} \pm \frac{241\left(\frac{30.66}{2} + 9.86\right) - 286\left(\frac{30.66}{2} - 3.5\right)}{(13)(30.66)^2/6} + \text{Uplift}$$

$$= 1.32 - 1.32 + 2.69 = 0. + 2.69 = 2.69 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= 1.32 + 1.32 + 0.48 = 2.64 + 0.48 = 3.12 \text{ KSF} \quad \underline{\text{Toe}}$$

Figure A11. (Sheet 8 of 8)

SUBJECT: Brandon Road Sluice-Gate Monolith
Flood Condition

COMPUTED BY:
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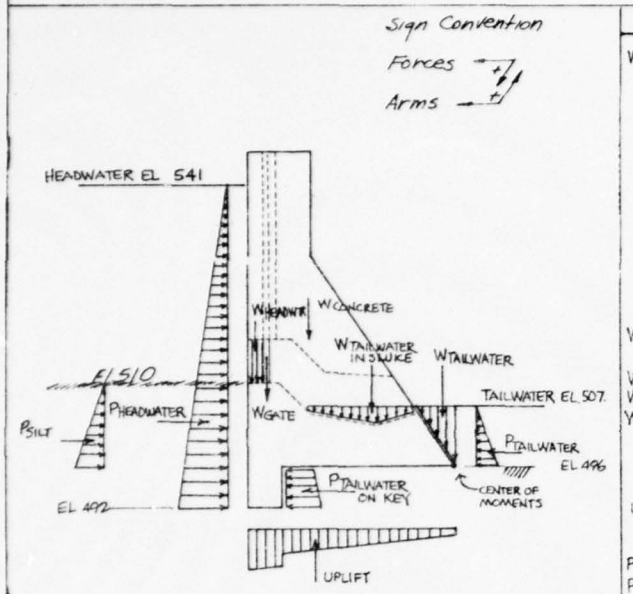
DATE:
DATE:



ITEM	FACTORS	F_V	F_H	ARM	MOMENTS
$W_{CONCRETE}$	$[.1536]\big((10)(16)+(\tfrac{1}{2})(8)(1)+(8)(9)+(\tfrac{1}{2})(8.67)(8)+(\tfrac{1}{2})(6.67)(10)+(2)(10)+(\tfrac{1}{2})(6.43)(8)+(\tfrac{1}{2})(6.43)(1)+(5)(4)+(27.33)(4)+(\tfrac{1}{2})(3.33)(5)+(10)(4.9)+(\tfrac{1}{2})(6.1)(7)+(6.1)(3)+(\tfrac{1}{2})(3)(8.5)+(\tfrac{1}{2})(1)(7.83)\big)(13)-(8.66)(1.302)(25)-(6)(2)(25)+(\tfrac{1}{2})(1)(8)(3.5)(2)+(7)(8)(3.5)(2)+(7)(6.6)(\tfrac{1}{2})(2)\left(\tfrac{3.5+2.94}{2}\right)+(\tfrac{1}{2})(6)(7)(2)\left(\tfrac{3.5+2.44}{2}\right)+(2)(3.6)(7)\left(\tfrac{2.58+3.07}{2}\right)+(2)(3)(8.5)(5)\left(\tfrac{3.07+2.09}{2}\right)+(2)(5)(8.06)\left(\tfrac{1.89+2.58}{2}\right)+(\tfrac{1}{2})(8.06)(1)\left(\tfrac{1.89+2.58}{2}\right)+(2)(7)(4.67)(\tfrac{1}{2})\left(\tfrac{1.04+1.89}{2}\right)+(2)(7.83)(1)(\tfrac{1}{2})\left(\tfrac{1.64+2.09}{2}\right)+(3.16)(2)(2)\left(\tfrac{1.89+2.09}{2}\right)-(2)(1.33)(1.302)(8)$	1275.22		21.33	27196.12
W_{GATE}	VALUE TAKEN FROM APPENDIX E, BRANDON RD. STABILITY ANALYSIS DAM MASONRY: GATE + MISC. STEEL =	5.00		28.32	141.60
$W_{HEADWATER}$	$[.0625](8)(2.34)(6)$	7.02		29.49	207.02
$W_{TAILWATER}$	$[.0625](\tfrac{1}{2})(507.0-496)(7.33)(13)$	32.75		2.44	79.91
$W_{TAILWATER\ IN\ SLUICE}$	$[.0625]\big((8)(2.34)(6)+(8.5)(4)\left(\tfrac{8.85+6.7}{2}\right)+(\tfrac{1}{2})(4)(4)\left(\tfrac{6.49+6.7}{2}\right)+(3.83)(6)\left(\tfrac{8.85+9.86}{2}\right)+(\tfrac{1}{2})(8.5)(3)\left(\tfrac{8.85+6.7}{2}\right)+(\tfrac{1}{2})(1)(7.85)\left(\tfrac{8.85-10.92}{2}\right)+(\tfrac{1}{2})(4)(6)\left(\tfrac{8.86+10.92}{2}\right)\big)$	57.08		14.32	817.39
UPLIFT	$[(3.063)(\tfrac{1}{2})(5)+(2.757)(\tfrac{1}{2})(5)+(2.262)(\tfrac{1}{2})(25.66)+(0.688)(25.66)(\tfrac{1}{2})][13]$	-681.18		18.75	-12771.15
$P_{HEADWATER}$	$[.0625](541-492)^2(\tfrac{1}{2})(13)$		-975.56	12.33	-12028.65
$P_{TAILWATER}$	$[.0625](507-496)^2(\tfrac{1}{2})(13)(0.6)$		29.52	3.67	108.33
$P_{TAILWATER\ ON\ KEY}$	$[(2.262)(\tfrac{1}{2})(4)+(2.757)(\tfrac{1}{2})(4)][13]$		130.49	-2.06	-268.98
P_{SILT}	$[.0203](\tfrac{1}{2})(510-496)^2(5)(13)$		-12.93	4.67	-60.38
	FLOOD DISCHARGE CONDITION	695.89	-828.48		3421.20

Figure All. Stability analysis, sluice-gate monolith, flood condition (Sheet 1 of 5)

AD-A064 811 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 8/8
STABILITY AND STRESS ANALYSES OF BRANDON ROAD DAM, ILLINOIS WAT--ETC(U)
DEC 78 C E PACE, R L CAMPBELL

UNCLASSIFIED WES-MP-C-78-18 NL

2 OF 3
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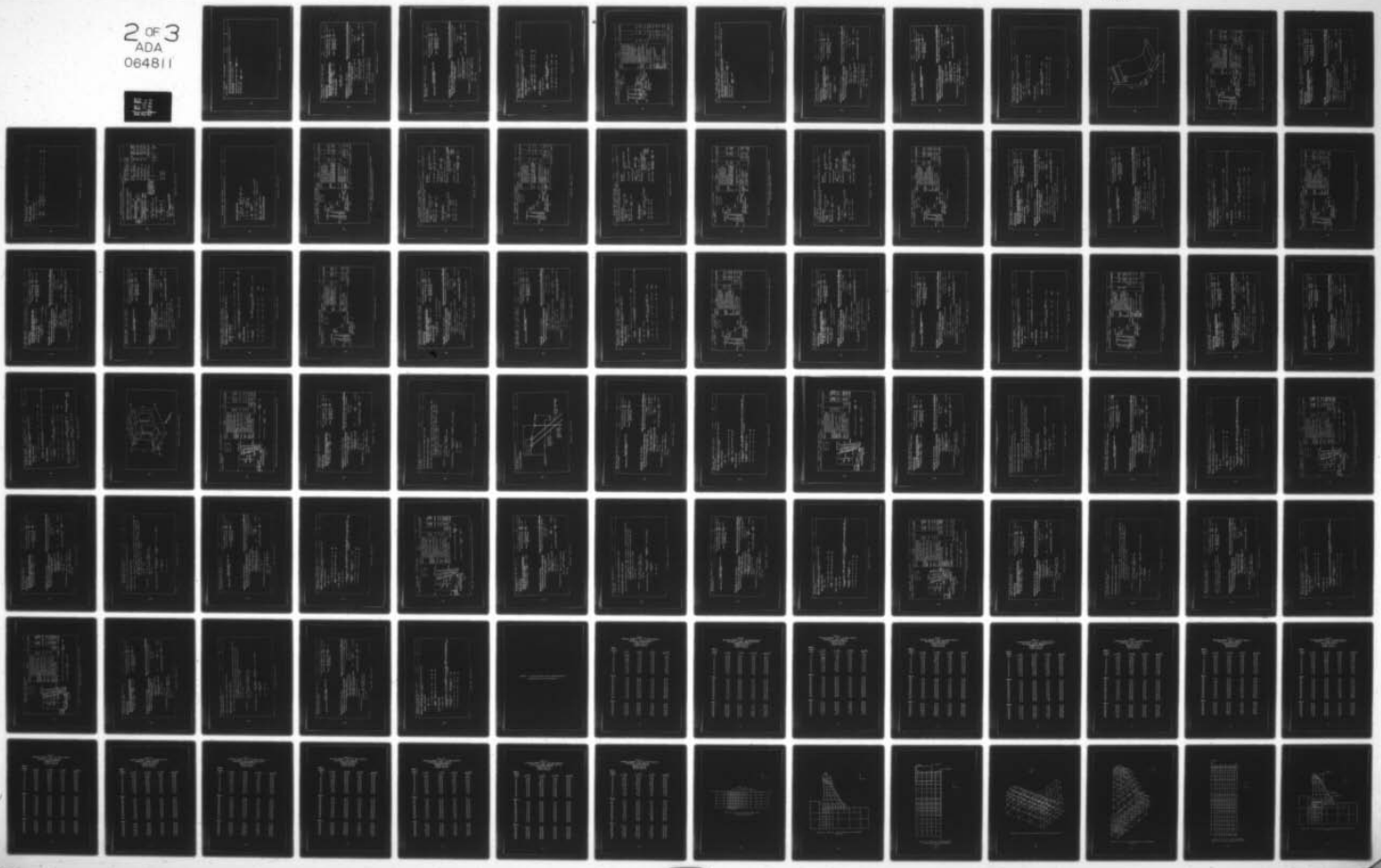


SUBJECT: Brandon Road Sluice-Gate Monolith Flood condition	COMPUTED BY: CHECKED BY:	DATE: DATE:

FIRST TRIAL SOLUTION TO SEE IF PART OF THE BASE IS NOT IN COMPRESSION. IF SO, THEN FULL UPLIFT MUST BE APPLIED UNDER NON-COMPRESSIVE AREAS

OVERTURNING (FIRST TRIAL SOLUTION)

Resultant location from Moment Center = $\frac{3421.20}{696.89}$ = 4.92'

Base width = 30.66'

% Effective base = $\frac{3(4.92)}{30.66}$ = 48.10 %

Figure A12. (Sheet 2 of 5)

SUBJECT: Brandon Road - Sluice-Gate Monolith
Flood Condition

COMPUTED BY:
CHECKED BY:
DATE:
DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(-6.22)}{30.66} \rightarrow 0\%$$

Prestress Needed

$$\frac{239.81\left(\frac{30.66}{3} + 6.22\right)}{30.66 - 10.22 - 3.5} = 233 \text{ Kips}$$

Shear Friction Safety Factor ($S_{s\text{-}f}$) $= \frac{8801}{806} = 10.92 > 4.0$

Without {Strut Resistance} $= \frac{1261}{806} = 1.56$

Without {Strut Resistance, Cohesion, Key Resistance} $= \frac{201}{806} = 0.25$

SLIDING (Before Prestress)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance

$$= 1.1\sqrt{f'_c}\,A_{key} + [F_v - \text{Wt of Key}]\tan 45° + CA_{BASE} + 2sdw$$

$$= 1.1\sqrt{5630}\,(5)(13)\left(\frac{144}{1000}\right) + [239.81 - 0.15(5)(4)(13)](1) + 0.86\,(25.66)(13) + 2(58)(5)(13)$$

$$= 773 + 201 + 287 + 7540 = 8801 \text{ Kips}$$

Driving Force = $F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$

$$= 828.48 - 0.0625\left[541 - \frac{492 + 496}{2}\right](4)(13) + 130.49$$

$$= 806.22 \text{ Kips}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance

$$= 201 \tan 26° + 7540$$

$$= 7638 \text{ Kips}$$

$$S_{s\text{-}f} = \frac{7638}{806} = 9.48 > 1.5$$

Without {Strut Resistance} $= \frac{98.0}{806} = 0.12$

A54

Figure A12. (Sheet 3 of 5)

SUBJECT: Brandon Road - Sluice-Gate Monolith
Flood Condition

COMPUTED BY: DATE:
CHECKED BY: DATE:

Shear Friction Safety Factor ($S_{s\text{-}f}$) = $\frac{9087}{806}$ = 11.27 > 4.0

Without {Strut Resistance} = $\frac{1547}{806}$ = 1.92

Without {Strut Resistance, Cohesion, Key Resistance} = $\frac{487}{806}$ = 0.60

Compressive Full Uplift Applied Under non-Area of Base.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 1.1\sqrt{f'_c}\,A_{key} + [F_V + PS - Wt\ of\ Key]\tan 45° + cA_{BASE} + 2\,sdw$

$= 1.1\sqrt{5430}(5)(13)\left(\frac{144}{1000}\right) + [239.81 + 286 - 0.15(5)(4)(13)](1) + .0.86(25.44)(13) + 2(58)(5)(13)$

$= 773 + 487 + 287 + 7540 = 9087$ Kips

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 828.48 - 0.0625\left[541 - \frac{492+496}{2}\right](4)(13) + 130.49$

$= 806.22$ Kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance

$= 487 \tan 26° + 7540$

$= 7778$ Kips

$S_{s\text{-}f} = \frac{7778}{806} = 9.65 > 1.5$

Without {Strut Resistance} = $\frac{238}{806}$ = 0.30

A55

Figure A12. (Sheet 4 of 5)

SUBJECT: Brandon Road - Sluice-Gate Monolith Flood Condition	COMPUTED BY: CHECKED BY:	DATE: DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{Uplift}$$

$= 0. + 0.0625[541 - 496] = 0. + 2.81 = 2.81$ KSF Heel

$= \frac{2(239.81)}{3(0)} + 0.0625[507 - 496] = \infty + 0.69 = \infty$ KSF Toe

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{Uplift}$$

$$= \frac{239.81 + 286}{(13)(30.46)} \pm \frac{239.81\left(\frac{33.46}{2} + 6.22\right) - 286\left(\frac{33.46}{2} - 3.5\right)}{(13)(30.46)^2/6} + \text{Uplift}$$

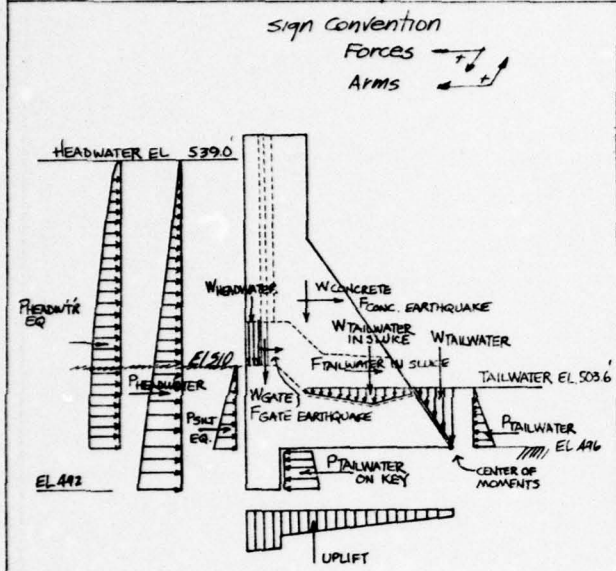
$= 1.32 - 0.88 + 2.81 = 0.44 + 2.81 = 3.25$ KSF Heel

$= 1.32 + 0.88 + 0.69 = 2.20 + 0.69 = 2.89$ KSF Toe

Figure A12. (Sheet 5 of 5)

SUBJECT: Brandon Road Sluice-Gate Monolith
Normal Operation + Earthquake condition

COMPUTED BY: DATE:
CHECKED BY: DATE:



ITEM	FACTORS	F_V	F_H	ARM	MOMENTS
$W_{CONCRETE}$	$[.1536]\big((10)(16)+(1/2)(8)(1)+(8)(9)+(1/2)(8.67)(8)+(1/2)(6.67)(10)+(2)(10)+(1/2)(6.43)(8)+(1/2)(6.43)(1)+(5)(4)+(27.33)(4)+(1/2)(3.33)(5)+(10)(4.9)+(1/2)(6.1)(7)+(6.1)(3)+(1/2)(3)(8.5)+(1/2)(1)(7.83)\big)(13)-(8.66)(1.302)(25)-(6)(2)(25)+(1/2)(1)(8)(3.5)(2)+(7)(8)(3.5)(2)+(7)(6.6)(1/2)(2)\left(\frac{3.5+2.44}{2}\right)+(1/2)(6)(7)(2)\left(\frac{3.5+2.44}{2}\right)+(2)(3.6)(7)\left(\frac{2.58+3.07}{2}\right)+(2)(3)(8.5)(.5)\left(\frac{3.07+2.09}{2}\right)+(2)(5)(8.06)\left(\frac{1.89+2.58}{2}\right)+(1/2)(8.06)(1)\left(\frac{1.89+2.58}{2}\right)+(2)(7)(4.67)(1/2)\left(\frac{1.04+1.89}{2}\right)+(2)(7.83)(1)(1/2)\left(\frac{1.04+2.09}{2}\right)+(3.16)(2)(2)\left(\frac{1.89+2.09}{2}\right)-(2)(1.33)(1.302)(8)$	1275.22		21.33	27196.12
W_{GATE}	VALUE TAKEN FROM APPENDIX E, BRANDON RD. STABILITY ANALYSIS DAM MASONRY GATE + MISC. STEEL =	5.00		28.32	141.60
$W_{HEADWATER}$	$[.0625](8)(2.34)(6)$	7.02		29.49	207.02
$W_{TAILWATER}$	$[.0625](1/2)(503.6-496)(3.33)(13)$	10.28		1.11	11.42
$W_{TAILWATER\ IN\ SLUICE}$	$[.0625]\big((8)(2.34)(6)+(1/2)(8.5)(3.6)\left(\frac{8.85+6.7}{2}\right)+(1/2)(7.83)(3.6)\left(\frac{10.92+8.85}{2}\right)+(1/2)(2.6)(6.1)\left(\frac{10.92+8.85}{2}\right)\big)$	31.17		16.15	503.40
UPLIFT	$[(1/2)(5)(2.938)+(1/2)(5)(2.619)+(1/2)(25.66)(2.114)+(1/2)(25.66)(0.475)][13]$	-612.42		19.28	-11980.98
$P_{HEADWATER}$	$[.0625](539-492)^2(1/2)(13)$		-897.56	11.67	-10474.53
$P_{TAILWATER}$	$[.0625](503.6-496)^2(1/2)(13)(0.6)$		14.08	2.53	35.62
$P_{TAILWATER\ ON\ KEY}$	$[(2.114)(1/2)(4)+(2.619)(1/2)(4)][13]$		123.05	-2.06	-254.23
	EARTHQUAKE FORCES				
FORCE CONC. EARTHQUAKE	$(.05)(1275.22)$		-63.76	17.63	-1124.09
FORCE GATE EARTHQUAKE	$(.05)(5)$		-0.25	18.00	-4.50
FORCE TAILWATER IN SLUICE	$(.05)(31.17)$		-1.56	7.00	-10.92
$P_{SILT\ EARTHQUAKE}$	$[.0203](510-496)^2(.5)(.54)(13)$		-13.97	5.21	-72.78
$P_{HEADWATER\ EARTHQUAKE}$	$(2/3)(51.03)(0.05)(38)\sqrt{38^2}(13)/1000$		-31.93	20.20	-645.00
		716.27	-871.90		3528.15

Figure A13. Stability analysis, sluice-gate monolith, normal operation plus earthquake (Sheet 1 of 5)

SUBJECT: Brandon Road Sluice-Gate Monolith Normal Operation + Earthquake condition	COMPUTED BY: CHECKED BY:	DATE: DATE:

FIRST TRIAL SOLUTION TO DETERMINE IF PART OF THE BASE IS NOT IN COMPRESSION. IF SO, THEN FULL UPLIFT MUST BE APPLIED TO NON-COMPRESSIVE AREAS

OVERTURNING (FIRST TRIAL SOLUTION)

Resultant location from Moment Center = $\frac{3528.15}{716.27} = 4.93$

Base width = 30.66'

% Effective base = $\frac{(3)(4.93)}{30.66} = 48.24\%$

Figure A13. (Sheet 2 of 5)

SUBJECT: Brandon Road - Sluice - Gate Monolith
Normal Operation + Earthquake

COMPUTED BY: | CHECKED BY: | DATE: | DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(-4.21)}{30.66} \rightarrow 0\ \%$$

Prestress Needed

$$\frac{309.85(4.21)}{30.66 - 3.5} = 48 \text{ Kips}$$

Shear Friction Safety Factor $(S_{s\text{-}f}) = \frac{8871}{849} = 10.45 > 4.0$

Without $\left\{\text{Strut Resistance}\right\} = \frac{1331}{849} = 1.57$

Without $\left\{\begin{matrix}\text{Strut Resistance}\\ \text{Cohesion}\\ \text{Key Resistance}\end{matrix}\right\} = \frac{227}{849} = 0.32$

SLIDING (Before Prestressing)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$$= 1.1\sqrt{f'_c}\,A_{key} + [F_V - \text{wt of Key}]\tan 45° + cA_{BASE} + 2sdw$$

$$= 1.1\sqrt{5430}\,(5)(13)\left(\frac{144}{1000}\right) + [309.85 - 0.15(5)(4)(13)](1) + 0.86(25.66)(13) + 2(58)(5)(13)$$

$$= 773 + 271 + 287 + 7540 = 8871 \text{ Kips}$$

Driving Force = $F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$

$$= 871.90 - 0.0625\left[539 - \frac{492+496}{2}\right](4)(13) + 123.05$$

$$= 848.7 \text{ Kips}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance

$$= 271 \tan 26° + 7540$$

$$= 7672 \text{ Kips}$$

$$S_{s\text{-}f} = \frac{7672}{849} = 9.04 > 1.5$$

Without $\left\{\text{Strut Resistance}\right\} = \frac{132}{849} = 0.16$

A59

Figure A13. (Sheet 3 of 5)

SUBJECT: Brandon Road - Sluice-Gate Monolith Normal Operation + Earthquake	COMPUTED BY: CHECKED BY:	DATE: DATE:

Shear Friction Safety Factor (S_{s-f}) = $\frac{9157}{849}$ = 10.79 > 4.0

Without {Strut Resistance} = $\frac{1617}{849}$ = 1.90

Without {Strut Resistance, Cohesion, Key Resistance} = $\frac{557}{849}$ = 0.66

Full Uplift Applied Under non-Compressive Area of Base.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 1.1\sqrt{f'_c}\,A_{key} + [F_V + PS - \text{Wt of Key}]\tan 45° + cA_{base} + 2sd\cdot w$

$= 1.1\sqrt{5430}\,(5)(13)\left(\frac{144}{1000}\right) + [309.85 + 286 - 0.15(5)(4)(13)](1) + 0.86(25.66)(3) + 2(58)(5)(13)$

$= 773 + 557 + 287 + 7540 = 9157$ Kips

Driving Force = $F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$

$= 871.90 - 0.0625\left[539 - \frac{492 + 496}{2}\right](4)(13) + 1230.5$

$= 848.7$ Kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance

$= 557 \tan 26° + 7540$

$= 7812$ Kips

$S_{s-f} = \frac{7812}{849} = 9.20 > 1.5$

Without {Strut Resistance} = $\frac{272}{849}$ = 0.32

Figure A13. (Sheet 4 of 5)

SUBJECT	COMPUTED BY	DATE
Brandon Road - Sluice-Gate Monolith Normal Operation + Earthquake	CHECKED BY:	DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{Uplift}$$

$$= 0. + 0.0625[539 - 496] = 0. + 2.69 = 2.69 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= \frac{2(309.85)}{3(0)} + 0.0625[503.6 - 496] = \infty + 0.48 = \infty \text{ KSF} \quad \underline{\text{Toe}}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{Uplift}$$

$$= \frac{309.85 + 286}{(13)(30.46)} \pm \frac{309.85\left(\frac{30.46}{2} + 4.21\right) - 286\left(\frac{30.46}{2} - 3.5\right)}{(13)(30.46)^2/6} + \text{Uplift}$$

$$= 1.49 - 1.31 + 2.69 = 0.18 + 2.69 = 2.87 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= 1.49 + 1.31 + 0.48 = 2.80 + 0.48 = 3.28 \text{ KSF} \quad \underline{\text{Toe}}$$

Figure A13. (Sheet 5 of 5)

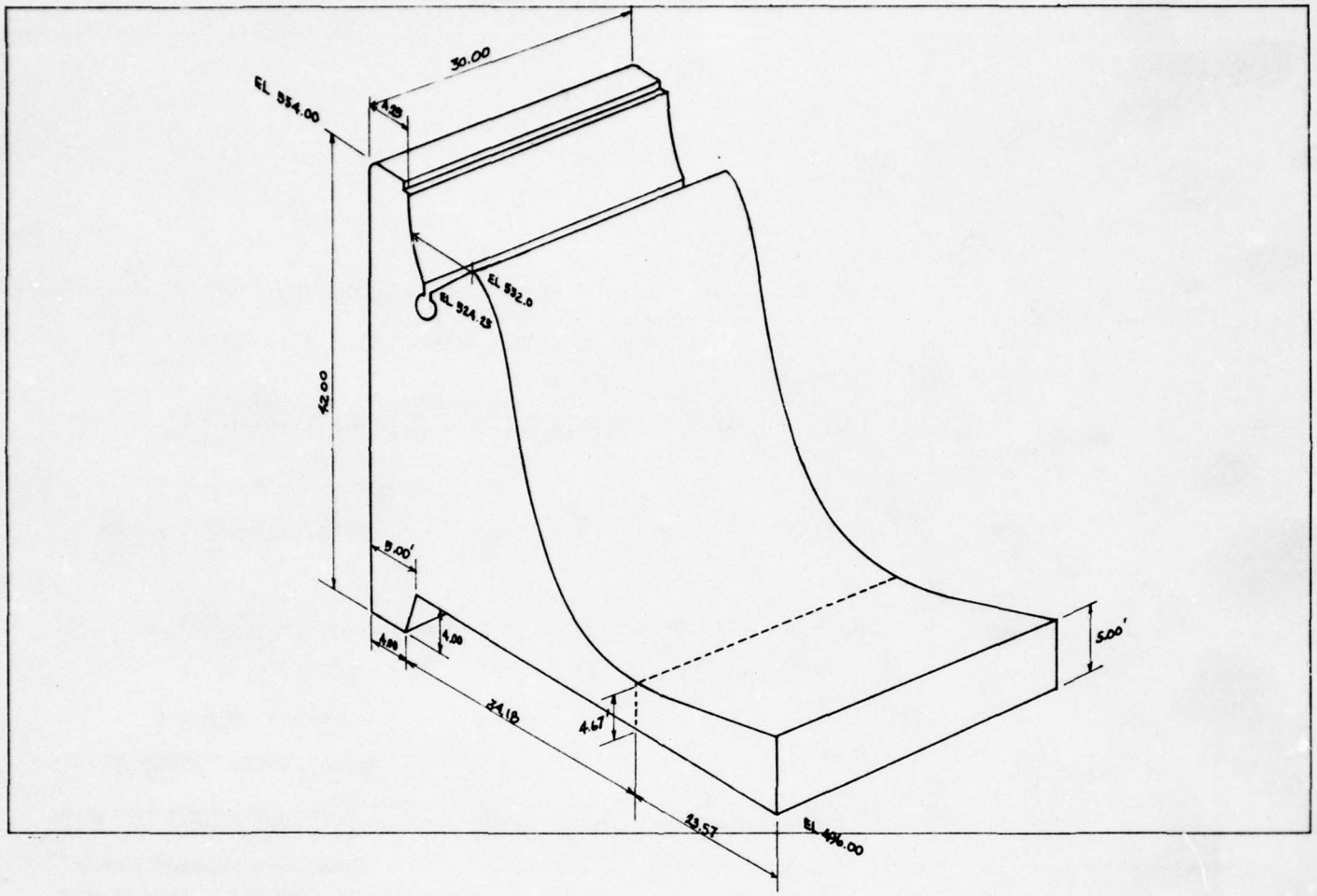


Figure A14. Typical ice-chute monolith

SUBJECT: Brandon Road Ice Chute Monolith — Normal Operation

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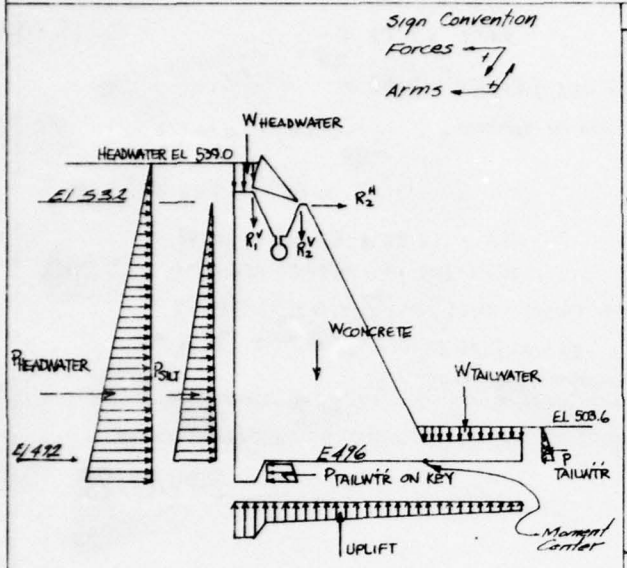


ITEM	FORCES	F_V	F_H	ARM	MOMENTS
$W_{CONCRETE}$	[1520][(4.25)(534 - 524.25) + (½)(2.17)(534 - 524.25) + (½)(7.415)(532 - 524.25) + (14.5)(524.25 - 496) + (2.08)(532 - 496) + (4)(496 - 492) + (½)(1)(496 - 492) + (½)(21.6)(532 - 496) + (½)(23.57)(501 - 500.67) + (23.57)(500.67 - 496) + (½)(6.5)(500.67 - 496) − (π/4)(2.5)²]	+166.64		+19.82	+3302.80
$W_{HEADWATER}$	[.0625](4.25)(539 - 534)	+ 1.33		+36.06	+ 47.96
$W_{TAILWATER}$	[.0625][(½)(23.57)(503.6 - 501) + (½)(23.57)(503.6 - 500.67) + (½)(3.09)(503.6 - 500.67)]	+ 4.36		-10.73	- 46.78
R_1^V	} VALUES CALCULATED FROM THE SUMMATION OF FORCES ON THE GATE: GATE WEIGHT, WATER PRESSURE, WATER WEIGHT, ICE PRESSURE	+ 0.29		+33.93	+ 9.91
R_2^V		+ 0.75		+22.62	+ 16.90
UPLIFT	(½)(.475)(56.75) + (½)(2.41)(56.75) + (½)(1)(2.41) + (½)(1)(2.8) + (½)(4)(2.8) + (½)(4)(2.937)	-95.94		+14.75	- 1415.12
$P_{HEADWATER}$	[.0625][(539 - 534)(534 - 492) + (½)(534 - 492)²]		-68.25	+11.35	- 774.64
$P_{TAILWATER}$	[.0625][(503.6 - 496)²(½)(0.6)]		+ 1.08	+2.53	+ 2.74
$P_{TAILWATER\ ON\ KEY}$	(2.80)(4)(½) + (2.41)(4)(½)		+ 10.42	- 2.05	- 21.36
P_{SILT}	[.0203](532 - 496)²(.5)(½)		- 6.58	+12.00	- 78.96
R_2^H	[.0625](539 - 534)²(.5)		- 0.78	+36.00	- 28.12
		77.43	64.11		1015.33

Resultant Location from Moment Center = $\frac{1015.53}{77.43}$ = 13.11'

e = 23.57 + 13.11 = 36.68 (from downstream toe)

Base Width = 61.75'

A63

Figure A15. Stability analysis, ice-chute monolith, total monolith, normal operation (Sheet 1 of 5)

SUBJECT	COMPUTED BY	DATE
Brandon Road - ICE – CHUTE MONOLITH NORMAL OPERATION, TOTAL MONOLITH	CHECKED BY	DATE

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{(3)(36.68)}{61.75} = 100.0\ \%$$

$$\text{Shear Friction Safety Factor } (S_{s\text{-}f}) = \frac{743.73}{63.28} = 11.75\ 740$$

$$\text{Without } \{\text{Strut Resistance}\}\ S_{s\text{-}f} = \frac{163.73}{63.28} = 2.59$$

$$\text{Without } \{\text{Strut Resistance, Cohesion, Key Resistance}\}\ S_{s\text{-}f} = \frac{74.73}{63.28} = 1.18$$

SLIDING

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + $V \tan 45^\circ$ + CA + Strut Resistance

$$= 1.1\sqrt{f'_c}\ \text{Area} + [F_V - \text{WT OF KEY}]\tan 45^\circ + C\ \text{Area} + 2S_d W$$

$$= 1.1\sqrt{5830}\,(5)(1)\left(\frac{144}{1000}\right) + [77.43 - (0.15)(4.5)(4)(1)]\tan 45^\circ + (0.86)(33.18)(1) + (2)(58)(5)(1)$$

$$= 60.47 + 74.73 + 28.53 + 580$$

$$= 743.73 \text{ kips}$$

$$\text{Driving Force} = F_H - F_{\text{HEADWTR ON KEY}} + F_{\text{TAILWTR ON KEY}}$$

$$= 64.11 - 0.0625\left[539 - \frac{492+496}{2}\right](4)(1) + 10.42$$

$$= 63.28 \text{ kips}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = $V \cdot \tan\phi$ + STRUT RESISTANCE

$$= 74.73 \tan 26^\circ + 580$$

$$= 616.45 \text{ kips}$$

$$S_{s\text{-}f} = \frac{616.45}{63.28} = 9.74\ 715$$

$$\text{Without } \{\text{Strut Resistance}\}\ S_{s\text{-}f} = \frac{36.45}{63.28} = 0.58$$

Figure A15. (Sheet 2 of 5)

SUBJECT	COMPUTED BY:	DATE
Brandon Road ICE-CHUTE MONOLITH NORMAL OPERATION, TOTAL MONOLITH	CHECKED BY:	DATE:

BASE PRESSURES

Without Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{UPLIFT}$$

$$= \frac{99.43}{61.75} + \frac{99.43\left(\frac{61.75}{2} - 36.68\right)}{(1)(61.75)^2/6} + 0.0625\,[539 - 496] = 1.25 + 0.91 + 2.69 = 4.65 \quad \underline{\text{HEEL}}$$

$$= \frac{99.43}{61.75} - \frac{99.43\left(\frac{61.75}{2} - 36.68\right)}{(1)(61.75)^2/6} + 0.0625\,[503.6 - 496] = 1.25 - 0.91 + 0.48 = 1.02 \quad \underline{\text{TOE}}$$

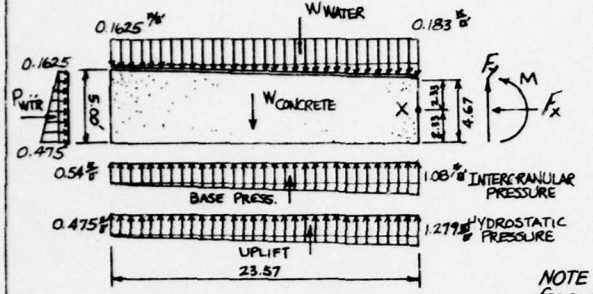
Figure A15. (Sheet 3 of 5)

SUBJECT: Brandon Road Ice-Chute Monolith
Determination of concrete stresses at minimum cross section

COMPUTED BY: DATE:
CHECKED BY: DATE:

Monolith minimum cross section is directly above, center of moments - concrete thickness = 4.67'

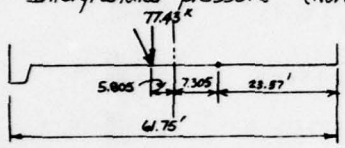
Σ Forces to one side of the cross section



Area = (1)(61.75) = 61.75 ft.sq.

$I = \frac{bh^3}{12} = \frac{(1)(61.75)^3}{12} = 19621.38\ ft^4$

Intergranular pressure (Normal op.)



$\sigma = \frac{P}{A} \pm \frac{Mc}{I}$

$= \frac{77.43}{61.75} \pm \frac{(77.43)(23.57 + 13.11 - \frac{61.75}{2})\frac{61.75}{2}}{19621.38}$

$= 1.957^{KSF} \mp 0.543^{KSF}$

NOTE: In summation of forces on section, neglect frictional resistance because the amount taken by the foundation is indeterminate and neglecting them is on the conservative side

Tailwater Pressure

$P_{501} = (503.6 - 500)(0.0625) = 0.1625\ ^k/_{ft}$

$P_{500.67} = (503.6 - 500.67)(0.0625) = 0.183\ ^k/_{ft}$

$P_{496} = (503.6 - 496)(0.0625) = 0.475\ ^k/_{ft}$

ITEM	FORCE	F_v	F_H	ARM (ft)	MOMENT (k-ft)
$W_{concrete}$	4.67(23.57)(1)(0.1536)	16.91		$\frac{23.57}{2} = 11.79$	199.37
	$(\frac{1}{2})(5-4.67)(23.57)(1)(0.1536)$	0.61		$\frac{2}{3}(23.57) = 15.71$	9.43
W_{water}	(0.1625)(23.57)(1)	3.83		$\frac{23.57}{2} = 11.79'$	45.16
	$\frac{1}{2}(0.183 - 0.1625)(23.57)$	0.24		$\frac{2}{3}(23.57) = 7.86$	1.89
Uplift	(0.475)(23.57)(1)	-11.20		$\frac{23.57}{2} = 11.79'$	-132.05
	$(\frac{1}{2})(1.279 - 0.475)(23.57)(1)$	-9.48		$\frac{1}{3}(23.57) = 7.86'$	-74.51
Base Pressure	(0.54)(23.57)(1)	-12.73		$\frac{23.57}{2} = 11.79'$	-150.09
	$(\frac{1}{2})(1.08 - 0.54)(23.57)(1)$	-6.36		$\frac{1}{3}(23.57) = 7.86'$	-49.99
Σ_i / W_{water}	(0.1625)(5)(1)		-0.81	$\frac{5}{2} \cdot \frac{4.67}{2} = 0.165$	-0.13
	$\frac{1}{2}(0.475 - 0.1625)(5)(1)$		-0.78	$\frac{2}{3} \cdot \frac{4.67}{3} = 0.949$	+0.74
		-18.19	-1.59		-150.18

$F_y = 18.19^k$

$F_x = 1.59^k$

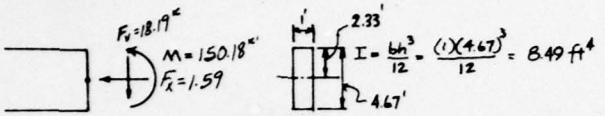
$M = 150.18^{k'}$

A66

Figure A15. (Sheet 4 of 5)

SUBJECT: Brandon Road – Ice-Chute Monolith Determination of Concrete stresses at minimum cross section	COMPUTED BY: CHECKED BY:	DATE: DATE:

STRESS ON CROSS SECTION



$I = \frac{bh^3}{12} = \frac{(1)(4.67)^3}{12} = 8.49\ ft^4$

$\sigma = \frac{P}{A} \pm \frac{Mc}{I}$

$P = F_x = 1.59^K$
$c = 4.67/2 = 2.33'$
$A = (4.67)(1) = 4.67\ \square'$

$\sigma = \frac{1.59}{4.67} \pm \frac{(150.18)(2.33)}{8.49}$

$\sigma_{max} = .34 + 41.22 = 41.56$ KSF or 289 psi (compression)
$\sigma_{min} = .34 - 41.22 = 40.88$ KSF or − 284 psi (Tension)

BOTTOM FACE OF SECTION SUBJECTED TO
284 PSI TENSILE STRESS

SECTION IS OVERSTRESSED

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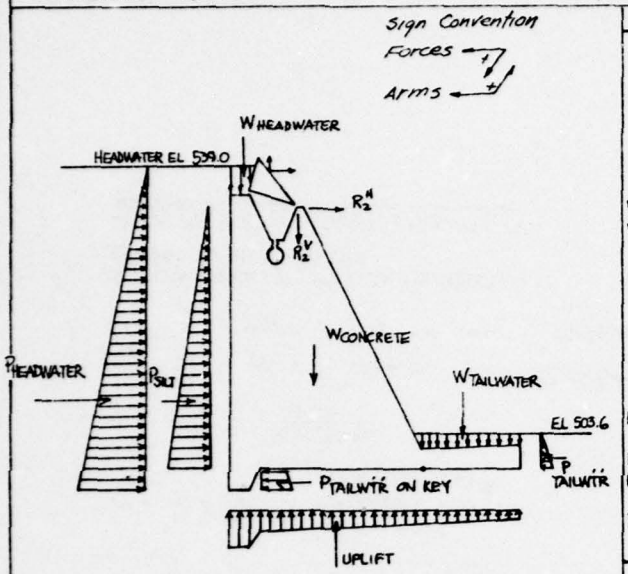
Figure A15. (Sheet 5 of 5)

SUBJECT: Brandon Road Ice-Chute Monolith
Normal Operation + Ice Condition (with gate raised)

COMPUTED BY:
CHECKED BY:
DATE
DATE:



ITEM	FORCES	F_V	F_H	ARM	MOMENTS
$W_{CONCRETE}$	$[.1520][(4.25)(534-524.25)+(1/2)(2.17)(534-524.25)+(1/2)(7.415)(532-524.25)+(14.5)(524.25-496)+(2.08)(532-496)+(4)(496-492)+(1/2)(1)(496-492)+(1/2)(2.16)(532-496)+(1/2)(23.57)(501-500.67)+(23.57)(500.67-496)+(1/2)(6.5)(500.67-496)-(11/4)(2.5)^2]$	+166.64		+19.82	+3302.80
$W_{HEADWATER}$	$[.0625](4.25)(539-334)$	+ 1.33		+36.06	+ 47.96
$W_{TAILWATER}$	$[.0625][(1/2)(23.57)(503.6-501)+(1/2)(23.57)(503.6-500.67)+(1/2)(3.09)(503.6-500.67)]$	+ 4.36		-10.73	- 46.78
R_2^H	VALUES CALCULATED FROM THE SUMMATION OF FORCES ON THE GATE. GATE WEIGHT, WATER PRESSURE, WATER WEIGHT, ICE PRESSURE		- 2.69	+36.00	- 96.84
R_2^V		+ 2.48		+22.62	+ 56.10
UPLIFT	$(1/2)(.475)(56.75)+(1/2)(2.41)(56.75)+(1/2)(1)(2.41)+(1/2)(1)(2.8)+(1/2)(4)(2.8)+(1/2)(4)(2.937)$	-95.94		+14.75	- 1415.12
$P_{HEADWATER}$	$[.0625][(539-534)(534-492)+(1/2)(534-492)^2]$		-68.25	+11.35	- 774.6
$P_{TAILWATER}$	$[.0625][(503.6-496)^2(1/2)(0.6)]$		+ 1.08	+2.53	+ 2.74
$P_{TAILWATER\ ON\ KEY}$	$(2.80)(4)(1/2)+(2.41)(4)(1/2)$		+ 10.42	- 2.05	- 21.36
P_{SILT}	$[.0203](532-496)^2(.5)(1/2)$		- 6.58	+12.00	- 78.96
		78.87	66.02		975.90

Figure A16. Stability analysis, ice-chute monolith, total monolith, normal operation plus ice (Sheet 1 of 4)

SUBJECT: Brandon Road Ice-Chute Monolith
Normal Operation + Ice Condition (with gate raised)

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

FIRST TRIAL SOLUTION TO DETERMINE IF PART OF THE BASE IS NOT IN COMPRESSION. IF NOT, FULL UPLIFT MUST BE APPLIED UNDER NON-COMPRESSIVE AREAS

OVERTURNING

Resultant location from moment center

$= \frac{+975.90}{78.87} = 12.37$ $\quad e = 23.57 + 12.37 = 35.94$

Base width = 61.75

% Effective Base = $\frac{(3)(35.94)}{61.75} = 100.0\ \%$

BASE PRESSURES

$$\sigma = \frac{P}{A} \pm \frac{Mc}{I}$$

$$= \frac{975.90}{61.75} \pm \frac{(975.90)(23.57 + 12.37 - \frac{61.75}{2})(\frac{61.75}{2})}{\frac{(1)(61.75)^3}{12}}$$

$\sigma_{min} = 15.80 - 7.77 = 8.02$ KSF

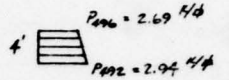
$\sigma_{max} = 15.80 + 7.77 = 23.58$ KSF

SLIDING

ΣF_V above base = $78.87 - [(4)(4) + (\frac{1}{2})(4)(1)](.1520)$
$= 78.87 - 2.736$
$= 76.13^{K}$

ΣF_H above base = 66.02 + Ptailwater on key − Pheadwater below El 496

Pheadwater below El 496



$(2.69)(4) = 10.76$
$(\frac{1}{2})(0.25)(4) = 0.50$
11.26^{K}

$\Sigma F_H = 66.02 + 10.42 - 11.26 = 65.18^{K}$

Resisting force = $\Sigma F_V \tan 26^\circ$ + key resistance* + foundation resistance
$= 76.13(.4877) + (5)(1)(12.09) + (2)(7.86)(5)$
$= 37.13 + 60.45 + 78.6$
$= 176.18$

*unit shear = $1.1\sqrt{f'_c} = 1.1\sqrt{5830}$ psi

Driving force = $\Sigma F_H = 65.18^{K}$

SAFETY FACTOR = $\frac{\text{Resisting force}}{\text{Driving force}} = \frac{176.18}{65.18} = 2.70$

Figure A16. (Sheet 2 of 4)

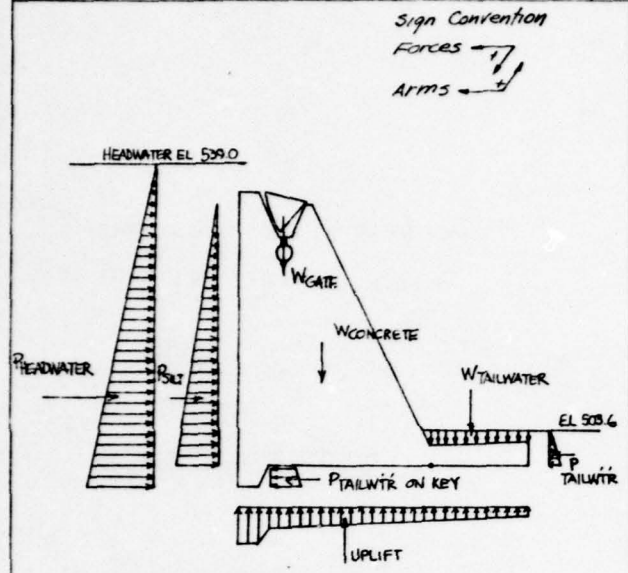
SUBJECT: Brandon Road Ice-Chute Monolith
Normal Operation + Ice Condition (with gate lowered)

COMPUTED BY:

CHECKED BY:

DATE:

DATE:



ITEM	FORCES	F_V	F_H	ARM	MOMENTS
$W_{CONCRETE}$	[.1520][(4.75)(534-524.25) + (½)(2.17)(534-524.25) + (½)(7.415)(532-524.25) + (14.5)(524.25-496) + (2.08)(532-496) + (4)(496-492) + (½)(1)(496-492) + (½)(2.16)(532-496) + (½)(23.57)(501-500.67) + (23.57)(500.67-496) + (½)(6.5)(500.67-496) - (π/4)(2.5)²]	+166.64		+19.82	+3302.80
$W_{TAILWATER}$	[.0625][(½)(23.57)(503.6-501) + (½)(23.57)(503.6-500.67) + (½)(3.09)(503.6-500.67)]	+ 4.36		-10.73	- 46.78
W_{GATE}	VALUE TAKEN FROM APPENDIX E, BRANDON ROAD STABILITY ANALYSIS OF LOCK AND DAM MASONRY	+ 0.72		+26.62	+ 19.16
UPLIFT	(½)(.475)(56.75) + (½)(2.41)(56.75) + (½)(1)(2.41) + (½)(1)(2.8) + (½)(4)(2.8) + (½)(4)(2.937)	-95.94		+14.75	- 1415.12
$P_{HEADWATER}$	[.0625][(539-534)(534-492) + (½)(534-492)²]		-68.25	+11.35	- 774.64
$P_{TAILWATER}$	[.0625][(503.6-496)²(½)(0.6)]		+ 1.08	+2.53	+ 2.74
$P_{TAILWATER\ ON\ KEY}$	(2.80)(4)(½) + (2.41)(4)(½)		+ 10.42	- 2.05	- 21.36
P_{SILT}	[.0203](532-496)²(.5)(½)		- 6.58	+12.00	- 78.96
		+75.78	-63.33		+ 987.84

Figure A16. (Sheet 3 of 4)

SUBJECT: Brandon Road - Ice-Chute Monolith
Normal Operation + Ice Condition (with gate lowered)

COMPUTED BY: DATE:

CHECKED BY: DATE:

FIRST TRIAL SOLUTION TO DETERMINE IF PART OF THE BASE IS NOT IN COMPRESSION. IF NOT, FULL UPLIFT MUST BE APPLIED UNDER NON-COMPRESSIVE AREAS

OVERTURNING

Resultant location from moment center

$= \frac{+987.84}{75.78} = 13.04$ $\quad e = 23.57 + 13.04 = 36.61$

Base width = 61.75

% Effective Base $= \frac{(3)(36.61)}{61.75} = 100.00\%$

BASE PRESSURES

$$\sigma = \frac{P}{A} \pm \frac{Mc}{I}$$

$$= \frac{987.84}{61.75} \pm \frac{(987.84)\left(23.57 + 13.04 - \frac{61.75}{2}\right)\left(\frac{61.75}{2}\right)}{\frac{(1)(61.75)^3}{12}}$$

$\sigma_{min} = 16.00 - 8.91 = 7.08$ KSF

$\sigma_{max} = 16.00 + 8.91 = 24.91$ KSF

SLIDING

ΣF_V above base $= 75.78 - [(4)(4) + (\frac{1}{2})(4)(1)](.1520)$
$= 75.78 - 2.736$
$= 73.04$ K

ΣF_H above base = 63.33 + Ptailwater on key − Pheadwater below El 496

Pheadwater below El 496



$(2.69)(4) = 10.76$
$(\frac{1}{2})(0.25)(4) = 0.50$
11.26 K

$\Sigma F_H = 63.33 + 10.42 - 11.26 = 62.48$ K

Resisting force = $\Sigma F_V \tan 26° +$ key resistance* + foundation resistance
$= 73.04(.4877) + (5)(1)(12.09) + (2)(7.86)(5)$
$= 35.62 + 60.45 + 78.6$
$= 174.67$ K

*Unit shear = $1.1\sqrt{f'_c} = 1.1\sqrt{5830}$ psi

Driving force = $\Sigma F_H = 62.48$ K

SAFETY FACTOR = $\frac{\text{Resisting force}}{\text{Driving force}} = \frac{174.67}{62.48} = 2.80$

Figure A16. (Sheet 4 of 4)

SUBJECT: Brandon Rd Ice-Chute Monolith
Flood Condition

COMPUTED BY:

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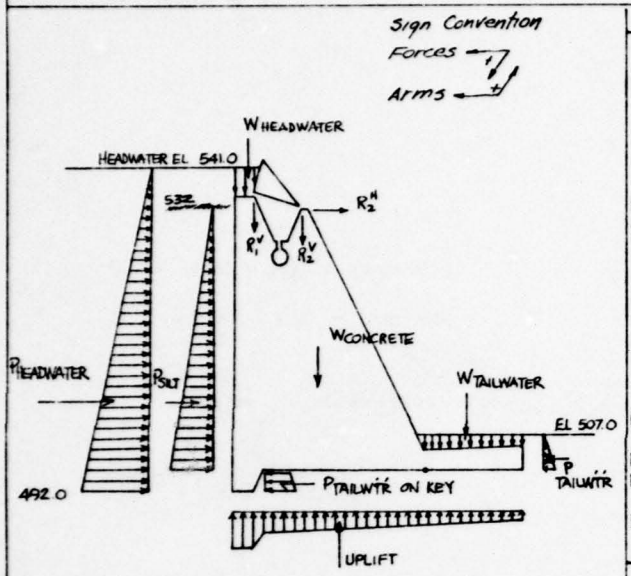
DATE:



ITEM	FORCES	F_V	F_H	ARM	MOMENTS
$W_{CONCRETE}$	[.1520][(4.25)(534-524.25) + (½)(2.17)(534-524.25) + (½)(7.415)(532-524.25) + (14.5)(524.25-496) + (2.08)(532-496) + (4)(496-492) + (½)(1)(496-492) + (½)(2.16)(532-496) + (½)(23.57)(501-500.67) + (23.57)(500.67-496) + (½)(6.5)(500.67-496) - (π/4)(2.5)²]	+166.64		+19.82	+3302.80
$W_{HEADWATER}$	[.0625](4.25)(541-534)	+ 1.86		+36.06	+ 67.07
$W_{TAILWATER}$	[.0625][(½)(23.57)(507.0-501) + (½)(23.57)(507.0-500.67) + (½)(3.09)(507.0-500.67)]	+ 10.37		- 9.96	- 103.28
R_1^V	VALUES CALCULATED FROM THE SUMMATION OF FORCES ON THE GATE: GATE WEIGHT, WATER PRESSURE, WATER WEIGHT, ICE PRESSURE	+ 0.29		+33.93	+ 9.84
R_2^V		+ 1.25		+22.62	+ 28.28
UPLIFT	(.687)(56.75) + (½)(1.86)(56.75) + (½)(1)(.385) + (4)(3.062)	-105.80		+13.81	-1416.10
$P_{HEADWATER}$	[.0625][(541-534)(534-492) + (½)(534-492)²]		- 73.50	+11.75	-863.63
$P_{TAILWATER}$	[.0625][(507.0-496)²(½)(0.6)]		+ 2.27	+ 3.67	+ 8.33
$P_{TAILWATER\ ON\ KEY}$	(2.55)(4) + (.385)(4)(½)		+ 10.95	- 2.05	- 22.44
P_{SILT}	[.0203](532-496)²(.5)(½)		- 6.58	+12.00	- 78.96
R_2^H	[.0625](541-534)²(.5)		- 1.53	+36.00	- 55.08
		74.61	-68.39		876.83

Figure A17. Stability analysis, ice-chute monolith, total monolith, flood condition (Sheet 1 of 2)

SUBJECT	COMPUTED BY	DATE
Brandon Road Ice-Chute Monolith Flood Condition	CHECKED BY	DATE

FIRST TRIAL SOLUTION TO DETERMINE IF PART OF THE BASE IS NOT IN COMPRESSION. IF NOT, FULL UPLIFT MUST BE APPLIED UNDER NON-COMPRESSIVE AREAS

OVERTURNING

Resultant location from moment center

$= \frac{+876.83}{74.61} = 11.75$ $\quad e = 23.57 + 11.75 = 35.32$

Base width = 61.75

% Effective Base = $\frac{(3)(35.32)}{61.75} = 100.0\%$

BASE PRESSURES

$$\sigma = \frac{P}{A} \pm \frac{Mc}{I}$$

$$= \frac{876.83}{61.75} \pm \frac{(876.83)(23.57+11.75-\frac{61.75}{2})(\frac{61.75}{2})}{\frac{(1)(61.75)^3}{12}}$$

$\sigma_{min} = 14.20 - 6.13 = 8.07$ KSF

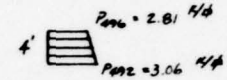
$\sigma_{max} = 14.20 + 6.13 = 20.33$ KSF

SLIDING

ΣF_V above base = $74.61 - [(4)(4) + (\frac{1}{2})(4)(1)](.1520)$
$= 74.61 - 2.736$
$= 71.87$ K

ΣF_H above base = 68.39 + Ptailwater on key - Pheadwater below El 496

Pheadwater below El 496



$(2.81)(4) = 11.24$
$(\frac{1}{2})(0.25)(4) = 0.50$
11.74 K

$\Sigma F_H = 68.39 + 10.95 - 11.74 = 67.59$ K

Resisting force = ΣF_V tan 26° + key resistance* + foundation resistance
$= 71.87(.48773) + (5)(1)(12.09) + (2)(7.86)(5)$
$= 35.05 + 60.45 + 78.60$
$= 174.10$ K

* unit shear = $1.1\sqrt{f'_c} = 1.1\sqrt{5830}$ psi

Driving force = $\Sigma F_H = 67.59$ K

SAFETY FACTOR = $\frac{174.10^K}{67.59^K} = 2.58$

Figure A17. (Sheet 2 of 2)

SUBJECT: Brandon Road - Ice-Chute Monolith
Normal Operation - Overstressed Toe eliminated

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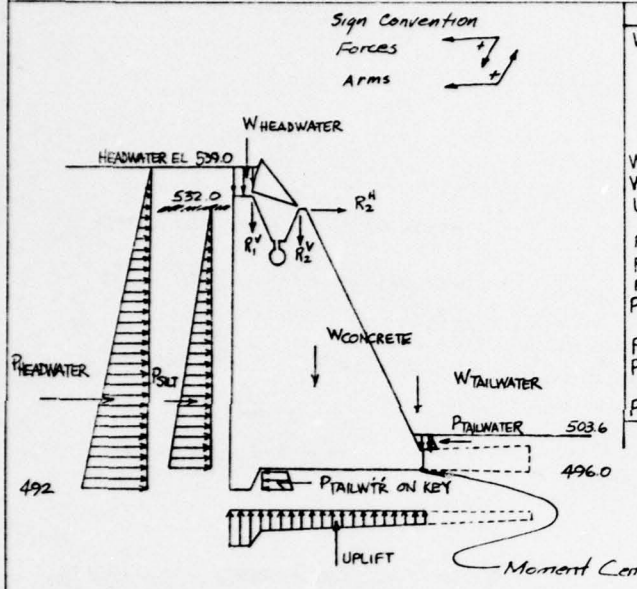


ITEM	FACTORS	F_V	F_H	ARM	MOMENT
$W_{CONCRETE}$	[.1520][(4.25)(534 - 524.25) + (½)(2.17)(534 - 524.25) + (½)(7.415)(532 - 524.25) + (14.5)(524.5 - 496) + (2.08)(532 - 496) + (4)(496 - 492) + (½)(1)(496 - 492) + (½)(21.6)(532 - 496) + (½)(6.5)(500.67 - 496) - (π/4)(2.6)²]	+149.31		+20.73	+3095.20
$W_{HEADWATER}$	[.0625](4.25)(539 - 534)	+1.33		+36.06	+ 47.96
$W_{TAILWATER}$	[.0625](½)(3.09)(2.93)(.6)	+0.17		+1.03	+ 0.17
UPLIFT	(2.8)(4) + (½)(.137)(4) + (½)(.39)(1) + (1)(2.41) + (1.27)(33.18) + (½)(1.133)(33.18)	- 75.25		+21.55	-1621.64
R_1^V	VALUES CALCULATED FROM THE SUMMATION OF GATE WEIGHT, WATER PRESSURE AND WEIGHT FORCES ON THE GATE.	+0.29		+33.93	+ 9.84
R_2^V		+0.75		+22.62	+ 16.97
R_2^H			- 0.78	+36.00	- 28.08
$P_{HEADWATER}$	[.0625][(539 - 534)(534 - 492) + (½)(534 - 492)²]		-68.25	+11.35	- 774.64
P_{SILT}	[.0203](½)(532 - 496)²(.5)		- 6.58	+12.00	- 78.96
$P_{TAILWATER\ ON\ KEY}$	(2.8)(4)(½) + (2.41)(½)(4)		+10.42	- 2.05	- 21.36
$P_{TAILWATER}$	[.0625](2.93)²(.5)		+ 0.27	+ 5.63	+ 1.52
		+ 76.60	-64.92		+646.98

Figure A18. Stability analysis, ice-chute monolith, normal operation (Sheet 1 of 4)

SUBJECT: Brandon Road - ICE - CHUTE MONOLITH
NORMAL OPERATION - OVERSTRESSED TOE ELIMINATED

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(5.57)}{38.18} = 43.77\ \%$$

Prestress Needed

$$= \frac{55.98\left(\frac{38.18}{3} - 5.57\right)}{\left(\frac{2}{3}\right)38.18 - 3.5} = 18.18 \text{ KIPS/ft of MONOLITH}$$

$$= 545 \text{ KIPS/MONOLITH}$$

Shear Friction Safety Factor $(S_{s\text{-}f}) = \frac{722.08}{64.09} = 11.27 > 4.0$

Without {Strut Resistance} $S_{s\text{-}f} = \frac{142.08}{64.09} = 2.22$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s\text{-}f} = \frac{53.08}{64.09} = 0.83$

SLIDING (BEFORE PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$$= 1.1\sqrt{f'_c}\,A_{KEY} + [F_V - \text{wt of KEY}]\tan 45° + cA_{BASE} + 2SdW$$

$$= 1.1\sqrt{5830}\,(5)(1)\left(\frac{144}{1000}\right) + [55.98 - .15(4.5)(4)(1)]\tan 45° + 0.86(33.18)(1) + 2(58)(5)(1)$$

$$= 60.47 + 53.08 + 28.53 + 580 = 722.08 \text{ KIPS}$$

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$$= 64.92 - 0.0625\left[539 - \frac{492+496}{2}\right](4)(1) + 10.42 = 64.09 \text{ KIPS}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan φ + STRUT RESISTANCE

$$= 53.08 \tan 26° + 580$$

$$= 25.89 + 580$$

$$= 605.89 \text{ KIPS}$$

$$S_{s\text{-}f} = \frac{605.89}{64.09} = 9.45 > 1.5$$

Without {Strut Resistance} $S_{s\text{-}f} = \frac{25.89}{64.09} = 0.40$

A75

Figure A18. (Sheet 2 of 4)

SUBJECT: Brandon Road - ICE - CHUTE MONOLITH
NORMAL OPERATION

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

Shear Friction Safety Factor ($S_{s\text{-}f}$) = $\frac{744.4}{64.09}$ = 11.61 > 4.0

Without {Strut Resistance} $S_{s\text{-}f} = \frac{164.4}{64.09}$ = 2.57

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s\text{-}f} = \frac{75.4}{64.09}$ = 1.18

Full Uplift Applied Under non-Compressive Area of Base.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 1.1\sqrt{f'_c}\, A_{KEY} + [F_V + PS - \text{Wt of KEY}] \tan 45° + cA_{BASE} + 2 S_d W$

$= 1.1\sqrt{5830}\,(5)(1)\left(\frac{144}{1000}\right) + [55.78 + 22.32 - 2.7]\tan 45° + 0.86(33.18)(1) + 2(58)(5)(1)$

$= 60.47 + 75.40 + 28.53 + 580 = 744.4$ KIPS

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan φ + STRUT RESISTANCE

$= 75.40 \tan 26° + 580$

$= 36.78 + 580 = 616.78$

$S_{s\text{-}f} = \frac{616.78}{64.09} = 9.62 > 1.5$

Without {Strut Resistance} $S_{s\text{-}f} = \frac{36.78}{64.09} = 0.57$

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 64.92 - 0.0625\left[539 - \frac{492 + 496}{2}\right](4)(1) + 10.41 = 64.09^{K}$

A76

Figure A18. (Sheet 3 of 4)

SUBJECT: Brandon Road ICE - CHUTE MONOLITH
NORMAL OPERATION

COMPUTED BY: DATE

CHECKED BY: DATE

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3C} + \text{UPLIFT}$$

$$= 0 + 0.0625(539 - 496) = 0 + 2.69 = 2.69 \text{ KSF} \quad \underline{\text{HEEL}}$$

$$= \frac{2(55.78)}{3(5.57)} + 0.0625\left[\frac{(23.57)(539 - 503.6)}{3(5.57) + 23.57}\right] + 0.0625(503.6 - 496) = 6.68 + 1.77 = 8.45 \text{ KSF} \quad \underline{\text{TOE}}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{UPLIFT}$$

$$= \frac{55.78 + 22.32}{(1)\,38.18} \pm \frac{55.78\left(\frac{38.18}{2} - 5.57\right) - 22.32\left(\frac{38.18}{2} - 3.5\right)}{(1)(38.18)^2/6} + \text{UPLIFT}$$

$$= 2.05 - 1.67 + 2.69 = 0.38 + 2.69 = 3.07 \text{ KSF} \quad \underline{\text{HEEL}}$$

$$= 2.05 + 1.67 + 1.77 = 3.72 + 1.77 = 5.49 \text{ KSF} \quad \underline{\text{TOE}}$$

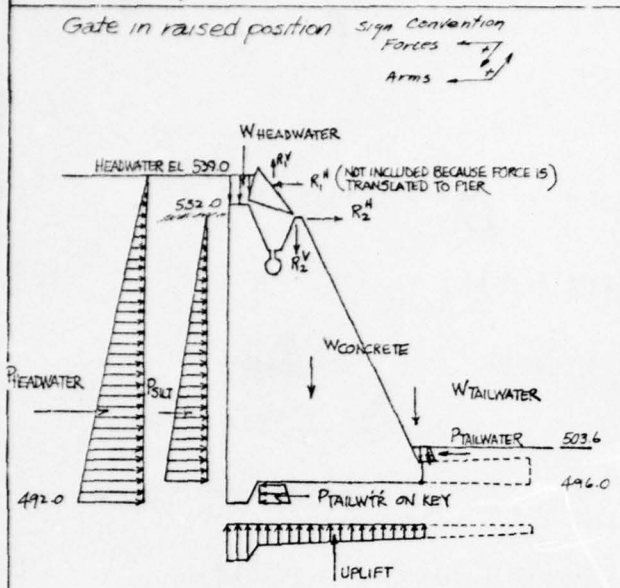
A17

Figure A18. (Sheet 4 of 4)

SUBJECT: Brandon Road Ice-Chute Monolith
Normal Operation + ICE - Overstressed Toe eliminated

COMPUTED BY: DATE:
CHECKED BY: DATE:

Gate in raised position



ITEM	FACTORS	F_V	F_H	ARM	MOMENT
W CONCRETE	[.1520][(4.25)(534-524.25) + (1/2)(2.17)(534-524.25) + (1/2)(7.415)(532-524.25) + (14.5)(524.5-496) + (2.08)(532-496) + (4)(496-492) + (1/2)(1)(496-492) + (1/2)(21.6)(532-496) + (1/2)(6.5)(500.67-496) - (π/4)(2.5)²]	+149.31		+20.73	+3095.20
W HEADWATER	[.0625] (4.25)(539-534)	+1.33		+36.06	+ 47.96
W TAILWATER	[.0625] (1/2)(3.09)(2.93)(.6)	+0.17		+1.03	+ 0.17
UPLIFT	(2.8)(4) + (1/2)(.137)(4) + (1/2)(.39)(1) + (1)(2.41) + (1.277)(33.18) + (1/2)(1.133)(33.18)	- 75.25		+21.55	-1621.64
R_2^V	VALUES CALCULATED FROM THE SUMMATION OF GATE WEIGHT, WATER PRESSURE AND WEIGHT FORCES ON THE GATE.	+ 2.48		+22.62	+ 56.10
R_2^H			- 2.69	+36.00	- 96.84
P HEADWATER	[.0625][(539-534)(534-492) + (1/2)(534-492)²]		-68.25	+11.35	- 774.64
P SILT	[.0203](1/2)(532-496)²(.5)		- 6.58	+12.00	- 78.96
P TAILWATER ON KEY	(2.8)(4)(1/2) + (2.41)(1/2)(4)		+10.42	- 2.05	- 21.36
P TAILWATER	[.0625](2.93)²(.5)		+ 0.27	+ 5.63	+ 1.52
		+ 78.04	-66.83		+ 607.51

Figure A19. Stability analysis, ice-chute monolith, normal operation plus ice (Sheet 1 of 8)

SUBJECT: Brandon Road ICE-CHUTE MONOLITH
NORMAL OPERATION + ICE CONDITION (GATE RAISED)

COMPUTED BY: DATE:
CHECKED BY: DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(4.61)}{38.18} = 36.22\ \%$$

Prestress Needed

$$= \frac{55.21\left(\frac{38.18}{3} - 4.61\right)}{\left(\frac{2}{3}\right)38.18 - 3.5} = 20.41 \text{ kips/ft of MONOLITH}$$

$$= 612 \text{ kips/MONOLITH}$$

Shear Friction Safety Factor ($S_{S.F}$) $= \frac{721.51}{66.0} = 10.93 > 4.0$

Without {Strut Resistance} $S_{S.F} = \frac{141.51}{66.0} = 2.14$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{S.F} = \frac{52.51}{66.0} = 0.80$

SLIDING (BEFORE PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$$= 1.1\sqrt{f'_c}\,A_{key} + [F_v - \text{WT OF KEY}]\tan 45° + C A_{BASE} + 2SdW$$

$$= 1.1\sqrt{5830}\,(5)(1)\left(\frac{144}{1000}\right) + [55.21 - 0.15(4.5)(4)(1)]\tan 45° + 0.86(33.18)(1) + 2(58)(5)(1)$$

$$= 60.47 + 52.51 + 28.53 + 580$$

$$= 721.51 \text{ kips}$$

Driving Force = $F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$

$$= 66.83 - 0.0625\left[539 - \frac{492+496}{2}\right](4)(1) + 10.42 = 66.0 \text{ kips}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan φ + STRUT RESISTANCE

$$= 52.51 \tan 26° + 580$$

$$= 25.61 + 580$$

$$= 605.61 \text{ kips}$$

$$S_{S.F} = \frac{605.61}{66.0} = 9.18 > 1.5$$

Without {Strut Resistance} $S_{S.F} = \frac{25.61}{66.0} = 0.39$

A79

Figure A19. (Sheet 2 of 8)

SUBJECT	COMPUTED BY:	DATE:
Brandon Road ICE-CHUTE MONOLITH NORMAL OPERATION + ICE (GATE RAISED)	CHECKED BY:	DATE:

Shear Friction Safety Factor ($S_{s.f}$) = $\frac{743.83}{66.0}$ = 11.27 > 4.0

Without {Strut Resistance} $S_{s.f} = \frac{163.83}{66.0}$ = 2.48

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s.f} = \frac{74.83}{66.0}$ = 1.13

Full Uplift Applied Under non-Compressive Area of Base.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 1.1\sqrt{f'_c}\, A_{KEY} + [F_v + PS - WT\ OF\ KEY]\tan 45° + cA_{BASE} + 2S\sqrt{W}$

$= 1.1\sqrt{5830}(5)(1)\left(\frac{144}{1000}\right) + [55.21 + 22.32 - 2.7]\tan 45° + 0.86(33.18)(1) + 2(58)(5)(1)$

$= 60.47 + 74.83 + 28.53 + 580 = 743.83$ kips

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 66.83 - 0.0625\left[539 - \frac{492+496}{2}\right](4)(1) + 10.42$

$= 66.0$ kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan φ + STRUT RESISTANCE

$= 74.83 \tan 26° + 580$

$= 36.50 + 580$

$= 616.50$ kips

$S_{s.f} = \frac{616.50}{66.0} = 9.34 > 1.5$

Without {Strut Resistance} $S_{s.f} = \frac{36.50}{66.0} = 0.55$

Figure A19. (Sheet 3 of 8)

SUBJECT	COMPUTED BY:	DATE:
Brandon Road ICE-CHUTE MONOLITH NORMAL OPERATION + ICE (GATE RAISED)	CHECKED BY:	DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3c} + \text{UPLIFT}$$

$$= 0 + 0.0625(539 - 496) = 0 + 2.69 = 2.69 \text{ KSF} \quad \text{HEEL}$$

$$= \frac{2(55.21)}{3(4.61)} + 0.0625\left[\frac{23.57(539 - 503.6)}{3(4.61) + 23.57}\right] + 0.0625(503.6 - 496) = 7.98 + 1.87 = 9.85 \quad \text{TOE}$$

With Prestress

$$f = \frac{P}{A} + \frac{M}{S} + \text{UPLIFT}$$

$$f = \frac{55.21 + 22.32}{(1)(38.18)} \pm \frac{55.21\left(\frac{38.18}{2} - 4.61\right) - 22.32\left(\frac{38.18}{2} - 3.5\right)}{(1)(38.18)^2/6} + \text{UPLIFT}$$

$$f = 2.03 - 1.86 + 2.69 = 0.17 + 2.69 = 2.86 \text{ KSF} \quad \text{HEEL}$$

$$f = 2.03 + 1.86 + 1.87 = 3.89 + 1.87 = 5.76 \text{ KSF} \quad \text{TOE}$$

A81

Figure A19. (Sheet 4 of 8)

SUBJECT: Brandon Road - Ice-Chute Monolith

Normal Operation + Ice — Overstressed Toe Eliminated

COMPUTED BY:

CHECKED BY:

DATE:

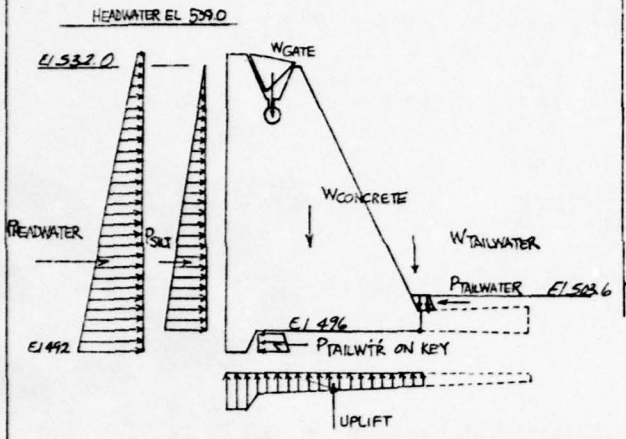
DATE:

with gate lowered

Sign Convention

Forces +

Arms +



ITEM	FACTORS	F_V	F_H	ARM	MOMENT
WCONCRETE	$[.1520][(4.25)(534-524.25)+(1/2)(2.17)(534-524.25)+(1/2)(7.415)(532-524.25)+(14.5)(524.5-496)+(2.08)(532-496)+(4)(496-492)+(1/2)(1)(496-492)+(1/2)(2.6)(532-496)+(1/2)(6.5)(500.67-496)-(11/4)(2.6)^2]$	+149.31		+20.73	+3095.20
WGATE	VALUE TAKEN FROM APPENDIX E, STABILITY ANALYSIS BRANDON RD. LOCK AND DAM	+0.72		+26.62	+19.16
WTAILWATER	$[.0625](1/2)(3.09)(2.93)(.6)$	+0.17		+1.03	+0.17
UPLIFT	$(2.8)(4)+(1/2)(.137)(4)+(1/2)(.39)(1)+(1)(2.41)+(1.277)(33.18)+(1/2)(1.133)(33.18)$	-75.25		+21.55	-1621.64
PHEADWATER	$[.0625][(539-534)(534-492)+(1/2)(534-492)^2]$		-68.25	+11.35	-774.64
PSILT	$[.0203](1/2)(532-496)^2(.6)$		-6.58	+12.00	-78.96
PTAILWATER ON KEY	$(2.8)(4)(1/2)+(2.41)(1/2)(4)$		+10.42	-2.05	-21.36
PTAILWATER	$[.0625](2.93)^2(.5)$		+0.27	+5.63	+1.52
		+74.95	-64.14		619.45

Figure A19. (Sheet 5 of 8)

SUBJECT: Brandon Road - ICE - CHUTE MONOLITH
NORMAL OPERATION + ICE (GATE LOWERED)

COMPUTED BY: DATE

CHECKED BY: DATE

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(5.17)}{38.18} = 40.62\ \%$$

Prestress Needed

$$= \frac{53.28\left(\frac{38.18}{3} - 5.17\right)}{\frac{2}{3}(38.18) - 3.5} = 18.34 \text{ KIPS/ft OF MONOLITH}$$

$$= 550 \text{ KIPS/MONOLITH}$$

Shear Friction Safety Factor ($S_{S.F}$) $= \frac{719.58}{63.31} = 11.37 \nearrow 4.0$

Without {Strut Resistance} $S_{S.F} = \frac{139.58}{63.31} = 2.20$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{S.F} = \frac{50.58}{63.31} = 0.80$

SLIDING (BEFORE PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance

$$= 1.1\sqrt{f'_c}\, A_{KEY} + [F_v - \text{wt of KEY}]\tan 45^\circ + CA_{BASE} + 2Sd\,W$$

$$= 1.1\sqrt{5830}\,(5)(1)\left(\frac{144}{1000}\right) + [53.28 - 0.15(4.5)(4)(1)]\tan 45^\circ + 0.86(33.18)(1) + 2(58)(5)(1)$$

$$= 60.47 + 50.58 + 28.53 + 580$$

$$= 719.58 \text{ KIPS}$$

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$$= 64.14 - 0.0625\left[539 - \frac{492+496}{2}\right](4)(1) + 10.42 = 63.31 \text{ KIPS}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan φ + STRUT RESISTANCE

$$= 50.58 \tan 26^\circ + 580$$

$$= 24.67 + 580$$

$$= 604.67 \text{ KIPS}$$

$S_{S.F} = \frac{604.67}{63.31} = 9.55 \nearrow 1.5$

Without {Strut Resistance} $S_{S.F} = \frac{24.67}{63.31} = 0.39$

A83

Figure A19. (Sheet 6 of 8)

SUBJECT: Brandon Road - ICE - CHUTE MONOLITH
NORMAL OPERATION + ICE (GATE LOWERED)

COMPUTED BY: | DATE:
CHECKED BY: | DATE

Shear Friction Safety Factor ($S_{S.F}$) = $\frac{741.9}{63.31} = 11.72 \rightarrow 4.0$

Without {Strut Resistance} $S_{S.F} = \frac{161.9}{63.31} = 2.56$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{S.F} = \frac{72.9}{63.31} = 1.15$

Full Uplift Applied Under non-Compressive Area of Base.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance

$= 1.1\sqrt{f'_c}\, A_{KEY} + [F_v + PS - \text{wt of KEY}] \tan 45° + CA + 2Sd(W)$

$= 1.1\sqrt{5830}\,(5)(1)\left(\frac{144}{1000}\right) + [53.28 + 22.32 - 2.7]\tan 45° + 0.86(33.18)(1) + 2(58)(5)(1)$

$= 60.47 + 72.90 + 28.53 + 580$

$= 741.90$ KIPS

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 64.14 - 0.0625\left[539 - \frac{492 + 494}{2}\right](4)(1) + 10.42$

$= 63.31$ KIPS

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + STRUT RESISTANCE

$= 72.90 \tan 26° + 580$

$= 35.56 + 580 = 615.56$

$S_{S.F} = \frac{615.56}{63.31} = 9.72 \rightarrow 1.5$

Without {Strut Resistance} $S_{S.F} = \frac{35.56}{63.31} = 0.56$

A84

Figure A19. (Sheet 7 of 8)

SUBJECT	COMPUTED BY:	DATE:
Brandon Road ICE-CHUTE MONOLITH NORMAL OPERATION + ICE (GATE LOWERED)	CHECKED BY:	DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{UPLIFT}$$

$$= 0 + 0.0625(539 - 496) = 0. + 2.69 = 2.69 \text{ KSF} \quad \underline{\text{HEEL}}$$

$$= \frac{2(53.28)}{3(5.17)} + 0.0625\left[\frac{(23.57)(539-503.6)}{3(5.17)+23.57}\right] + 0.0625(503.6-496) = 6.87 + 1.81 = 8.68 \text{ KSF} \quad \underline{\text{TOE}}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{UPLIFT}$$

$$= \frac{53.28 + 22.32}{(1)(38.18)} \pm \frac{53.18\left(\frac{38.18}{2} - 5.17\right) - 22.32\left(\frac{38.18}{2} - 3.5\right)}{(1)(38.18)^2/6} + \text{UPLIFT}$$

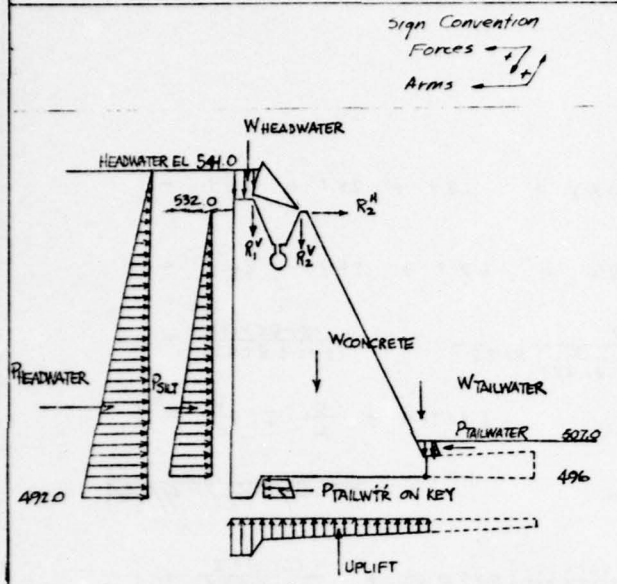
$$= 1.98 - 1.62 + 2.69 = 0.36 + 2.69 = 3.05 \text{ KSF} \quad \underline{\text{HEEL}}$$

$$= 1.98 + 1.62 + 1.81 = 3.60 + 1.81 = 5.41 \text{ KSF} \quad \underline{\text{TOE}}$$

Figure A19. (Sheet 8 of 8)

SUBJECT: Brandon Road Ice-Chute Monolith
Flood Condition Overstressed toe eliminated

COMPUTED BY: DATE:
CHECKED BY: DATE:



ITEM	FACTORS	F_V	F_H	ARM	MOMENT
$W_{CONCRETE}$	[.1520][(4.25)(534 - 524.25) + (½)(2.17)(534 - 524.25) + (½)(7.415)(532 - 524.25) + (14.5)(524.5 - 496) + (2.08)(532 - 496) + (4)(496 - 492) + (½)(1)(496 - 492) + (½)(21.6)(532 - 496) + (½)(6.5)(500.67 - 496) - (π/4)(2.5)²]	+149.31		+20.73	+3095.20
$W_{HEADWATER}$	[.0625](4.25)(541 - 534)	+1.86		+36.06	+ 67.07
$W_{TAILWATER}$	[.0625](½)(6.51)(507.0 - 500.67)(6)	+0.77		12.17	+ 1.67
UPLIFT	(2.93)(4) + (½)(.132)(4) + (1/4)(.39)(1) + (1)(2.546) + (1.46)(33.18) + (½)(1.08)(33.18)	-81.08		+21.28	-1726.09
R_1^V	VALUES CALCULATED FROM THE SUMMATION OF GATE WEIGHT, WATER PRESSURE AND WEIGHT FORCES ON THE GATE.	+ 0.29		+33.93	+ 9.84
R_2^V		+ 1.25		+22.62	+ 28.27
R_2^H			- 1.53	+36.00	- 55.08
$P_{HEADWATER}$	[.0625][(541 - 534)(534 - 492) + (½)(534 - 492)²]		- 73.50	+11.75	- 863.63
P_{SILT}	[.0203](½)(532 - 496)²(.5)		- 6.58	+12.00	- 78.96
$P_{TAILWATER\ ON\ KEY}$	(2.93)(4)(½) + (2.55)(½)(4)		+10.96	- 2.05	- 22.47
$P_{TAILWATER}$	[.0625](507 - 500.67)²(.5)		+ 1.25	+ 6.78	+ 8.47
		72.4	-69.4		464.29

Figure 20. Stability analysis, ice-chute monolith, flood condition (Sheet 1 of 4)

SUBJECT: Brandon Road ICE-CHUTE MONOLITH FLOOD CONDITION OVERSTRESSED TOE ELIMINATED	COMPUTED BY: CHECKED BY:	DATE DATE

OVERTURNING

Shear Friction Safety Factor $(S_{s.f}) = \frac{712.8}{68.61} = 10.39 \not> 4.0$

Without {Strut Resistance} $S_{s.f} = \frac{132.8}{68.61} = 1.94$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s.f} = \frac{43.8}{68.61} = 0.64$

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(2.19)}{38.18} = 17.21\ \%$$

Prestress Needed

$$= \frac{46.50\left(\frac{38.18}{3} - 2.19\right)}{\frac{2}{3}(38.18) - 3.5} = 22.32 \text{ KIPS/ft of MONOLITH}$$

$$= 670 \text{ KIPS/MONOLITH}$$

SLIDING (BEFORE PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance

$$= 1.1\sqrt{f_c'}\,A_{key} + [F_V - \text{WT OF KEY}]\tan 45° + C A_{BASE} + 2 S d w$$

$$= 1.1\sqrt{5830}\,(5)(1)\left(\frac{144}{1000}\right) + [46.5 - 0.15(4.5)(4)(1)]\tan 45° + 0.86(33.18)(1) + (2)(58)(5)(1)$$

$$= 60.47 + 43.80 + 28.53 + 580 = 712.80 \text{ KIPS}$$

Driving Force = $F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$

$$= 69.4 - 0.0625\left[541 - \frac{492 + 496}{2}\right](4)(1) + 10.96$$

$$= 68.61 \text{ KIPS}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + STRUT RESISTANCE

$$= 43.80 \tan 26° + 580$$

$$= 21.36 + 580$$

$$= 601.36$$

$$S_{s.f} = \frac{601.36}{68.61} = 8.76 \not> 1.5$$

Without {Strut Resistance} $S_{s.f} = \frac{21.36}{68.61} = 0.31$

Figure A20. (Sheet 2 of 4)

SUBJECT: Brandon Road ICE-CHUTE MONOLITH
FLOOD CONDITION

COMPUTED BY: | DATE
CHECKED BY: | DATE

Shear Friction Safety Factor ($S_{s.f}$) = $\frac{735.12}{68.61}$ = 10.71 > 4.0

Without {Strut Resistance} $S_{s.f} = \frac{155.12}{68.61}$ = 2.26

Without {Strut Resistance, Cohesion, Key Resistance} $S_{s.f} = \frac{66.12}{68.61}$ = 0.96

Full Uplift Applied Under non-Compressive Area of Base.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance

$= 1.1\sqrt{f'_c}\,A_{KEY} + [F_V + PS - WT\ OF\ KEY]\tan 45° + C A_{BASE} + 2 S d W$

$= 1.1\sqrt{5830}\,(5)(1)\left(\frac{144}{1000}\right) + [46.5 + 22.32 - 2.7]\tan 45° + 0.86(33.18)(1) + 2(58)(5)(1)$

$= 60.47 + 66.12 + 28.53 + 580 = 735.12$ KIPS

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 69.4 - 0.0625\left[541 - \frac{492+496}{2}\right](4)(1) + 10.96$

$= 68.61$ KIPS

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V · tan φ + STRUT RESISTANCE

$= 66.12 \tan 26° + 580$

$= 32.25 + 580 = 612.25$

$S_{s.f} = \frac{612.25}{68.61} = 8.92 > 1.5$

Without {Strut Resistance} $S_{s.f} = \frac{32.25}{68.61}$ = 0.47

Figure A20. (Sheet 3 of 4)

SUBJECT: Brandon Road ICE-CHUTE MONOLITH FLOOD CONDITION	COMPUTED BY: CHECKED BY:	DATE: DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{UPLIFT}$$

$$= 0 + 0.0625(541 - 496) = 0 + 2.81 = 2.81 \text{ KSF} \quad \underline{\text{HEEL}}$$

$$= \frac{2(46.50)}{3(2.19)} + 0.0625\left[\frac{23.57(541-509)}{3(2.19)+23.57}\right] + 0.0625(509 - 496) = 14.16 + 2.35 = 16.51 \text{ KSF} \quad \underline{\text{TOE}}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{UPLIFT}$$

$$= \frac{46.50 + 22.32}{(1)(38.18)} \pm \frac{46.5\left(\frac{38.18}{2} - 2.19\right) - 22.32\left(\frac{38.18}{2} - 3.5\right)}{(1)(38.18)^2/16} + \text{UPLIFT}$$

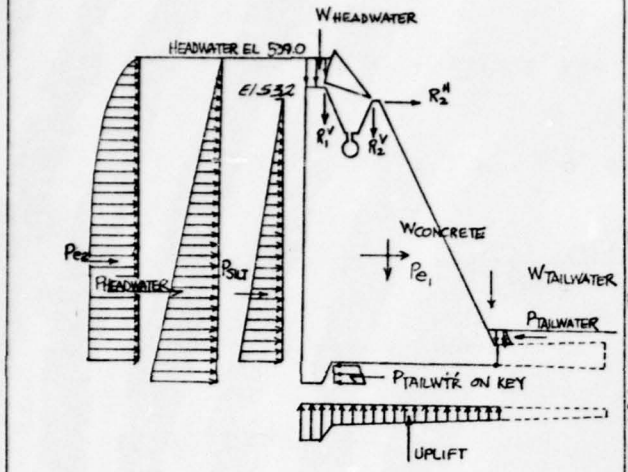
$$= 1.80 - 1.80 + 2.81 = 0 + 2.81 = 2.81 \text{ KSF} \quad \underline{\text{HEEL}}$$

$$= 1.80 + 1.80 + 2.35 = 3.60 + 2.35 = 5.95 \text{ KSF} \quad \underline{\text{TOE}}$$

Figure A20. (Sheet 4 of 4)

SUBJECT: Brandon Road Ice-Chute Monolith
Normal Operation + Earthquake Overstressed Toe Eliminated

COMPUTED BY: DATE:
CHECKED BY: DATE:



ITEM	FACTORS	F_V	F_H	ARM	MOMENTS
$W_{CONCRETE}$	[1520][(4.25)(534 − 524.25) + (½)(2.17)(534 − 524.25) + (½)(7.415)(532 − 524.25) + (14.5)(524.5 − 496) + (208)(532 − 496) + (4)(496 − 492) + (½)(1)(496 − 492) + (½)(21.6)(532 − 496) + (½)(6.5)(500.67 − 496) − (π/4)(2.5)²]	+ 149.31		+20.73	+3095.20
$W_{HEADWATER}$	[.0625](4.25)(539 − 534)	+ 1.33		+36.06	+ 47.96
$W_{TAILWATER}$	[.0625](½)(3.09)(503.6 − 500.67)(.6)	+ 0.17		+ 1.03	+ 0.17
UPLIFT	(2.8)(4) + (½)(.134)(4) + (1½)(.39)(1) + (1)(2.41) + (1.277)(33.18) + (½)(1.133)(33.18)	− 75.25		+ 21.55	− 1621.64
R_1^V	VALUES CALCULATED FROM THE SUMMATION	+ 0.29		+ 33.93	+ 9.84
R_2^V	OF GATE WEIGHT, WATER PRESSURE AND	+ 0.75		+ 22.62	+ 16.97
R_2^H	WATER WEIGHT ON THE GATE.		− 0.78	+ 36.00	− 28.08
$P_{HEADWATER}$	[.0625][(539 − 534)(534 − 492) + (½)(534 − 492)²]		− 68.25	+ 11.35	− 774.64
$P_{SILT-ERTHQK}$	[.0203](½)(532 − 496)²(.54)		− 7.10	+ 13.41	− 95.26
$P_{TAILWATER}$	[.0625](503.6 − 500.67)²(½)		+ 0.27	+ 5.63	+ 1.52
$P_{TAILWATER\ ON\ KEY}$	(2.8)(4)(½) + (2.41)(4)(½)		+ 10.42	− 2.05	− 21.36
EARTHQUAKE FORCE OF CONCRETE, GATE, HEADWTR, TAILWTR WEIGHTS	$P_{e_1} = aw = [.05][149.31 + 0.72 + 0.28 + 1.33]$		− 7.58	+ 14.94	− 113.25
EARTHQUAKE FORCE OF HEADWATER	$P_{e_2} = (2/3)(5105)(43)(43^2)^{1/2}/1000$		− 3.15		− 54.12
		+ 76.60	− 76.17		+ 463.31

Figure A21. Stability analysis, ice-chute monolith, normal operation plus earthquake (Sheet 1 of 4)

SUBJECT: Brandon Road ICE-CHUTE MONOLITH
NORMAL OPERATION + EARTHQUAKE

COMPUTED BY: DATE:
CHECKED BY: DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(2.27)}{38.18} = 17.84\ \%$$

Prestress Needed : NONE

Shear Friction Safety Factor $(S_{S.F}) = \frac{722.08}{75.34} = 9.58\ \ 7^{2.67}$

Without {Strut Resistance} $S_{S.F} = \frac{142.08}{75.34} = 1.89$

Without {Strut Resistance, Cohesion, Key Resistance} $S_{S.F} = \frac{53.08}{75.34} = 0.70$

SLIDING (BEFORE PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance

$$= 1.1\sqrt{f_c'}\,A_{KEY} + [F_v - \text{Wt OF KEY}]\tan 45° + CA_{BASE} + 2Sdw$$

$$= 1.1\sqrt{5830}\,(5)(1)\left(\frac{144}{1000}\right) + [55.78 - 0.15(4.5)(4)(1)]\tan 45° + 0.86(33.18)(1) + 2(58)(5)(1)$$

$$= 60.47 + 53.08 + 28.53 + 580 = 722.08 \text{ KIPS}$$

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$$= 76.17 - 0.0625\left[539 - \frac{492+496}{2}\right](4)(1) + 10.42 = 75.34 \text{ KIPS}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + STRUT RESISTANCE

$$= 53.08 \tan 26° + 580$$

$$= 25.89 + 580$$

$$= 605.89$$

$$S_{S.F} = \frac{605.89}{75.34} = 8.04\ \ 7^{1.15}$$

Without {Strut Resistance} $S_{S.F} = \frac{25.89}{75.34} = 0.34$

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Figure A21. (Sheet 2 of 4)

SUBJECT: Brandon Road - ICE-CHUTE MONOLITH
NORMAL OPERATION + EARTHQUAKE

COMPUTED BY: DATE:
CHECKED BY: DATE:

Shear Friction Safety Factor ($S_{S\cdot F}$) = $\frac{744.4}{75.34}$ = 9.88 72.69

Without {Strut Resistance} $S_{S\cdot F} = \frac{164.4}{75.34}$ = 2.18

Without {Strut Resistance, Cohesion, Key Resistance} $S_{S\cdot F} = \frac{75.4}{75.34}$ = 1.0

Compressive $\frac{\text{Full Uplift Applied Under non-}}{\text{Area of Base}}$.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$= 1.1\sqrt{f'_c}\, A_{KEY} + [F_V + PS - wt\ of\ KEY]\tan 45° + cA_{BASE} + 2Sdw$

$= 1.1\sqrt{5830}(5)(1)\left(\frac{144}{1000}\right) + [55.98 + 22.32 - 2.9]\tan 45° + 0.86(33.18)(1) + 2(58)(5)(1)$

$= 60.47 + 75.4 + 28.53 + 580 = 744.4$ KIPS

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 76.17 - 0.0625\left[539 - \frac{492 + 496}{2}\right](4)(1) + 10.42 = 75.34$ KIPS

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan φ + STRUT RESISTANCE

$= 75.4 \tan 26° + 580$

$= 36.78 + 580$

$= 616.78$ KIPS

$S_{S\cdot F} = \frac{616.78}{75.34} = 8.19 > 1.5$

Without {Strut Resistance} $S_{S\cdot F} = \frac{36.78}{75.34} = 0.49$

Figure A21. (Sheet 3 of 4)

SUBJECT: Brandon Road ICE-CHUTE MONOLITH NORMAL OPERATION + EARTHQUAKE	COMPUTED BY: / CHECKED BY:	DATE: / DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3C} + \text{UPLIFT}$$

$$= 0 + 0.0625(539 - 496) = 0 + 2.69 = 2.69 \text{ KSF} \quad \text{HEEL}$$

$$= \frac{2(55.78)}{3(2.27)} + 0.0625\left[\frac{23.57(539 - 503.6)}{3(2.27) + 23.57}\right] + 0.0625(503.6 - 496) = 16.38 + 2.19 = 18.57 \text{ KSF} \quad \text{TOE}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{UPLIFT}$$

$$= \frac{55.78 + 22.32}{(1)(38.18)} \pm \frac{55.78\left(\frac{38.18}{2} - 2.27\right) - 22.32\left(\frac{38.18}{2} - 3.5\right)}{(1)(38.18)^2/6} + \text{UPLIFT}$$

$$= 2.05 - 2.43 + 2.69 = 0 + 2.69 = 2.69 \text{ KSF} \quad \text{HEEL}$$

$$= 2.05 + 2.43 + 2.19 = 4.48 + 2.19 = 6.67 \text{ KSF} \quad \text{TOE}$$

$$\text{Location of Resultant From Center of Gravity of Base} = \frac{55.78\left(\frac{38.18}{2} - 2.27\right) - 22.32\left(\frac{38.18}{2} - 3.5\right)}{55.78 + 22.32} = \frac{938.22 + 347.97}{78.10} = \frac{590.25}{78.10} = 7.56'$$

$$\% \text{ Effective Base} = \frac{3\left(\frac{38.18}{2} - 7.56\right)}{38.18} = 90.60\ \%$$

Figure A21. (Sheet 4 of 4)

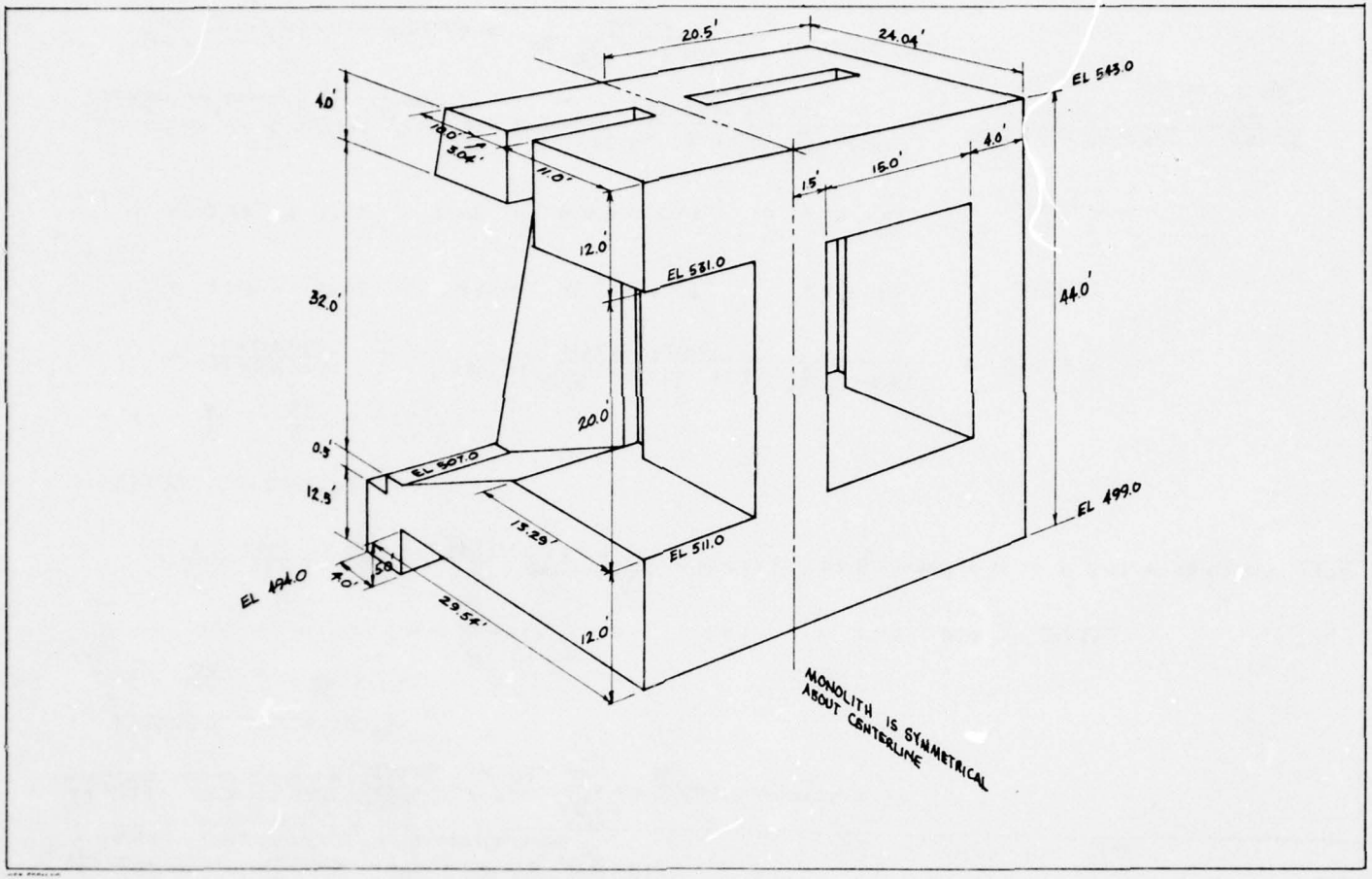

Figure A22. Typical head-gate monolith

SUBJECT: Brandon Road - Head-Gate Monolith
Normal Operation

COMPUTED BY:
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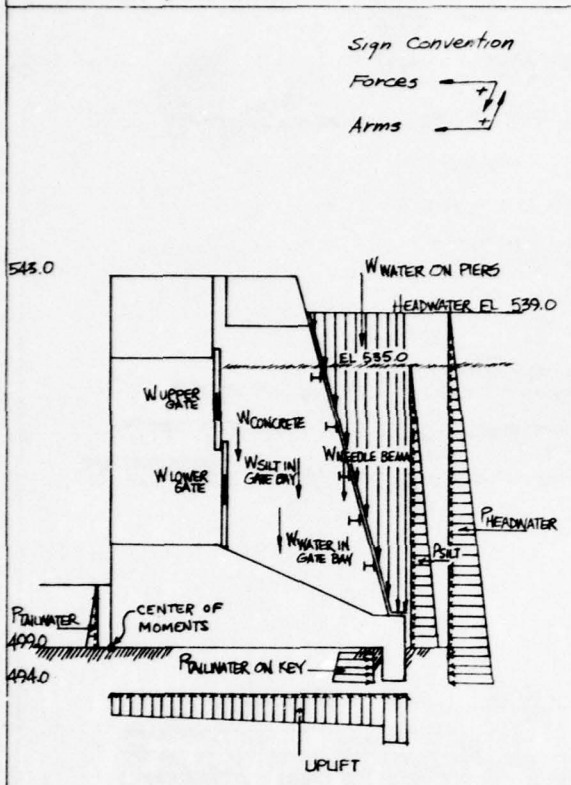
DATE:
DATE:



ITEM	FACTORS	Fv	Fh	ARM	MOMENT
W CONCRETE	[.1493][2][(12)(15)(11) + (10)(4)(15) + (½)(4)(.83)(15) + (13.29)(15)(12) + (15)(½)(15.25)(511-507) + (15)(507-499)(15.25+5) + (20.5)(506.5-494)(2) + (20.5)(2)(499-494) + (5.5)(543-499)(24.04) + (5.5)(½)(543-499)(33.54-2-24.04)]	+4505.1		+14.14	+63,702.11
W LOWER GATE	VALUES VERIFIED AND TAKEN FROM APPENDIX E,	+ 22.0		+13.29	+ 292.38
W UPPER GATE	BRANDON RD. STABILITY ANALYSIS OF DAM	+ 15.2		+11.69	+ 177.69
W NEEDLE BEAMS	MASONRY	+ 14.72		+28.84	+ 424.52
W WATER IN GATE BAYS	[.0625][2][(7.25)(22.54)(15) + (10.5)(21.16)(15) + (10.25)(19.5)(15) + (5)(4)(15) + (½)(14.5)(4)(15)]	+1189.63		+23.33	+27,754.07
W SILT IN GATE BAYS	[.0203][2][(3.25)(22.54)(15) + (10.5)(21.16)(15) + (10.25)(19.5)(15) + (5)(4)(15) + (½)(14.5)(4)(15)]	+ 331.48		+23.51	+ 7,793.09
W WATER ON PIERS	[.0625][(2)(4+4+3)(32) + (½)(9.5)(32)(4+4+3)]	+ 148.50		+29.61	+ 4,397.09
UPLIFT	[(2.812-2.583)(½)(4) + (2.583)(4) + (1.983-0.287)(½)(29.54) + (0.287)(29.54)][41]	- 1817.53		+21.64	- 39,331.35
P HEADWATER	[.0625](½)(539-494)²(4+15+3+15+4)		+2594.53	- 10.00	- 25,945.30
P TAILWATER	[.0625](½)(508.6-499)²(4+15+3+15+4)(.6)		- 16.27	- 1.53	+ 24.89
P SILT	[.0203](½)(.5)(535-499)²(41)		+ 269.67	-12.00	- 3,236.04
P TAILWATER ON KEY	[(1.983)(5) + (½)(.599)(5)][41]		- 468.02	+ 2.61	- 1,221.53
		+4409.1	+2379.91		+ 34,831.62

Resultant location from Moment Center = $\frac{34,831.62}{4,409.10} = 7.90'$

% Effective Base = $\frac{3(7.90)}{33.54} = 70.66\%$

Figure A23. Stability analysis, head-gate monolith, normal operation (Sheet 1 of 6)

SUBJECT: Brandon Road - Head-Gate MONOLITH
NORMAL OPERATION

COMPUTED BY: | DATE
CHECKED BY: | DATE

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(5.38)}{33.54} = 48.12\%$$

$$\text{Shear Friction Safety Factor } (S_{s\text{-}f}) = \frac{6455}{2303} = 2.80 < 4.0$$

$$\text{Without } \{\text{Strut Resistance}\} = \frac{6455}{2303} = 2.80$$

$$\text{Without } \{\text{Strut Resistance, Cohesion, Key Resistance}\} = \frac{3347}{2303} = 1.45$$

SLIDING (Before Prestressing)

Under Conditions of Least Probable Existing Parameters

$$\text{Resistance to Sliding} = \text{Key Resistance} + V\tan 45° + cA + \text{Strut Resistance}$$

$$= 1.1\sqrt{f'_c}\,A_{KEY} + [F_V - \text{Wt of Key}]\tan 45° + cA_{BASE} + 2sdw$$

$$= 1.1\sqrt{6327}(9)(41)\left(\frac{144}{12^2}\right) + [3470 - 0.15(9)(5)(41)](1) + 0.86(29.54)(41) + 0$$

$$= 2066 + 3347 + 1042 + 0$$

$$= 6455 \text{ Kips}$$

$$\text{Driving Force} = F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$$

$$= 2379.91 - 0.0625\left[539 - \frac{494+499}{2}\right](5)(41) + 468.02$$

$$= 2303 \text{ Kips}$$

Under Conditions Using Lower Bound Parameters

$$\text{Resistance to Sliding} = V\tan\phi + \text{Strut Resistance}$$

$$= 3347\tan 26° + 0$$

$$= 1632 \text{ Kips}$$

$$S_{s\text{-}f} = \frac{1632}{2303} = 0.71 < 1.5$$

$$\text{Without } \{\text{Strut Resistance}\} = \frac{1632}{2303} = 0.71$$

Figure A23. (Sheet 2 of 6)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Normal Operation

COMPUTED BY: DATE:

CHECKED BY: DATE:

APPLYING FULL UPLIFT UNDER NON-COMPRESSIVE AREA OF BASE

PRESTRESS NEEDED TO MEET SLIDING CRITERIA

Resistance to Sliding = Key Resistance + V tan ϕ + CA_{BASE} + Strut Resistance + Horizontal Component of Prestress Force

$$= 1.1\sqrt{f'_c}\,A_{key} + \left[F_V + \left(\tfrac{3}{4}\right) PS \cos 40^\circ + \left(\tfrac{1}{4}\right) PS - \text{Wt of Key}\right] \tan 45^\circ + CA_{BASE} + 2sdw + \left(\tfrac{3}{4}\right) PS \sin 40^\circ$$

$$= 1.1\sqrt{6327}\,(4)(41)\left(\tfrac{144}{1000}\right) + \left[3470 + \left(\tfrac{3}{4}\right) PS \cos 40^\circ + \left(\tfrac{1}{4}\right) PS - 0.15(5)(4)(41)\right] \tan 45^\circ + 0.86(29.54)(41) + 0 + \left(\tfrac{3}{4}\right) PS \sin 40^\circ$$

$$= 2066 + \left[3347 + 0.825\,PS\right] + 1042 + 0 + 0.482\,PS$$

$$= 1.307\,PS + 6455$$

Driving Force $= F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$$= 2379.91 - 0.0625\left[539 - \frac{494+499}{2}\right](5)(41) + 468.02$$

$$= 2303 \text{ Kips}$$

Shear Friction Safety Factor $(S_{S-F}) = \dfrac{\text{Resistance to Sliding}}{\text{Driving Force}} = \dfrac{1.307\,PS + 6455}{2303} = 4.0$ (Minimum Required)

$$PS = \frac{4(2303) - 6455}{1.307}$$

$$PS = 2109 \text{ Kips}$$

Figure A23. (Sheet 3 of 6)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Normal Operation

COMPUTED BY:
CHECKED BY:
DATE:
DATE:

LOCATION OF PRESTRESSING

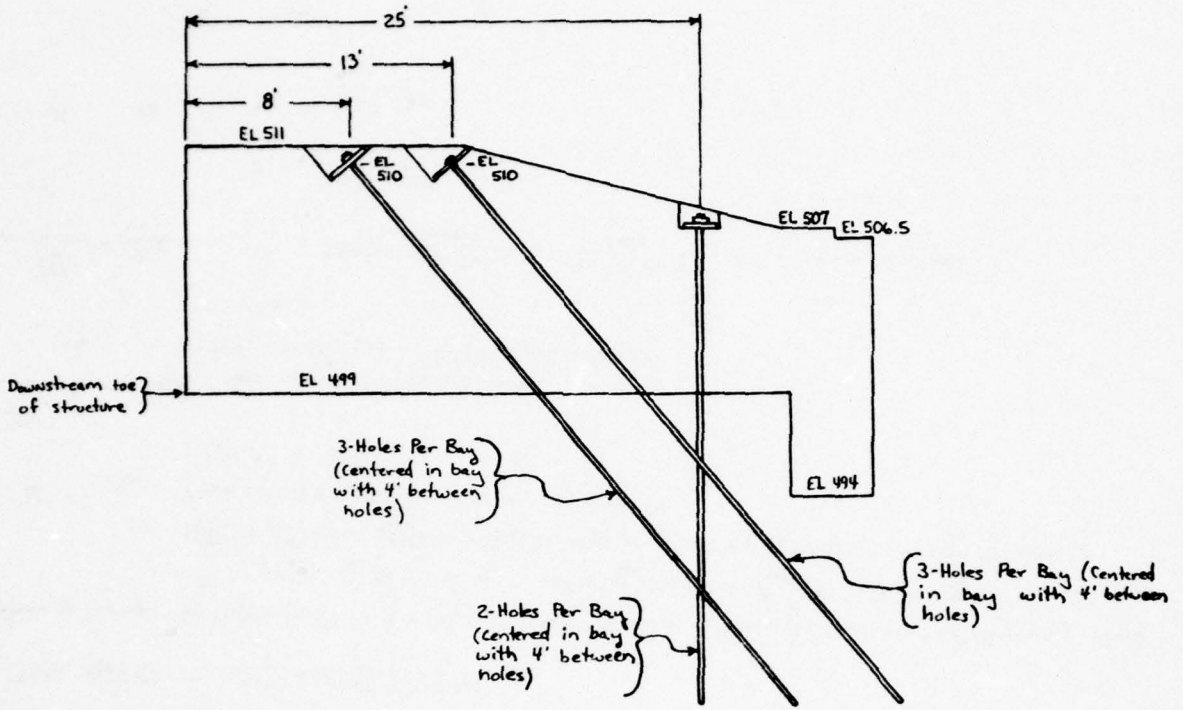


Figure A23. (Sheet 4 of 6)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Normal Operation

COMPUTED BY: DATE:
CHECKED BY: DATE:

Full Uplift Applied Under non-Compressive Area of Base.

Shear Friction Safety Factor $(S_{S-F}) = \frac{11,077}{2,303} = 4.81 > 4.0$

Without {Strut Resistance} $= \frac{11,077}{2,303} = 4.81$

Without {Strut Resistance, Cohesion, Key Resistance} $= \frac{6264+1705}{2,303} = 3.46$

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance + Prestress_{HORZ}

$= 1.1\sqrt{f'_c}\,A_{KEY} + \left[F_V + \left(\frac{3}{4}\right)PS\cos 40° + \left(\frac{1}{4}\right)PS - \text{wt of Key}\right]\tan 45° + cA_{BASE} + 2\,sdw + \left(\frac{3}{4}\right)PS\sin 40°$

$= 1.1\sqrt{6327}\,(4)(41)\left(\frac{144}{1000}\right) + \left[3470 + \left(\frac{3}{4}\right)(3538)\cos 40° + \left(\frac{1}{4}\right)(3538) - 0.15(4)(5)(41)\right](1) + 0.86\,(29.54)(41) + 0 + \left(\frac{3}{4}\right)(3538)\sin 40°$

$= 2066 + 6264 + 1042 + 0 + 1705$

$= 11,077$ Kips

Driving Force $= F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 2379.91 - 0.0625\left[539 - \frac{494+499}{2}\right](5)(41) + 468.02$

$= 2303$ Kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance + PRESTRESS

$= 6264\tan 26° + 0 + \left(\frac{3}{4}\right)(3538)\sin 40°$

$= 3055 + 0 + 1705 = 4760$ Kips

$S_{S-F} = \frac{4760}{2303} = 2.07 > 1.5$

Without {Strut Resistance} $= \frac{4760}{2303} = 2.07$

Figure A23. (Sheet 5 of 6)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Normal Operation

COMPUTED BY:

CHECKED BY:

DATE

DATE

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{Uplift}$$

$$= 0. + 0.0625[539 - 499] = 0. + 2.50 = 2.50 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= \frac{2(3470)}{3(5.38)} + 0.0625[503.6 - 499] = 429.99 + 0.29 = 430.28 \quad \underline{\text{Toe}}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{Uplift}$$

$$= \frac{3470 + (\frac{3}{8})(3538)\cos 40^\circ + \frac{3538}{4}}{(41)(33.54)} \pm \frac{3470\left(\frac{33.54}{2} - 5.38\right) + (\frac{3}{8})(3538)\left[\left(\frac{33.54}{2} - 8\right)\cos 40^\circ - (570 - 499)\sin 40^\circ\right] + (\frac{3}{8})(3538)\left[\left(\frac{33.54}{2} - 13\right)\cos 40^\circ - (510 - 499)\sin 40^\circ\right] - \left(\frac{3538}{4}\right)\left(25 - \frac{33.54}{2}\right)}{(41)(33.54)^2/6.} + \text{Uplift}$$

$$= \frac{3470 + 2033 + 885}{(41)(33.54)} \pm \frac{39,523 - 468 - 5549 - 7279}{(41)(33.54)^2/6} + \text{Uplift}$$

$$= 4.65 - 3.41 + 2.50 = 1.24 + 2.50 = 3.74 \text{ KSF} \quad \underline{\text{Heel}}$$

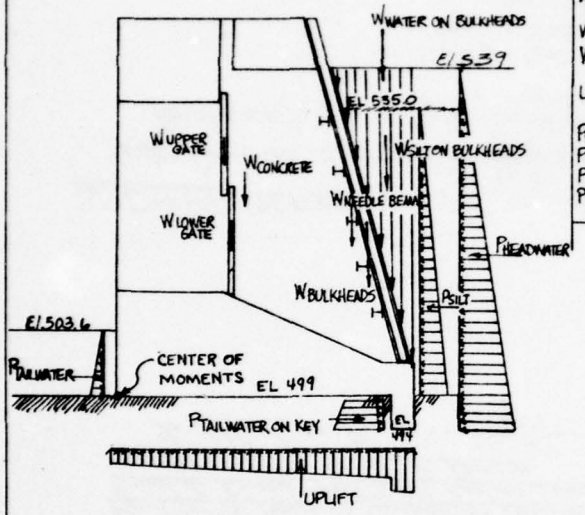
$$= 4.65 + 3.41 + 0.29 = 8.06 + 0.29 = 8.35 \text{ KSF} \quad \underline{\text{Toe}}$$

A100

Figure A23. (Sheet 6 of 6)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Extreme Maintenance Condition with both bays dewatered

COMPUTED BY: CHECKED BY: DATE: DATE:



ITEM	FACTORS	FV	FH	ARM	MOMENT
W CONCRETE	[.1493][2][(12)(15)(11) + (10)(4)(15) + (½)(4)(.85)(15) + (13.29)(15)(12) + (15)(½)(15.25)(511-507) + (15)(507-499)(15.25+5) + (20.5)(506.5-494)(2) + (20.5)(2)(499-494) + (5.5)(543-499)(24.04) + (5.5)(½)(543-499)(33.54-2-24.04)]	+4505.1		+ 14.14	+ 63,702.11
W LOWER GATE	(VALUES VERIFIED AND TAKEN FROM APPENDIX E,	+ 22.0		+ 13.29	+ 292.38
W UPPER GATE	BRANDON RD. STABILITY ANALYSIS OF DAM	+ 15.2		+11.69	+ 177.69
W NEEDLE BEAMS	MASONRY)	+ 14.72		+ 28.84	+ 424.52
W WATER ON BULKHEADS	[.0625][(1)(41)(32) + (½)(746)(32)(41)]	+ 396.06		+ 30.62	+ 12,127.36
W BULKHEADS	[1.14 K/Lin FT](41 FT)	+ 46.96		+ 28.71	+ 1,348.22
W SILT ON BULKHEADS	[.0103][(1)(41)(28) + (½)(6.02)(28)(41)]	+ 93.45		+ 31.16	+ 2,911.90
UPLIFT	[(2.812-2.583)(½)(4) + (2.583)(4) + (1.983-0.287)(½)(29.54) + (0.287)(29.54)][41]	- 1817.53		+ 21.64	- 39,331.35
P HEADWATER	[.0625](½)(539-494)²(4+15+3+15+4)		+ 2594.53	- 10.00	- 25,945.30
P TAILWATER	[.0625](½)(508.6-499)²(4+15+3+15+4)(.6)		- 16.27	- 1.53	+ 24.89
P SILT	[.0103](½)(.5)(535-499)²(41)		+ 269.67	- 12.00	- 3,236.04
P TAILWATER ON KEY	[(1.983)(5) + (½)(.599)(5)][41]		- 468.02	+ 2.61	- 1,221.53
		+3275.96	+2379.91		+ 11,274.85

Resultant location from Moment Center = $\frac{11,274.85}{3,275.96} = 3.44'$

% Effective Base = $\frac{3(3.44)}{33.54} = 30.77\ \%$

A101

Figure A24. Stability analysis, head-gate monolith, extreme maintenance condition (Sheet 1 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Extreme Maintenance Condition with both bays dewatered

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(-5.51)}{33.54} \rightarrow 0\%$$

$$\text{Shear Friction Safety Factor } (S_{s\text{-}f}) = \frac{4589}{2303} = 1.99 < 4.00$$

$$\text{Without} \left\{\text{Strut Resistance}\right\} = \frac{4589}{2303} = 1.99$$

$$\text{Without} \left\{\begin{matrix}\text{Strut Resistance} \\ \text{Cohesion} \\ \text{Key Resistance}\end{matrix}\right\} = \frac{1481}{2303} = 0.64$$

SLIDING (BEFORE PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$$= 1.1\sqrt{f'_c}\, A_{KEY} + \left[F_V - \text{Wt of Key}\right] \tan 45° + cA_{BASE} + \Sigma sd\text{-}w$$

$$= 1.1\sqrt{6327}(4)(41)\left(\frac{494}{600}\right) + \left[1404 - 0.15(4)(5)(41)\right](1) + 0.86(29.54)(41) + 0$$

$$= 2066 + 1481 + 1042 + 0$$

$$= 4589 \text{ Kips}$$

$$\text{Driving Force} = F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$$

$$= 2379.91 - 0.0625\left[539 - \frac{494+499}{2}\right](5)(41) + 468.02$$

$$= 2303 \text{ Kips}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance

$$= 1481 \tan 26° + 0$$

$$= 722 \text{ Kips}$$

$$S_{s\text{-}f} = \frac{722}{2303} = 0.31 < 1.5$$

$$\text{Without} \left\{\text{Strut Resistance}\right\} = \frac{722}{2303} = 0.31$$

A102

Figure A24. (Sheet 2 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH Extreme Maintenance Condition with both bays dewatered	COMPUTED BY: CHECKED BY:	DATE: DATE:

APPLYING FULL UPLIFT UNDER NON-COMPRESSIVE AREA OF BASE

PRESTRESS NEEDED TO MEET SLIDING CRITERIA

Resistance to Sliding = Key Resistance + $V \tan\phi + cA_{BASE}$ + Strut Resistance + Horizontal Component of Prestress Force

$= 1.1\sqrt{f'_c}\, A_{KEY} + \left[F_V + \frac{3}{4} PS \cos 40^\circ + \frac{PS}{4} - \text{Wt of Key}\right] \tan 45^\circ + cA_{BASE} + 2sdw + \frac{3}{4} PS \sin 40^\circ$

$= 1.1\sqrt{6327}\,(4)(41)\left(\frac{144}{1000}\right) + \left[1604 + \frac{3}{4} PS \cos 40^\circ + \frac{PS}{4} - 0.15(4)(5)(41)\right](1) + 0.86(29.54)(41) + 0 + \frac{3}{4} PS \sin 40^\circ$

$= 2066 + \left[1481 + 0.825\,PS\right] + 1042 + 0 + 0.482\,PS$

$= 1.307\,PS + 4589$

Driving Force $= F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 2379.91 - 0.0625\left[539 - \frac{454+449}{2}\right](5)(41) + 468.02$

$= 2303$ Kips

Shear Faction Safety Factor(S_{S-F}) = $\frac{\text{Resistance to Sliding}}{\text{Driving Force}} = \frac{1.307PS + 4589}{2303} = 4.0$ (Minimum Required)

$$PS = \frac{4(2303) - 4589}{1.307}$$

$PS = 3538$ Kips OR $\frac{3538}{16} = 221$ Kips/Hole

A103

Figure A24. (Sheet 3 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Extreme Maintenance Condition with both bays dewatered

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

Shear Friction Safety Factor $(S_{s\text{-}f}) = \frac{9211}{2303} = 4.00 = 4.00$ (Minimum Required)

Without {Strut Resistance} $= \frac{9211}{2303} = 4.00$

Without {Strut Resistance, Cohesion, Key Resistance} $= \frac{4398 + 1705}{2303} = 2.65$

Full Uplift Applied Under non-Compressive Area of Base.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance + Prestress$_{HORZ.}$

$= 1.1\sqrt{f'_c}\,A_{key} + \left[F_V + \frac{3}{4}PS\cos 40° + \frac{PS}{4} - \text{wt of key}\right]\tan 45° + cA_{BASE} + 2sdw + \frac{3}{4}PS\sin 40°$

$= 1.1\sqrt{6327}\,(4)(41)\left(\frac{144}{1000}\right) + \left[1604 + \frac{3}{4}(3538)\cos 40° + \frac{3538}{4} - 0.15(4)(5)(41)\right](1) + 0.8(29.54)(44) + 0 + \frac{3}{4}(3538)\sin 40°$

$= 2066 + 4398 + 1072 + 0 + 1705$

$= 9211$ Kips

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 2379.91 - 0.0625\left[539 - \frac{471+479}{2}\right](5)(41) + 468.02$

$= 2303$ Kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance + Prestress$_{HORZ.}$

$= 4398\tan 26° + 0 + \frac{3}{4}(3538)\sin 40°$

$= 2145 + 0 + 1705$

$= 3850$ Kips

$S_{s\text{-}f} = \frac{3850}{2303} = 1.67 > 1.5$

Without {Strut Resistance} $= \frac{3850}{2303} = 1.67$

A104

Figure A24. (Sheet 4 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Extreme Maintenance Condition with both bays dewatered

COMPUTED BY: DATE:

CHECKED BY: DATE:

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{Uplift}$$

$$= 0 + 0.0625[539-499] = 0 + 2.50 = 2.50 \quad \text{KSF} \quad \underline{\text{Heel}}$$

$$= \frac{2(1604)}{3(\cancel{-5.51})_{\to 0}} + 0.0625[503.6-499] = \infty + 0.29 = \infty \quad \text{KSF} \quad \underline{\text{Toe}}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{Uplift}$$

$$= \frac{1604 + \frac{3}{4}(3538)\cos 40^\circ + \frac{3538}{4}}{(41)(33.54)} \pm \frac{1604\left(\frac{33.54}{2}+5.51\right) + \frac{3}{8}(3538)\left[\left(\frac{33.54}{2}-8\right)\cos 40^\circ - (510-499)\sin 40^\circ\right] + \frac{3}{8}(3538)\left[\left(\frac{33.54}{2}-13\right)\cos 40^\circ - (510-499)\sin 40^\circ\right] - \frac{3538}{4}\left(25-\frac{33.54}{2}\right)}{(41)(33.54)^2/6} + \text{Uplift}$$

$$= \frac{1604+2033+885}{(41)(33.54)} \pm \frac{35737-468-5549-7279}{(41)(33.54)^2/6} + \text{Uplift}$$

$$= 3.29 - 2.92 + 2.50 = 0.37 + 2.50 = 2.87 \quad \text{KSF} \quad \underline{\text{Heel}}$$

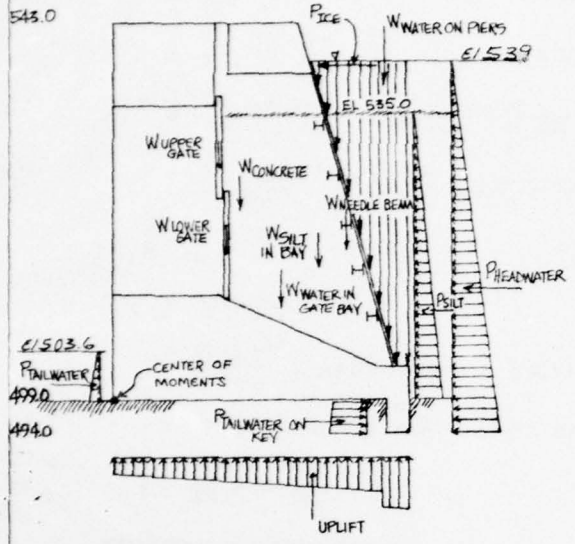
$$= 3.29 + 2.92 + 0.29 = 6.21 + 0.29 = 6.50 \quad \text{KSF} \quad \underline{\text{Toe}}$$

Figure A24. (Sheet 5 of 5)

SUBJECT: Brandon Road Head-Gate Monolith
Normal Operation + Ice Condition

COMPUTED BY:
CHECKED BY:
DATE
DATE

Sign Convention
Forces +/
Arms +/



ITEM	FACTORS	F_V	F_H	ARM	MOMENT
$W_{CONCRETE}$	$[.1493][2][(12)(15)(11)+(10)(4)(15)+(1/2)(4)(.83)(15)+(13.29)(15)(12)+(15)(1/2)(15.25)(511-507)+(15)(507-499)(15.25+5)+(20.5)(506.5-494)(2)+(20.5)(2)(.499-494)+(5.5)(543-499)(24.04)+(5.5)(1/2)(543-499)(33.54-2-24.04)]$	+4505.1		+14.14	+63,702.11
$W_{LOWER\ GATE}$	(VALUES VERIFIED AND TAKEN FROM APPENDIX E,	+ 22.0		+13.29	+292.38
$W_{UPPER\ GATE}$	BRANDON RD STABILITY ANALYSIS OF DAM	+ 15.2		+11.69	+177.69
$W_{NEEDLE\ BEAM}$	MASONRY	+ 14.72		+28.84	+424.52
$W_{WATER\ IN\ GATE\ BAYS}$	$[.0625][2][(7.25)(22.54)(15)+(10.5)(21.16)(15)+(10.25)(19.5)(15)+(5)(4)(15)+(1/2)(14.5)(4)(15)]$	+11 89.63		+23.33	+27,754.87
$W_{SILT\ IN\ GATE\ BAYS}$	$[.0203][2][(3.25)(22.54)(15)+(10.5)(21.16)(15)+(10.25)(19.5)(15)+(5)(4)(15)+(1/2)(14.5)(4)(15)]$	+ 331.48		+23.51	+ 7,793.09
$W_{WATER\ ON\ PIERS}$	$[.0625][(2)(4+4+3)(32)+(1/2)(9.5)(32)(4+4+3)]$	+ 148.50		+29.61	+ 4,397.09
UPLIFT	$[(2.812-2.583)(1/2)(4)+(2.583)(4)+(1.983-0.287)(1/2)(29.54)+(0.287)(29.54)][41]$	- 1817.53		+21.64	- 39,331.35
$P_{HEADWATER}$	$[.0625](1/2)(539-494)^2(4+15+3+15+4)$		+2594.53	-10.00	- 25,945.30
$P_{TAILWATER}$	$[.0625](1/2)(508.6-499)^2(4+15+3+15+4)(6)$		- 16.27	-1.53	+ 24.89
P_{SILT}	$[.0203](1/2)(.5)(535-499)^2(41)$		+ 269.67	-12.00	- 3,236.04
$P_{TAILWATER\ ON\ KEY}$	$[(1.983)(5)+(1/2)(.596)(5)][41]$		- 468.02	+2.61	- 1,221.53
P_{ICE}	$[5^K](1)(41)$		+ 205.00	-39.50	- 8097.50
		+4409.10	+2584.91		+ 26,734.12

Resultant location from moment center $= \frac{26,734}{4409.1} = 6.06'$

% Effective Base $= \frac{3(6.06)}{33.54} = 54.20\%$

Figure A25. Stability analysis, head-gate monolith, normal operation plus ice (Sheet 1 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Normal Operation + Ice Condition

COMPUTED BY:

CHECKED BY:

DATE

DATE

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(2.41)}{33.54} = 21.56\%$$

$$\text{Shear Friction Safety Factor } (S_{s\cdot f}) = \frac{6050}{2508} = 2.41 < 4.00$$

$$\text{Without} \left\{ \text{Strut Resistance} \right\} = \frac{6050}{2508} = 2.41$$

$$\text{Without} \left\{ \begin{matrix} \text{Strut Resistance} \\ \text{Cohesion,} \\ \text{Key Resistance} \end{matrix} \right\} = \frac{2942}{2508} = 1.17$$

SLIDING (BEFORE PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance

$$= 1.1\sqrt{5000}\, A_{key} + \left[F_V - \text{Wt of Key}\right] \tan 45° + cA_{base} + 2sd\cdot w$$

$$= 1.1\sqrt{6327}(4)(41)\left(\frac{144}{1000}\right) + \left[3065 - 0.15(4)(5)(41)\right](1) + 0.86(29.54)(41) + 0$$

$$= 2066 + 2942 + 1042 + 0$$

$$= 6050 \text{ Kips}$$

$$\text{Driving Force} = F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$$

$$= 2584.91 - 0.0625\left[539 - \frac{494+499}{2}\right](5)(41) + 468.02$$

$$= 2508 \text{ Kips}$$

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan φ + Strut Resistance

$$= 2942 \tan 26° + 0$$

$$= 1435 \text{ Kips}$$

$$S_{s\cdot f} = \frac{1435}{2508} = 0.57 < 1.5$$

$$\text{Without} \left\{ \text{Strut Resistance} \right\} = \frac{1435}{2508} = 0.57$$

A107

Figure A25. (Sheet 2 of 5)

SUBJECT	COMPUTED BY	DATE
Brandon Road - Head-Gate MONOLITH Normal Operation + Ice Condition	CHECKED BY	DATE

APPLYING FULL UPLIFT UNDER NON-COMPRESSIVE AREA OF BASE

PRESTRESS NEEDED TO MEET SLIDING CRITERIA

Resistance to Sliding = Key Resistance + $V \tan\phi$ + CA_{BASE} + STRUT RESISTANCE + HORIZONTAL COMPONENT OF PRESTRESS FORCE

$= 1.1\sqrt{f'_c}\, A_{KEY} + \left[F_V + \left(\frac{3}{4}\right) PS \cos 40^\circ + \left(\frac{1}{4}\right) PS - \text{Wt of } K_{ey}\right] \tan 45^\circ + CA_{BASE} + 2sdw + \left(\frac{3}{4}\right) PS \sin 40^\circ$

$= 1.1\sqrt{6327}(4)(41)\left(\frac{144}{1000}\right) + \left[3065 + \left(\frac{3}{4}\right) PS \cos 40^\circ + \left(\frac{1}{4}\right) PS - 0.15(5)(4)(41)\right] \tan 45^\circ + 0.86(29.54)(41) + 0 + \left(\frac{3}{4}\right) PS \sin 40^\circ$

$= 2066 + \left[2942 + 0.825\, PS\right] + 1042 + 0 + 0.482\, PS$

$= 1.307\, PS + 6050$

DRIVING FORCE $= F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 2584.91 - 0.0625\left[539 - \frac{494 + 499}{2}\right](5)(41) + 468.02$

$= 2508$ Kips

Shear Friction Safety Factor ($S_{S\text{-}F}$) $= \frac{\text{Resistance to Sliding}}{\text{Driving Force}} = \frac{1.307\, PS + 6050}{2508} = 4.0$ (Minimum Required)

$PS = \frac{4(2508) - 6050}{1.307}$

$PS = 3047$ Kips

NES FORM NO. 1253A

Figure A25. (Sheet 3 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Normal Operation + Ice Condition

COMPUTED BY | DATE
CHECKED BY | DATE

Shear Friction Safety Factor $(S_{S.F.}) = \frac{10,672}{2508} = 4.26 > 4.00$

Without {Strut Resistance} $= \frac{10,672}{2508} = 4.26$

Without {Strut Resistance, Cohesion, Key Resistance} $= \frac{5859 + 1705}{2508} = 3.02$

Full Uplift Applied Under non-Compressive Area of Base.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance + Prestress$_{HORZ}$

$= 1.1\sqrt{f'_c}\,A_{KEY} + \left[F_V + \frac{3}{4}PS\cos 40° + \frac{PS}{4} - \text{Wt of Key}\right]\tan 45° + CA_{BASE} + 2sd_{TW} + \frac{3}{4}PS\sin 40°$

$= 1.1\sqrt{6327}(9)(41)\left(\frac{144}{1000}\right) + \left[3065 + \frac{3}{4}(3538)\cos 40° + \frac{3538}{4} - 0.15(9)(5)(41)\right](1) + 0.86(29.54)(41) + 0 + \frac{3}{4}(3538)\sin 40°$

$= 2066 + 5859 + 1042 + 0 + 1705$

$= 10,672$ Kips

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 2584.91 - 0.0625\left[539 - \frac{494 + 499}{2}\right](5)(41) + 468.02$

$= 2508$ Kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan Φ + Strut Resistance + Prestress$_{HORZ}$

$= 5859 \tan 26° + 0 + \frac{3}{4}(3538)\sin 40°$

$= 2858 + 0 + 1705$

$= 4563$ Kips

$S_{S-F} = \frac{4563}{2508} = 1.82 > 1.5$

Without {Strut Resistance} $= \frac{4563}{2508} = 1.82$

A109

Figure A25. (Sheet 4 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Normal Operation + Ice Condition

COMPUTED BY | DATE
CHECKED BY | DATE

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{Uplift}$$

$= 0. + 0.0625[539 - 499] = 0. + 2.50 = 2.50$ KSF Heel

$= \frac{2(3065)}{3(2.41)} + 0.0625[503.6 - 499] = 847.86 + 0.29 = 848.15$ KSF Toe

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{Uplift}$$

$$= \frac{3065 + \frac{3}{8}(3538)\cos 40^\circ + \frac{3538}{4}}{(41)(33.54)} \pm \frac{3065\left(\frac{33.54}{2} - 2.41\right) + \frac{3}{8}(3538)\left[\left(\frac{33.54}{2} - 8\right)\cos 40^\circ - (510 - 499)\sin 40^\circ\right] + \frac{3}{8}(3538)\left[\left(\frac{33.54}{2} - 13\right)\cos 40^\circ - (510 - 499)\sin 40^\circ\right] - \frac{3538}{4}\left(25 - \frac{33.54}{2}\right)}{(41)(33.54)^2/6} + \text{Uplift}$$

$$= \frac{3065 + 2033 + 885}{(41)(33.54)} \pm \frac{44{,}013 - 468 - 5549 - 7279}{(41)(33.54)^2/6} + \text{Uplift}$$

$= 4.35 - 4.00 + 2.50 = 0.35 + 2.50 = 2.85$ KSF Heel

$= 4.35 + 4.00 + 0.29 = 8.35 + 0.29 = 8.64$ KSF Toe

A110

Figure A25. (Sheet 5 of 5)

SUBJECT: Brandon Road - Head-Gate Monolith
Flood Condition

COMPUTED BY:
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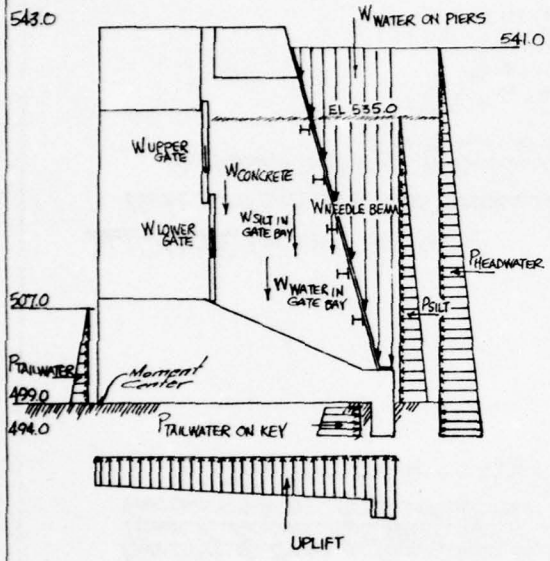
DATE:
DATE:

Sign Convention
Forces +
Arms +



ITEM	FACTORS	Fv	FH	ARM	MOMENT
W CONCRETE	[.1493][2][(12)(15)(11) + (10)(4)(15) + (½)(4)(.83)(15) + (13.29)(15)(12) + (15)(½)(15.25)(511-507) + (15)(507-499)(15.25+3) + (20.5)(506.5-494)(2) + (20.5)(2)(499-494) + (5.5)(543-499)(24.04) + (5.5)(½)(543-499)(33.54-2-24.04)]	+4505.1		+ 14.14	+ 63,702.11
W LOWER GATE	(VALUES VERIFIED AND TAKEN FROM APPENDIX E,	+ 22.0		+ 13.29	+ 292.38
W UPPER GATE	BRANDON RD. STABILITY ANALYSIS OF DAM	+ 15.2		+ 11.69	+ 177.69
W NEEDLE BEAMS	MASONRY	+ 14.72		+ 28.84	+ 424.52
W WATER IN GATE BAYS	[.0625][2][(7.25)(22.54)(15) + (10.5)(21.16)(15) + (10.25)(19.5)(15) + (5)(4)(15) + (½)(14.5)(4)(15) + (2)(8.44)(15)]	+ 1221.28		+ 23.49	+ 28,687.87
W SILT IN GATE BAYS	[.0203][2][(3.25)(22.54)(15) + (10.5)(21.16)(15) + (10.25)(19.5)(15) + (5)(4)(15) + (½)(14.5)(4)(15)]	+ 331.48		+ 23.51	+ 7,793.09
W WATER ON PIERS	[.0625][(2)(4+4+3)(34) + (½)(8.97)(34)(4+4+3)]	+ 151.59		+ 29.78	+ 4,514.35
UPLIFT	[(2.938-2.717)(½)(4) + (2.717)(4) + (2.129-0.500)(½)(29.54) + (0.500)(29.54)][41]	- 2055.74		+ 20.92	- 43,006.08
P HEADWATER	[.0625](½)(541-494)²(4+15+3+15+4)		+ 2830.28	- 10.66	- 30,170.78
P TAILWATER	[.0625](½)(507.0-499)²(4+15+3+15+4)(.6)		- 49.20	- 2.66	+ 130.87
P SILT	[.0203](½)(5)(535-499)²(41)		+ 269.67	- 12.00	- 3,236.04
P TAILWATER ON KEY	[(2.129)(5) + (½)(.588)(5)][41]		- 496.72	+ 2.60	- 1,291.47
		+ 4205.63	+ 2554.03		+ 28,018.51

Resultant location from center of moments = $\frac{28,018.51}{4205.63} = 6.66'$

% Effective Base = $\frac{3(6.66)}{33.54} = 59.57\%$

A111

Figure A26. Stability analysis, head-gate monolith, flood condition (Sheet 1 of 5)

SUBJECT: Brandon Road - Head - Gate MONOLITH
Flood Condition

COMPUTED BY: DATE:
CHECKED BY: DATE:

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(3.34)}{33.54} = 29.87\%$$

$$\text{Shear Friction Safety Factor } (S_{S\text{-}F}) = \frac{6022}{2481} = 2.43 < 4.00$$

$$\text{Without } \{\text{Strut Resistance}\} = \frac{6022}{2481} = 2.43$$

$$\text{Without } \left\{\begin{matrix}\text{Strut Resistance} \\ \text{Cohesion} \\ \text{Key Resistance}\end{matrix}\right\} = \frac{2914}{2481} = 1.17$$

SLIDING (BEFORE PRESTRESS)

Under Conditions of Least Probable Existing Parameters

$$\text{Resistance to Sliding} = \text{Key Resistance} + V \tan 45° + CA + \text{Strut Resistance}$$

$$= 1.1\sqrt{f'_c}\, A_{KEY} + [F_v - \text{wt of Key}] \tan 45° + C A_{BASE} + 2\, s d w$$

$$= 1.1\sqrt{6327}\,(4)(41)\left(\tfrac{144}{1000}\right) + [3037 - 0.15(4)(5)(41)](1) + 0.86\,(29.54)\,(41) + 0$$

$$= 2066 + 2914 + 1042 + 0$$

$$= 6022 \text{ Kips}$$

$$\text{Driving Force} = F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$$

$$= 2554.03 - 0.0625\left[541 - \frac{494+499}{2}\right](5)(41) + 496.72$$

$$= 2481 \text{ Kips}$$

Under Conditions Using Lower Bound Parameters

$$\text{Resistance to Sliding} = V \tan \phi + \text{Strut Resistance}$$

$$= 2914 \tan 26° + 0$$

$$= 1421 \text{ Kips}$$

$$S_{S\text{-}F} = \frac{1421}{2481} = 0.57 < 1.5$$

$$\text{Without } \{\text{Strut Resistance}\} = \frac{1421}{2481} = 0.57$$

Figure A26. (Sheet 2 of 5)

SUBJECT	COMPUTED BY	DATE
Brandon Road - Head-Gate MONOLITH Flood Condition	CHECKED BY	DATE

APPLYING FULL UPLIFT UNDER NON-COMPRESSIVE AREA OF BASE

PRESTRESS NEEDED TO MEET SLIDING CRITERIA

Resistance to Sliding = Key Resistance + $V \tan\phi$ + CA_{BASE} + Strut Resistance + Horizontal Component of Prestress Force

$= 1.1\sqrt{f'_c}\, A_{Key} + \left[F_V + \frac{3}{4} PS \cos 40^\circ + \frac{PS}{4} - \text{Wt of Key}\right] \tan 45^\circ + CA_{BASE} + 2sdw + \frac{3}{4} PS \sin 40^\circ$

$= 1.1\sqrt{6327}(4)(41)\left(\frac{144}{1000}\right) + \left[3037 + \frac{3}{4} PS \cos 40^\circ + \frac{PS}{4} - 0.15(6)(4)(41)\right] \tan 45^\circ + 0.86(29.54)(41) + 0 + \frac{3}{4} PS \sin 40^\circ$

$= 2066 + [2914 + 0.825\, PS] + 1042 + 0 + 0.482\, PS$

$= 1.307\, PS + 6022$

Driving Force $= F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$

$= 255403 - 0.0625\left[541 - \frac{494+499}{2}\right](5)(41) + 496.72$

$= 2481$ Kips

Shear Feiction Safety Factor $(S_{S-F}) = \frac{\text{Resistance to Sliding}}{\text{Driving Force}} = \frac{1.307\,PS + 6022}{2481} = 4.0$ (Minimum Required)

$PS = \frac{4(2481) - 6022}{1.307}$

$PS = 2985$ Kips

A113

Figure A26. (Sheet 3 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Flood Condition

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

Full Uplift Applied Under non-Compressive Area of Base.

Shear Friction Safety Factor $(S_{S-F}) = \frac{10,644}{2481} = 4.29 > 4.00$

Without {Strut Resistance} $= \frac{10,644}{2481} = 4.29$

Without {Strut Resistance, Cohesion, Key Resistance} $= \frac{5831 + 1705}{2481} = 3.04$

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance + Prestress_{HORZ}

$= 1.1\sqrt{f'_c}A_{KEY} + \left[F_V + \frac{3}{4}PS\cos 40° + \frac{PS}{4} - \text{Wt of Key}\right]\tan 45° + CA_{BASE} + 2sdw + \frac{3}{4}PS\sin 40°$

$= 1.1\sqrt{6327}(4)(41)\left(\frac{144}{1000}\right) + \left[3037 + \frac{3}{4}(3538)\cos 40° + \frac{3538}{4} - 0.15(4)(5)(41)\right](1) + 0.86(29.54)(41) + 0 + \frac{3}{4}(3538)\sin 40°$

$= 2066 + 5831 + 1042 + 0 + 1705$

$= 10,644$ Kips

Driving Force $= F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 2554.03 - 0.0625\left[541 - \frac{494+499}{2}\right](5)(41) + 496.72$

$= 2481$ Kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance + Prestress_{HORZ}

$= 5831 \tan 26° + 0 + \frac{3}{4}(3538)\sin 40°$

$= 2844 + 0 + 1705$

$= 4549$ Kips

$S_{S-F} = \frac{4549}{2481} = 1.83 > 1.5$

Without {Strut Resistance} $= \frac{4549}{2481} = 1.83$

Figure A26. (Sheet 4 of 5)

SUBJECT	COMPUTED BY	DATE
Brandon Road - Head-Gate MONOLITH Flood Condition	CHECKED BY	DATE

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{Uplift}$$

$$= 0. + 0.0625\left[541 - 499\right] = 0. + 2.63 = 2.63 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= \frac{2(3037)}{3(3.34)} + 0.0625\left[507 - 499\right] = 606.19 + 0.50 = 606.69 \text{ KSF} \quad \underline{\text{Toe}}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{Uplift}$$

$$= \frac{3037 + \frac{3}{8}(3538)\cos 40^\circ + \frac{3538}{4}}{(41)(33.54)} \pm \frac{3037\left(\frac{33.54}{2} - 3.34\right) + \frac{3}{8}(3538)\left[\left(\frac{33.54}{2} - 8\right)\cos 40^\circ - (510-499)\sin 40^\circ\right] + \frac{3}{8}(3538)\left[\left(\frac{33.54}{2} - 13\right)\cos 40^\circ - (510-499)\sin 40^\circ\right] - \frac{3538}{4}\left(25 - \frac{33.54}{2}\right)}{(41)(33.54)^2/6} + \text{Uplift}$$

$$= \frac{3037 + 2033 + 885}{(41)(33.54)} \pm \frac{49787 - 468 - 5549 - 7279}{41(33.54)^2/6} + \text{Uplift}$$

$$= 4.33 - 3.58 + 2.63 = 0.75 + 2.63 = 3.38 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= 4.33 + 3.58 + 0.50 = 7.91 + 0.50 = 8.41 \text{ KSF} \quad \underline{\text{Toe}}$$

Figure A26. (Sheet 5 of 5)

SUBJECT: Brandon Road Head-Gate Monolith
Normal Operation + Earthquake

COMPUTED BY:
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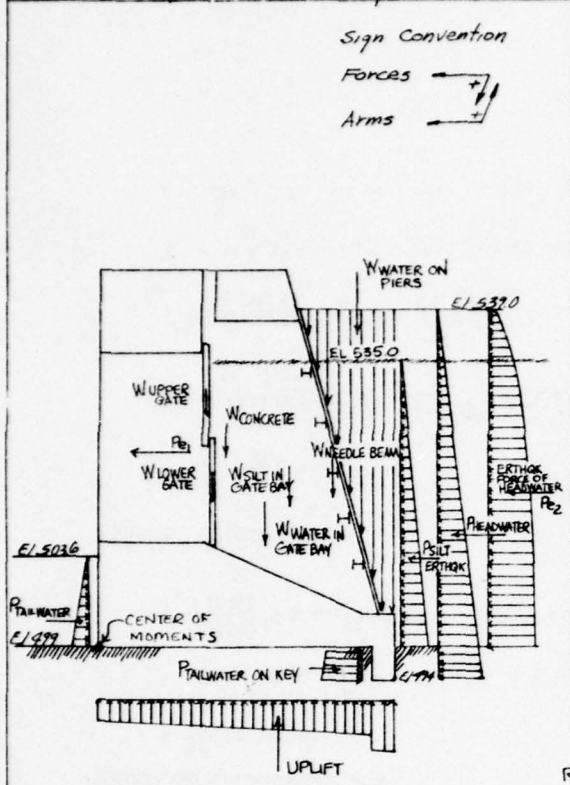

ITEM	FACTORS	Fv	FH	ARM	MOMENT
W CONCRETE	[.1493][2][(12)(15)(11) + (10)(4)(15) + (½)(4)(.83)(15) + (13.29)(15)(12) + (15)(½)(16.25)(511-507) + (15)(507-499)(15.25+5) + (20.5)(506.5-494)(2) + (20.5)(2)(499-494) + (5.5)(543-499)(24.04) + (5.5)(½)(543-499)(33.54-2-24.04)]	+4505.1		+14.14	+63,702.11
W LOWER GATE	(VALUES VERIFIED AND TAKEN FROM APPENDIX E,	+ 22.0		+13.29	+ 292.38
W UPPER GATE	BRANDON RD. STABILITY ANALYSIS OF DAM	+ 15.2		+11.69	+ 177.69
W NEEDLE BEAMS	MASONRY)	+ 14.72		+28.84	+ 424.52
W WATER IN GATE BAYS	[.0625][2][(7.25)(22.54)(15) + (10.5)(21.16)(15) + (10.25)(19.5)(15) + (5)(4)(15) + (½)(14.5)(4)(15)]	+1189.63		+23.33	+27,754.07
W SILT IN GATE BAYS	[.0203][2][(3.25)(22.54)(15) + (10.5)(21.16)(15) + (10.25)(19.5)(15) + (5)(4)(15) + (½)(14.5)(4)(15)]	+ 331.48		+23.51	+ 7,793.09
W WATER ON PIERS	[.0625][(2)(4+4+3)(32) + (½)(9.5)(32)(4+4+3)]	+ 148.50		+ 29.61	+ 4,397.09
UPLIFT	[(2.812-2.583)(½)(4) + (2.583)(4) + (1.983-0.287)(½)(29.54) + (0.287)(29.54)][41]	- 1817.53		+21.64	-39,331.35
PHEADWATER	[.0625][(½)(539-494)²(4+15+3+15+4)		+2594.53	- 10.00	-25,945.30
PTAILWATER	[.0625][(½)(508.6-499)²(4+15+3+15+4)(.6)		- 16.27	- 1.53	+ 24.89
PSILT ERTHQK	[.0203][(½)(54)(535-499)²(41)		+ 291.24	-13.41	- 3,905.53
PTAILWATER ON KEY	[(1.983)(5) + (½)(.599)(5)][41]		- 468.02	+ 2.61	- 1,221.53
ERTHQK FORCE OF GATES, CONCRETE, NEEDLE BEAMS, SILT IN BAYS, AND WATER IN BAYS	$P_{e1} = \alpha(\omega) = [0.05][(4505.1 + 22 + 15.2 + 14.72 + 331.48 + 1189.63)]$		+ 303.91	- 19.74	- 5,999.18
ERTHQK FORCE OF HEADWATER	$P_{e2} = [(2/3)(52.5)(.05)(40)\sqrt{40^2}]\frac{41}{1000}$ (1)		+ 114.80	- 16.00	- 1,836.80
		+ 4409.1	+2820.19		+26,326.15

Resultant location from moment center = $\frac{26,326.15}{4409.1} = 5.97'$

% Effective Base = $\frac{3(5.97)}{33.54} = 53.40\%$

Figure A27. Stability analysis, head-gate monolith, normal operation plus earthquake (Sheet 1 of 5)

SUBJECT	COMPUTED BY	DATE
Brandon Road - Head-Gate MONOLITH Normal Operation + Earthquake	CHECKED BY:	DATE

OVERTURNING

Portion of Base in Compression Determined by Trial & Error, Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(2.91)}{33.54} = 26.03\%$$

$$\text{Shear Friction Safety Factor } (S_{s\text{-}f}) = \frac{6455}{2744} = 2.35 < 2.67$$

$$\text{Without } \{\text{Strut Resistance}\} = \frac{6455}{2744} = 2.35$$

$$\text{Without } \{\text{Strut Resistance, Cohesion, Key Resistance}\} = \frac{3347}{2744} = 1.22$$

SLIDING (BEFORE PRESTRESS)

Under Conditions of Least Probable Existing Parameters

$$\text{Resistance to Sliding} = \text{Key Resistance} + V\tan 45° + cA + \text{Strut Resistance}$$

$$= 1.1\sqrt{f'_c}\,A_{key} + [F_V - \text{Wt of Key}]\tan 45° + c\,A_{base} + 2sdw$$

$$= 1.1\sqrt{6327}\,(4)(41)\left(\frac{144}{1000}\right) + \left[3470 - 0.15(4)(5)(41)\right](1) + 0.86(29.54)(41) + 0$$

$$= 2066 + 3347 + 1042 + 0$$

$$= 6455 \text{ Kips}$$

$$\text{Driving Force} = F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$$

$$= 2820.19 - 0.0625\left[539 - \frac{494+499}{2}\right](5)(41) + 468.02$$

$$= 2744 \text{ Kips}$$

Under Conditions Using Lower Bound Parameters

$$\text{Resistance to Sliding} = V\tan\phi + \text{Strut Resistance}$$

$$= 3347\tan 26° + 0$$

$$= 1632 \text{ Kips}$$

$$S_{s\text{-}f} = \frac{1632}{2744} = 0.59 < 1.5$$

$$\text{Without } \{\text{Strut Resistance}\} = \frac{1632}{2744} = 0.59$$

Figure A27. (Sheet 2 of 5)

SUBJECT	COMPUTED BY:	DATE:
Brandon Road - Head-Gate MONOLITH NORMAL OPERATION + EARTHQUAKE	CHECKED BY:	DATE:

APPLYING FULL UPLIFT UNDER NON-COMPRESSIVE AREA OF BASE

PRESTRESS NEEDED TO MEET SLIDING CRITERIA

Resistance to Sliding = Key Resistance + $V \tan\phi + cA_{BASE}$ + STRUT RESISTANCE + HORIZONTAL Component of Prestress Force

$= 1.1\sqrt{5'_c} + \left[F_v + \left(\frac{3}{4}\right) PS \cos 40° + \left(\frac{1}{4}\right) PS - wt \text{ of Key}\right] \tan 45° + cA_{BASE} + 2sdw + \left(\frac{3}{4}\right) PS \sin 40°$

$= 1.1\sqrt{6327}\ (4)(41)\left(\frac{144}{1000}\right) + \left[3470 + \left(\frac{3}{4}\right) PS \cos 40° + \left(\frac{1}{4}\right) PS - 0.15(5)(4)(41)\right] \tan 45° + 0.86(29.54)(41) + 0 + \left(\frac{3}{4}\right) PS \sin 40°$

$= 2066 + \left[3347 + 0.825\ PS\right] + 1042 + 0 + 0.482\ PS$

$= 1.307\ PS + 6455$

Driving Force = $F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 2820.19 - 0.0625\left[539 - \frac{494+499}{2}\right](5)(41) + 468.02$

$= 2744$ kips

Shear Friction Safety Factor $\left(S_{S-F}\right) = \frac{\text{Resistance to Sliding}}{\text{Driving Force}} = \frac{1.307\ PS + 6455}{2744} = 2.67$ (MINIMUM REQUIRED)

$PS = \frac{2.67(2744) - 6455}{1.307}$

$PS = 667$ Kips

WES FORM NO. 1253A

Figure A27. (Sheet 3 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Normal Operation + Earthquake

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

Shear Friction Safety Factor (S_{s-f}) = $\frac{11,077}{2,744}$ = 4.04 > 2.67

Without {Strut Resistance} = $\frac{11,077}{2,744}$ = 4.04

Without {Strut Resistance, Cohesion, Key Resistance} = $\frac{6264 + 1705}{2,744}$ = 2.90

Full Uplift Applied Under Non-Compressive Area of Base Using Uplift as Determined in the Normal Operating Case.

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + CA + Strut Resistance + Prestress_{HOR}

$= 1.1\sqrt{f'_c}\,A_{KEY} + \left[F_V + \left(\frac{3}{4}\right)PS\cos 40° + \frac{PS}{4} - \text{Wt of Key}\right]\tan 45° + CA_{BASE} + 2\,s\,d_{WT} + \left(\frac{3}{4}\right)PS\sin 40°$

$= 1.1\sqrt{6327}(4)(41)\left(\frac{144}{1000}\right) + \left[3470 + \left(\frac{3}{4}\right)(3538)\cos 40° + \frac{3538}{4}\right] 0.15(4)(5)(41)\,(1) + 0.86(29.54)(41) + 0 + \left(\frac{3}{4}\right)(3538)\sin 40°$

$= 2066 + 6264 + 1042 + 0 + 1705$

$= 11,077$ Kips

$S_{s-f} = \frac{4760}{2744} = 1.73 > 1.15$

Without {Strut Resistance} = $\frac{4760}{2744}$ = 1.73

Driving Force = $F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$

$= 2820.19 - 0.0625\left[539 - \frac{494 + 499}{2}\right](5)(41) + 468.02$

$= 2744$ Kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan φ + Strut Resistance + Prestress_{HOR}

$= 6264 \tan 26° + 0 + \left(\frac{3}{4}\right)(3538)\sin 40°$

$= 3055 + 0 + 1705$

$= 4760$ Kips

$S_{s-f} = \frac{4760}{2744} = 1.73 > 1.15$

Without {Strut Resistance} = $\frac{4760}{2744}$ = 1.73

Figure A27. (Sheet 4 of 5)

SUBJECT: Brandon Road - Head - Gate MONOLITH
Normal Operation + Earthquake

COMPUTED BY | DATE

CHECKED BY | DATE

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{Uplift}$$

$$= 0 + 0.0625\left[539 - 499\right] = 0 + 2.50 = 2.50 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= \frac{2(3470)}{3(2.91)} + 0.0625\left[503.6 - 499\right] = 794.96 + 0.29 = 795.25 \text{ KSF} \quad \underline{\text{Toe}}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{Uplift}$$

$$= \frac{3470 + \frac{3}{10}(3538)\cos 40^\circ + \frac{1}{10}(3538)}{(41)(33.54)} \pm \frac{3470\left(\frac{33.54}{2} - 2.91\right) + \frac{3}{10}(3538)\left[\left(\frac{33.54}{2} - 8\right)\cos 40^\circ - (510 - 499)\sin 40^\circ\right] + \frac{3}{10}(3538)\left[\left(\frac{33.54}{2} - 13\right)\cos 40^\circ - (510 - 499)\sin 40^\circ\right] - \left(\frac{3538}{4}\right)\left(25 - \frac{33.54}{2}\right)}{(41)(33.54)^2/6} + \text{Uplift}$$

$$= \frac{3470 + 2033 + 885}{(41)(33.54)} \pm \frac{48,094 - 468 - 5549 - 7279}{(41)(33.54)^2/6} + \text{Uplift}$$

$$= 4.65 - 4.53 + 2.50 = 0.12 + 2.50 = 2.62 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= 4.65 + 4.53 + 0.29 = 9.18 + 0.29 = 9.47 \text{ KSF} \quad \underline{\text{Toe}}$$

REES FORM NO. 1253A

Figure A27. (Sheet 5 of 5)

SUBJECT: Brandon Road Head Gate Monolith
induced surcharge condition

COMPUTED BY:
CHECKED BY:
DATE:
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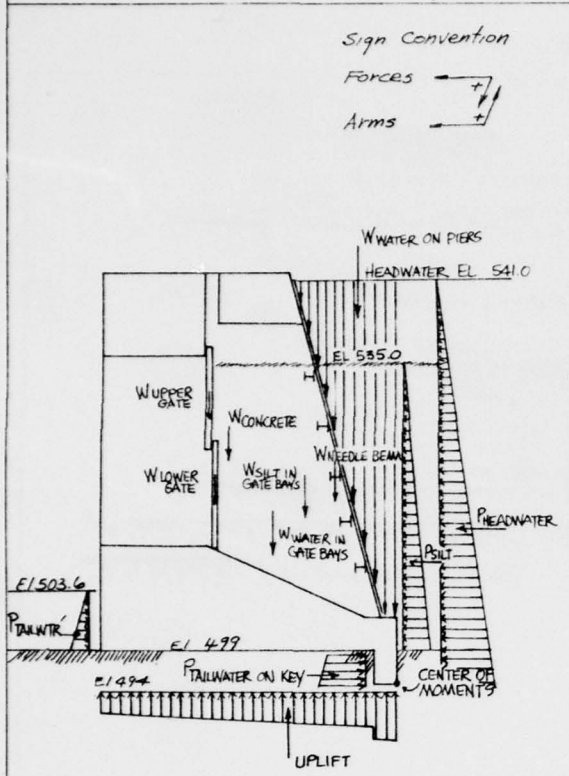

ITEM	FACTORS	Fv	FH	ARM	MOMENT
W CONCRETE	[.1493][2][(12)(15)(11) + (10)(4)(15) + (½)(4)(.83)(15) + (13.29)(15)(12) + (15)(½)(13.25)(511-507) + (15)(507-499)(15.25+5) + (20.5)(506.5-494)(2) + (20.5)(2)(499-494) + (5.5)(543-499)(24.04) + (5.5)(½)(543-499)(33.54-2-24.04)]	+ 4505.1		+ 14.14	+ 63,702.11
W LOWER GATE	VALUES VERIFIED AND TAKEN FROM APPENDIX E,	+ 22.0		+ 13.29	+ 292.38
W UPPER GATE	BRANDON RD. STABILITY ANALYSIS OF DAM	+ 15.2		+ 11.69	+ 177.69
W NEEDLE BEAMS	MASONRY	+ 14.72		+ 28.84	+ 424.52
W WATER IN GATE BAYS	[.0625][2][(7.25)(22.54)(15) + (10.5)(21.16)(15) + (10.25)(19.5)(15) + (5)(4)(15) + (½)(14.5)(4)(15) + (2)(8.44)(15)]	+ 1221.28		+ 23.49	+ 28,687.87
W SILT IN GATE BAYS	[.0203][2][(3.25)(22.54)(15) + (10.5)(21.16)(15) + (10.25)(19.5)(15) + (5)(4)(15) + (½)(14.5)(4)(15)]	+ 331.48		+ 23.51	+ 7,793.09
W WATER ON PIERS	[.0625][(2)(4+4+3)(34) + (½)(8.97)(34)(4+4+3)]	+ 151.59		+ 29.78	+ 4,514.35
UPLIFT	[(2.937-2.695)(½)(4) + (2.695)(4) + (2.079-0.287)(½)(29.54) + (0.287)(29.54)][41]	- 1894.99		+ 21.68	- 41,083.38
P HEADWATER	[.0625](½)(541-494)²(4+15+3+15+4)		+ 2830.28	- 10.66	- 30,170.78
P TAILWATER	[.0625](½)(508.6-499)²(4+15+3+15+4)(.6)		- 16.27	- 1.53	+ 24.89
P SILT	[.0203](½)(.5)(535-499)²(41)		+ 269.67	- 12.00	- 3,236.04
P TAILWATER ON KEY	[(2.079)(5) + (½)(.616)(5)][41]		- 489.33	2.61	- 1,277.15
		+ 4366.38	+ 2594.05		+ 29,849.55

Resultant location from center of moments = $\frac{29,849.55}{4,366.38} = 6.84'$

% Effective Base = $\frac{3(6.84)}{33.54} = 61.18\%$

Figure A28. Stability analysis, head-gate monolith, induced surcharge condition (Sheet 1 of 5)

SUBJECT: Brandon Road -Head-Gate MONOLITH
Induced Surcharge Condition

COMPUTED BY: DATE
CHECKED BY: DATE

OVERTURNING

Portion of Base in Compression Determined by Trial & Error. Full Uplift Applied Under non-Compressive Area of Base.

$$\% \text{ Effective Base} = \frac{3(3.30)}{33.54} = 29.52\ \%$$

$$\text{Shear Friction Safety Factor } (S_{s\text{-}f}) = \frac{6060}{2513} = 2.41 < 4.00$$

$$\text{Without } \{\text{Strut Resistance}\} = \frac{6060}{2513} = 2.41$$

$$\text{Without } \{\text{Strut Resistance, Cohesion, Key Resistance}\} = \frac{2952}{2513} = 1.17$$

SLIDING (BEFORE PRESTRESS)

Under Conditions of Least Probable Existing Parameters

$$\text{Resistance to Sliding} = \text{Key Resistance} + V\tan 45° + CA + \text{Strut Resistance}$$

$$= 1.1\sqrt{f'_c}\,A_{KEY} + [F_V - \text{Wt of Key}]\tan 45° + cA_{BASE} + 2\,sdw$$

$$= 1.1\sqrt{6327}\,(4)(41)\left(\frac{144}{1000}\right) + [3075 - 0.15(4)(5)(41)](1) + 0.86(29.54)(41) + 0$$

$$= 2066 + 2952 + 1042 + 0$$

$$= 6060 \text{ Kips}$$

$$\text{Driving Force} = F_H - P_{\text{HEADWTR ON KEY}} + P_{\text{TAILWTR ON KEY}}$$

$$= 2594.05 - 0.0625\left[541 - \frac{494+489}{2}\right](5)(41) + 489.33$$

$$= 2513 \text{ Kips}$$

Under Conditions Using Lower Bound Parameters

$$\text{Resistance to Sliding} = V\tan\phi + \text{Shear Resistance}$$

$$= 2952 \tan 26° + 0$$

$$= 1440 \text{ Kips}$$

$$S_{s\text{-}f} = \frac{1440}{2513} = 0.57 < 1.5$$

$$\text{Without } \{\text{Strut Resistance}\} = \frac{1440}{2513} = 0.57$$

A122

Figure A28. (Sheet 2 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH Induced Surcharge Condition	COMPUTED BY: CHECKED BY:	DATE: DATE:

APPLYING FULL UPLIFT UNDER NON-COMPRESSIVE AREA OF BASE

PRESTRESS NEEDED TO MEET SLIDING CRITERIA

Resistance to Sliding = Key Resistance + V tan ϕ + cA_{BASE} + Strut Resistance + Horizontal Component of Prestress Force

$= 1.1\sqrt{f'_c}\,A_{key} + \left[F_V + \frac{3}{4}PS\cos 40^\circ + \frac{PS}{4} - \text{wt of Key}\right]\tan 45^\circ + cA_{BASE} + 2sdw + \frac{3}{4}PS\sin 40^\circ$

$= 1.1\sqrt{6327}\,(4)(41)\left(\frac{144}{1000}\right) + \left[3075 + \frac{3}{4}PS\cos 40^\circ + \frac{PS}{4} - 0.15(4)(5)(41)\right](1) + 0.86(29.54)(41) + 0 + \frac{3}{4}PS\sin 40^\circ$

$= 2066 + \left[2952 + 0.825\,PS\right] + 1042 + 0 + 0.482\,PS$

$= 1307\,PS + 6060$

Driving Force $= F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 2594.05 - 0.0625\left[541 - \frac{494+499}{2}\right](5)(41) + 489.33$

$= 2513$ Kips

Shear Friction Safety Factor $(S_{s-F}) = \frac{\text{Resistance to Sliding}}{\text{Driving Force}} = \frac{1.307\,PS + 6060}{2513} = 4.0$ (Minimum Required)

$PS = \frac{4(2513) - 6060}{1.307}$

$PS = 3054$ Kips

A123

Figure A28. (Sheet 3 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Induced Surcharge Condition

COMPUTED BY: DATE:
CHECKED BY: DATE:

Full Uplift Applied Under non-Compressive Area of Base.

Shear Friction Safety Factor $(S_{S.F}) = \frac{10,682}{2513} = 4.25 > 4.00$

Without {Strut Resistance} $= \frac{10,682}{2513} = 4.25$

Without {Strut Resistance, Cohesion, Key Resistance} $= \frac{5869 + 1705}{2513} = 3.01$

SLIDING (AFTER PRESTRESS)

Under Conditions of Least Probable Existing Parameters

Resistance to Sliding = Key Resistance + V tan 45° + cA + Strut Resistance + $P_{Prestress_{HORZ}}$

$= 1.1\sqrt{f'_c}\, A_{KEY} + \left[F_V + \frac{3}{4} PS\cos 40° + \frac{PS}{4} - \text{wt of Key}\right]\tan 45°$
$cA_{BASE} + 2\,sdw + \frac{3}{4} PS \sin 40°$

$= 1.1\sqrt{6327}\,(4)(41)\left(\frac{144}{1000}\right) + \left[3075 + \frac{3}{4}(3538)\cos 40° + \frac{3538}{4} - 0.15(4)(5)(41)\right](1)$
$+ 0.86(29.54)(41) + 0 + \frac{3}{4}(3538)\sin 40°$

$= 2066 + 5869 + 1042 + 0 + 1705$

$= 10,682$ Kips

Driving Force $= F_H - P_{HEADWTR\ ON\ KEY} + P_{TAILWTR\ ON\ KEY}$

$= 2594.05 - 0.0625\left[541 - \frac{494 + 499}{2}\right](5)(41) + 489.33$

$= 2513$ Kips

Under Conditions Using Lower Bound Parameters

Resistance to Sliding = V tan ϕ + Strut Resistance + $P_{Prestress_{HORZ}}$

$= 5869 \tan 26° + 0 + \frac{3}{4}(3538)\sin 40°$

$= 2863 + 0 + 1705$

$= 4568$ Kips

$S_{S.F} = \frac{4568}{2513} = 1.82 < 1.5$

Without {Strut Resistance} $= \frac{4568}{2513} = 1.82$

WES FORM NO. 1243A

Figure A28. (Sheet 4 of 5)

SUBJECT: Brandon Road - Head-Gate MONOLITH
Induced Surcharge Condition

COMPUTED BY:

CHECKED BY:

DATE

DATE

BASE PRESSURES (With Full Uplift Under Non-Compressive Area of Base)

Without Prestress

$$f = \frac{2P}{3e} + \text{Uplift}$$

$$= 0. + 0.0625[541 - 499] = 0. + 2.63 = 2.63 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= \frac{2(3075)}{3(3.70)} + 0.0625[503.6 - 499] = 621.21 + 0.29 = 621.50 \text{ KSF} \quad \underline{\text{Toe}}$$

With Prestress

$$f = \frac{P}{A} \pm \frac{M}{S} + \text{Uplift}$$

$$= \frac{3075 + \frac{3}{4}(3538)\cos 40^\circ + \frac{3538}{4}}{(41)(33.54)} \pm \frac{3075\left(\frac{33.54}{2} - 330\right) + \frac{3}{8}(3538)\left[\left(\frac{33.54}{2} - 8\right)\cos 40^\circ - (510-499)\sin 40^\circ\right] + \frac{3}{8}(3538)\left[\left(\frac{33.54}{2} - 13\right)\cos 40^\circ - (510-499)\sin 40^\circ\right] + \frac{3538}{4}\left(25 - \frac{33.54}{2}\right)}{(41)(33.54)^2/6} + \text{Uplift}$$

$$= \frac{3075 + 2033 + 885}{(41)(33.54)} \pm \frac{41,420 - 468 - 5549 - 7279}{(41)(33.54)^2/6} + \text{Uplift}$$

$$= 4.36 - 3.66 + 2.63 = 0.70 + 2.63 = 3.33 \text{ KSF} \quad \underline{\text{Heel}}$$

$$= 4.36 + 3.66 + 0.29 = 8.02 + 0.29 = 8.31 \text{ KSF} \quad \underline{\text{Toe}}$$

Figure A28. (Sheet 5 of 5)

APPENDIX B: THREE-DIMENSIONAL FINITE ELEMENT ANALYSIS OF TAINTER-GATE MONOLITH AND FOUNDATION

TABLE B1
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION AA - NORMAL OPERATION
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1(psi)	σ_2(psi)	σ_3(psi)	γ_{max}(psi)
AREA A				
1	-11.63	3.00	-2.09	7.31
6	-10.84	7.71	-1.14	9.28
11	0.03	9.62	1.98	4.80
16	-8.84	6.50	-3.50	7.67
21	-14.67	1.28	-3.18	7.98
26	-6.22	2.94	-0.01	4.58
31	1.40	14.38	4.82	6.49
36	1.61	10.03	3.92	4.21
41	-2.39	4.39	1.09	3.39
46	3.78	25.16	8.06	10.69
51	2.13	13.80	3.33	5.84
56	-0.44	5.79	0.81	3.12
AREA B				
356	0.99	39.54	6.72	19.28
361	2.37	38.66	5.91	18.15
366	2.28	41.50	6.14	19.61
371	1.39	41.28	6.62	19.95
376	4.30	40.60	7.68	18.15
381	5.48	45.71	8.70	20.12
386	5.74	43.37	7.98	18.82
391	5.50	43.46	7.86	18.98
396	5.78	43.97	8.19	19.10
401	6.54	44.61	8.81	19.04
431	6.03	47.34	7.27	20.66
436	6.18	47.39	7.28	20.61
441	6.00	47.97	7.39	20.99
AREA C				
236	-23.15	29.82	5.16	26.49
241	-8.91	36.78	9.24	22.85
246	-10.35	34.20	7.23	22.28
251	-1.32	34.25	8.43	17.79
281	-17.75	20.68	4.19	19.22
286	-8.70	35.15	8.81	21.93
291	-10.18	9.57	-2.55	9.88
296	-7.14	27.56	5.18	17.35

TABLE B2

PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION AA - NORMAL OPERATION WITH ICE
TAINTER GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
1	-39.60	27.87	-0.33	33.74
6	-32.80	23.42	-3.83	28.11
11	-32.66	24.78	-0.02	28.72
16	-32.35	23.41	-4.36	27.88
21	-30.41	26.82	-14.30	28.62
26	-21.44	20.30	-2.79	20.87
31	-15.56	22.44	7.09	19.00
36	-11.58	24.21	4.35	17.90
41	-12.47	20.90	0.92	16.69
46	-9.39	24.77	5.04	17.08
51	-1.37	24.08	4.22	12.73
56	4.71	24.91	1.84	10.10
AREA B				
356	-0.25	37.89	6.21	19.07
361	2.05	35.54	5.33	16.75
366	2.34	37.90	5.53	17.78
371	1.58	38.24	6.13	18.33
376	4.22	38.91	7.38	17.35
381	4.84	43.91	8.27	19.54
386	5.63	40.99	7.55	17.68
391	5.65	40.95	7.44	17.65
396	5.92	41.75	7.83	17.92
401	6.59	43.33	8.60	18.37
431	6.10	45.29	6.99	19.60
436	6.37	45.38	7.02	19.51
441	6.20	46.18	7.17	19.99
AREA C				
236	-34.67	22.31	1.06	28.49
241	-13.30	31.59	7.26	22.45
246	-12.82	30.32	5.93	21.57
251	-2.34	32.43	7.83	17.39
281	-22.70	11.14	0.65	16.92
286	-11.50	28.14	6.68	19.82
291	-11.89	5.18	-4.91	8.54
296	-8.06	22.18	3.85	15.12

TABLE B3

PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS

SECTION AA - FLOOD CONDITION

TAINTER-GATE MONOLITH

BRANDON ROAD L&D

CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
1	-11.40	3.69	-1.73	7.55
6	-10.77	7.70	-0.73	9.24
11	0.60	9.80	2.35	4.60
16	-8.90	7.33	-3.18	8.12
21	-14.24	1.30	-2.48	7.77
26	-6.10	3.27	0.13	4.69
31	1.79	14.50	5.36	6.36
36	1.70	10.35	4.59	4.33
41	-2.26	4.80	1.28	3.53
46	4.38	24.72	8.07	10.17
51	2.40	14.50	3.84	6.05
56	-0.24	6.68	0.91	3.46
AREA B				
356	0.29	39.37	6.56	19.54
361	2.19	37.67	5.70	17.74
366	2.30	40.37	5.94	19.04
371	1.45	40.42	6.47	19.49
376	4.45	40.33	7.66	17.94
381	5.20	45.47	8.61	20.14
386	5.75	42.79	7.88	18.52
391	5.65	42.80	7.77	18.58
396	5.98	43.45	8.13	18.74
401	6.79	44.54	8.84	18.88
431	6.15	46.92	7.23	20.39
436	6.39	46.98	7.25	20.30
441	6.23	47.68	7.38	20.73
AREA C				
236	-29.76	26.85	2.98	28.31
241	-11.75	35.39	8.27	23.57
246	-12.21	33.32	6.60	22.77
251	-1.84	34.17	8.29	18.01
281	-20.99	16.10	2.26	18.55
286	-10.63	32.32	7.70	21.48
291	-11.31	7.26	-3.78	9.29
296	-7.87	25.14	4.45	16.51

TABLE B4

PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION BB - NORMAL OPERATION
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
2	-4.61	23.89	11.04	14.25
7	-38.48	19.22	6.65	28 85
12	-6.87	22.08	3.95	14.48
17	-3.56	104.79	7.85	54.18
22	-6.81	107.76	23.43	57.29
27	-1.56	17.51	7.99	9.54
32	-4.77	43.98	0.20	24.38
37	-4.13	44.47	2.77	24.30
42	-1.80	7.11	-0.39	4.46
47	1.73	40.50	4.28	19.39
52	-0.38	21.93	2.27	11.16
57	0.14	6.25	0.39	3.06
AREA B				
357	-0.59	38.45	7.23	19.52
362	2.33	32.99	7 35	15.33
367	3.34	33.33	7.21	15.00
372	0.66	37.31	7.41	18.33
377	3.78	39.93	8.07	18.08
382	5.13	44.73	9.15	19.80
387	5.98	41.63	8.79	17.83
392	6.10	41.52	8.79	17.71
397	5.99	42.10	8.88	18.06
402	6.25	43.81	9.14	18.78
432	6.14	46.46	7.62	20.16
437	6.29	46.48	7.63	20.10
442	6.14	47.14	7.72	20.50
AREA C				
237	-20.18	37.89	1.90	29.04
242	-7.48	42.24	6.98	24.86
247	-6.92	36.19	6.63	21.56
252	-0.22	34.33	8.01	17.28
282	-27.48	43.01	-4.08	35.25
287	-4.07	48.91	7.36	26.49
292	8.95	129.27	12.00	60.16
297	-5.57	34.12	2.04	19.85

TABLE B5
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION BB - NORMAL OPERATION WITH ICE
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
2	-0.78	28.50	5.05	14.64
7	-38.39	21.81	11.95	30.10
12	-22.64	28.33	4.49	25.49
17	-0.12	105.91	5.04	53.02
22	-10.89	107.40	38.90	59.15
27	-3.74	22.34	12.36	13.04
32	-12.42	45.61	-0.42	29.02
37	-10.63	47.34	12.56	28.99
42	-3.35	16.29	-1.56	9.82
47	-7.81	38.99	3.79	23.40
52	-3.72	26.86	6.48	15.29
57	-1.73	17.30	-0.31	9.52
AREA B				
357	-1.95	36.92	6.72	19.44
362	1.60	30.23	6.83	14.32
367	3.38	29.82	6.54	13.22
372	0.76	34.37	6.93	16.81
377	3.66	38.29	7.76	17.32
382	4.46	42.98	8.71	19.26
387	5.85	39.27	8.35	16.71
392	6.25	39.02	8.37	16.39
397	6.12	39.90	8.52	16.89
402	6.27	42.56	8.93	18.15
432	6.21	44.42	7.34	19.11
437	6.48	44.49	7.37	19.01
442	6.34	45.35	7.50	19.51
AREA C				
237	-30.22	29.10	-2.20	29.66
242	-11.28	36.57	4.95	23.93
247	-9.33	32.35	5.26	20.84
252	-1.27	32.57	7.40	16.92
282	-31.96	33.21	-7.72	32.59
287	-6.75	42.06	5.01	24.41
292	7.32	123.74	10.72	58.21
297	-7.18	29.71	0.46	18.45

TABLE B6
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION BB - FLOOD CONDITION
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
2	-3.86	24.21	11.45	14.04
7	-38.46	19.61	6.84	29.04
12	-6.66	22.36	4.84	14.51
17	-2.69	104.83	8.16	53.76
22	-6.74	108.31	24.01	57.53
27	-1.54	17.81	8.24	9.68
32	-4.15	43.97	0.68	24.01
37	-4.03	45.03	3.30	24.53
42	-1.83	7.79	0.27	4.81
47	2.13	40.08	4.78	18.98
52	-0.14	22.71	2.73	11.43
57	0.14	7.25	0.57	3.56
AREA B				
357	-1.36	38.34	7.07	19.85
362	1.96	32.17	7.18	15.11
367	3.40	32.21	6.97	14.41
372	0.71	36.46	7.27	17.88
377	3.92	39.67	8.06	17.88
382	4.83	44.52	9.05	19.85
387	5.98	41.05	8.69	17.54
392	6.25	40.87	8.70	17.31
397	6.19	41.58	8.82	17.70
402	6.48	43.75	9.18	18.64
432	6.27	46.04	7.58	19.89
437	6.50	46.08	7.60	19.79
442	6.37	46.85	7.72	20.24
AREA C				
237	-26.08	34.18	-0.26	30.13
242	-9.94	40.47	6.02	25.21
247	-8.68	35.21	5.98	21.95
252	-0.73	34.25	7.87	17.49
282	-30.49	38.27	-6.09	34.38
287	-5.71	45.85	6.19	25.78
292	7.83	126.51	11.20	59.34
297	-6.40	31.94	1.17	19.17

TABLE B7
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION CC - NORMAL OPERATION
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
3	-6.62	19.81	12.56	13.22
8	-34.60	22.23	3.75	28.42
13	-0.70	20.28	3.94	10.49
18	-4.47	92.02	10.91	48.25
23	-9.54	101.70	17.06	55.62
28	-0.76	20.59	5.78	10.68
33	-3.45	42.34	6.13	22.90
38	+0.56	47.42	8.24	23.43
43	-1.24	9.37	2.03	5.31
48	2.49	43.87	7.87	20.69
53	-0.26	25.26	5.24	12.76
58	0.05	7.66	1.89	3.81
AREA B				
358	-0.73	37.82	7.04	19.28
363	2.51	31.38	6.58	14.44
368	3.48	31.50	6.61	14.01
373	0.87	36.13	7.20	17.63
378	3.68	39.39	8.07	17.86
383	5.01	44.10	9.22	19.55
388	6.12	40.30	8.91	17.09
393	6.29	39.96	8.91	16.84
398	6.07	40.95	8.95	17.44
403	6.18	43.28	9.23	18.55
433	6.25	45.68	7.87	19.72
438	6.44	45.65	7.90	19.61
443	6.24	46.37	7.95	20.07
AREA C				
238	-19.06	39.66	3.13	29.36
243	-6.04	43.92	7.54	24.98
248	-5.88	37.05	6.50	21.47
253	0.39	34.61	7.77	17.11
283	-25.31	42.54	1.44	33.93
288	-4.16	49.27	9.78	26.72
293	-0.42	109.32	4.88	54.87
298	-6.19	34.09	3.93	20.14

TABLE B8
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION CC - NORMAL OPERATION WITH ICE
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
3	-9.01	18.10	14.62	13.56
8	-33.93	27.25	0.55	30.59
13	-4.05	15.75	3.95	9.90
18	-6.71	90.88	13.96	48.80
23	-6.97	108.92	13.70	57.95
28	-0.07	26.66	4.19	13.37
33	-2.99	39.28	2.83	21.14
38	-0.68	52.97	9.75	26.83
43	-1.95	16.71	1.73	9.33
48	1.66	40.00	2.98	19.17
53	-1.36	29.94	8.18	15.65
58	-0.32	15.86	2.37	8.09
AREA B				
358	-2.13	36.36	6.51	19.25
363	1.82	28.67	5.99	13.43
368	3.55	27.97	5.96	12.21
373	0.97	33.22	6.69	16.13
378	3.53	37.79	7.75	17.13
383	4.32	42.38	8.78	19.03
388	5.98	37.97	8.46	16.00
393	6.44	37.47	8.48	15.52
398	6.20	38.76	8.58	16.28
403	6.20	42.05	9.01	17.93
433	6.31	43.64	7.58	18.67
438	6.62	43.66	7.63	18.52
443	6.44	44.60	7.72	19.08
AREA C				
238	-28.61	30.81	-1.14	29.71
243	-9.69	38.30	5.38	24.00
248	-8.28	33.30	5.07	20.79
253	-0.67	32.90	7.13	16.79
283	-29.72	32.91	2.29	31.32
288	-6.86	42.55	7.41	24.71
293	-3.23	104.30	4.28	53.77
298	-7.67	29.76	2.14	18.72

TABLE B9
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION CC - FLOOD CONDITION
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
3	-5.99	20.13	13.00	13.06
8	-34.58	22.58	3.93	28.58
13	-0.32	20.51	4.71	10.42
18	-3.75	92.10	11.34	47.93
23	-9.46	102.23	17.65	55.85
28	-0.73	20.90	6.04	10.82
33	-2.57	42.31	6.40	22.44
38	0.91	48.01	8.48	23.55
43	-1.21	9.98	2.15	5.60
48	3.35	43.37	7.95	20.01
53	0.16	26.07	5.51	12.96
58	0.01	8.64	2.04	4.32
AREA B				
358	-1.52	37.74	6.88	19.63
363	2.15	30.58	6.38	14.22
368	3.54	30.36	6.40	13.41
373	0.93	35.27	7.06	17.17
378	3.82	39.14	8.05	17.66
383	4.69	43.90	9.13	19.61
388	6.11	39.74	8.81	16.82
393	6.44	39.30	8.81	16.43
398	6.27	40.43	8.89	17.08
403	6.41	43.23	9.26	18.41
433	6.37	45.26	7.82	19.45
438	6.65	45.25	7.87	19.30
443	6.47	46.09	7.95	19.81
AREA C				
238	-24.75	35.80	0.93	30.28
243	-8.41	42.07	6.57	25.24
248	-7.62	36.04	5.87	21.83
253	-0.12	34.52	7.63	17.32
283	-28.30	37.72	0.51	33.01
288	-5.81	46.17	8.65	25.99
293	-1.92	106.70	4.32	54.31
298	-7.00	31.87	3.06	19.44

TABLE B10
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION DD - NORMAL OPERATION
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
4	-6.07	19.64	10.10	12.86
9	-36.26	19.85	5.84	28.06
14	-1.64	20.94	3.85	11.29
19	-3.60	94.75	9.31	49.18
24	-10.63	101.84	20.65	56.24
29	-0.83	18.38	7.53	9.61
34	-3.67	43.53	6.72	23.60
39	-0.52	45.38	9.97	22.95
44	-1.16	8.01	3.28	4.59
49	2.47	45.60	8.71	21.57
54	0.05	25.61	6.64	12.78
59	0.27	7.67	2.51	3.70
AREA B				
359	-0.79	37.71	6.95	19.25
364	2.58	31.47	6.42	14.45
369	3.56	31.66	6.39	14.05
374	0.83	36.07	6.98	17.62
379	3.63	39.24	8.00	17.81
384	4.98	43.84	9.16	19.43
389	6.14	39.93	8.71	16.90
394	6.33	39.58	8.69	16.63
399	6.10	40.62	8.83	17.26
404	6.15	43.05	9.20	18.45
434	6.30	45.26	7.89	19.48
439	6.50	45.21	7.92	19.36
444	6.29	45.97	7.97	19.84
AREA C				
239	-19.05	39.90	3.99	24.48
244	-6.11	44.21	8.10	25.16
249	-5.84	37.34	6.74	21.59
254	0.49	34.79	7.74	17.15
284	-26.13	42.06	1.10	34.10
289	-4.20	49.23	9.84	26.72
294	0.47	115.58	5.93	57.56
299	-6.18	34.05	3.42	20.12

TABLE B11
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION DD - NORMAL OPERATION WITH ICE
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
4	-6.31	19.95	7.18	13.13
9	-36.14	19.19	8.58	27.67
14	-8.44	20.99	3.49	14.72
19	-2.40	94.92	6.74	48.66
24	-10.56	101.72	25.01	56.14
29	-0.18	18.27	11.52	9.23
34	-4.75	43.31	2.25	24.03
39	-1.31	46.39	14.67	23.85
44	-1.24	11.33	5.88	6.29
49	1.17	43.57	3.81	21.20
54	0.13	28.14	10.34	14.01
59	0.27	13.02	4.72	6.38
AREA B				
359	-2.19	36.26	6.41	19.23
364	1.89	28.78	5.83	13.45
369	3.60	28.16	5.75	12.28
374	0.92	33.19	6.46	16.14
379	3.48	37.66	7.68	17.09
384	4.29	42.14	8.71	18.93
389	6.00	37.62	8.25	15.81
394	6.48	37.11	8.26	15.32
399	6.23	38.45	8.44	16.11
404	6.16	41.84	8.98	17.84
434	6.37	43.24	7.59	18.44
439	6.69	43.23	7.65	18.27
444	6.49	44.21	7.74	18.86
AREA C				
239	-28.42	31.15	-0.33	29.79
244	-9.71	38.69	5.86	24.20
249	-8.21	33.68	5.24	20.95
254	-0.58	33.11	7.08	16.85
284	-30.49	32.43	-2.53	31.46
289	-6.88	42.56	7.49	24.72
294	-2.15	110.43	5.29	56.29
299	-7.67	29.68	1.71	18.68

TABLE B12
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION DD - FLOOD CONDITION
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
4	-5.44	19.94	10.55	12.69
9	-36.24	20.20	6.03	28.22
14	-1.34	21.19	4.67	11.27
19	-2.82	94.82	9.68	48.82
24	-10.56	102.33	21.28	56.45
29	-0.80	18.66	7.82	9.73
34	-2.80	43.51	6.99	23.16
39	-0.21	45.95	10.30	23.08
44	-1.17	8.66	3.40	4.92
49	3.32	45.12	8.80	20.90
54	0.48	26.39	6.93	12.96
59	0.29	8.62	2.72	4.17
AREA B				
359	-1.59	37.63	6.79	19.61
364	2.22	30.67	6.23	14.23
369	3.61	30.52	6.18	13.46
374	0.89	35.22	6.83	17.17
379	3.77	38.99	7.98	17.61
384	4.66	43.65	9.06	19.50
389	6.13	39.37	8.61	16.62
394	6.48	38.93	8.60	16.23
399	6.30	40.10	8.77	16.90
404	6.38	43.01	9.24	18.32
434	6.43	44.84	7.84	19.21
439	6.71	44.81	7.89	19.05
444	6.53	45.69	7.97	19.58
AREA C				
239	-24.73	36.02	1.79	30.38
244	-8.48	42.35	7.13	25.42
249	-7.57	36.33	6.11	21.95
254	-0.03	34.70	7.60	17.37
284	-29.12	37.25	-0.86	33.19
289	-5.85	46.14	8.71	26.00
294	-1.01	112.95	5.35	56.98
299	-6.99	31.84	2.56	19.42

TABLE B13
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION EE - NORMAL OPERATION
TAINTER GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
5	-6.57	19.23	10.65	12.90
10	-36.03	20.58	4.79	28.31
15	-1.13	20.31	3.82	10.72
20	-4.48	94.20	10.02	49.34
25	-10.56	102.45	19.04	56.51
30	-0.68	19.23	6.57	9.96
35	-3.60	43.19	7.03	23.40
40	-0.14	45.98	9.70	23.06
45	-1.21	8.25	3.22	4.73
50	2.47	45.61	9.41	21.57
55	-0.06	25.67	7.12	12.87
60	0.21	7.43	2.91	3.61
AREA B				
360	-0.78	37.64	6.91	19.21
365	2.59	31.32	6.36	14.37
370	3.58	31.50	6.33	13.96
375	0.86	36.01	6.92	17.58
380	3.63	39.21	7.95	17.79
385	4.98	43.76	9.12	19.39
390	6.16	39.85	8.66	16.85
395	6.36	39.49	8.64	16.57
400	6.12	40.52	8.76	17.20
405	6.15	42.98	9.17	18.42
435	6.32	45.12	7.86	19.40
440	6.53	45.07	7.89	19.27
445	6.31	45.83	7.95	19.76
AREA C				
240	-19.05	40.05	4.05	29.55
245	-6.09	44.35	8.13	25.22
250	-5.80	37.46	6.74	21.63
255	0.52	34.88	7.69	17.18
285	-26.02	42.31	1.37	34.17
290	-4.21	49.43	9.89	26.82
295	-0.10	114.57	5.64	57.34
300	-6.25	34.12	3.49	20.19

TABLE B14
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION EE - NORMAL OPERATION WITH ICE
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
5	-8.08	18.73	9.56	13.41
10	-35.62	21.84	4.86	28.73
15	-5.73	18.29	3.53	12.01
20	-5.06	93.71	9.71	49.39
25	-9.24	104.51	19.42	56.88
30	0.72	21.17	7.41	10.23
35	-3.91	41.94	3.00	22.93
40	-0.11	47.87	12.28	23.99
45	-1.28	10.78	6.37	6.03
50	2.46	43.27	3.98	20.41
55	0.21	27.86	10.76	13.83
60	0.23	10.71	6.80	5.24
AREA B				
360	-2.18	36.20	6.37	19.19
365	1.90	28.65	5.76	13.38
370	3.63	28.02	5.67	12.20
375	0.95	33.15	6.39	16.10
380	3.47	37.64	7.63	17.09
385	4.28	42.06	8.67	18.89
390	6.02	37.54	8.20	15.76
395	6.51	37.03	8.20	15.26
400	6.24	38.36	8.38	16.06
405	6.16	41.77	8.94	17.81
435	6.39	43.10	7.56	18.36
440	6.71	43.09	7.61	18.19
445	6.51	44.07	7.71	18.78
AREA C				
240	-28.33	31.42	-0.34	29.88
245	-9.67	38.93	5.82	24.30
250	-8.16	33.86	5.19	21.01
255	-0.55	33.22	7.01	16.89
285	-30.36	32.86	-2.37	31.61
290	-6.88	42.87	7.45	24.88
295	-2.85	109.55	5.01	56.20
300	-7.73	29.85	1.68	18.79

TABLE B15
PRINCIPAL STRESSES - SAP 5 3D STRESS ANALYSIS
SECTION EE - FLOOD CONDITION
TAINTER-GATE MONOLITH
BRANDON ROAD L&D
CHICAGO DISTRICT

Element No.	σ_1 (psi)	σ_2 (psi)	σ_3 (psi)	γ_{max} (psi)
AREA A				
5	-5.95	19.53	11.12	12.74
10	-36.01	20.93	4.98	28.47
15	-0.81	20.55	4.63	10.68
20	-3.73	94.26	10.41	49.00
25	-10.49	102.95	19.65	56.72
30	-0.65	19.51	6.86	10.08
35	-2.71	43.16	7.28	22.94
40	-0.20	46.55	9.99	23.38
45	-1.21	8.86	3.36	5.04
50	3.33	45.12	9.48	20.90
55	0.39	26.44	7.41	13.03
60	0.24	8.40	3.10	4.08
AREA B				
360	-1.58	37.57	6.75	19.58
365	2.23	30.52	6.17	14.15
370	3.64	30.35	6.12	13.36
375	0.91	35.15	6.77	17.12
380	3.76	38.96	7.93	17.60
385	4.66	43.57	9.03	19.46
390	6.16	39.28	8.55	16.56
395	6.51	38.84	8.54	16.17
400	6.32	40.01	8.70	16.85
405	6.38	42.93	9.20	18.28
435	6.45	44.70	7.82	19.13
440	6.74	44.66	7.86	18.96
445	6.54	45.55	7.94	19.51
AREA C				
240	-24.73	36.15	1.85	30.44
245	-8.46	42.49	7.16	25.48
250	-7.54	36.45	6.10	22.00
255	0.00	34.79	7.55	17.40
285	-29.01	37.49	-0.59	33.25
290	-5.86	46.33	8.76	26.10
295	-1.58	111.94	5.06	56.71
300	-7.06	31.91	2.63	19.49

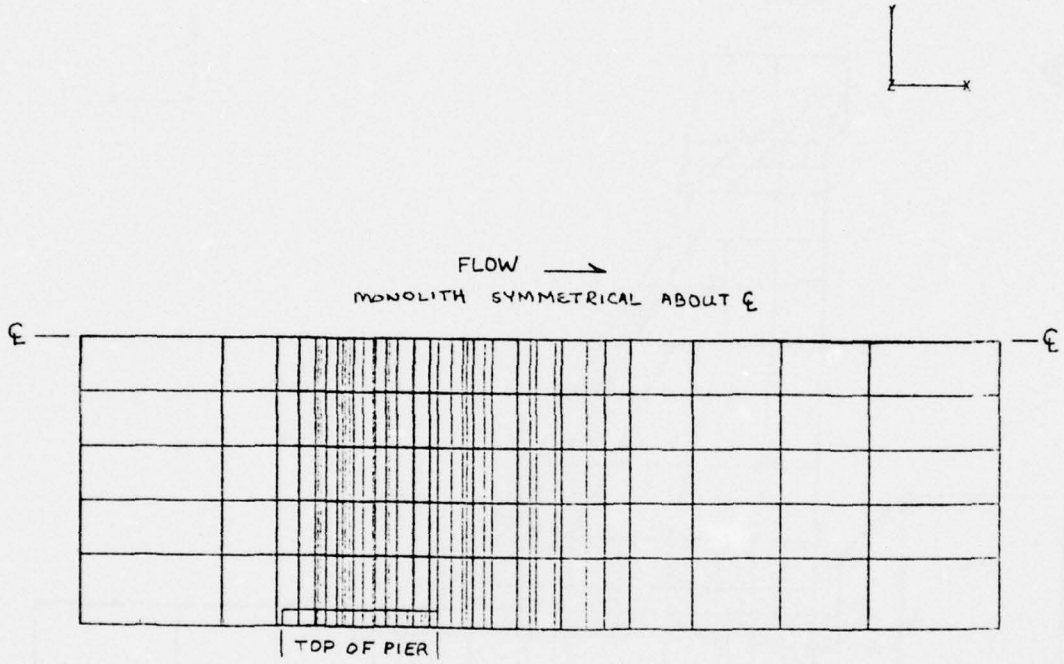

Figure B1. Plan view, finite-element grid, tainter-gate monolith

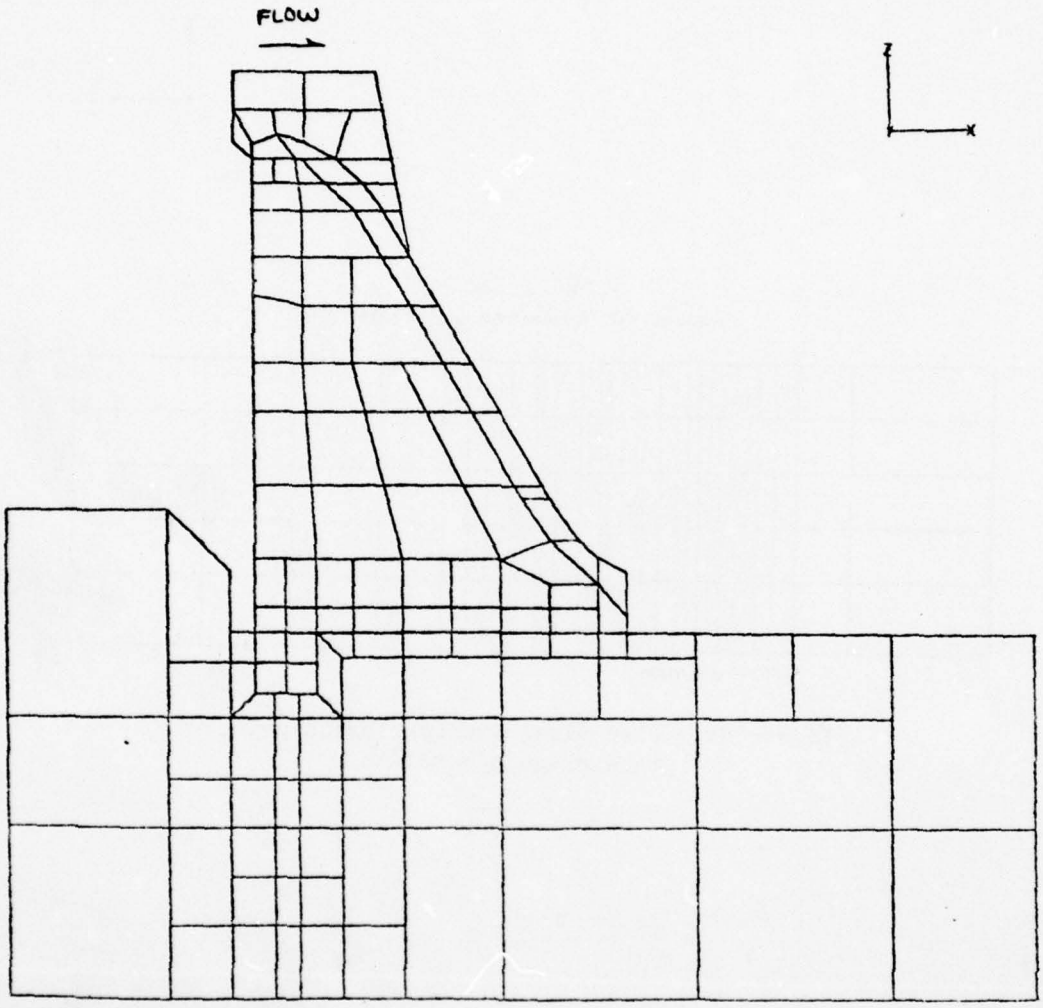

Figure B2. End view, finite-element grid, tainter-gate monolith

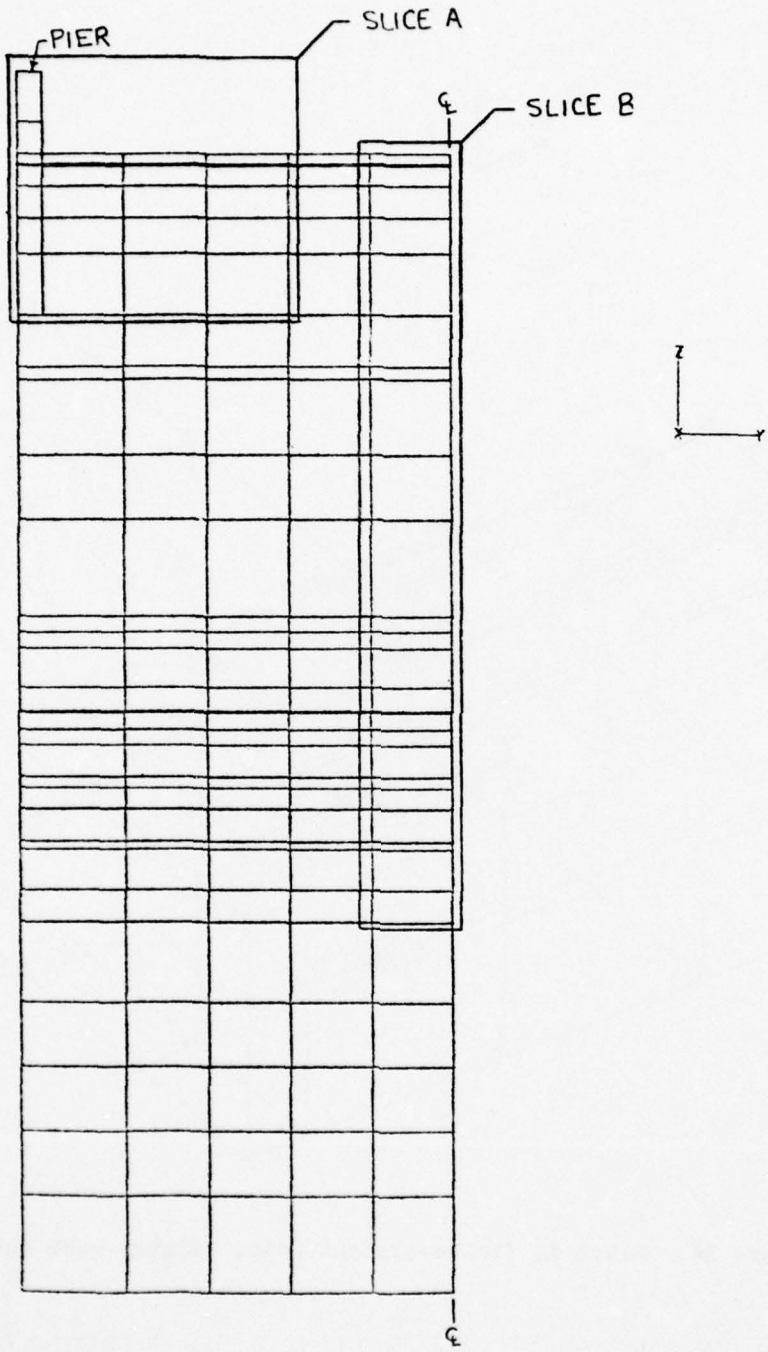

Figure B3. Upstream to downstream view, finite-element grid, tainter-gate monolith

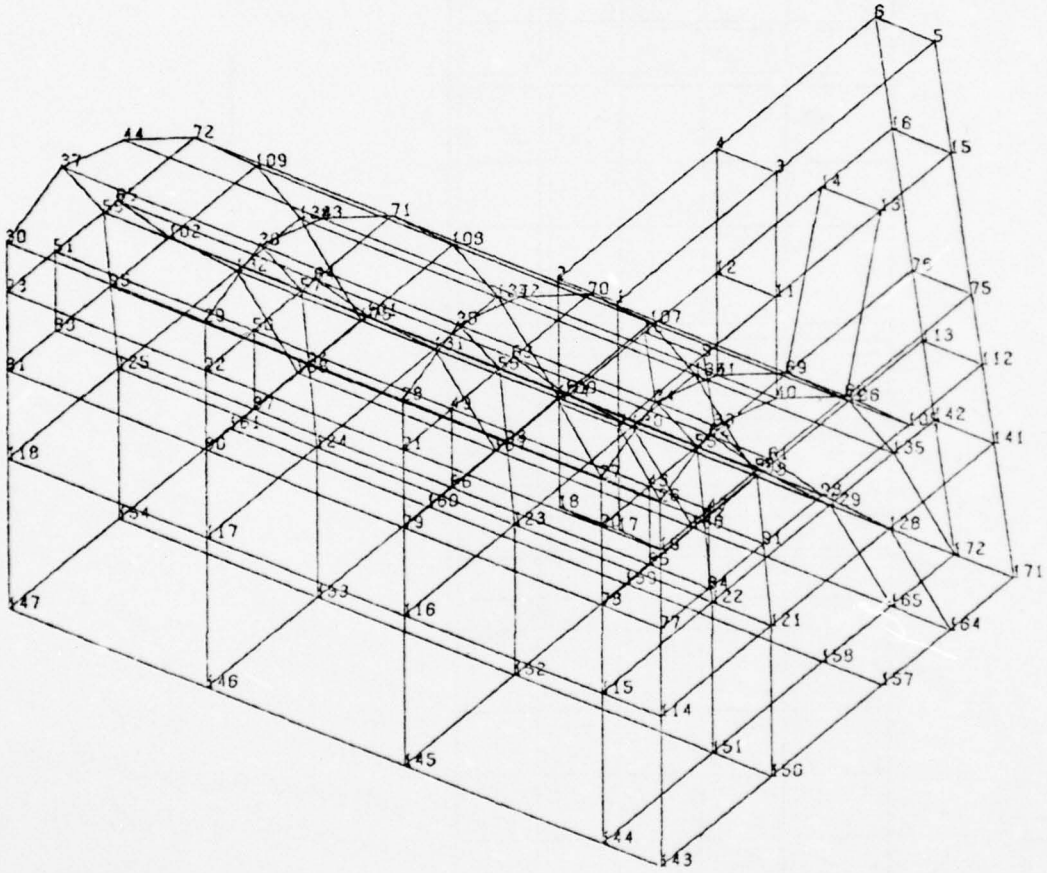

Figure B4. Slice A, finite-element grid, tainter-gate monolith

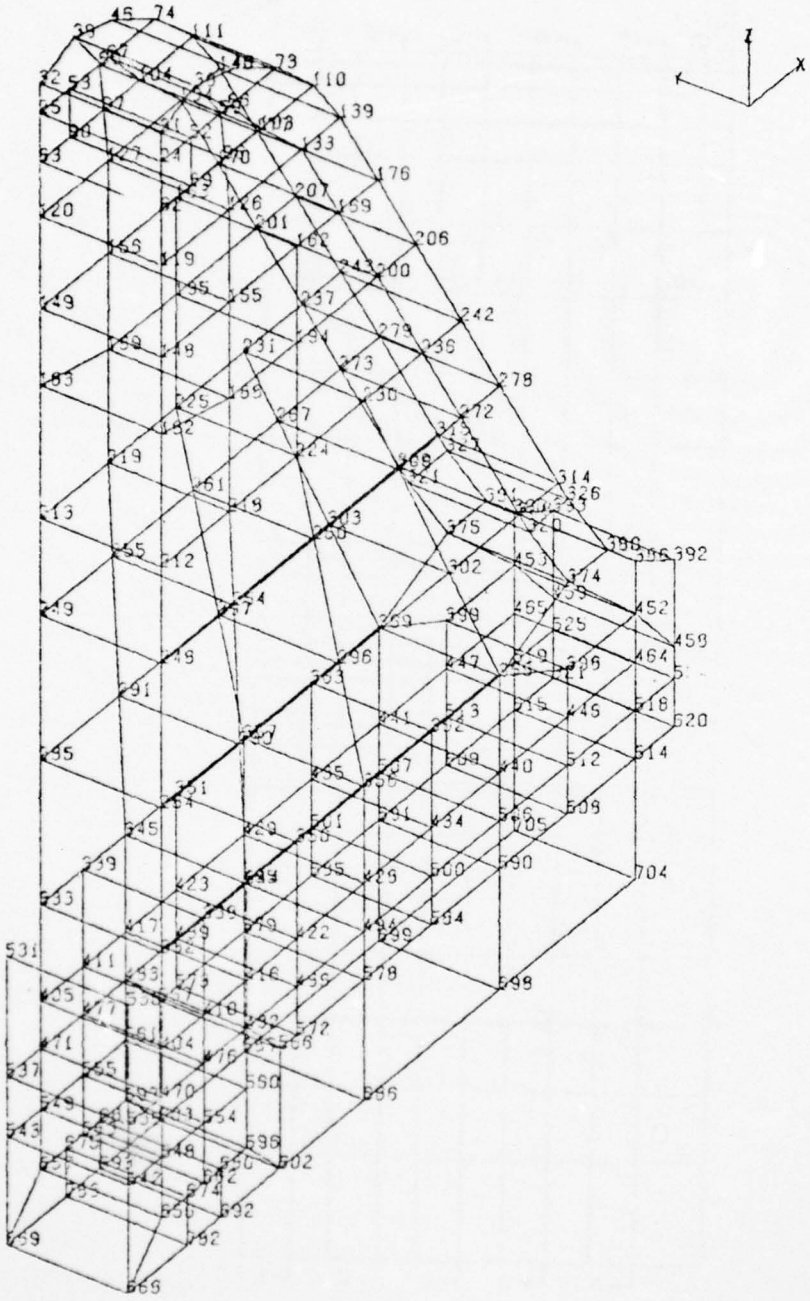

Figure B5. Slice B, finite-element grid, tainter-gate monolith

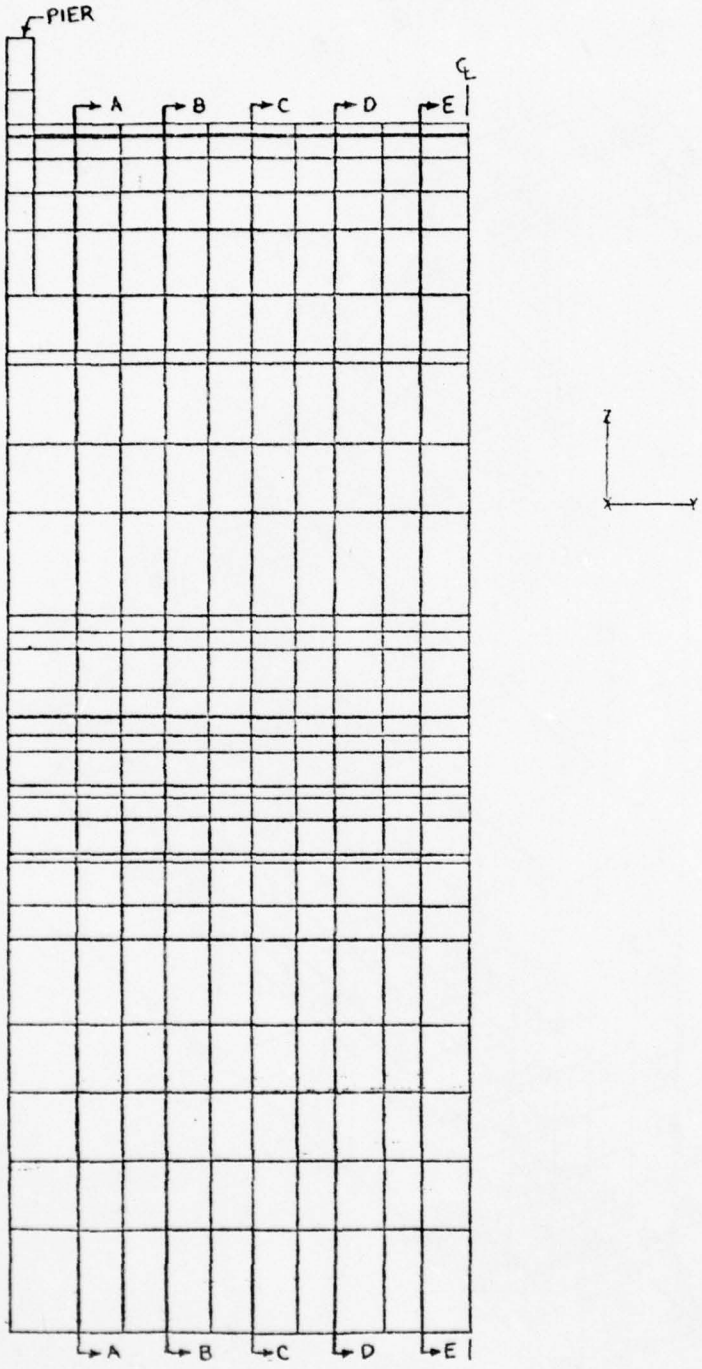

Figure B6. Upstream to downstream view, finite-element grid, tainter-gate monolith

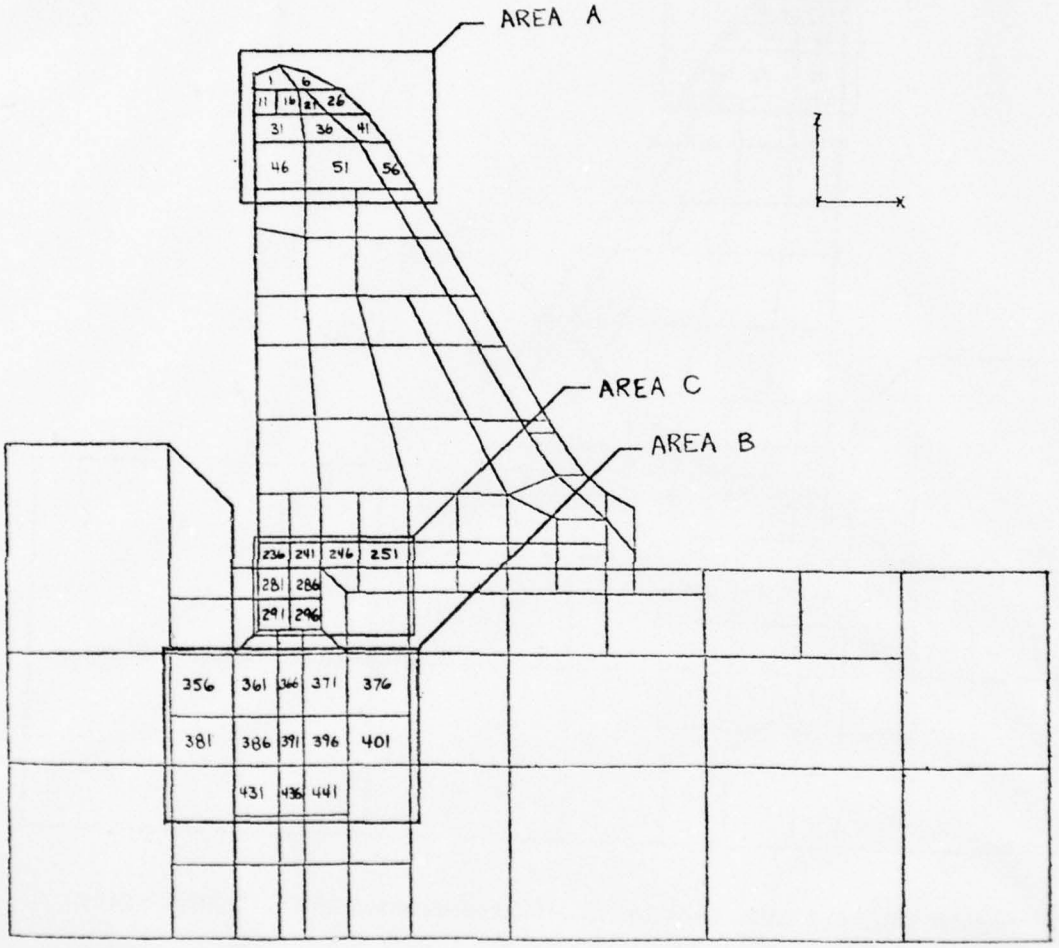

Figure B7. Spillway Section AA, finite-element grid, tainter-gate monolith

AD-A064 811 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 8/8
STABILITY AND STRESS ANALYSES OF BRANDON ROAD DAM, ILLINOIS WAT--ETC(U)
DEC 78 C E PACE, R L CAMPBELL

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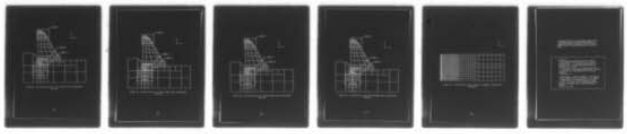

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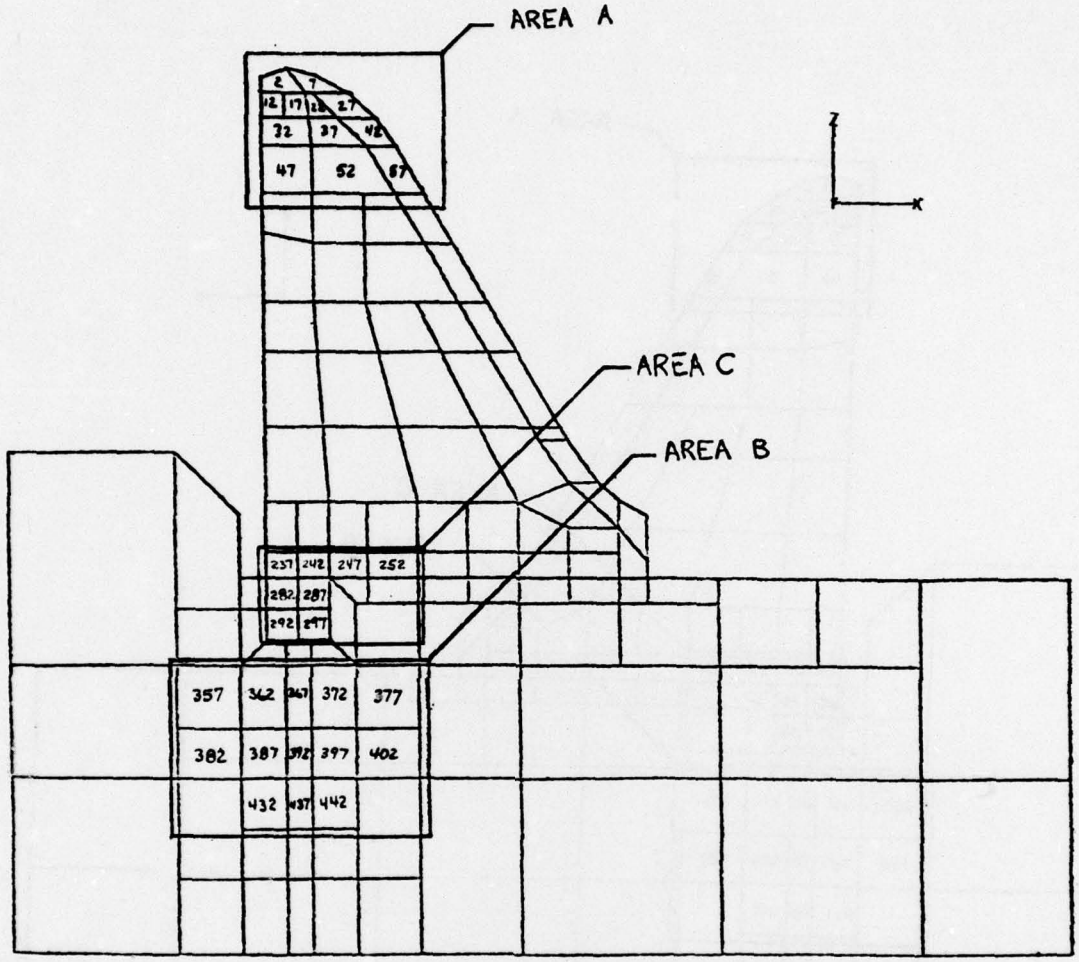

Figure B8. Spillway Section BB, finite-element grid, tainter-gate monolith

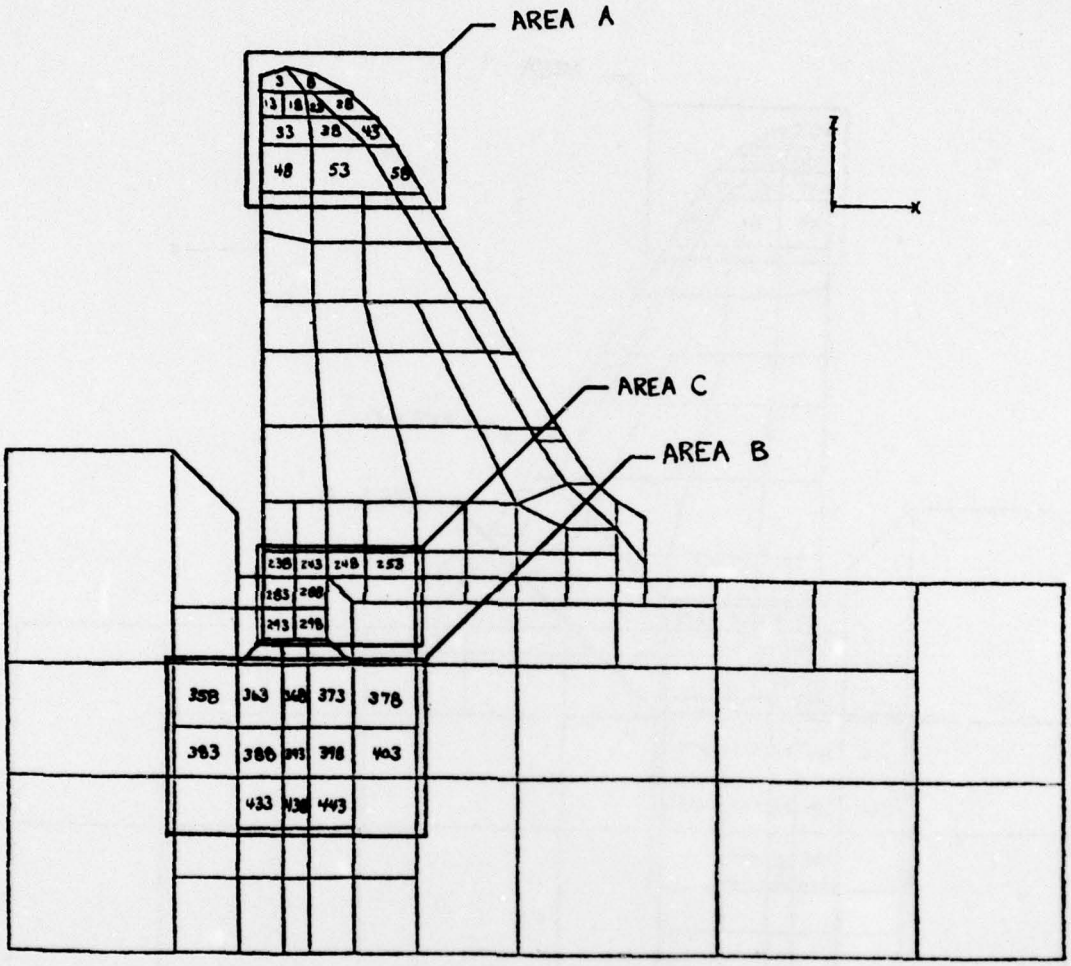

Figure B9. Spillway Section CC, finite-element grid, tainter-gate monolith

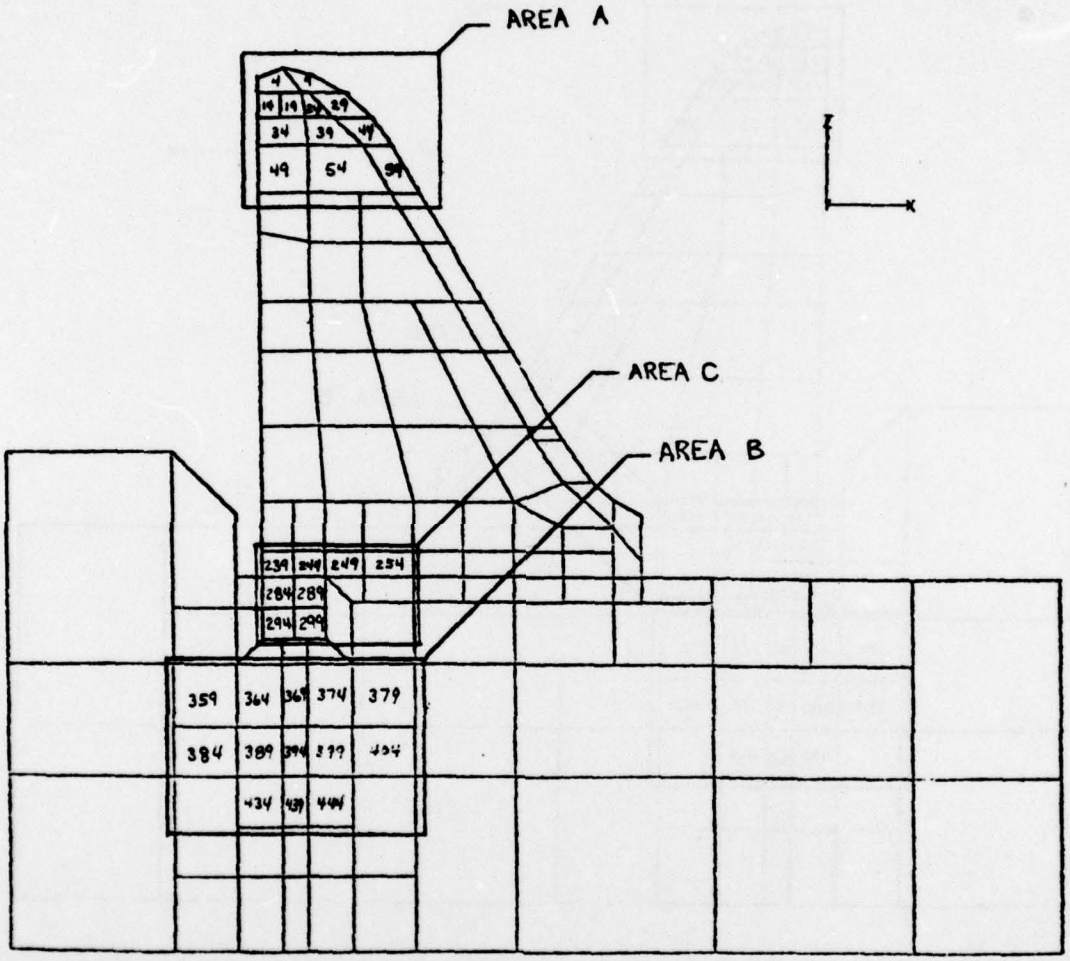

Figure B10. Spillway Section DD, finite-element grid, tainter-gate monolith

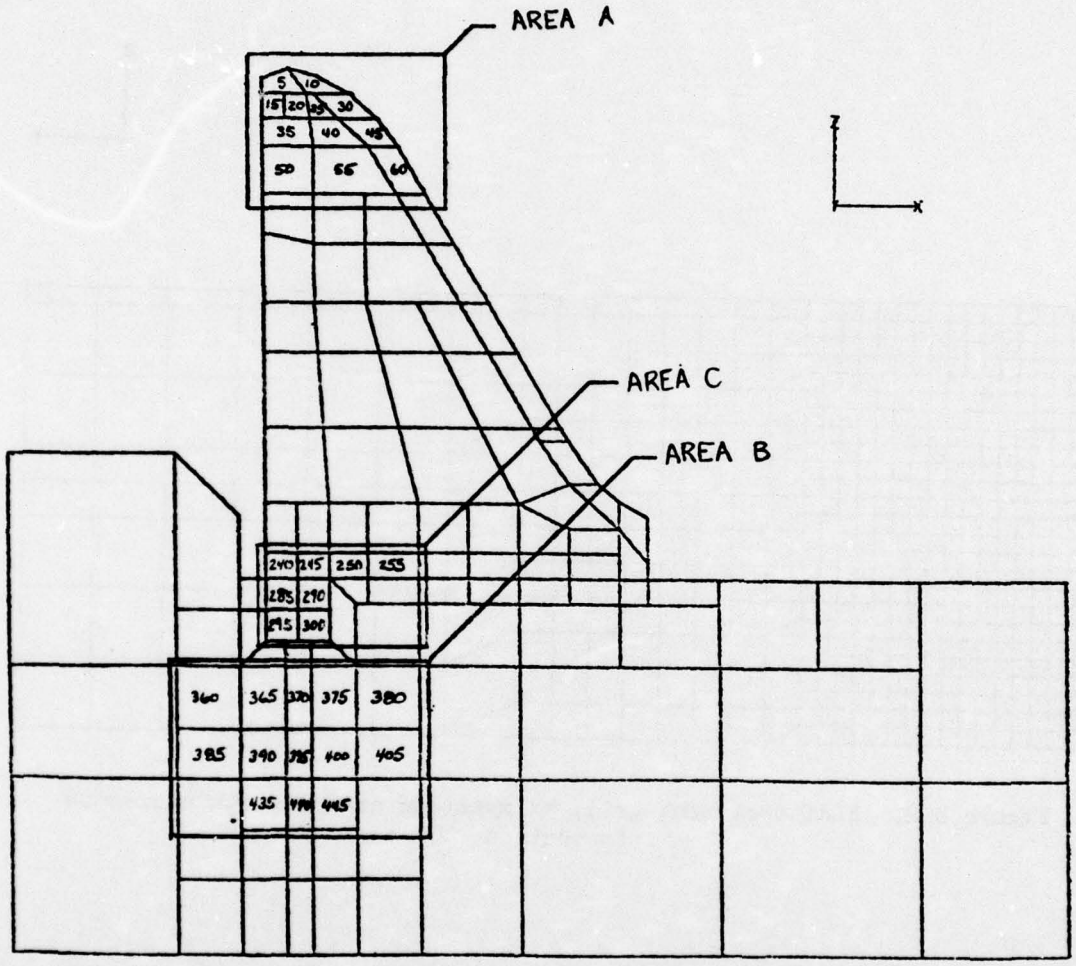

Figure B11. Spillway Section EE, finite-element grid, tainter-gate monolith

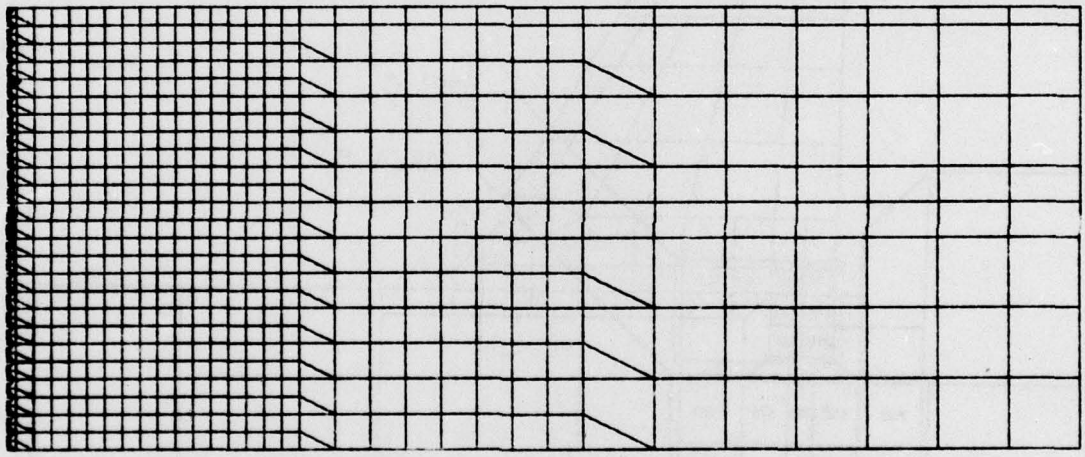

Figure B12. Finite-element grid, axisymetric analysis, tainter-gate foundation

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Pace, Carl E
Stability and stress analyses of Brandon Road Dam, Illinois Waterway / by Carl E. Pace, Roy L. Campbell. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.
40, 125, 28 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; C-78-18)
Prepared for U. S. Army Engineer District, Chicago, Chicago, Ill.
References: p. 21.

1. Base pressure. 2. Brandon Road Dam. 3. Dam stability. 4. Finite element method. 5. Prestressing. 6. Stability. 7. Stress analysis. I. Campbell, Roy L., joint author. II. United States. Army. Corps of Engineers. Chicago District. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; C-78-18.
TA7.W34m no.C-78-18