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混凝土試驗研究中心
NATIONAL CHUNG HSING UNIVERSITY-TAIWAN POWER COMPANY
CONCRETE TEST & RESEARCH CENTER

TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No.: FK-019 Source of Sample: 大陸工程公司

Type of Cement: Type I

Date of Sampling: Apr. 12, 1976 Date of Testing: Apr. 12 - 19, 1976

Test Result:

1. Fineness: Specific Surface	3057 cm^2/gm
2. Time of Setting: Gillmore Test	
Initial Set	150 min
Final Set	4 hr. 45 min.
3. Soundness: Autoclave Expansion	0.112 %
4. Compressive Strength	
3 days	2363 psi
7 days	3633 psi

Test Method: A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No.: FK-019 Source of Sample: 大陸工程公司

Type of Cement: Type I

Date of Sample: Apr. 12, 1976 Date of Testing: Apr. 12 - 19, 1976

Test Result:

A. Chemical Analysis

1. Silicon Dioxide (SiO_2)	19.9 %
2. Aluminum Oxide (Al_2O_3)	7.0 %
3. Ferric Oxide (Fe_2O_3)	3.6 %
4. Calcium Oxide (CaO)	63.4 %
5. Magnesium Oxide (MgO)	1.5 %
6. Sulfur Trioxide (SO_3)	2.2 %
7. Loss on Ignition	0.9 %
8. Insoluble Residue	0.14%
9. Free Lime (CaO)	1.2 %

B. Compound Composite

1. Tricalcium Silicate (C_3S)	48.5 %
2. Dicalcium Silicate (C_2S)	20.5 %
3. Tricalcium Aluminate (C_3A)	12.5 %
4. Tetracalcium Aluminoferrite (C_4AF)	11.0 %
5. Sum of C_3S & C_3A	61.0 %

Test Method: A S T M C 150-74

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TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No.: FK - 023 Source of Sample: 大陸工程公司

Type of Cement: Modified Type I

Date of Sample: Jun. 9, 1976 Date of Testing: Jun. 9 - 16, 1976

Test Result:

1. Fineness: Specific Surface	3374 cm^2/gm
2. Time of Setting: Gillmore Test	
Initial Set	180 min.
Final Set	5 hr. 15 min.
3. Soundness: Autoclave Expansion	0.050 %
4. Compressive Strength	
3 days	2538 psi
28 days	pending 4192 PSI
5. False Set	68.8 %
6. Air Content of Mortar	10.7 %

Test Method: A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No.: FK - 023 Source of Sample: 大陸工程公司

Type of Cement: Modified Type I

Date of Sample: Jun. 9, 1976 Date of Testing: Jun. 9 - 16, 1976

Test Result:

A. Chemical Analysis

1. Silicon Dioxide (SiO_2)	21.6 %
2. Aluminum Oxide (Al_2O_3)	4.8 %
3. Ferric Oxide (Fe_2O_3)	3.6 %
4. Calcium Oxide (CaO)	62.9 %
5. Magnesium Oxide (MgO)	2.3 %
6. Sulfur TrioXide (SO_3)	2.2 %
7. Loss on Ignition	1.1 %
8. Insoluble Residue	0.22%
9. Free Lime (CaO)	1.1 %

B. Compound Composite

1. Tricalcium Silicate (C_3S)	48.0 %
2. Dicalcium Silicate (C_2S)	25.8 %
3. Tricalcium Aluminate (C_3A)	6.6 %
4. Tetracalcium Aluminoferrite (C_4AF)	10.9 %
5. Sum of C_3S & C_3A	54.6 %

Test Method: A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No.: P E - 025 Source of Sample: 大陸工程公司
Type of Cement: Modified Type I
Date of Sample: July 20, 1976 Date of Testing: July 20 - 27, '76
Test Result:

1. Fineness: Specific Surface	3425 cm^2/gm
2. Time of Setting: Gillmore Test	
Initial Set	180 min
Final Set	5 hr. 30 min.
3. Soundness: Autoclave Expansion	0.052 %
4. Compressive Strength	
3 days	2767 psi
28 days	pending 4634 PSI
5. False Set	80.0 %
6. Air Content of Mortar	9.6 %

Test Method: A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No.: P E - 0 2 5 Source of Sample: 大陸工程公司
Type of Cement: Modified Type I
Date of Sample: July 20, '76 Date of Testing: July 20 - 27, '76
Test result:

A. Chemical Analysis	
1. Silicon Dioxide (SiO_2)	21.2 %
2. Aluminum Oxide (Al_2O_3)	5.5 %
3. Ferric Oxide (Fe_2O_3)	3.1 %
4. Calcium Oxide (CaO)	62.5 %
5. Magnesium Oxide (MgO)	2.5 %
6. Sulfur Trioxide (SO_3)	2.3 %
7. Loss on Ignition	1.2 %
8. Insoluble Residue	0.28 %
9. Free Lime (CaO)	0.9 %
B. Compound Composite	
1. Tricalcium Silicate (C_3S)	45.3 %
2. Dicalcium Silicate (C_2S)	26.6 %
3. Tricalcium Aluminate (C_3A)	9.4 %
4. Tetracalcium Aluminoferrite (C_4AF)	9.4 %
5. Sum of C_3S & C_3A	54.7 %

Test Method: A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No. : PE - 030 Source of sample : 大陸工程公司
Type of cement : Modified Type I
Date of sampling : Aug. 19, 1976 Date of testing : Aug. 19-26, 1976
Test result :

A. Chemical Analysis	
1. Silicon dioxide (SiO_2)	21.9 %
2. Aluminum oxide (Al_2O_3)	5.5 %
3. Ferric oxide (Fe_2O_3)	3.3 %
4. Calcium oxide (CaO)	63.4 %
5. Magnesium oxide (MgO)	1.8 %
6. Sulfur trioxide (SO_3)	1.7 %
7. Loss on ignition	0.8 %
8. Insoluble residue	0.10 %
9. Free lime (CaO)	1.3 %
B. Compound Composite	
1. Tricalcium silicate (C_3S)	45.1 %
2. Dicalcium silicate (C_2S)	28.9 %
3. Tricalcium aluminate (C_3A)	9.0 %
4. Tetracalcium aluminoferrite (C_4AF)	10.0 %
5. Sum of C_3S & C_3A	54.1 %

Test Method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No. : PE - 030 Source of Sample : 大陸工程公司
Type of cement : Modified Type I
Date of sampling : Aug. 19, 1976 Date of testing : Aug.19-26,1976
Test result :

1. Fineness : Specific surface	3323 cm^2/gm
2. Time of setting : Gillmore test	
Initial set	150 min.
Final set	4 hr. 30 min.
3.Soundness : Autoclave expansion	0.037 %
4. Compressive strength	
3 day	2538 psi
28 day	pending PSI
5. False set	77.4 %
6. Air content of mortar	10.4 %

Test method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No. : FK - 034 Source of sample : 大陸工程公司

Type of cement : Modified Type I

Date of sampling : Sep. 3, 1976 Date of testing : Sep. 3 - 10, 1976

Test result :

A. Chemical Analysis

1. Silicon dioxide (SiO_2)	21.6 %
2. Aluminum oxide (Al_2O_3)	5.5 %
3. Ferric oxide (Fe_2O_3)	3.2 %
4. Calcium oxide (CaO)	62.7 %
5. Magnesium oxide (MgO)	1.7 %
6. Sulfur trioxide (SO_3)	1.9 %
7. Loss on ignition	0.9 %
8. Insoluble residue	0.12 %
9. Free lime (CaO)	1.2 %

B. Compound Composite

1. Tricalcium silicate (C_3S)	40.0 %
2. Dicalcium silicate (C_2S)	32.8 %
3. Tricalcium aluminate (C_3A)	9.2 %
4. Tetracalcium aluminoferrite (C_4AF)	9.7 %
5. Sum of C_3S & C_3A	49.2 %

Test Method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No. : FK - 034 Source of sample : 大陸工程公司

Type of cement : Modified Type I

Date of sampling : Sep. 3, 1976 Date of testing : Sep. 3 - 10, 1976

Test result :

1. Fineness : Specific surface	3510 cm^2/gm
2. Time of setting : Gillmore test	
Initial set	150 min.
Final set	4 hr. 30 min.
3. Soundness : Autoclave expansion	0.041 %
4. Compressive strength	
3 day	2584 psi ±267 PSI passing
28 day	
5. False set	73.3 %
6 .Air content of mortar	10.7 %

Test method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No. : FK - 041 Source of sample : 大陸工程公司

Type of cement : Modified Type I

Date of sampling : Nov. 3, 1976 Date of testing : Nov. 3 - 10,1976

Test result :

1. Fineness : Specific surface	3323 cm^2/gm.
2. Time of setting : Gillmore test	
Initial set	170 min.
Final set	5 hr.
3. Soundness : Autoclave expansion	0.026 %
4. Compressive strength	
3 days	2671 psi ±233 PSI passing
28 days	
5. False set	75.8 %
6. Air content of mortar	10.9 %

Test Method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No. : FK - 040 Source of sample : 大陸工程公司

Type of cement : Type I

Date of sampling : Nov. 3, 1976 Date of testing : Nov. 3 - 10, 1976

Test result :

A. Chemical Analysis

1. Silicon dioxide (SiO_2)	21.0 %
2. Aluminum oxide (Al_2O_3)	6.1 %
3. Ferric oxide (Fe_2O_3)	3.3 %
4. Calcium oxide (CaO)	62.8 %
5. Magnesium oxide (MgO)	1.2 %
6. Sulfur trioxide (SO_3)	2.1 %
7. Loss on ignition	0.7 %
8. Insoluble residue	0.23%
9. Free lime (CaO)	1.6 %

B. Compound Composite

1. Tricalcium silicate (C_3S)	44.3 %
2. Dicalcium silicate (C_2S)	26.9 %
3. Tricalcium aluminate (C_3A)	10.6 %
4. Tetracalcium aluminoferrite (C_4AF)	10.0 %
5. Sum of C_3S & C_3A	54.9 %

Test method : A S T M C150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No. FE - 048 Report No. FE - 048

Type of Cement : Modified Type I Source of Sample : 大陸工程公司

Date of Sampling : Feb. 4, 1977 Date of Testing : Feb. 4-11, 1977

Test Result :

1. Fineness : Specific Surface	3357	cm^2/gm
2. Time of Setting : Gillmore Test		
Initial Set	190	min.
Final Set	5 hr. 30	min.
3. Soundness : Autoclave Expansion	0.009	%
4. Compressive Strength		
3 days	2596	psi
28 days	pending 4883	PSI
5. False Set	83.3	%
6. Air Content of Motar	10.5	%

Test Method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No. FE - 048 Report No. FE - 048

Type of Cement : Modified Type I Source of Sample : 大陸工程公司

Date of Sampling : Feb. 4, 1977 Date of Testing : Feb. 4 - 11, 1977

Test Result :

A. Chemical Analysis	
1. Silicon Dioxide (SiO_2)	21.1 %
2. Aluminum Oxide (Al_2O_3)	5.5 %
3. Ferric Oxide (Fe_2O_3)	4.1 %
4. Calcium Oxide (CaO)	63.8 %
5. Magnesium Oxide (MgO)	1.2 %
6. Sulfur Trioxide (SO_3)	1.8 %
7. Loss on Ignition	0.8 %
8. Insoluble Residue	0.17%
9. Free Lime (CaO)	1.2 %
B. Compound Composite	
1. Tricalcium Silicate (C_3S)	51.3 %
2. Dicalcium Silicate (C_2S)	21.9 %
3. Tricalcium Aluminate (C_3A)	7.7 %
4. Tetracalcium Aluminoferrite (C_4AF)	12.5 %
5. Sum of C_3S & C_3A	59.0 %

Test Method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No. FE - 053 Report No. FE - 053

Type of Cement : Modified Type I Source of Sample : 大陸工程公司

Date of Sampling : Mar. 10, 1977 Date of Testing : Mar. 10 - 17, 1977

Test Result :

A. Chemical Analysis	
1. Silicon Dioxide (SiO_2)	21.0 %
2. Aluminum Oxide (Al_2O_3)	5.8 %
3. Ferric Oxide (Fe_2O_3)	3.6 %
4. Calcium Oxide (CaO)	63.5 %
5. Magnesium Oxide (MgO)	1.4 %
6. Sulfur Trioxide (SO_3)	2.0 %
7. Loss on Ignition	0.6 %
8. Insoluble Residue	0.14%
9. Free Lime (CaO)	1.2 %
B. Compound Composite	
1. Tricalcium Silicate (C_3S)	49.1 %
2. Dicalcium Silicate (C_2S)	23.2 %
3. Trisalcium Aluminate (C_3A)	9.3 %
4. Tetrasalium Alumioaferrite (C_4AF)	11.0 %
5. Sum of C_3S & C_3A	58.4 %

Test Method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No. FE - 053 Report No. FE - 053

Type of Cement : Modified Type I Source of Sample : 大陸工程公司

Date of Sampling : Mar. 10,1977 Date of Testing : Mar. 10-17, 1977

Test Result :

1. Fineness : Specific Surface	3374 cm^2/ gm
2. Time of Setting : Gillmore Test	
Initial Set	170 min.
Final Set	5 hr.
3. Soundness : Autoclave Expansion	0.011 %
4. Compressive Strength	
3 days	2383 psi
28 days	pending 4370 PSI
5. False Set	91.2 %
6. Air Content of Motar	11.1 %

Test Method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No. FE - 058 Report No. FE - 058
Type of Cement : Modified Type I Source of Sample : 大陸工程公司
Date of Sampling : Apr. 11, 1977 Date of Testing : Apr. 11 - 18, 1977
Test Result :

A. Chemical Analysis	
1. Silicon Dioxide (SiO_2)	21.1 %
2. Aluminum Oxide (Al_2O_3)	6.1 %
3. Ferric Oxide (Fe_2O_3)	3.6 %
4. Calcium Oxide (CaO)	63.6 %
5. Magnesium Oxide (MgO)	1.2 %
6. Sulfur Trioxide (SO_3)	1.8 %
7. Loss on Ignition	0.7 %
8. Insoluble Residue	0.17%
9. Free Lime (CaO)	1.2 %
B. Compound Composite	
1. Tricalcium Silicate (C_3S)	47.3 %
2. Dicalcium Silicate (C_2S)	24.9 %
3. Tricalcium Aliminate (C_3A)	10.1 %
4. Tetracalcium Aluminoferrite (C_4AF)	10.9 %
5. Sum of C_3S & C_3A	57.4 %

Test Method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No. FE - 058 Report No. FE - 058
Type of Cement : Modified Type I Source of Sample : 大陸工程公司
Date of Sampling : Apr. 11, 1977 Date of Testing : Apr. 11 - 18, 1977
Test Result :

1. Fineness : Specific Surface	3425 cm^2/gm
2. Time of Setting : Gillmore Test	
Initial Set	165 min.
Final Set	5 hr.
3. Soundness : Autoclave Expansion	0.009 %
4. Compressive Strength	
3 days	2794 psi
28 days	5475 psi pending
5. False Set	72.2 %
6. Air Content of Motar	11.3 %

Test Method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No. FE - 063 Report No. FE - 063
Type of Cement : Modified Type I Source of Sample : 大陸工程公司
Date of Sampling : May 30, 1977 Date of Testing : May 30 - Jun. 6, 1977
Test Result :

1. Fineness : Specific Surface	3459 cm^2/gm
2. Time of Setting : Gillmore Test	
Initial set	165 min.
Final Set	5 hr.
3. Soundness : Autoclave Expansion	0.012 %
4. Compressive Strength	
3 days	2825 psi
28 days	5475 psi pending
5. False Set	75.9 %
6. Air Content of Motar	10.9 %

Test Method : A S T M C 150 - 74

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TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No. FE - 063 Report No. FE - 063
Type of Cement : Modified Type I Source of Sample : 大陸工程公司
Date of Sampling : May 30, 1977 Date of Testing : May 30, - Jun. 6, 1977
Test Result :

A. Chemical Analysis	
1. Silicon Dioxide (SiO_2)	20.7 %
2. Aluminum Oxide (Al_2O_3)	5.9 %
3. Ferric Oxide (Fe_2O_3)	3.6 %
4. Calcium Oxide (CaO)	63.6 %
5. Magnesium Oxide (MgO)	1.0 %
6. Sulfur Trioxide (SO_3)	1.8 %
7. Loss on Ignition	0.8 %
8. Insoluble Residue	0.19%
9. Free Lime (CaO)	1.3 %
B. Compound Composite	
1. Tricalcium Silicate (C_3S)	51.8 %
2. Dicalcium Silicate (C_2S)	20.3%
3. Tricalcium Aliminate (C_3A)	9.5 %
4. Tetracalcium Aluminoferrite (C_4AF)	10.9 %
5. Sum of C_3S & C_3A	61.3 %

Test Method : A S T M C 150 - 74

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Approved by : Checked by : Tested by :

國立中興大學・臺灣電力公司
混凝土試驗研究中心
NATIONAL CHUNG HSING UNIVERSITY-TAIWAN POWER COMPANY
CONCRETE TEST & RESEARCH CENTER

250 Kuokuang Rd.
Taichung, Taiwan
Republic of China

TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No. FE - 069 | Report No. FE - 069
Type of Cement : Type I | Source of Sample : 大陸工程公司
Date of Sampling : July 2, 1977 | Date of Testing : July 4 - 18, 1977

Test Result :

1. Fineness : Specific Surface	3234 cm^2/gm
2. Time of Setting : Gillmore Test	
Initial set	140 min.
Final set	4 hr. 20 min.
3. Soundness : Autoclave Expansion	0.075 %
4. Compressive Strength	
3 days	2996 psi
7 days	3703 psi
28 days	pending 4442 PSI
5. False set	90.9 %
6. Air Content of Motar	8.4 %

Test Method : A S T M C 150 - 74

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250 Kuokuang Rd.
Taichung, Taiwan
Republic of China

TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No. FE - 069 | Report No. FE - 069
Type of Cement : Type I | Source of Sample : 大陸工程公司
Date of Sampling : July 2, 1977 | Date of Testing : July 4 - 11, 1977

Test Result :

A. Chemical Analysis	
1. Silicon Dioxide (SiO_2)	20.7 %
2. Aluminum Oxide (Al_2O_3)	6.0 %
3. Ferric Oxide (Fe_2O_3)	3.6 %
4. Calcium Oxide (CaO)	62.8 %
5. Magnesium Oxide (MgO)	1.4 %
6. Sulfur Trioxide (SO_3)	2.0 %
7. Loss on Ignition	0.6 %
8. Insoluble Residue	0.16%
9. Free Lime (CaO)	1.2 %
B. Compound Composite	
1. Tricalcium Silicate (C_3S)	47.2 %
2. Dicalcium Silicate (C_2S)	23.8 %
3. Tricalcium Aluminate (C_3A)	9.8 %
4. Tetracalcium Aluminoferrite (C_4AF)	10.9 %
5. Sum of C_3S & C_3A	58.1 %

Test Method : A S T M C 150 - 74

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250 Kuokuang Rd.
Taichung, Taiwan
Republic of China

TESTING REPORT OF PORTLAND CEMENT ON PHYSICAL PROPERTIES

Sample No. : FE - 073 | Report No. FE - 073
Type of Cement : Modified Type I | Source of Sample : 大陸工程公司
Date of Sampling : Aug. 23, 1977 | Date of Testing : Aug. 24 - 30, 1977

Test Result :

1. Fineness : Specific Surface	3476 cm^2/gm
2. Time of Setting : Gillmore Test	
Initial Set	165 min
Final Set	4 hr. 30 min.
3. Soundness : Autoclave Expansion	0.014 %
4. Compressive Strength	
3 days	3029 psi
28 days	Pending 5025 PSI
5. False Set	72.2 %
6. Air Content of Motar	9.5 %

Test Method : A S T M C 150 - 74

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Approved by : Checked by : Tested by :

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混凝土試驗研究中心
NATIONAL CHUNG HSING UNIVERSITY-TAIWAN POWER COMPANY
CONCRETE TEST & RESEARCH CENTER

250 Kuokuang Rd.
Taichung, Taiwan
Republic of China

TESTING REPORT OF PORTLAND CEMENT ON CHEMICAL PROPERTIES

Sample No. : FE - 073 | Report No. : FE - 073
Type of Cement : Modified Type I | Source of Sample : 大陸工程公司
Date of Sampling : Aug. 23, 1977 | Date of Testing : Aug. 24, - 30, 1977

Test Result :

A. Chemical Analysis	
1. Silicon Dioxide (SiO_2)	20.9 %
2. Aluminum Oxide (Al_2O_3)	6.0 %
3. Ferric Oxide (Fe_2O_3)	3.6 %
4. Calcium Oxide (CaO)	62.9 %
5. Magnesium Oxide (MgO)	1.4 %
6. Sulfur Trioxide (SO_3)	2.1 %
7. Loss on Ignition	0.8 %
8. Insoluble Residue	0.21 %
9. Free Lime (CaO)	1.1 %
B. Compound Composite	
1. Tricalcium Silicate (C_3S)	45.8 %
2. Dicalcium Silicate (C_2S)	25.4 %
3. Tricalcium Aluminate (C_3A)	11.1 %
4. Tetracalcium Aluminoferrite (C_4AF)	10.9 %
5. Sum of C_3S & C_3A	56.9 %

Test Method : A S T M C 150 - 74

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Approved by : Checked by : Tested by :

附 錄 八

SPECIAL PROVISIONS

FOR

NORTH-SOUTH FREEWAY

CHUNGKING NORTH ROAD TO NEIHU SECTION

PROJECT NO. 12

(YUAN SHAN BRIDGE)

STATION 0+821.90 N TO STATION 1+558.30 N

THE REPUBLIC OF CHINA

MINISTRY OF COMMUNICATIONS

TAIWAN AREA FREEWAY CONSTRUCTION BUREAU

TAIPEI, TAIWAN

TABLE OF CONTENTS

PROJECT NO. 12

STA. 0+821.9 N to STA. 1+558.3 N

GENERAL DESCRIPTION

This project begins at STA. 0+821.9 N and ends at STA. 1+558.3 N about 736 meters (671 ^{m} of box girders & 65.4 ^{m} of I-girders) of six-lane roadway bridge as shown on the plans.

GD - 1

COMPLETION TIME

The "Time for Completion" for this project is within 910 calendar days from the date stipulated in the "Notice to Proceed".

SECTION A

GENERAL

1. FORWARD

Work under this Section and the subsequent Section are subject to the Standard Specifications and other requirements of the Contract. In case disagreement between this provisions and Standard Specifications, this special provisions will govern.

2. SCOPE

The work includes all labors, materials, equipment, transportation and services necessary to complete construction of the project as shown on contract drawings. The measurement and payment of each item, listed in the bidding forms, are specified as below:

A. Main Bridge is from Sta. 0+856.5 to Sta. 1+527.5.

I. Superstructure includes all items constructed above the pier top or box girder bottom.

350 kg/cm^2 Concrete: It also includes travel wagons, form works, rubbed finish of visible surfaces, concrete epoxy bonding materials, curing and other necessary services of completion this item. The quantities of concrete will be measured in cublic meters in accordance with the dimensions shown on the drawings. No deduction will be made for the volume occupied by bar reinforcing steel or high tension wire tendons in the concrete.

240 kg/cm^2 Concrete: It also includes form works, rubbed finish of visible surfaces, curing and other necessary services of completion this item. The measurement of this item is same as that of 350 kg/cm^2 Concrete.

Rebars, fy = 2800 kg/cm^2: Refer to Standard Specifications Section 14-01 "Steel Reinforcing Bars."

Rebars, fy = 4200 kg/cm^2: Refer to Standard Specifications Section 14-01 "Steel Reinforcing Bars."

Main Tendons: Except vertical tendons, all other tendons used for superstructure shall include anchorage, tendon ducts, grouting, coupling if necessary and other services to complete this item. Its quantities will be measured in ton-meters based on each effective force times its length shown on the plans or authorized.

Vertical Tendons: It also includes anchorages, tendon ducts, grouting, and other services to complete this item. Its quantities will be measured in ton-meters based on each effective force times its length shown on the plans or authorized.

Elastomeric Expansion Joint, No. 650: It's also including labor of erection, equipment to complete the bridge deck expansion joint seal and other necessary

services to complete this item. The quantities of expansion joint will be measured in lineal meters in accordance with the actural nember of completed and accepted work.

Elastomeric Expansion Joint No. 400A and No. 250: Same as above item.

Frunishing & Erecting Metal Railing: Refer to Standard Specifications Section 13-04, Grard Rail.

Drainage: This item includes the materials, labor, connection, cast iron frames, gratings, pipe fittings, hangers and other necessary to complete this item as shown on the drawings. The Item of Drainage shall be paid for on the basis of the lump sum.

Asphalt Concrete, Aggregate Dense Grade: Refer to Standard Specifications Section 14-02, Asphalt Concrete Pavement.

Asphalt Concrete, Aggregate Open Grade: Refer to Standard Specifications Section 14-02, Asphalt Concrete Pavement.

Asphalt Liquid, RC-70, Tack Coat: Refer to Standard Specification Section 14-02, Asphalt Concrete Pavement.

Non-Reflective Pavement Markers, Type "A": Refer to Standard Specifications Section 15-04, Pavement Markers.

Reflective Pavement Markers, Type "C" & "D": Refer to Standard Specifications Section 15-04, Pavement Markers.

Painting, Pavement Striping: Refer to Standard Specifications Section 15-02, Pavement Striping.

Roadway Painting Contrast Treatment: Refer to Standard Specifications Section 15-03, Roadway Contrast Treatment.

Center Hinges: It also includes the bearing plats, additional rebars, structure steel, welding and other services necessary to complete this item as shown on the drawings. This work shall be paid for on the basis of the unit set.

End Connection at Pier N & S: Same as Center Hinges.

II. Substructure includes all item constructed below the pier top or box girder bottom.

Excavation, Pier A: This item includes cofferdam, dewatering, excavation, backfilling, 140 kg/cm^2 seal Concrete and other services necessary to complete the item as shown on drawings. The payment shall be based on the lump sum, except changing the bottom elevation of the pier. If the elevation of the pier bottom would be changed, in accordance with Engineer's written form, then the lump sum of this item should be negotiated at that time.

Excavation, Pier B, D, E, N, & S: Same as above.

Excavation, Pier C: It also includes the backfilling with concrete or compacted granular material as shown on drawings, the exceeded concrete for over cutting and other services necessary to complete this item. The quantity of excavation to be paid for shall be the nember of cubic meters measured in original position within the vertical planes of the neat line of footings as shown on plans or directed by the Engineer.

140 kg/cm^2 Concrete: This item is only the seal concrete under the Pier C and it may be lean concrete placed in dry condition. The quantities to be paid for shall be measured in cubic meters in accordance with the dimensions shown on the drawings.

280 kg/cm^2 Concrete Footings: This item includes form works, dewatering, pouring, curing and other necessary services of completion this item. The quantities of concrete will be measured in cubic meters in accordance with the dimensions shown on the drawings. No deduction will be made for the volume occupied by bar reinforcing steel in the concrete.

350 kg/cm^2 Concrete Piers: This item shall include rubbed finish for visible surfaces and all other are same as above item of "280 kg/cm^2 Concrete Footing".

40^{cm} x 40^{cm} P.C. Precast Piles: It includes concrete, reinforcing bars, strands, driving, splice, cutting and other services necessary to complete the item. This item also includes the probe piles and boring, if necessary, for determination of the pile length. The quantity of piles to be paid for shall be the nember of lineal meter of actural length measured from the plane of pile cut-off down to the top plate of steel H-pile. Exceeding length of the pile cut-off shall not be paid for and its expense shall be included in the unit price of this item.

Steel H-Piles: This item includes top plate, anchorage, welding, driving and other services necessary to complete this item. The payment shall be based on number of lineal meter of actural length to be used in this project.

Rebars, fy = 2800 kg/cm^2: Refer to Standard Specifications Section 14-01 "Steel Reinforcing Bars".

Rebars, fy = 4200 kg/cm^2: Refer to Standard Specifications Section 14-01 "Steel Reinforing Bars".

Loading Tests: This item includes anchor piles, jacking, steel I-beam, test record and other services necessary to complete the item in accordance with this special provisions. The payment for this item shall be based on each set of the test.

Steel Sheet Piles (19.5^M long): This item is only for Pier A & E, it includes driving, anchoring, baracing, cutting and other services necessary to be complete the item. The quantities to be paid for shall be based on number of sheet at 19.5^M long.

Miscellaneous

Lighting Fixtures: It includes the materials, labor wiring, conduits, outlets and other necessary services to complete this item as shown in drawings and special provisions. This item shall be paid for on the basis of the lump sum.

Pitches round Pier C: The existing pitching at the location of pier C will be demolished due to the excavation of Pier C. The pitching shall be reconstructed with same materials at the new location as shown on the drawings. The existing concrete blocks may be reused for the reconstructed pitching. The payment for this item shall be based on the lump sum.

Ditches round Pier C: At Pier C all new ditches, manholes, pipe drainage, connections to existing ditch and recover existing ditch etc. shall be included in this item. The payment for this item shall be based on the lump sum.

Recover All Facilities: All existing structures and facilities including retaining wall, side walk, road way and etc., which will be demolished during construction period for this project, shall be recovered to the original form with same materials and construction as existing. This item shall be paid for on the basis of the lump sum.

Security and Traffic Protection for Roadway and Public Spaces: When the construction of this project will be crossed over the roadways and public spaces, the Contractor shall keep the traffic way free, and shall prepare the facilities and signs for security purpose in accordance with the Government Law and the Engineer's requirements. These facilities include temporal fence, frames with sheet covering and siding, sign-boards and any other necessary temporal structures. This item shall also paid for on the basis of the lump sum. In the case of special situation or requirement indicated by the Government or the Engineer, the work shall be stopped temporily. All expenses or losses due to temporal stop of the work shall be included in this item.

B. Approach at each end of the main bridge. All items shall be refer to Standard Specifications respectively.

3. CODES AND STANDARDS

Unless otherwise stated, the U. S. Codes of Practices are used herein to determine the minimum standard of practice required. The following publications are hereby made a direct part of this Provisions and all concrete works included in this "Concrete" shall conform with the applicable requirements therein except as specified herein. If these Codes are in conflict with local codes of practices, the more restrictive requirements shall govern.

A. American Society of Testing Materials (ASTM).

B. American Concrete Instituet (ACI).

C. Pretressed Concrete Institute (PCI).

4. MATERIALS

All materials shall be of the best quality and new unless otherwise stated, and shall comply with the Standard Specifications.

5. WORKMANSHIP

Must be the best practice in all respects. All work must be done in a thorough manner.

6. COORDINATION

Contractor shall verify all dimensions as shown on drawings before beginning of work. Coordinate with sub-contractors or other trades (electrical, mechanical, plumbing, prestressing, etc.) to make certain that all openings, ducts, inserts, anchors and the like as specified for their work are in the form prior to placing concrete.

7. REQUIRED SUBMITTALS

A. Shop drawing showing all necessary construction details and layout for formwork, falswework reinforcing steel and prestressing steel shall be submitted to the Engineer for approval prior to starting work.

B. Samples and/or mill certificated from supplier of meterials to be used shall be submitted to the Engineer for approval and/or for laboratory tests as required.

8. INSPECTION

All work and materials furnished by the Contractor shall be subject to inspection and rejection by the Engineer.
Any work or material furnished by the Contractor found to be in any way unsatisfactory or defective before final acceptance of the work shall be corrected or replaced immediately by the Contractor at his own expense.

SECTION B

FORMWORK

1. SCOPE

This Section includes all labor, materials, equipment, transportation and services required to furnish, install and remove all forms for cast-in-place concrete, including all shoring and form supports.

2. REQUIRED SUBMITTALS

Shop Drawings showing all construction details of formwork, falsework and proposed locations and details of construction joints shall be submitted to the Engineer for approval prior to the work starts.

3. MATERIALS

Timber, plywood or steel or a combination of these will be permitted, provided that the required finish is produced to the satisfaction of the Engineer.

4. FORMWORK

A. Forms shall result in a final structure which conforms to the shapes, sizes, lines, dimensions and location of the member as required by the drawings and specifications.

B. Shall be substantial and sufficiently tight to prevent leakage of mortar, and shall be properly braced or tied together so as to maintain position and shape.

C. Chamfer strips of 2 cm x 2 cm shall be provided for corners of all beams, girders and colums unless otherwise specified on drawings.

D. Construction Joints if not indicated on the drawings shall be so made and located as not to impair significantly the strength of the structure, and shall be arranged prior to placing of concrete and the approval of the Engineer

1. Joints shall be located near the middle of spans of slabs, beams or girders, unless a beam intersects a girder at this point, in which case the joints in the girders shall be off-set a distance equal to twice the width of the beam.

2. Offset keyway shall be formed in all construction joints for transfer of shear and other forces through the joint.

E. Cleanouts: Where bottom of form is inaccessible from within, temporary openings shall be provided to permit thorough removal of extraneous material and debris before placing concrete.

F. Form Coating: All form surfaces to receive concrete shall be smooth, clean and shall be thoroughly coated with form-releasing material of approved type which will not contaminate the concrete.

G. No pipes, plates, inserts etc. made of aluminum shall be embedded into concrete.

H. Provisions for Other Trades: Obtain information from sub-contractors of other trades (electrical, mechanical, etc.) and provide all openings, offsets, block-outs, etc. to accommodate their work. Allow other trades ample opportunity for installing pipes, inserts, ties, anchors and the like in the form as specified for their work.

5. FALSEWORK

All forms and falsework shall be designed and constructed to provide the necessary rigidity in safely supporting all the vertical, lateral and unsymmetrical loads without deflection and settlement.

6. REMOVAL OF FORMS

A. Forms may be removed when concrete has developed sufficient strength to safely sustain its weight and all superimposed loads.

B. Forms shall be removed in such a manner as to insure the complete safety of the structure and to avoid damage to concrete surfaces.

C. No form shall be removed without the approval of the Engineer. Reshoring may be required if the Engineer deems necessary.

D. Forms for footings and foundations shall remain undisturbed for at least 24 hours.

E. Side forms for slabs, beams and vertical forms for columns and walls shall remain undisturbed for at least 2 days.

F. Bottom forms and shores for regular R. C . slabs and beams shall remain undisturbed for at least 14 days or until concrete has reached the designed strength.

G. Bottom forms and shores for prestressed slabs and beams shall remain undisturbed until all tendons have been stressed.

SECTION C

STEEL REINFORCEMENT

1. SCOPE

This Section includes all labor, materials, equipment, transportation and services required to furnish, cut, bend and place all reinforcing steel as shown on drawings and/or as specified herein.

2. REQUIRED SUBMITTALS

A. Shop Drawings including all necessary elevations, sections, plans, and diagrams showing placement, spacing, splicing, bending details and schedules as well as erection marks for all reinforcing bars shall be submitted to the Engineer for approval prior to the beginning of fabrication.

B. Samples of reinforcing bars of each size and grade shall be submitted to testing laboratory for tension and bending tests as per ASTM A-15 and A-305.

3. MATERIALS

A. Reinforcing Steel shall be billet steel, weldable quality and conforming to ASTM requirements as follows:

1. #2 bars, plain, ASTM A-82.

2. Deck rebar #6 or smaller, deformed, ASTM A-615, grade 40, #7 or larger, deformed, ASTM A-615, Grade 60.

3. Others #5 or smaller, deformed, ASTM A-615, Grade 40.

4. #6 or larger, deformed, ASTM A-615, Grade 60.

B. Welded Wire Fabric shall conform to ASTM A-185.

C. Tie Wire shall be #16 black annealed wire.

D. Bar Supports shall be approved type.

4. FABRICATION

A. All bars shall be of size, grade and length as indicated, and accurately cut, bent or formed to shapes as detailed or scheduled on drawings by methods that will not injure the materials.

B. Hooks and Bends shall be located as specified on drawings and shall conform to the Standard Hooks and Bends as recommended in ACI-315. All bars shall be bent cold. Heating of reinforcement for bending shall not be permitted.

C. Erection Marks: Reinforcement shall be bundled and tagged with erection marks corresponding to those shown on shop drawings to facilitate sorting and placing at the job site.

5. PLACING

A. Reinforcing bars shall be accurately placed as to spacing and clearance and securely tied at intersections with #16 black anneal wire.

B. Bar Supports of metal chairs, cement blocks, etc., of approved type shall be securely supported; fasten bars in proper position to permit walking upon them without deflection or dislocation during placing of concrete.

C. Spacing: The clear space between parallel bars in a layer shall not be less than 1-1/2 times the nominal diameter of the bars, 1-1/3 times the maximum size of aggregate, nor 4 cm. Where bars are placed in two or more layers, the clear space between layers shall not be less than 2.5 cm and bars in the upper layer shall be placed directly above those in the bottom layers.

D. Concrete Protection: Unless otherwise noted, the minimum concrete cover for reinforcing bars shall be as follows:

1. Walls: 2.5 cm clear for not exposed to weather or earth.
   4 cm clear for exposed to weather.

2. Slabs: 2.5 cm clear for not exposed to weather or earth.
   4 cm exposed to weather.

3. Beams: 4 cm clear all around.

4. Columns: 4 cm clear to main bars.

5. Footings: 5 cm clear for poured against form.
   7.5 cm clear for poured against earth.

E. Splices of reinforcement shall be made only as specified, or as authorized by the Engineer.

1. No splices are permitted to be located at points of maximum stress. Splice bottom bars at point of support and top bars at midspan of slabs, beams and girders.

2. Splices shall be staggered wherever feasible.

3. Where lapped splices are used, the minimum length of lap, unless otherwise noted, shall be as follows:

   a. Vertical bars in columns - 36 diameter or minimum 75 cm.

   b. Horizontal bars in beams - 36 diameter or minimum 75 cm.

   c. Vertical bars in walls - 30 diameter or minimum 45 cm.

   d. Horizontal bars in walls - 24 diameter or minimum 30 cm.

4. Lapped splices shall not be used for bar sizes larger than #11. They shall be spliced by butt welding which shall develop in tension at least 125% of the specified yield strength of the bar by test.

F. Welding of reinforcement shall be done only where shown on drawings, or as specified, or as approved by the Engineer. Welding shall be performed only by qualified welders and shall comply with American Welding Society recommended practices AWS D-12.1.

G. Welded Wire Fabric used as reinforcement in slab shall avoid to be spliced in region of maximum stress wherever possible. Lap adjoining pieces with at least one full mesh at sides and ends, and securely wired to each other and other reinforcement.

H. Dowels extending from footing to columns and walls shall be same size and spacing as the vertical bars in columns and walls, and shall be embedded into the footing with length equal to the lapped length spliced to the vertical bars above.

I. Cleaning: Before placing, and again before concrete is poured, all reinfocing steel shall be thoroughly cleaned for loose rust, oil, dirt and other coating detrimental to bond.

J. Maintain Reinforcement in Position at all time during placing of concrete. There shall be a competent representative of the Contractor present who shall keep watching and maintain all reinforcement in proper position.

6. INSPECTION

All reinforcement shall be inspected and approved by the Engineer before placing of concrete.

SECTION D

CONCRETE, CAST-IN-PLACE

1. SCOPE

This Section includes all labor, materials, equipment, transportation and services required to furnish and pour all concrete members as shown on drawings and/or as specified herein.

2. REQUIRED SUBMITTALS

A. Concrete placing schedule including location of proposed construction joints.

B. Mill certificates of cement from supplier.

C. Laboratory test reports on aggregate as per Paragraph 10.A.1 of this Section.

D. Laboratory test reports on Mix Designs for all classes of concrete required as per Paragraph 4 of this Section.

E. Drying Shrinkage test reports on concrete as per Paragraph10.B.1 of this Section

MATERIALS

A. Cement shall conform to ASTM C-150, type I or II, and shall be constant and of same brand and source throughout the project.

B. Coarse Aggregate

1. Shall comply with ASTM C-33, sound crushed stone or hard gravel from sources with proven history of successful use. Sources shall be constant unless prior notice is given to the Engineer for approval after re-check of Mix Design.

2. Shall have no pieces larger than specified in General Notes, and shall be properly graded from 0.6 cm in size to maximum size.

3. Shall be clean, chemically inert, hard, durable, of limited porosity and free from adhering coatings, clay lumps and organic or other impurities.

C. Fine Aggregate shall comply with ASTM C-33, of hard, durable grains natural sand, and shall be free from coagulated lumps and shall contain not more than 1% of clay and silt by volume.

D. Water shall be clean and free of impurities detrimental to concrete.

E. Concrete Admixture for water reduction, increase of plasticity and early strength may be used subject to prior approval by the Engineer.

1. No admixture containing calcium chloride shall be used.

2. All admixtures shall be used in strict accordance with the manufacturer's recommendations and under the control of the testing laboratory which designs the concrete mixes.

4. MIX DESIGNS

Concrete mixes shall be designed based on Trial Batch Method, conforming to ACI-613, by a qualified testing laboratory. All final designed mixes shall be submitted to the Engineer for approval prior to beginning work.

A. All mixes shall meet the requirements as called for in General Notes.

B. All materials shall be mixed in proportion by weight.

C. Cement content shall be kept to a minimum in order to prevent shrinkage crack.

D. Water cement ratio shall be kept to a minimum, and the concrete slump shall not exceed the requirements as called for in General Notes.

E. Drying-Shrinkage test for each trial batch of each proposed min design for prestressed concrete as per Paragraph 10.B.1 of this Section.

5. MIXING

The seal concrete under the piers may be Job-Mixed and all other concrete shall be Ready Mixed in one Central Mixing Plant set up near the Job Site. All mixes made from the concrete plant is used only for the Bridge Project except subject to the approval by the Engineer.

A. Job-Mixed Concrete conforming to ACI-614, shall be done in a batch mixer of approved type. All materials shall be measured in weigh-batcher separately in proper order to assure that they are in right proportion. Mixing shall be continued after all ingredients are in mixer for at least 1-1/2 minutes before any part of the batch is released. The mixing drum shall revolve at rate of peripheral speed of 60 M per minute and shall be completely emptied before any portion of succeeding batch is placed herein.

B. Ready Mixed or Transit Mixed Concrete shall meet all the requirements of ASTM C-94 and to the following conditions:

1. Central Mixing Plant shall be equipped to properly segregate and accurately weigh various components of the mix. Equipment shall be adequate and kept in good mechanical condition at all times.

2. Rate of delivery, hauling time, mixing time and hopper capacity shall be such that all mixed concrete shall be placed into the forms within 60 minutes from time of introduction of cement and water to mixer.

3. Rotation of transit mixing drums shall produce peripheral speed of approximately 60 M per minute. Mixing period shall be no less than 5 minutes.

4. All concrete shall be kept continuously agitated until discharged into the hopper at the jobsite.

5. No water shall be added to any truck unless specifically authorized, and in such quantity as will be necessary in the opinion of the Engineer to secure the desire slump.

6. PLACING

A. No concrete shall be placed without prior approval by the Engineer.

B. All forms shall be thoroughly wetted before placing of concrete.

C. Concrete shall be placed as soon as possible to its final position by approved methods of conveying which will prevent segregation and shall be carried on in a continuous operation as far as practical to avoid cold joints.

D. No concrete that has been partially hardened or has been contaminated by foreign materials shall be deposited in the structure.

E. No concrete shall be placed during rainy weather.

7. COMPACTING

All concrete, immediately upon placing into forms, shall be thoroughly consolidated by vibrators. All vibrators must be of approved type and used strictly in accordance with the Engineer's instructions.

8. CONSTRUCTION JOINTS

Where a joint has been made in the structure, the surface of concrete shall be thoroughly cleaned and roughened by approved methods, and shall be wetted and applied with a coat of epoxy concrete bonding agent or cement grout as specified by the Engineer immediately before placing of new concrete.

9. CURING

A. Fresh concrete shall be protected from direct hot sun or dry wind by proper methods to cover the exposed surface as directed by the Engineer if such a weather condition were encountered.

B. Fresh concrete shall be maintained at above 50°F in moist condition for at least 7 days after placing by continuous wetting or covering materials of approved type. The details of curing method shall refer to Section 9-01.7(8) of Standard Specifications for The North-South Freeway.

10. TESTING

A. Material Tests

1. Aggregate analysis shall be made for both Coarse and Fine as per ASTM C-33.

2. Cement Test shall be made as per ASTM C-150 unless mill certificates are furnished by the supplier.

B. Concrete Tests

1. Drying-Shrinkage Test for each trial batch of each proposed Mix Design for prestressed concrete shall be made as per ASTM C 157 with the following modifications:

a. Make three 10 cm x 10 cm x 28 cm concrete specimens for each test with 2 cm maximum size of hardrock aggregate.

b. The average Drying-Shrinkage after 7 days of moist curing and 21 days of actual drying (28 days after casting) shall not exceed the specified limit 0.05%.

2. Make Slump Test as per ASTM C-143 at time of taking compression test cylinders at jobsite during placing of concrete.

3. Make Test Cylinders of 15 cm x 30 cm standard size as per ASTM C-31 with modifications as follows for prestressed concrete and regular concrete respectively:

   a. For Prestressed Concrete:

      1. Make one set of at least 4 cylinders from each 50 cubic meters of concrete, or fraction thereof, placed each day for each mix.

      2 Mark each set of cylinders and keep accurate record showing the location of concrete in the structure which the cylinders represent.

      3. All test cylinders shall be carefully stored at job site under the same curing condition as the concrete, and delivered to the testing laboratory without damage as per ASTM C-31.

      4. One cylinder of each set for 3-day test or the intended time period for Tensioning or Detensioning. One each set for 7-day test; one each set for 28-day test; and one spare for further test in case the 28-day test falls below the required strength.

   b. For Regular Concrete: Similar procedure as above except three test cylinders shall be required for each set, one each set for 7-day test, one each set for 28-day test and one for spare.

4. Make Compression Test by testing laboratory as per ASTM C-39.

5. Core Tests: In the event of the last cylinder, when test is below the specified strength, then Engineer may require test cores of hardened structure to be taken by the testing laboratory in accordance with ASTM C-42 and C-39.

6. Air Content Test as per ASTM C-260 or C-494 at time of taking test cylinders at jobsite, if any concrete admixture has been used in the mix.

SECTION F

CONCRETE, CAST-IN-PLACE, POST-TENSIONED

1. SCOPE

This Section includes all labor, materials, equipment, transportation and services required to furnish, fabricate and install all post-tensioned concrete work as shown on drawings and/or as specified herein

2. GENERAL REQUIREMENTS

A. Design Criteria of stresses in prestressing steel.

1. Working Stress shall be 60% of the ultimate tensile strength after all losses.

2. Initial Stress immediately after tensioning and anchoring shall not exceed 70% of the ultimate tensile strength.

3. Stress Loss due to friction shall not exceed a magnitude which would make it necessary to stress the steel above 80% of its ultimate tensile strength.

4. Maximum Concentrated Bearing Stress in concrete shall not exceed 6/10 of the compressive strength of concrete at the time of prestressing. Should a higher stress be utilized, additional reinforcement shall be designed and provided for this purpose.

B. Method and Equipment

Prestressing work shall be done by method and related equipment that are in conformance with general accepted system. Variations will be permitted provided equal results can be obtained. The proposed stressing system shall be submitted to the Engineer for approval prior to the beginning of work.

C. Qualification of Prestressing Operator

1. Prestressing work shall be performed by an organization that has successfully performed previous installations of a similar nature as those shown on drawings and specified herein.

2. Prestressing work shall be under the immediate control of a person experienced in this type of work. He shall exercise close checks and rigid control of all operations as necessary for full compliance with all requirements. This person shall be named, and shall furnish such proof of experience as the Engineer may required.

3. REQUIRED SUBMITTALS

A. Shop Drawings including the following shall be submitted to the Engineer for approval prior to fabrication of tendons.

1. Identification Marks shall be assigned to tendons of same size, length and type of anchorage, and shall be plainly shown on shop drawings for all tendons.

2. Slab Tendon Layout showing tendon locations, identification marks, spacings, profile control points, placing sequence and arrangement of tie bars.

3. Beam Tendon Profiles showing identification marks and control points. If tendons are bonded type, showing locations and details of grout port, vent and drain hole. Arrangement of end anchorages shall be detailed in elevations.

4. Installation Details of Anchoring Fittings to concrete forms.

5. Stressing Data including jacking force, gauge reading and calculated elongation for each type of tendon referred to the corresponding identification mark.

B. Calculation of Friction Loss and Elongation for each type of tendon based on ACI 318-63, Section 2607 recommended "K" and "U" values.

C. Mill Certificates and Load-Strain Curve for each heat of prestressing steel and certified test reports on anchorage and coupler conforming to ASTM requirements. If mill certificates and/or test eports are not available, then samples as follows shall be required for tests by testing laboratory prior to acceptance.

Samples for

1. Test on Prestressing Steel

   a. For Wire or Strand, submit one sample of 2 M long for each size of each heat.

   b. For bars, submit one sample of 1.8 M long for each size of each heat.

2. Test on Anchorage: One completely fabricated tendon of 1.5 M in length for each size, including anchorage assemblies.

3. Test on coupler: If couplers are to be used with bars, submit two 1 M lengths of bar equipped with one coupler and fabricated to fit the coupler.

D. Supplier's Literature describing technical data, instructions, etc. for their equipment, tendons, anchor fittings and the prestressing system.

E. Recently Certified Calibration Curve for the pressure gauges of prestressing equipment to be used.

F. Field Records of Stressing, including the actual jacking force applied to and the resulting elongation measured from each tendon, shall be submitted to the Engineer promptly upon the completion of stressing on each member.

4. MATERIALS

A. Prestressing Steel

1. Wire: Cold drawn, uncoated, stress-relieved, minimum 16,900 kg/cm^2 (240 ksi) ultimate tensile strength, conforming to ASTM A-421.

2. Strand: Cold drawn, uncoated, stress-relieved, seven-wire, minimum 19,000 kg/cm^2 (270 ksi) ultimate tensile strength, conforming to ASTM A-416.

3. Bar: Uncoated, stress-relieved, minimum 10,200 kg/cm^2 (145 ksi) ultimate tensile strength, conforming to ACI 318-63, Section 405 (f).

B. Tendon Enclosures

1. Unbonded Tendons shall be completely coated with suitable coating compound to prevent bond, then covered with slippage sheathing to prevent intrusion of cement mortar or loss of coating material during concreting.

   a. Coating Compound shall be a rust preventing, low friction, non-hardening material and non-reactive to concrete and prestressing steel.

   b. Slippage Sheathing shall be of waterproof material with sufficient tensile strength to maintain the group of prestressing wires tightly bundled, as in the case of parallel-wire tendons, and to confine the coating compound from loss during shipping and concreting. Slippage sheathing may be a continuous plastic tubing or spiral wrapping of double layer asphalt-impregnated, reinforced kraft paper or approve equal.

2. Bonded Tendons

   a. Tendon Ducts: Prestressing steel shall be encased in mortar-tight, flexible metal ducts of ferrous material with a minimum wall thickness of 0.25 mm, and the inside diameter of ducts shall be at least 6mm larger than prestressing bar or large enough to produce an internal area at least twice the gross area of prestressing wires or strands to facilitate grout injection.

   b. Grout Ports shall be provided at each end of the tendon as inlet and outlet for grouting. For continuous beams or girders where tendon profile moves up and down over the supports, additional vent shall be provided at each high point of the profile to prevent air pocket and drain hole at each low point to drain off the accumulated water. All grout ports, vent and drains shall be fitted with valves or plugs which can positively close the openings immediately without leakage under pressure during grouting.

3. Anchorages and Couplers

   a. Anchoring Devices and Couplers shall hold the tendon without slip of more than 3.2 mm at a load equal to the applied load on the tendon at tensioning, and shall be so designed that the tendon will not kink, neckdown, or otherwise be damaged. Coupler shall be able to develop the full strength of the tendon.

   b. Distribution Plates which shall distribute load from anchoring devices to concrete shall not be subjected to bending stresses greater than 1,400 kg/cm^2 (20 ksi) if structural steel

or 1,050 kg/cm^2 (15 ksi) if cast steel except where experimental data indicate higher stresses are satisfactory. Materials shall meet requirements of ASTM A-36 for structural shapes or ASTM A-148 for cast steel.

5. FORMWORK

A. Conform with applicable requirements of Section B - "FORMWORK" except modified herein.

B. All bottom forms and falsework for post-tensioned members shall be constructed to minimize resistance to the shortening of the member. Deflection of members due to the prestressing force and deformation of falsework shall be considered in the design of falsework.

6. STEEL REINFORCEMENT

Conform with requirement of Section C - "STEEL REINFORCEMENT".

7. PLACING TENDONS

A. All tendons, before delivery to the job, shall be tagged with identification marks corresponding to those shown on shop drawings to facilitate sorting and placing at the job. Heat number or supplier's production number of tendons which can identify the original sources of the prestressing steel shall also be shown on the tag of each tendon for inspection.

B. Bonded tendons may be placed, at Contractor's option, by either one of the following methods:

1. Only the tendon ducts, bearing plates, grout ports and the like shall be installed in position prior to placing of concrete, leaving the prestressing steel and anchorages to be placed after concreting.

2. The completed assembly of tendons shall be placed in position at one time, prior to placing the concrete.

C. All tendons shall be accurately placed in parabolic profile conforming to the control points as shown on drawings and shall be securely supported by metal chairs, tie bars, etc., at spacing of not more than 1.8 M apart to prevent movement or dislocation before or during placing of concrete.

D. Coupler, if authorized to be used, shall not be located at point of sharp curvature, and shall be encased in mortar-tight metal housing long enough to permit the necessary movement.

E. Vertical Deviation in tendon profile shall not vary more than 3 mm in slabs and 6 mm in beams. Horizontal deviations in slab tendons where required to avoid opening, sleeves, etc., shall be in shape of smooth curvature with maximum 1 to 12 tangent offset.

F. Minimum Clearance for slab tendons, unless otherwise noted, shall be as follows:

1. 5 cm clear between tendon and edge of slab or duct.

2. 15 cm clear between tendon and edge of slab or large opening.

3. Vertical holes of 8 cm or larger in diameter located within 60 cm to the anchor plates shall be sleeved with minimum 4.5 mm (3/16") thick galvanized pipe.

G. Damage in Tendon Enclosures of any size shall be repaired before placing of concrete.

H. Inserts and Anchors for suspending mechanical and electrical work shall be cast in place wherever possible. When additional fasteners are required, they shall be approved by the Engineer. Only those that are anchored in drill holes of 2.5 cm maximum penetration will be permitted, to avoid any possible chance of damaging the tendons.

8. CONCRETE WORK

A. Conform with applicable requirements of Section D - "CONCRETE, CAST-IN-PLACE" with the following modification.

B. Steam Curing for concrete will be permitted at Contractor's option. The method, equipment and installation for steam curing shall be submitted to the Engineer for approval prior to acceptance.

9. STRESSING

A. Stressing shall commence only when concrete cylinder strength has reached 260 kg/cm^2 (3,750 psi) and after the approval of the Engineer.

B. All tendons shall be stressed by hydraulic jacks equipped with recently calibrated pressure gauges accompanied with calibration curve for each gauge to permit the stress in tendon to be computed at any time.

C. Any discrepancy exceeding 5% between the measured elongation and the gauge reading shall be ascertained and corrected. Countercheck the gauge in question with another gauge immediately. If the gauge is found inaccurate, replace and recalibrate the gauge. If the elongation is found doubtful, notify the Engineer immediately.

D. Under no circumstances shall be any tendon be stressed in excess of 80% of its ultimate tensile strength.

E. Check friction loss on each type of tendon at the beginning of stressing and make proper adjustment on the calculated elongation.

F. For two-end stressed tendons, stressing shall be performed from both ends of the tendon simultaneously unless otherwise approved by the Engineer.

G. Stressing sequence, unless otherwise specified, shall be as follows:

1. Floor system: Stress slab tendons first, beams next, then girders.

2. Slabs: Starting from the center tendon both ways, if any, proceed alternately toward both ends, then back to the center from both ends.

3. Beams and Girders: Starting from the one at the c.g. of tendons, proceed outward alternately and then back to the center from the extremes.

H. Record elongation and gauge reading of each tendon as specified in Paragraph 3.F. "Field Records of Stressing" of this Section.

10. SAFETY PRECAUTIONS

A. Stressing operation and handling of stressing equipment shall be strictly in accordance with the instructions of the supplier.

B. Ensure every part of the anchoring device is positively clean, without dirt or any sign of defect before stressing.

C. When gas cutting or arc welding work has to be performed near the tendons, proper protection shall be made to keep tendons from being subjected to excessive heat, welding sparks, or ground currents which might cause hard-to-detect damage to the tendon.

D. Prevent any persons from standing behind the hydraulic jacks or close to the hydraulic hoses during stressing.

11. GROUTING - Applicable to bonded tendons only.

A. Grout for bonded tendons shall be neat cement grout of non-shrink type and shall have a compressive strength on 7.5 cm x 15 cm test cylinder of 280 kg/cm^2 (4,000 psi) at 28 days.

B. Admixtures to increase workability and reduce shrinkage may be used subject to approval by the Engineer. Admixtures containing chlorides, fluorides, sulphites, nitrates, fly-ash or aluminium powder shall not be used.

C. Proportion of grouting materials shall be based on results of tests prior to the beginning of work. Water cement ratio of grout shall not be more than 0.50 the content of cement by weight.

D. The pumpability of grout shall be determined by Standard Flow Cone Test with time of efflux of grout sample immediately after mixing not less than 11 seconds.

E. Grouting materials shall be mixed in a high speed mechanical mixer until becoming uniformly colloidal consistency before being passed through a strainer into the pump.

F. Just prior to grouting, tendon ducts shall be made free of dirts and other foreign substances by thoroughly flushing with water and blowing out with oil-free air.

G. Grouting shall not begin until 24 hours after stressing.

H. Temperature of members at time of grouting must be above 50 F and shall be maintained at this temperature for at least 48 hours.

I. Grout shall be pumped through the duct from inlet with all high point vents and outlet opened when grouting starts except drain hole at low points which may be plugged after cleaning of duct. Grout shall be allowed to flow from the vents and outlet continuously until no visible slugs of water or air are ejected, at which time the vents shall be closed in sequence from the first vent after the inlet. When all vents and the outlet have been closed, a pressure of approximately 7 kg/cm2 (100 psi) shall be applied by the pump for at least 1 minute then close the inlet valve which shall remain closed until the grout has set.

12. PROTECTION OF END ANCHORAGES

All exposed parts of anchorage shall be permanently protected against corrosion by approved method and material before covering the concrete or drypacking, as directed by the Engineer.

SECTION G

CONCRETE, PRECAST, PRETENSIONED

1. SCOPE

This Section includes all labor, materials, equipment, transportation and services required to fabricate and install all precast pretensioned members as shown on drawings and as specified herein including all accessories and related items appurtenant hereto.

2. GENERAL REQUIREMENTS

A. Design Criteria of stresses in prestressing steel.

1. Working Stress: 60% of the ultimate tensile strength after all losses.

2. Initial Stress: 70% of the ultimate tensile strength immediately after tensioning and anchoring.

B. Method and Equipment

Precast and pretensioning works shall be done by method and related equipment that are in conformance with general accepted practice The proposed method of fabrication shall be submitted to the Engineer for approval prior to the beginning of work.

C. Qualification of Manufacturer

Fabrication of precast pretensioned concrete work shall be undertaken by manufacturer experienced in the production of this type of product, and has been successful in similar work as those shown on our drawings or as specified herein.

3. REQUIRED SUBMITTALS

A. Shop Drawings including the following shall be submitted to the Engineer for approval prior to the beginning of work.

1. A Complete Erection Plan showing the locations of all precast pretensioned units with respect to the entire structure. Each pretensioned unit shall be assigned with an Identification Mark plainly shown on the erection plan. Placing sequence shall also be noted on the plan.

2. Complete Details of Fabrication for each type of pretensioned unit including prestressing steel, reinforcement, miscellaneous attachment and pickup fittings that are required to be embedded in concrete.

B. Complete Production Record including identification mark of each pretensioned unit, date of pretensioning, casting, detensioning and the heat number of prestressing steel.

4. MATERIALS - Prestressing Steel

A. Wire: Cold drawn, uncoated, stress-relieved, minimum 16,900 kg/cm^2 (240 ksi) ultimate tensile strength, conforming to ASTM A-421.

B. Strand: Cold drawn, uncoated, stress-relieved, seven-wire, minimum 19,000 kg/cm2 (270 ksi) ultimate tensile strength, conforming to ASTM A-416.

5. FORMWORK

A. Conform with applicable requirements of Section B - "FORMWORK" except modified herein.

B. Bottom forms for pretensioned members shall be constructed to permit movement of the member without damage during release of prestressing force.

6. STEEL REINFORCEMENT

Conform with applicable requirements of Section C - "STEEL REINFORCEMENT".

7. PLACING TENDONS

A. All prestressing steel shall be accurately placed along the tensioning bed in exact size, number, pattern and position as called for on drawings. No tendons shall be permitted to cross or twist.

B. Proper means shall be provided to hold all tendons in true position throughout their full length without sags after tensioning.

C. All tendons and reinforcement shall be clean, free from oil, loose rust, dirt or other foreign matter detrimental to bond prior to placing of concrete.

8. TENSIONING

Shall be done by either one of the following methods at Contractor's option. No matter what method is used, all tendons shall be pretensioned to a specified low tension first then continue to be stressed to the required full load to insure all tendons are uniformly stressed.

A. Stress All Tendons Simultaneously

Pull each tendon individually to the specified low tension as measured by a dymanometer, anchor the tendon to the anchor plate at bulkhead of the jacking unit. After all tendons have been held on the anchor plate, then stress all tendons simultaneously by jacking the bulkhead to the required elongation as measured from the point of low tension to the point of full load.

B. Stress One Tendon at A Time Individually

Stress each individual tendon by mono-wire/strand jack to the specified low tension as observed from the pressure gauge of the jack. Measure the jack extension or set a reference mark at this point, then continue to stress the tendon to the required elongation as measured from the point of low tension to the point of full load.

9. CONCRETE WORK

A. Conform with applicable requirements of Section D - "CONCRETE, CAST-IN-PLACE" except modified herein.

B. Unless otherwise noted, tops of all beams and the like shall be roughened by wire brush at the time of initial setting of concrete.

C. Steam curing for concrete will be permitted at Contractor's option. The method, equipment and installation for steam curing shall be subject to the approval of the Engineer prior to acceptance.

10. DETENSIONING

A. Detensioning shall commence only when concrete cylinder strength has reached 260 kg/cm^2 (3,750 psi).

B. All forms which may restrict either horizontal or vertical movement of the prestressed members shall be loosened or stripped prior to detensioning.

C. Detensioning shall be performed by either one of the following methods at Contractor's option.

D. Gradually transfer all prestressing force from tendons to concrete simultaneously by slowly releasing the bulkhead with hydraulic jacks at the stressing end.

E. By Cutting tendons with acetylene torch one at a time in proper sequence and position which will not cause damage to the concrete.

11. IDENTIFICATION MARKS

All finished products, before delivery to the job, shall be marked with identification marks corresponding to those shown on the erection plan to facilitate sorting and placing at the job.

12. HANDLING

A. Special lifting devices of approved type shall be provided at the specified Pickup points on each pretensioned unit and lifting shall only be done at these points. The use of other points or methods of pickup shall be subject to the approval of the Engineer.

B. All beams and the like, except piles, shall be maintained in an upright position at all times, and shall rest at pickup points only.

C. Any damaged or marred units shall be subject to rejection.

D. Make no repairs to damaged units without the Engineer's approval.

13. INSTALLATION

A. Each pretensioned unit shall be set in the position assigned it, as indicated on the approved erection plan.

B. All units shall be place in accurate alignment with joints carefully spaced and properly anchored according to the details as shown on approved shop drawings.

SECTION H

PRECAST, PRESTRESSED CONCRETE PILES

1. SCOPE

Work under this Section includes complete responsibility for furnishing and driving all piles on the jobsite, penetrations and alignments, including test piles and load tests as shown on drawings and/or as specified elesewhere herein.

2. REQUIRED SUBMITTALS

A. Shop Drawings for piles to be fabricated conforming to all applicable requirements as per Section G - "Concrete, Precast, Pretensioned."

B. Piling Layout detailed in plan indicating location of each pile, including test piles, penetration, tip elevation, cut-off elevation and assigned number for each pile as identification in pile driving record thereafter.

C. Manufacturer's Publications and information related to pile driving equipment including tabular or graphic driving data for the particular hammer to be used.

D. Arrangement of Load Test detailed in drawings including equipment used for applying loads, method of measuring pile settlement and procedures of conducting load test.

E. Pile Driving Record as per Paragraph 6.M.of this Section.

F. Load Test Record as per Paragraph 12 of this Section.

3. PILING CRITERIA

A. Working Load: Minimum 130 MT per pile.

B. Driving Energy of Hammer: Minimum 7,760 M-kg (56,000 ft. lbs.) per blow.

4. PILING EQUIPMENT

All piles shall be driven with a steam, air or diesel hammer of approved type as generally used in standard pile driving practice and shall be capable of developing a minimum dynamic energy as indicated in above Paragraph "Piling Criteria" of this Section.

5. FABRICATION OF PILES

A. Concrete: Minimum 28-day compressive strength 350 kg/cm^2 (5,000 psi.)

B. Do not fabricate pile until a correct schedule of required pile lengths have been established and approved by the Engineer from results of driving test piles and load tests.

C. All piles shall be fabricated to required sizes, lengths and shapes with proper reinforcement and attachment, if any, as shown on approved shop drawings and shall conform to all applicable requirements as specified in Section G - "Concrete, Precast, Pretensioned" and General Notes.

D. All piles shall be clearly marked with cross lines at 20 cm intervals and numbered every 1.0 M starting from the tip.

6. DRIVING

A. No piles shall be driven in the absence of the Engineer or Inspector.

B. Piles shall be driven at location and alignment as indicated on drawings with approved hammer and equipment to the specified penetration in continuous driving without interruption.

C. Pile shall be plumbed to the exact location before driving.

D. Pile lead shall be firmly supported to guide the hammer and pile in position and aligment while driven.

E. Cushion: Pile head shall be properly protected from direct impact of hammer by cushion block made of approved material. Cushion block shall closely fit the head of pile and shall be inspected periodically during driving. Cushion block that has been unduly worn or damaged shall be replaced immediately.

F. Pile Length and Driving Criteria shall be established in the field following the installation of probe piles. At least 10 probe piles shall be driven at each pier before the beginning of construction. The probe piles shall be exactly the same type and dimensions as the piles to be used in construction and shall be driven by the same equipment and manner of driving as used in construction. The probe piles shall be driven at a location of permanent piles.

G. Pile may be stopped short of the required 3 meter in the underlying rock if the resistance to driving exceeds 2.5 times that of the ENR formula for the last 6 inches of penetration.

H. Pile heaved during driving of adjacent pile shall be re-driven to the original elevation.

I. Driving Sequence in pile group shall begin at center of the group then proceed from center outward.

J. Pre-Drilling: Where driving conditions are encountered at random with rock or concrete rubble which may cause damage to the pile or premature refusal is encountered before achieving the specified penetration. Drilling holes prior to driving may be required to enable penetrating the refusal layer. The diameter of drilled hole shall not exceed 75% of the average pile diameter or average side dimension.

K. Water-Jetting in lieu of pre-drilling may be allowed only where the site conditions are permissible for such an operation and with prior approval of the Engineer. No additional cost will be allowed for pre-drilling or water-jetting.

L. Reduction of Hammer Energy: When driving through soft soil of little or no resistance to penetration: the length of stroke of the hammer shall be reduced to prevent any possible build-up of longitudinal tensile stress in the pile shaft by elastic shock waves travelling up and down the pile. When the point of the pile is being driven into firm ground, full stroke of hammer shall be used.

M. Daily Pile Driving Record shall be kept by the Contractor and shall be submitted to the Engineer daily. Pile driving record shall include type of hammer to be used, pile number, size, penetration, resistance, tip elevation, cut-off elevation, pile condition after driving, starting time of drive and finish; time and cause of interruption, if any.

7. SPLICING

Shall be made only as shown on drawings, or as specified, or as authorized by the Engineer. The method of splicing shall conform to the details as shown on drawings or as directed by the Engineer. When the alternate splicing method would be approved to use for this project, the cost of splices shall be negotiated again.

8. CUT-OFF AND EXTENSION

Cut-off concrete piles at such elevations that they will extend into pile cap or footing as shown on drawings.

B. Where piles are required to be cut-off, cutting shall be performed with pneumatic tools, sawing, or any other method approved by the Engineer. The cut-off shall be a level flat surface.

9. TOLERANCES

Center of pile at cut-off elevation shall not exceed 8 cm from the design location.

10. REJECTION

When driven piles exceed the specified tolerances, are cracked, or spalled below cut-off elevation they shall be subject to rejection. Any rejected pile shall be corrected to the satisfaction of the Engineer by repair, if feasible, or remove and replaced or adding piles and enlarging pile cap at Contractor's expense.

11. TEST PILES

A. Shall be driven before the beginning of construction, allow ample time for determination of load test, pile capacity and fabrication.

B. Shall be exactly the same type and dimension as the piles to be used in construction and shall be driven by the same equipment and manner of driving as used in construction.

C. Shall be driven at a location of permanent pile, near the soil boring where the soil characteristics are known, and shall be cut-off as permanent pile after load test.

D. Shall be driven to refusal or to a bearing capacity at least 100% greater than the design load, The required penetration of permanent piles will be determined by that of the pile test.

E. Shall have their top elevation, after driving, higher than the cut-off elevation to facilitate conducting load test.

12. LOAD TEST: Refer to Standard Specifications Section 11-04.3(2).

SECTION I

CONCRETE SURFACE FINISHES

1. SCOPE

All concrete shall be given a Class 1, Ordinary Surface Finish, unless otherwise specified. The following surfaces shall be given a Class 2, Rubbed Finish: the exposed visible faces of piers, girders, walls, curbs, median, underside of copings and such other exposed visible surfaces where smooth, uniform surfaces are specified.

The surface finish on piers shall include all exposed surfaces above low water level (-0.35 M) or 60 centimeters below finish ground line when such ground line is above the water surface. Walls shall be finished from the top to 60 centimeters below the finish slope lines on the outside face and shall be finished on top and for a depth of 30 centimeters below the top on the back side.

2. SURFACE FINISHES

A. Class 1, Ordinary surface Finish:

Immediately following the removal of forms, all fins and irregular projection shall be removed from all surfaces except from those which are not to be exposed or are not to be waterproofed. On all surfaces, the cavities produced by form ties and all other holes, Honey-comb spots, broken corners or edges and other defects shall be thoroughly cleaned, and after having been kept saturated with water for a period of not less than three hours shall be carefully pointed and trued with a mortar of cement and fine aggregate mixed in the proportions used in the grade of the concrete being finished. Mortar used in pointing shall not be more than one hour old. The mortar patches shall be cured as specified under Curing. All construction and expansion joints in the completed work shall be left carefully tooled and free of all mortar and concrete. The joint filler shall be left exposed for its full length with clean and true edges.

The resulting surfaces shall be true and uniform. All surfaces which cannot be repaired to the satisfaction of the Engineer shall be urbbed as specified for Class 2. Rubbed Finish.

B. Class 2, Rubbed Finish: After removal of forms the rubbing of concrete shall be started as soon as conditions permit. Immediately before starting this work the concrete shall be kept thoroughly saturated with water for a minimum period of three hours. Sufficient time shall have elapse before the wetting down to allow the mortar used in the pointing of rod holes and defects to thoroughly set. Surfaces to be finished shall be rubbed with a medium coarse carborundum stone, using a small amount of mortar on its face. The mortar shall be composed of cement and fine sand mixed in proportions used in the concrete being finished. Rubbing shall be continued until all form marks, projections and irregularities have been removed. All voids filled and a uniform surface has been obtained. The paste produced by this rubbing shall be left in place at this time.

After all concrete above the surface being treated has been cast, the final finish shall be obtained by rubbing with a fine carborundum stone and water. The rubbing shall be continued until the entire surface is of a smooth texture and uniform color.

After the final rubbing is completed and the surface has dried, it shall be rubbed with burlap to remove loose powder and shall be left free from all unsound patches, paste, powder and objectionable marks."

SECTION J

SUBSTRUCTURE

1. SCOPE

Work under this Section shall consist of furnishing all labor, materials, equipment, transportation and services to perform all work necessary for construction of the substructure for the Yuan Shan Bridge, which includes, excavation and construction of piers as shown on drawings and/or as specified herein.

2. GENERAL REQUIREMENTS

A. Restrictions

1. For the sake of public safety and preventing interference to the near by traffic, no blasting shall be permitted in foundation excavation.

2. Foundation excavation for pier (A), (B), (D) and (E) may be carried out in dry condition or under water at Contractor's option with methods and equipment that will surely make no injury or damage to piles.

3. Bottom seal concrete beneath pile caps shall be placed in static water or dry condition at Contractor's option.

4. Construction of R. C. pile caps and pier shafts shall be carried out in dry condition. No underwater work shall be permitted for this part.

B. REQUIRED SUBMITTALS

The following shall be prepared and submitted to the Engineer for approval prior to the beginning of work.

No work shall be done until such approval is given, but such approval shall not relieve the Contractor of responsibility for the safety of his methods and equipment or from carrying out the work in accordance with the drawings and specifications.

1. Schedule of Work and sequence of construction operation should be in consistency with the superstructure operation.

2. Methods and Equipment proposed to be used for excavation of rock in pier (C) and excavation under water and dewatering in pier (A), (B), (D) and (E) shall be detailed in drawings and/or written information.

3. Shop Drawings of falsework, formwork and reinforcing steel as per Section B and C of this Specification.

3. EXCAVATION

A. The Contractor shall take full responsibility for maintaining the foundation construction in safe condition at all times, and shall

further be held responsible for any personnel and/or property damages that are caused by his construction operation under the Contract.

B. Sheeting, shoring, bracing or coferdam as required to protect the excavation in deep foundation shall be extended deep enough to hold the unsupported length in place and to prevent bottom from heaving and shall be in such a manner so as not to interfere with the construction operations.

C. Excavation shall be carried out to the elevation as specified on drawings and shall be wide enough permitting to install concrete forms. Any explosion for rock excavation shall not be allowed.

D All material from excavation shall be removed, transported and disposed to locations as specified by the Engineer at Contractor's cost.

E. Excavations for shallow footings in dry ground where soil conditions are stiff enough to remain stable as it has been cut. It may be permitted to excavate to lines and grades as required for placing concrete on footings without forms provided prior approval is obtained from the Engineer.

F. Clamp shell bucket, or the like, for underwater excavation in pier foundation shall be limited to the depth above the pile head. Any excavation below pile head elevation shall be carried out by high power water jet incorporated with sand pumping, or hand digging by divers, or any approved method that shall make no injury or damage to piles and will also clean up the dirt on surfaces of piles and sheeting.

4. BOTTOM SEAL TREMIE CONCRETE

A. Prior to the placing of tremie concrete according to the Contractor's option, any muddy water if found to be confined inside the sheeting enclosure of the pier foundation shall be made clean by circulating clear river water in and muddy water out of the enclosure simultaneously by pumps of equal capacity.

B. Tremie concrete shall be conveyed to the bottom of the excavation under water by means of flexible seamless rubber Elephant Trunks of minimum 20 cm in diameter, in smooth and continuous placement without causing seggregation of aggregate or intrusion of muddy water. The bottom end of the Elephant Trunk shall be deepened into concrete being place about 1 M at all times. Sump pits shall be formed on top of the concrete for dewatering use later.

C. Keep water inside the sheeting enclosure at same level as the river water level outside right before and after the placing of concrete until the concrete has set.

5. DEWATERING

After the bottom seal concrete has hardened, the water inside the sheeting enclosure shall be emptied by pumping to make feasible the construction of the reinforced concrete pile cap in dry condition.

6. PILE CAP AND PIER

Shall be constructed in conformance to details as shown on the drawings. Stagger dowel bars from pile cap to pier shaft in different elevation, as indicated on drawing.

SECTION K

SUPERSTRUCTURE

1. SCOPE

Work under this section shall consist of furnishing all labor, materials, equipment, transportation and services to perform all work necessary for construction of the superstructure for the Yuan Shan Bridge as shown on drawings and/or specified herein.

2. GENERAL EQUIPMENTS

A. Principal Construction Method: The multiple-cell two end cantilever box girders shall be started from each pier progressively extending out north-south direction with consecutive segments to meet the opposite girders at the mid-span. The end spans will meet piers (N) and (S).

B. Movable Construction Wagon:

1. The construction wagon shall be easy to move on the top of the girder deck along the rails and shall have sufficient strength to substain maximum segment dead load plus all construction live loads, wind and earthquake effect without appreciable deflection. No horizontal movement shall be allowed during pouring concrete.

2. The line of reaction from the wagon such as front bearings, back anchorages shall be limited in the web areas of the box girder.

3. Framing members of the wagon shall not interfere with erecting and removing forms, pouring concrete or prestress operation.

4. The construction wagon shall provide enough space for installing counterweights and shall provide enough suspended scaffolding around and under the segment for the safety and convenience of the construction.

5. Total weight of each construction wagon, including counterweights, scaffloding, forms and all construction loads shall not exceed 90 tons.

6. Steel forms (1/8" Plate) shall be specified for all outer surfaces of the box girder segments, and wooden form may be used for all inner surfaces of the box girder segments. Adjustment of forms in elevation shall be made possible to compensate for proper deflection during the course of construction, and due to creep and shrinkage later. No horizontal joints will be permitted in the forms for the exterior vertical face of the girder.

3. REQUIRED SUBMITTALS

The following shall be prepared and submitted to the Engineer for approval prior to the beginning of work.

No work shall be done until such approval is given, but such approval shall not relieve the Contractor of responsibility for the safety of his methods and equipment or from carrying the work in accordance with drawings and specifications.

A. Proposed Methods, Equipment, Construction procedure and schedule shall be detailed in full for the construction of the superstructure, including details of the construction wagon that will be used.

B. Shop Drawings of formwork, falsework, reinforcing steel and prestressing tendons as per Section B, C and F of this specification.

C. Complete layout of locations of front bearings and back anchorages of construction wagon at each stage of construction including details of additional reinforcing steel in concrete for front bearings and back anchorages.

D. Proposed methods, procedure and detail of bracing system to adjust and fix the relative position of the opposing cantilever end segments at center of span for placement of the closure segment.

4. CONSTRUCTION SEQUENCE

A. General Description

1. The superstructure supported by each pier consists of two parallel multiple-cell cantilever box girders tied to each other by deck slab on top and by cross beams over the pier support.

2. The construction procedures are similar and identical for all individual girders which shall be classified into 5 parts: 1) Pier Segment, 2) Cantilever Segments, 3) Closure Segment, 4) End Segments in End Spans, and 5) Median Strip in deck slab according to different construction methods to be used. The individual operations are outlined as follows:

1). Pier Segment

a. Shall be the particular segment over the pier support between section mark (B) and (2) as shown on drawings. The whole segment shall include two parallel box girders, madian strip, cross beams, diaphragms and bottom slab on top of pier support.

b. The pier segment shall be the first part in the superstructure to be constructed. Coventional construction methods shall be used in this stage by erecting falsework directly on pier footing to support all concrete formwork. The exterior forms shall be so constructed as to give the same texture and appearance as for the rest part of the bridge that is constructed by cantilevel method.

c. Enough screwjacks shall be provided for falsework to adjust deflection or camber of the superstructure before and during the placing of concrete.

d. Sequence of casting box segments shall be as follows and shall be typical for all the subsequent box segments throughout the entire superstructure:

1. Cast bottom slab.
2. Cast all vertical web of floor beams and girders up to the botton of deck slab.
3. Cast deck slab.

4. Stress prestressing tendons for only those specified on drawings when concrete cylinder strength reaches 260 kg/cm^2 (3,750 psi).
5. Grouting of tendons shall not be earlier than 24 hours after stressing, nor later than one week after placing of prestressing steel in the ducts for longitudinal tendons, nor later than 2 weeks for transverse tendons.

e. All construction joints, vertical and/or horizontal, shall be thoroughly cleaned, roughened and coated with an epoxy bonding agent of approved type prior to placing concrete.

f. Formwork, reinforcing steel, postensioning tendons and concrete work shall confirm to all applicable requirements as per Section B, C, D and F of this Specifications.

g. All necessary inserts for anchoring the construction wagons and for other purposes shall be pre-arranged and installed in place prior to concreting.

2). Cantilever Segments

a. Shall begin with the first segment north of pier segment, Section marked (B-C),then the south segment, Section marked (2-3), and then back to the next north segment, marked (C-D) for another cycle and so on till the last segment at cantilever end on both sides where the longest prestressing tendons terminate.

b. Cantilever method by using movable construction wagons on serve as working platforms and to suspend the concrete formwork in space shall be used throughout this stage.

c. Each direction of each girder shall require one construction wagon, a total of four wagons shall be required for the construction of the superstructure over each pier support.

d. The construction wagon shall be located, erected, anchored, loaded, suspending formwork, adjusted, etc., conforming to the approved submittals as per Paragraph 3.A "Proposed Methods, Equipment, Construction Procedure and Schedule" of this Section.

e. The sequence of casting each box segment shall be the same as outlined in previous paragraph.

f. Diaphragms shall be constructed at any convenient moment where and when there is no interference with the construction wagon.

g. Proper amount of camber shall be provided for each segment so as to achieve the design elevation throughout the entire stretch of the girder when finished. A complete list of calculated cambers for all segments of the Yuan Shan Bridge based on the concrete drying-shrinkage test results will be available after concrete mix design has been set up.

h. Prior to placing concrete, proper adjustment on forms shall be made for camber, construction errors, deformation of wagon, etc., to the correct elevation of each segment. During placing concrete, further adjustment on form level shall be made to compensate for deflections due to construction load.

3). Closure Segment

a. Shall be the only segment right at the mid-span in between the two opposing prestressed cantilever end segments, and also where the expansion joint of two opposing girders is located.

b. A combination of cantilever method with special bracing system conforming to the approved submittal as per Paragraph 3.D of this Section shall be used in the construction of this segment.

c. Anchoring devices for bracing system shall be provided in the last opposing cantilever end segments before they are constructed.

d. It shall be the Contractor's responsibility to adjust the two opposing cantilever end segments to match each other at the same elevation and rigidly connected them by means of steel members to fix their relative position.

e. The closure segment shall then be constructed in the same manner as for any typical cantilever segment except without prestressing.

f. Expansion joints at the center of closure segments shall be made as detailed and specified on drawings.

1. The Slide Bearings used in the expansion joint shall consist of:

A top pad of 2.4 mm (3/32") thk. glass reinforced virgin Tetrafluoroethylene sheet with a coefficient of friction .06, compressive strength of 140 kg/cm^2 (2,000 psi) with .002 deformation and temperature range of - 320°F - + 500°F. This material shall be factory epoxy bonded to a 106A galvanized carbon steel plate which will be tack welded to the structural steel frame.

The bottom pad shall be the same as the above with the exception that it will have radius ends to permit rotation. This curved pad will be tack welded to a radius base plate; which in turn will be tack welded to the steel frame.

This top and bottom slide bearing assembly to be P/N FC-1010-GL as manufactured by the Fluorocarbon Co, Pine Brook, N. J., or approved equal.

2. The Expansion Joint Seals shall be TRANSFLEX-650 as manufactured by General Tire, U.S.A. or approved equal.

4) End Segments in End Spans

a. Shall be the last segment on Pier (N) and (S) at both extremes of the bridge.

b. Permanent bearings shall be installed and secured in position as detailed and specified on drawings prior to concreting.

c. The construction procedure shall be the same as for any typical cantilever segment.

5) Madian Strip

a. Shall be the longitudinal closure joint along the center line of the bridge deck between the two parallel box girders as shown on drawings.

b. Ordinary formwork shall be used in construction of madian strip.

c. Shall be constructed at any convenient moment and length where and when there is no interference with the construction wagons and other operations.

SECTION L

Electrical Work

1. DESCRIPTION

The electrical work shall consist of furnishing and installing hig'way lighting systems, as required by the plans, and as specified herein.

The locations of lighting standards, are approximate and the exact locations may be modified by the Engineer in the field to suit unforeseen requirements.

All materials furnished and used shall be new, andshall be handled, and installed in a workmanlike manner.

All systems shall be complete and in operation to the satisfaction of the Engineer at the time of acceptance of the work.

2. EQUIPMENT LIST AND DRAWINGS

Unless otherwise permitted in writing by the Engineer, the Contractor, shall, within 60 days following award of the contract, submit to the Engineer for review and approval, a list of equipment and materials which he proposes to install. The list shall be complete as to name of manufacturer, size and identifying number of each item. The list shall be supplemented by descriptive technical data, including detailed scale drawings and wiring diagrams of any special equipment, and of any proposed deviationfrom the plans. Five sets of the above data shall be submitted in both in Chinese and English. Following review, checking, correction and acceptance, three complete record sets shall be resubmitted to the Engineer, in both Chinese and English. The Ower will not be liable for any material purchased, labor performed, or delay to the work prior to such review and approval.

If ordered by the Engineer, the Contractor shall submit sample articles, of any of the material proposed for use for the Engineer's approval.

Upon completion of the work, the Contractor shall submit three complete sets of "as-built" or corrected plans, and any data therefor, as required by the Engineer showing in detail all constraction changes, especially location of cables, standards and pull boxes. At least one copy shall be in English. The Contracotor, at his option, may submit bilingual documents.

3. WARRANTIES, GUARANTIES AND INSTRUCTION SHEETS

Manufacturers' warranties and guaranties furnished for materials used in the work shall be delivered to the Engineer. Instruction sheets and parts lists supplied with materials shall also be delivered to the Engineer. At least one set shall be in English or all documents may be bilingual

4. SCHEDULING OF WORK

Work shall be so scheduled that each highway lighting shall be completed and ready for operation prior to opening to traffic of the corresponding section of the roadway.

5. MATERIALS AND INSTALLATION

a. Removing and Replacing Improvements - Improvements such as curbs, gutters, concrete and asphalt concrete pavement, base material, lawns and plants, and any other improvements removed, broken or damaged by the Contractor's operations, shall be replaced or reconstructed with the same kind of material as found on the work or with materials of equal quality. The new work shall be left in a condition satisfactory to the Engineer.

b. Foundations - Foundations for Lighting Standards, shall be "seven sack" portland cement concrete. Portland cement concrete shall conform to the Provisions in Section 35, "Portland Cement Concrete" and Section 37, "Portland Cement Concrete Structures". Construction methods shall conform to the provisions in Section 37, "Portland Cement Concrete Structures".

Forms for foundations shall include a template to hold anchor bolts and conduits securely in proper location, laterally and vertically, during placing and setting of concrete.

Anchor bolts shall conform to the specifications of ASTM Designation A307 and shall be provided with galvanized and lock washers.

6. LIGHTING STANDARDS

a. The poles shall consist of:

1. A tapered steel shaft having a base welded to the lower end.

2. Davit type arm.

b. Anchor Base:

1. A one-piece steel anchor base plate of adequate strength shape, size, and having a scalloped top flange, shall be secured to the lower end of the shaft by two (2) continuous electric arc welds. The base shall telescope the shaft and the one weld shall be on the inside of the base at the end of the shaft, while the other weld shall be on the outside at the top of the base. The two (2) welds shall be not less than 5cm apart so that the welded connection shall develop the full strength of the adjacent shaft section to resist bending action.

2. The base plate shall be provided with four (4) holes to receive the anchor bolts, and one (1) slotted hole to receive the conduits.

c. Shaft:

1. Steel shaft of the pole shall be fabricated from not less than #11 Manufacturers Standard Gauge, best grade, hot rolled basic open hearth steel. The shaft shall have only one (1) longitudinal, automatically, electrically welded joint, and shall have no intermediate horizontal joints nor welds. Only one (1) length of steel sheet shall be used, which shall be formed into a continuously tapered shaft, having a taper of approximately .14" per foot (1.17 cm./meter)

2. After forming and welding, the tapered shaft shall be longitudinally cold rolled under sufficient pressure to flatten the weld and increase the physical characteristics of the shaft so that the metal will have a minimum guaranteed yield strength of 48,000 psi.

3. A handhole on the shaft and cover shall be provided on the faces of those shafts which are to be anchor base mounted with no

transformer base available for wiring. The cover fasteners shall be a silicon-bronze or stainless steel round head screw.

d. Bracket Arms:

1. The davit type arm or section shall have a tenon adapter for receiving the luminaire. Arm ends shall be arranged to accommodate a 2 inch slip-fitter type luminaire.

e. Anchor Bolts:

Four (4) high-strength steel anchor bolts, each fitted with a hex nut, shall be furnished with the poles. Each anchor bolt shall have an "L" bend at the bottom end and be threaded at the top end. Threaded ends and all nuts shall be galvanized. The anchor bolts shall be capable of resisting at yield strength stress the bending moment of the shaft at its yield strength stress.

f. Following fabrication, standards shall be thoroughly cleaned preferably by sand or shot-blasting, and immediately hot-dipped galvanized inside and outside.

7. CONDUITS

The PVC conduit shall be heavy wall, high impact polyvinyl chloride conforming with CNS standard

PVC couplings, adapters and box connectors shall be solvent welded to the conduit, using the manufacturers recommended solvents and methods. Field bending of offsets and less than right angle bends shall be done according to the manufacturers recommendations for heat bending, without overheating or direct flame application.

The ends of all conduits, whether shop or field cut, shall be reamed to remove burrs and rough edges. Cuts shall be made square and true. Slip joints will not be permitted for coupling conduit.

8. CONDUCTORS

Unless otherwise specified, conductors shall consist of solid or stranded copper of the gauge shown on the plans. Copper wire shall conform to the specifications of ASTM Designations: B3 and B8.

For all electrical conductors, insulation shall be of solid colors, or of basic colors with a permanent colored stripe, with uniform code to identify phase conductors, Black-phase A, Red-phase B, Blue-phase C, White-Neutral, Green or bare-ground.

Lighting circuit conductors shall be rated for 600-volt operation. The insulation shall be cross linked polyethylene conforming to CNS standard.

9. WIRING

Powered soapstone, talc, or other inert lubricant shall be used in placing conductors in conduit.

At least 1 meter of slack shall be left for each conductor at each splice or termination. No conductor splices will be permitted in conduit. Lighting conductor splices, where required, shall be made only in pole bases.

10. BONDING AND GROUNDING

Grounding wire, ballast and service equipment, anchor bolts, and metal poles shall be made mechanically and electrically secure to form a continuous system, and shall be effectively grounded. Bonding and grounding jumpers shall be copper wire or copper strap of the same cross sectional areas as No. 6AWG for lighting systems and No. 8 AWG for all other systems.

Bonding of standards shall be by means of a bonding jumper attached to brass or bronze bolt installed in the lower portion of the shaft as indicated on the plans.

For bonding purposes, a ground wire shall be installed in each conduit.

11. ROADWAY LUMINAIRES

Luminaires for roadway lighting shall be General Electric, Type M-400A, Cat. No. C724G753 (250 W) or equivalent without photo cell, as shown on the plans, suitable for use with high pressure sodium lamps.

The luminaire is to be precision die-cast aluminum and is to be furnished complete with "POWR/DOOR" assembly (to which are mounted the major electrical components for multiple operation, including ballast, capacitors, and photo-electric control where used). Access to the loosening of a single captive screw on the door. The luminaire shall contain an internal ballast of the regulator type capable of operating at 220 volts line to neutral from a 380Y/220 volt, 3 phase, 4 wire, 60 Hz circuit. The ballast shall be pre-wired to the lamp socket and terminal board, requiring only connection of the power-supply leads to the terminal board. The entire "POWR/DOOR" assembly shall be quickly and easily removable and replaceable through the use of quick-disconnect plugs.

The optical assembly shall contain an activated-charcoal filter to filter containments in the air as the luminaire breathes. The prismatic refractor shall be of heat-resistant glass and shall be easily removable by unlatching the refractor door and turning a single refractor-holding clip.

The slipfitter shall be capble of adapting to 1-$\frac{1}{4}$" (3 cm), through 2-inch (5 cm) pipe size mounting brackets without the need of separate mounting parts of rearrangement of mounting components. Leveling and clamping of the luminaire to the bracket shall be accomplished by the tightening of two bolts accessible both externally and internally. The reflector shall be secured to the upper housing and shall contain an EPT rubber gasket for sealing between the reglector and refractor. The socket housing shall be securely rivated and sealed to the reflector and shall contain provision for setting the socket in the proper horizontal position in any of three vertical locations capable of producing IES type M-S-III or M-S-II distribution with the General Electric LU-250 BD lamp.

12. FIELD TESTS

Prior to completion of the work, the Contractor shall cause the follwing tests to be made on all circuits, in the presence of the Engineer.

Continuity - Each circuit shall be tested for continuity.
Ground - Each circuit shall be tested for grounds.

Megger - A megohm-meter test shall be made on each circuit between the circuit and a ground. The insulation resistance shall not be less than 10 megohms at a test level of 1000 volts, and the readings shall be recorded and given to the Engineer.

Functional - A functional test shall be made in which it is demonstrated that each and every part of the system functions as specified or intended.

The functional test for each system shall consist of not less than 5 days of continuous satisfactory operation is obtained.

During the 5-day test period, the owner's forces will maintain the system or systems. The cost of any maintenance necessary, except electrical energy and maintenance due to damage by public traffic, shall be at the Contractor's expense and will be considered as included in the price paid for the contract item involved and no additional compensation will be allowed therefor. The functional test for each highway lighting system shall consist of an operational test for 5 consecutive nights according to the regular lighting schedule.

Shutdown caused by factors beyond the Contractor's control shall not constitute discontinuity of the functional test.

13. REPLACEMENT PARKS

After completion of all field tests the Contractor shall replace defective lamps, luminaires, fuses, ballasts and other equipment.

The Contractor shall slso deliver to the Engineer the following additional spares and replacement items:

1. Luminaires, GE Type M-400A, Catalog No. C724G573, Five each.

2. Ballasts for the luminaires describes in item 1, Five each.

3. GE250 Watt Type LU-250BD lamps, Ten each.

14. MEASUREMENT AND PAYMENT

The work described herein and shown on the plans shall be paid for on a lump sum basis at the contract price shown in the "Schedule of Unit Prices" for Electrical Work and such price and payment shall be full compensation for providing all equipment, labor, materials, tools and incidentals and doing the work as planned, specified and directed by the Engineer. The cost of all listed replacement parts shall be paid for under this item of work.

附錄九

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YUAN SHAN BRIDGE–FREE SPAN STRUCTURE THROUGH TAIPEI CITY

SYNOPSIS

This paper describes the design and construction of a major freeway bridge through the capital of Taiwan and across the Keelung River. The bridge, with a width of 35 meters and a total length of 1450 meters employs free-span construction over 670 meters of its main crossing, with spans up to 150 meters. The cantilevering method of construction utilizing travelling wagons, with no falsework at all, was first employed in this area. Its successful and economical application leading to an aesthetic structure emphasizes its possible application to freeway construction in developing countries.

1. Introduction

To carry a major six-lane freeway through the heart of the city of Taipei and going across the Keelung River twice, required a special bridge designed to fit into the environment from both costructional and aesthetic points of view. To provide vertical clearance for the river and city traffic, a high level skewed bridge crossing was necessitated. Thus long spans were needed to eliminate undesirable and costly piers. Similarly, falsework during construction should be avoided. Furthermore, the maximum use of local labor and material was encouraged. All of these cosiderations led to the adoption of the free-span cantilever type of construction, using prestressed concrete as the major material.

This new North-South Expressway, located within the periphery of the city, must have easy access to the business district and yet separation from the local traffic. The bridge goes right in front of the imperial-stye Grand Hotel sitting on top of the hill and close to a beautiful existing arch bridge. The Keelung River bends around the Yuan shan hill and thus has to be crossed twice by the new bridge. Around this site is a very wellknown and much used recreation area, including parks, swimming pools, ice-skating rinks, and other historic and scenic spots. Thus, there is a demand to build a beautiful bridge to match the scenery of the site. The slender and sweeping looks of this structure was made possible by employing prestressed cocnrete, using cantilevered construction, which dispensed with the necessity of falsework construction and enabled long spans with minimum material.

2. Choice of Bridge Type

On account of the long spans for this structure, the material of construction was narrowed down to the choice between prestressed concrete and structural steel. At the time of the design and construction of the design and costruction of this bridge, a major steel plant was being constructed in Taiwan. However, steel products would not be available in time for this bridge and if structural steel was to be used, it had to be imported. In addition, it was pretty well known that prestressed concrete would be much more economical for the span and type of bridge considered for this site, as was confirmed by preliminary studies. In addition, it would require less maintenance and would be more adaptable to aesthetic treat-

ment. Hence, it was selected for the final design.

Different types of construction were considered. For the approach spans, local production of 30-meter and 40-meter precast concrete girders was the most economical. However, for the main spans, crossing a total length of 671 meters, special long span construction including one span at 150 meters and two spans at 142 meters dictated the use of special structures. Continuous prestressed concrete spans would require more falsework. Cable-stayed bridges would not fit into the enritonment and would not be more economical, particularly in view of the extreme width of the bridge and its obvious preference for the deck type (as versus the through type) of bridge construction. The free span cantilever method was uniquely suited for this site on account of the span lengths varying between 80 and 150 meters, absence of falsework, and the graceful proportions afforded by its outline.

A comparison between the precast segmental type of construction versus the in-place horizontal slip-forming as empoyed indicated the latter method to be much more economical, for two reasons.

First, the precast, segmental construction would require precasting plants, transportation and erection equipment, whereas the in-place type only needed travelling wagons. Secondly, it was easier to train the local labor for in-place concreting whereas precast construction would require more refined control which becomes particularly difficult with the varying span lengths and the long piers which complicated the problem of deflection and camber control. The smooth operation of the in-place cantilever const-ruction proved the above assumptions to be correct.

3. Superstructure Design

The bridge, 35 meters wide, was in fact divided into two parallel bridges, each 17.5 meters wide, carry-ing three traffic lanes in each direction plus sidewalks and utility width. A three-box section was employ-ed in order to reduce the top slab thickness. This did require more web concrete although it was not excessive in view of the limited depth of the deck. Suitable steel wagons were designed to accommod-ate three boxes

In Taipei, seismic design is an important consideration. In the transverse direction, the two columns of each pier are connected by a heavy girder across the top, thus forming an excellent rigid frame action against seismic load. in the longitudinal direction, it was decided to carry most of the seismic forces into the shorter piers, for reasons of economy. This was made possible by the limited horizontal movement at the hinges.

Due to the multiple span construction, it was not possible to make all the span continuous and hinges were provided at the junction of the cantilevers near midspan.

Based on previous experience with several bridges of similar type and spans, straight longitudinal tendons were employed in the top deck while the deck slab and the webs were all reinforced without prestressing. This was intended to simplify the prestressing procedures.

4 Superstructure Construction

The key equipment for construction is the travel wagon weighing 90 tons, which could carry up to 200 tons of concrete to be poured for each 4 meter segment. Each wagon would serve only half the width of the bridge - 17.5 meters. A total of 8 wagons were employed.

The superstructure cantilevers are cast in segments using travel wagons attached to both of the outer ends of the cantilever under construction. After the pouring of concrete and prestressing a segment of 4 meters, the wagon was advanced outward until eventually the two cantilevers of each span meet at the center and a hinge connection was made for them.

The time to work for each two segments, one on each side, is known as one working cycle. This cycle includes forming, adjustment, rebar placing, concrete pouring, prestressing after the concrete strength reached 260 kg/sq. cm. and the moving and settling of the wagon ready for the next segment. At the start of the work, one such cycle required 12 or more days. But as construction progressed, the cycle was efficiently consolidated to 8 or 7 days.

Prestress design made by T. Y. Lin International called for the amount of prestressing force at each section along the bridge. The prestress sub-contractor employed the Freyssinet system using 12 strands of ½-inch diameter, 270-k strands per cable. Tension force calculations were made for the prestressing jack and expected amount of cable lengthening was computed to be realized in the field. The initial tension force was limited to 80% of the strand's ultimate strength. Allowance was made for frictional loss and an average value of coefficient of friction μ=0.33 and wobble factor k=0.0029 were obtained. For certain cables over the top of piers in the cross girder, the angular change was rather large and higher coefficients of friction were obtained. It was necessary to apply soap water to lubricate the strands during stressing, which was washed away with water after tensioning.

The most important part of this type of cantilever construction was the control of camber and deflection as construction proceeds. It was necessary to predetermine for each segment, the amount of precambering, in anticipation of the pouring of additional segments and the prestress. It was necessary to allow for the weight of wagon, the wet concrete, the shrinkage and creep effect, the tensioning and loss effect, not only of the constructed segments but also of the future segments. Only by careful calculations and field control was it possible to have the tips of the cantilever meet with little differential. In addition, temperature check and movement of the piers under sunshine must sometimes be taken into account.

The connection of the tips at midspan involves careful control. First, a loading test with measured deformation produced by water as counterweight at the tips was made. Then, after the tips met, and while boring the connecting segments, tanks of water near the tips were controlled to insure the two tips remaining at the same elevation. Surveys were performed in early morning, hours before sunrise, using the pier head as benchmarks.

As mentioned previously, the hinges served to connect the adjoining spans longitudinally, as well as

vertically, but permitting temperature changes, shrinkage and creep to take place without affecting the stresses in the structure. If the structure were shorter, these hinges would have been eliminated and a continuous joint would be made across the closure at midspan.

Careful control by the contractor and the engineers was conducted both in the field and in the labor atory to insure proper concrete mixing, concrete strength, shrinkage control, etc. Indeed, even the texure of the concerte was tested and controlled to insure proper appearance.

5. Substructure

There were five main piers and two abutment piers for the cantilever spans. Originally, all these were to be supported on precast concrete pilles with H-shape shoes, designed to penetrate bedrock. But the foundation rock structure revealed to be different than anticipated. Some of the piers were switched to open caissons with the foundation sitting on firm sandstone. Pier C was supported on 8 caissons of 2.5-m diameter plus 16 caissons of 1.5-m diameter, going to a depth of 18 to 24 meters. Pier D employed six larger caissons of 6-m diameter. penetrating 20 to 24 meters. For each of these two piers, it was possible to work on several caissons simultaneously, say two to three caissons, using three to eight workmen per caisson, depending upon the size. As a result, each of these pier foundations were completed within three months.

6. Quantities and Cost

The Yuan Shan Bridge required 1700 tons of high tension steel, 4300 tons of reinforcing bars, and 41,000 cubic meters of concrete. Under normal conditions, about 500 workmen and engineers were employed working day and night. The bridge construction started October 1974 and was open to traffic by the end of 1977. Because of its unusual width and length, it may be considered as one of the biggest types of this bridge in the world, with a total construction cost over U. S $13 million. During the bidding period, we were faced with the world-wide energy crisis and as a result, the contract price was not favorable. However, considering the problems involved, including foundation, flood, trafic maintenance during construction, etc., the cost of the bridge in terms of $50/sq. ft. appeared very reasonable. This was largely attributed to good planning and design as well as execution during construction.

7. Conclusion

The successful completion of this project indicates the desirability and feasibility of employing the latest technology for bridge and highway construction in developing countries, because it was generally not difficult to train local engineers and workmen to execute such technology, which will hilp to save a lot of material. Particularly, the use of prestressed concrete would reduce considerably the amount of steel needed by efficiently utilizing local material of cement and aggregate.

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and the staff of our Highway Bureau who worked on this project.The excellent cooperation of all parties concerned helped to make this project a success. It should set a good example especially for developing countries.

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