Fermilab

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HIGH DENSITY CONCRETE PLATES FOR CALORIMETERS

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SUMMARY

High density concrete 5 gm/ccm was poured into a slab 3" x 100" x 80" and mechanically tested yielding experimental values of rigidity and strength.

INTRODUCTION

Large calorimeter interaction plates are usually made of materials of high density such as lead, steel, or similar. In some special cases a less dense material is acceptable, if substantially cheaper.

Casting concrete into a reusable form promised an attractive alternative especially when filled with inexpensive steel shot.

Small size plates were cast and used successfully but questions remained about the deformation of large plates from their own weight and the safety aspect connected with the strength of the cast material, without reinforcement.

Such values were not available and so a full scale test plate was made and subjected to loading, simulating an actual installation. A mixture of steel balls ranging from 1 to 3 millimeters in diameter as aggregate together with an iron oxide FE2O3 cement and water in a ratio of 12:3:1 1/2 by volume was used in the attempt to maximize density and strength. Some preliminary tests were performed to show if a definite ratio of ball sizes would yield higher densities but results indicate a flat dependence. (Samples were cast 5" in diameter, 3" high).

Considerations were given to stratification and sedimentation problems and the use of vibrators, but it seemed that "shallow" objects could be cast without difficulty provided the components were well mixed ahead of pouring. By coincidence the large slab was cast and cured under severe cold conditions, well below freezing. The use of heaters was interrupted frequently. The mixture handled well, and it did not seem to affect the quality of the sample adversely. The mix was diffiuclt to spread but feasible by using an electric vibrator and a flatness of the top layer, finished with a straight edge in the mold, was typically within + 1/8" across the 80" x 100" area.

The slab that was tested had a steel frame all around made of 3" channel 1/4" web, as shown in Figure 1, welded in all four corners along the 45^{o} seam. 1/2" diameter reinforcement steel bar was welded "inside" the channel as shown in Figure 1. Running one way close to the bottom of the slab and perpendicular on top. This "unusual" reinforcement allowed observation of both conditions namely tensile strength of the filled concrete "with" as well as "without" re-bars. A light gauge "chicken wire" mesh was put on the outside of the reinforcement, top and bottom. A wood mold properly levelled lined with a sheet of plastic provided a sealed enclosure. Several bathes of concrete were needed to fill the mold as the mixer held only about 1/6 of the slab volume but the pour was finished within one single day.

The concrete was cured for 4 weeks before testing started.

INSTRUMENTATION

A dial indicator accurate to 10^{-3} inches with a range of 1" (later 1/4") was used to measure vertical deflection in the middle point of the slab relative to the edges 100" apart. Two 6" high aluminum channels bolted together back-to-back provided the bridge for mounting the dial indicator, as shown in the photographs.

Loading was accomplished by placing lead bricks (2" x 4" x 8" approximately 30 lbs. each) in different ways on the upper surface of the slab to produce:

1. uniform,
2. triangular, or
3. concentrated

force patterns up to a total of 240 bricks representing 3.6 tons. The weight of the slab itself is equal to 2.2 tons and produced "normal" deflections dependent on the two different support configurations as described later.

TESTING

The slab was first lifted out of the mold using hydraulic jacks in each corner. As the plate was free from ground contact, two supporting bars were slipped under the 80" long edges and the jacks removed. The deflections from its own weight were measured in the process amounting to approximately 0.200", mostly elastic. The plate was twisted in the process of lifting giving rise to additional stress and shake downs, therefore, this value was not used for calculating stress and the module of elasticity. Further testing with lead bricks rendered far more accurate results, more elastic in character, linear, and completely free from ground contact.

Readings were taken after each step of 8 bricks spread out during the first test uniformly over the surface. A total of 240 bricks were used producing a deflection of over 1/2", total. Now the bricks were rearranged without changing the total weight, first into a triangular load distribution and then all weight resting along the center line within 8" on either side, (see load pattern, Figure 2).

The maximum deflection reached almost a full inch but still without any sign of cracking, mostly elastic and the plate returned to its original no load deflection within a small error when the bricks were removed.

It is important to note that in all these load configurations, reinforcement bars were lined up along the bottom fibers picking up the stress in tension while the compressive load from bending was intercepted by the filled concrete alone in the upper skin.

To reverse the sign of stressing, the plate was now supported along the center line instead resting only on a row of bricks and balanced transversely. To protect it from tipping over, non-contact rest points in all four corners were erected.

After the initial no load deformation from its own weight was established, lead bricks were piled along the far edges in steps of 12 at a time (see photograph), that is 6 bricks on either end, and deformation readings were taken. After reaching a total of 96 bricks, a cracking was audible and deformations displayed a step. With a total of 144 bricks resting along the outer edges, the plate failed catastrophically.

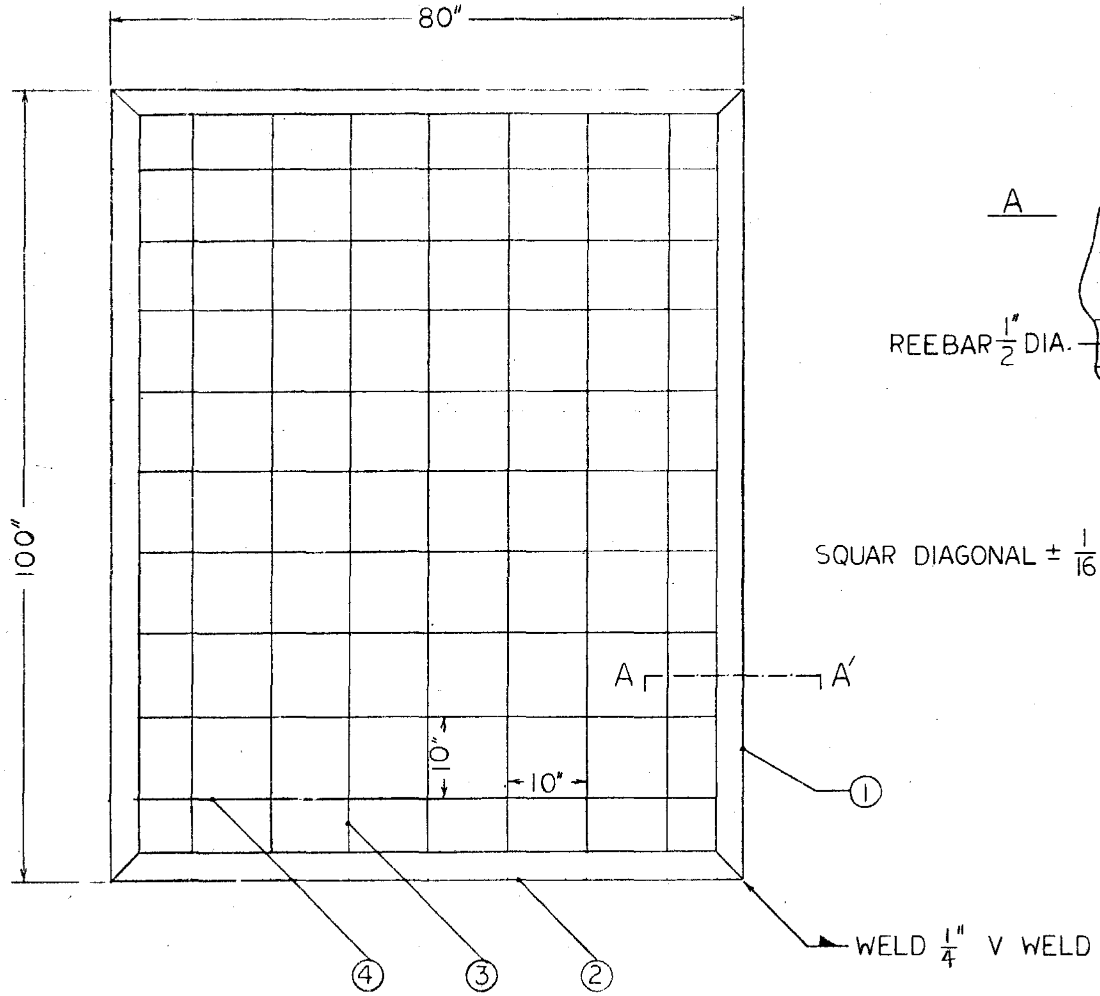
CONCLUSION

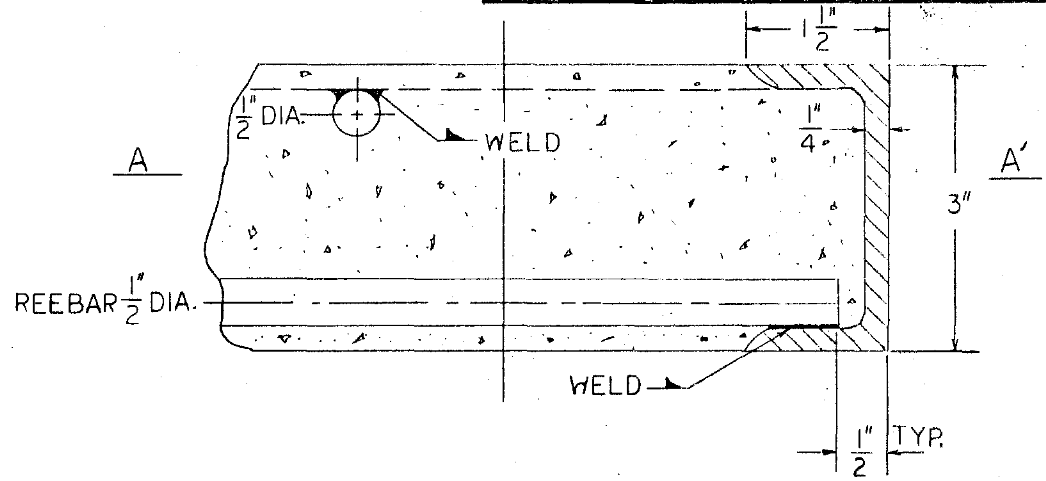
A selected sequence of non-destructive tests was accomplished on a single slab of high density concrete, representing a full scale unit of calorimeter plate contemplated as a substitute for steel. If used without steel reinforcement and cast into hard machinable shapes, it looks as an attractively inexpensive alternative. It was the intention to find out what the maximum tensile stress is in such materials without reinforcement and what safety factors to expect, defined as the ratio:maximal stress, to a stress from its own weight, in a plate of typical dimensions. With reinforcement, these values could be increased substantially, also making the parts more labor and cost intensive in the process.

The real surprise in testing the full scale slab was the very low modulus of elasticity, controlling deflections, $E = 1.2\ 10^6$ psi to be compared to steel $30\ 10^6$ psi, a factor of 25 times less. This is most likely due to the spherical contact of the steel balls in the aggregate.

The maximum stress in tension, inspite of being relatively high for concrete: $\sigma = 1{,}000$ psi, regular concrete fails at typically $\sigma = 100$ psi, yielded only a safety factor of $S = 2$, for the given support configuration, the size of the slab and defined as above.

Figure 1.





SQUAR DIAGONAL ± 1/16

REV.	DESCRIPTION	DRAWN / APPD.	DATE / DATE

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
4		1/2 DIA ROD 79" LONG	7
3		1/2 DIA ROD 99" LONG	9
2		[3"X1/2"X1/4", 80" LONG CUT 45°	2
1		[3"X1/2"X1/4", 100" LONG CUT 45°	2

PARTS LIST

UNLESS OTHERWISE SPECIFIED

FRACTIONS	DECIMALS	ANGLES
±	±	±

1. BREAK ALL SHARP EDGES 1/64 MAX.
2. DO NOT SCALE DWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5 STD's.

√ MAX. ALL MACHINED SURFACES

ORIGINATOR	HANS	
DRAWN	A A loc	2-23-79
CHECKED		
APPROVED		

USED ON

MATERIAL- STEEL CONCRETE

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

CALORIMETER CONCRETE MODULE
FRAME WELD ASSEMBLY

SCALE 12:1 | FILMED | DRAWING NUMBER | REV.

TM-855

NATIONAL ACCELERATOR LABORATORY

ENGINEERING NOTE

PROJECT

SERIAL-CATEGORY: TM 855

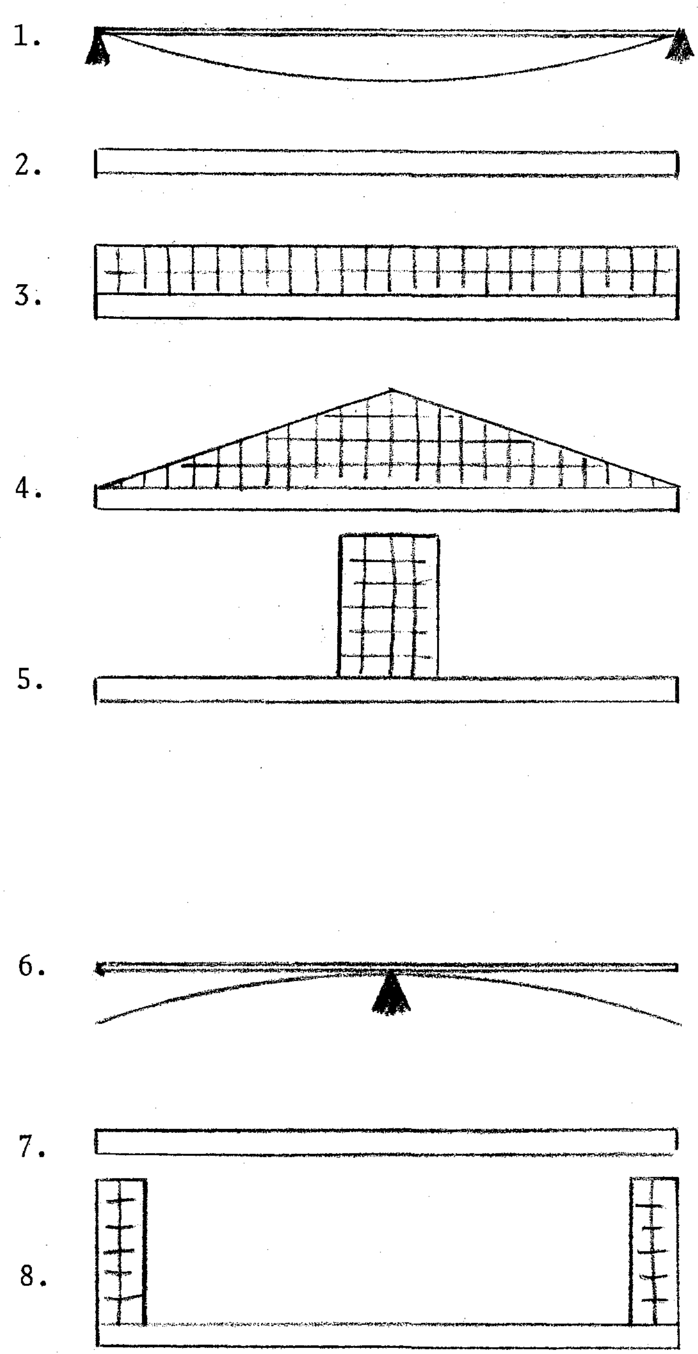
PAGE

SUBJECT: PLATE LOADING PATTERN

NAME: HANS

DATE: 3/11/79

REVISION DATE



1. End Supported
2. Its Own Weight
3. Uniform Load
4. Triangular Load
5. All Load In Center
6. Center Support
7. Its Own Weight
8. Load on Each End

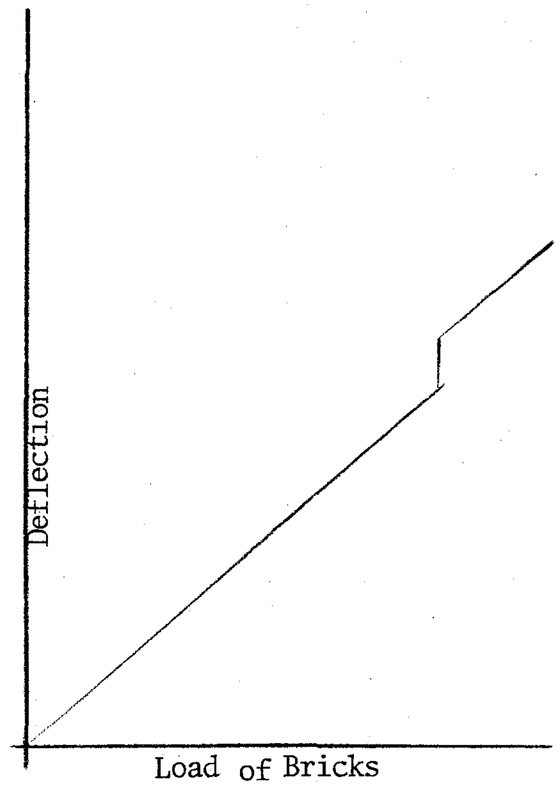


Figure 2