The proposed plans for the Iowa State College athletic field including the design of a reinforced concrete grandstand and wall

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THE PROPOSED PLANS
For
THE IOWA STATE COLLEGE ATHLETIC FIELD
Including the Design of
A REINFORCED CONCRETE GRANDSTAND AND WALL.

THESIS
For
DEGREE of B. S. in C. E. presented
By

Signatures have been redacted for privacy
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THE PROPOSED PLANS FOR THE IOWA STATE COLLEGE ATHLETIC FIELD, INCLUDING THE DESIGN OF A REINFORCED CONCRETE GRANDSTAND AND WALL.

INTRODUCTION

The recent appropriation for a new gymnasium and the steps which have been taken toward the construction of a new athletic field at Iowa State College, have suggested the need for some form of permanent bleachers.

The design herewith submitted consists of detailed plans for the construction of a reinforced concrete Grandstand and Wall.

Reinforced concrete, through the reduction in the price of first class portland cement and the greater perfection of the principles of design has lately become a formidable competitor of steel and of slow burning construction, a competitor of steel because of its lower cost, shorter time of construction and freedom from vibration; a competitor of slow burning construction because of its greater fire protection, lower insurance rates, durability, freedom from repairs and renewals and even in many cases from its lower actual cost.

As a general proposition, reinforced concrete is almost always the lowest fireproof material suitable for the construction of a structure as herewith designed. The cost is nearly always lower than for brick and tile, and with lumber at its present prices, it is often lower than brick and timber with the added advantage of durability and fire protection.

GENERAL FEATURES

It was thought advisable to design the Grandstand for a seating capacity of about 6000, with additional movable
bleachers on the opposite side of the football field. The Grandstand as designed has a length over all of 352', slightly longer than the football field, with ample room between the front of the Grandstand and the race track as shown on plate 3.

From a study of the designs of several large grandstands already constructed it was found that the main treads vary from 18" to 30" in width, and the main risers vary from 12" to 18" in height.

In order to improve the optical properties of the Grandstand a constant tread of 2' with a varying rise of 15", 17" and 19" for the first, second and third eight rows of seats respectively was used. This makes a break in the general slope of the floor in three places with a result to the optical properties of the Grandstand as shown on plate 3.

The enclosed space under the Grandstand may be used for an indoor race track, additional gymnasium room, toilet and dressing rooms etc.
DESIGN.

The following notation will be used in all computations:

- $F_s$: Unit stress in steel.
- $F_c$: Unit stress in concrete.
- $E_s$: Modulus of elasticity of steel (29,000,000)
- $E_c$: Modulus of elasticity of concrete (1,900,000)
- $n$: Steel ratio $E_s/E_c$ (assumed 15)
- $T$: Total tension.
- $C$: Total compression.
- $M$: Maximum bending moment.
- $A_t$: Area steel in compression.
- $A_b$: Area steel in tension.
- $b$: Breadth of beam.
- $d$: Effective depth of beam.
- $k$: Ratio of depth of neutral axis to $d$ (assumed $\frac{d}{2}$).
- $c$: Unit compressive stress on concrete.
- $j$: Ratio of lever arm of resisting couple to $d$ (assumed $\frac{d}{2}$).
- $P$: Total stress in steel.
- $z$: Depth of resultant of compressive stress from top of beam.

BEAMS & GIRDERS.

Computations for horizontal double reinforced beams supporting back wall.

Loading:

Beam to support a uniform dead load of 10,400# W

Length of beam $L = 16' - 0''$

Assumed total depth of beam $d = 14''$

Max Mom. $\frac{1}{12}WL = M = 250,000''#$.  

$P = \frac{m}{jd} = 30,000#$

$A_b = \frac{30,000}{F_s} = \frac{2''}{2} = 2''$ steel required at bottom of beam.

$F_c/2 \times bk_d = 30,000$

$F_c = 2000#$ (too high, use double reinforcement).

$F_c/c = kd/z$

$c \times 15 = 4200#$ = $F_s$
Design of main inclined beams (double reinforced)

Loading:

- 8 seat slabs @ 2000# = 16,000#
- 8" beams @ 1900# = 15,200#
- Weight of beam = 7,350#
- Total live load = 38,400#

\[ M = \frac{1}{2}WL = 2,110,000"# \text{ Max. bending Mom.} \]

Assume beam 12" x 28" (double reinforced)

\[ P = \frac{M}{jd} = 93,000# \]

\[ Ab = \frac{93,000#}{16,000#} = 5.8" \text{ steel required in tension at bottom of beam.} \]

\[ \frac{Fc}{kd} = \frac{c}{z} \]

\[ c \times 15 = 7160 = F_s. \]

\[ \frac{Fc}{2} \times \text{bkd} + 7160At = 93,000# \]

\[ At = 8.1" \text{ steel required at top for compression.} \]

Design of horizontal slab, front promenade (single reinforced).

Loading:

- Dead load = 8,100#
- Live load = 2,000#

\[ M = \frac{1}{4}WL = 482,000"# \]

\[ P = \frac{M}{jd} = 19,700# \]

\[ \frac{Fc}{E} \times \text{bkd} = 19,700 \]

\[ Fc = 625# (\text{hence no top reinforcement necessary}). \]

\[ 19,700#/16,000# = 1.3" \text{ steel required for tension at bottom.} \]
Design of concrete hand railing.

Loading:

- Weight of railing = 5600#
- Weight of slab = 2000
- Live load = 4800

\[ M = \frac{1}{8}WL = 298,000\# \]
\[ P = \frac{M}{jd} = 7730\# \]
\[ \frac{Fe}{2} \times bkd = 7730 \]
\[ Fe = 134\# \text{ (hence no steel required at top of beam).} \]

\[ 7730/16000 = .483" \text{ steel required at bottom for tension.} \]

Note:- All single reinforced beams designed on the same basis.

By use of expansion joints over supports all beams and girders were made simple beams supported at both ends. In all cases the maximum bending moment was determined by the use of the formula \( M = \frac{1}{8}WL \) in which \( M \) is the moment, \( W \) the entire dead load and live load, considered as uniformly distributed over the beam, and \( L \) is the distance between supports. In all cases where beams could be made of sufficient depth to prevent over stressing the concrete in compression they were designed as single reinforced beams, and reinforced for tension only.

The tension in the bottom of a beam decreases toward the supports, a part of the tension rods are bent up on an incline from about the quarter points in the beam. By experiment and practice it has been found that rods bent up in this manner will follow the lines of maximum tension in the beam and prevent diagonal cracks caused by secondary stresses of shear or diagonal tension.
COLUMNS.

Design of Column No. 1. as shown on Plate 2.

Loading:

Direct Stress = 44000#  
Bending Moment = 288000#  

Assume a section as shown in sketch  
12 x 14 = 168; 6 x 15 = 90  
252 Transformed section.  

44000/252 = 175# per sq. in. Direct stress.  

I = \frac{1}{12}bh^3 = 15(3 \times 5^2 \times 2) = 4994"^4  

P = \frac{My}{I} = \frac{288000 \times 7}{4994} = 410#  
Max. fibre stress.  

175# + 410# = 585# (allowable stress 600# per sq. in.).

Note: All columns were designed as above for the direct stress due to the superimposed load and for cross bending due to a wind load of 30# per sq. ft. on the entire vertical projection of the Grandstand and considered as acting in any direction.

The ratio of the length of the columns divided by the radius of gyration of the section was kept below 100 as required by good practice, by the use of horizontal struts.

FOUNDATIONS.

All column footings and wall foundations are to be placed with the bottom not less than 4' below grade in order to prevent heaving by frost.

All foundations were designed without reinforcing and for a safe pressure on the soil of 2 tons per sq. ft. working stress on concrete 600# per sq. inch in compression.

FLOOR SYSTEM.

A dead load of 150# per cu. ft. of concrete was assumed.
in all cases. A live load of 150# per square foot was assumed as acting over the entire horizontal projection of the floor space. The live loading assumed included about 50% for impact which is liable to occur on a structure of this kind.

The risers were designed to support the seat slabs and full live load and were figured as rectangular beams, double reinforced.
SPECIFICATIONS.
for
A REINFORCED CONCRETE GRANDSTAND AT IOWA STATE COLLEGE, AMES IA.

LOCATION OF THE WORK.

1. The work to be done under this contract will be the erection of a reinforced concrete Grandstand on the athletic field of the Iowa State College, Ames, Iowa. The Grandstand consists of twenty two (22) bays each sixteen feet (16') long, making a total length of three hundred fifty two feet between centers of end columns.

LINE & GRADE.

2. Lines and grade will be established by the engineer and no work shall be commenced until this has been done. Due care shall be exercised by the contractor in the protection of such line and grade stakes, and he will be held responsible for any defective work occasioned by his negligence in this regard.

PLANS

3. The several drawings with all dimensions and written explanation and these specifications are to be the basis of the contract, and are of equal force, and work or materials here specified, although not shown on drawings, must be included in the work, and any work or materials clearly shown on drawings although not mentioned in these specifications must be considered as a part of this contract.

REQUIREMENTS OF MATERIALS.

4. Cement. This term is applied to the finely pulverized product resulting from the calcination to incipient
fuson of an intimate mixture of properly proportioned artilaceous and calcareous materials, and to which no addition greater than 3% has been made subsequent to calcination.

Specific Gravity:-- The specific gravity shall not be less than 3.10.

Fineness:-- A residue of not more than 8% shall be left on the No.100 sieve, and not more than 25% shall be left on the No. 200 sieve.

Time of setting:-- It shall not develop initial set in less than thirty minutes; and must develop hard set in not less than one hour, nor more than ten hours.

Tensile Strength:-- The minimum requirements for tensile strength for briquettes one inch square in section shall be as follows and shall show no retrogression in strength within the periods specified.

<table>
<thead>
<tr>
<th>AGE</th>
<th>MEAT CEMENT</th>
<th>STRENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 hours in moist air.</td>
<td>..................................</td>
<td>175 lbs.</td>
</tr>
<tr>
<td>7 days (1 day in moist air, 6 days in water)</td>
<td>...........</td>
<td>500 &quot;</td>
</tr>
<tr>
<td>28 days (1 day in moist air, 27 days in water)</td>
<td>..........</td>
<td>600 &quot;</td>
</tr>
</tbody>
</table>

ONE PART CEMENT, THREE PARTS STANDARD OTTAWA SAND,

<table>
<thead>
<tr>
<th>AGE</th>
<th>MEAT CEMENT</th>
<th>STRENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 days (1 day in moist air, 6 days in water)</td>
<td>...........</td>
<td>200 lbs.</td>
</tr>
<tr>
<td>28 days (1 day in moist air, 27 days in water)</td>
<td>..........</td>
<td>275 &quot;</td>
</tr>
</tbody>
</table>

Constancy of volume:-- The constancy of volume will be tested by means of pats for a period of 28 days.

For the purpose of measuring volumes of mixture, a bag of cement shall contain ninety-four (94) lbs. net, approximately one cubic foot of cement, and each barrel shall contain four (4) bags.

All tests shall be made in accordance with the methods proposed by the committee on Uniform tests of Am.Soc.C.E.
5. Portland Cement Concrete:-- The concrete shall be composed of cement, sand, and broken stone mixed with clean water in the proportions here mentioned.

For Columns, Beams and Slabs.
1 part portland cement.
2½ parts sand
4 parts broken stone passing a 1" ring.

For Foundations and Footings.
1 part portland cement.
3 parts sand.
6 parts broken stone passing a 2½" ring.

For Walls.
1 part portland cement.
3 parts sand
5 parts broken stone passing a 1" ring.

An approved mixing machine shall be used. The ingredients shall be placed in the machine in a dry state, and in the volume specified and thoroughly mixed, after which clean water shall be added and the mixing continued until each piece of stone is covered with mortar and the mass uniform. The mixture shall be sufficiently wet for water to come to the surface under moderate ramming. As soon as the batch is mixed, it shall be deposited in the work without delay, and thoroughly compacted by ramming with hand tampers until free mortar shall appear on the surface. The concrete shall be deposited in layers six to eight inches thick.

6. Artificial Stone:-- All hand railings, panels, parapets, and other ornamental work shall be of the design shown on the plans, and shall be molded in smooth and suitable molds of approved pattern.
7. Broken Stone: -- The broken or crushed stone shall consist of pieces of hard durable rock, such as trap, limestone, granite, or conglomerate. The dust shall be removed by a ¼" screen, to be afterwards used if desired, mixed with and used as a part of the sand, except that if the product of the crusher is delivered to the mixer so regularly that the amount of dust, as determined by frequently screening samples, is uniform, the screening may be omitted and the average percentage of dust allowed for in measuring the sand.

8. Sand: -- The sand shall be clean and coarse, or a mixture of coarse and fine grains with the coarse grains predominating. It shall be free from clay, loam, sticks, organic matter and other impurities.

9. Steel: -- The reinforcement shall consist of patent deformed bars of the required cross-sectional area, and spaced as shown on the plans. The steel shall develop a tensile strength of 60,000# per square inch, and the elastic limit shall not be less than 30,000# per square inch.

METHODS OF CONSTRUCTION.

10. Connections: -- In connecting concrete already set with new concrete, the surface shall be cleaned and roughened and moped with mortar composed of 1 part portland cement and 1 part of sand, to cement the parts together.

11. Expansion joints: -- Expansion joints shall be placed at all points indicated on the plans, and all expansion joints in such a position to allow the entrance of water shall be filled with hot paving pitch.
## ESTIMATE OF COST

### Foundations

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Rate per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 Pedestals @ 1.2 cu. yds.</td>
<td>28.9 cu. yds.</td>
<td>$9.00</td>
<td>$260.00</td>
<td></td>
</tr>
<tr>
<td>23 &quot;       &quot; 1.9 &quot;   &quot;</td>
<td>44.3 &quot;   &quot; @ $9.00</td>
<td>= $383.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46 &quot;       &quot; 2.7 &quot;   &quot;</td>
<td>126.0 &quot;   &quot; @ $9.00</td>
<td>= $1140.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Wall Foundation

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Rate per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.5 &quot;       &quot; @ $10.00</td>
<td>= $575.00</td>
<td></td>
<td></td>
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</table>

### Front Wall

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Rate per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>76.0 &quot;       &quot; @ $10.00</td>
<td>= $760.00</td>
<td></td>
<td></td>
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</tbody>
</table>

### Slabs

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Rate per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>740.00 &quot;       &quot; @ $13.00</td>
<td>= $9600.00</td>
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</table>

### Railing

<table>
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<th>Item</th>
<th>Unit</th>
<th>Rate per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>38.0 &quot;       &quot; @ $13.00</td>
<td>= $494.00</td>
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</table>

### Beams

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Rate per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>235.0 &quot;       &quot; @ $15.00</td>
<td>= $3530.00</td>
<td></td>
<td></td>
</tr>
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</table>

### Walls (4"

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Rate per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>158.0 &quot;       &quot; @ $15.00</td>
<td>= $2380.00</td>
<td></td>
<td></td>
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</table>

### Columns

<table>
<thead>
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<th>Unit</th>
<th>Rate per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>75.0 &quot;       &quot; @ $15.00</td>
<td>= $1150.00</td>
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<td></td>
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</table>

### Stairways

<table>
<thead>
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<th>Item</th>
<th>Unit</th>
<th>Rate per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.0 &quot;       &quot; @ $13.00</td>
<td>= $143.00</td>
<td></td>
<td></td>
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</table>

### Steps

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Rate per Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.0 &quot;       &quot; @ $13.00</td>
<td>= $273.00</td>
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### Earth excavation 770 Cu Yds. @ 25¢

<table>
<thead>
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<th>Item</th>
<th>Unit</th>
<th>Rate</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>770 Cu Yds. @ 25¢</td>
<td>= $200.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Steel window sash in place 6 @ $75.00

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Rate</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 @ $75.00</td>
<td>= $450.00</td>
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<td></td>
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</table>

### Galvanized iron pipe railing 800' @ 25¢

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Rate</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>800' @ 25¢</td>
<td>= $200.00</td>
<td></td>
<td></td>
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</table>

### Engineering, superintendence and contingencies 10%

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>%</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>= $2154.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### T O T A L

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$23692.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Estimated cost of concrete fence $2.60 per lin. ft.
Expansion Joints

9-1/2" off bars
7-1/2" off bars

6-1/2" off bars

Note: For top connection of column No. 5 see Detail C.

8'x16' Beam in back wall and strut connection.

Detail B.
Scale: 1" = 10'

THESIS

CLASS 1951
For reinforcement of risers and treads see Detail A.

12 x 28° Inclined Beam. Reinforced as shown on Detail B.

8 x 8° Strut reinforced as shown on Detail B.

Expansion Joints

Col. No. 6

Pl. 3/4 x 15 x 1/3 in all reinforced columns

Scale 1/2" = 1'-0"
Top View

Slab Reinforcement:
Vertical: 3 rods @ 1'-6" c/c
Horizontal: 3 rods @ 2'-6" c/c

Elevation

End View

Section Thru Wall

Detail of Fence
Scale: 1" = 2'-0"

Thesis of

Class 1911