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BLAST ANALYSIS AND DESIGN OF ROCKET ENGINE TEST FACILITY CONTROL ROOMS

by

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In support of plans to add a second control room to the Rocket Engine Test Facility at NASA Lewis Research Center, Celveland, OH, the existing control room was analyzed to determine the most severe accidental explosion it could safely withstand. This potential accident was used as the design threat to develop a preliminary design for the new control room. The analysis and design calculations were based on procedures from Army Technical Manual TM 5-1300/NAVFAC P-397/AFM 88-22, "Structures to Resist the Effects of Accidental Explosions," and the computer program CBARCS, which automates some of the procedures in the manual. To evaluate the degree of conservatism in the analysis, experimental data with charge weights and structural dimensions similar to the control room's were selected and analyzed. Results indicate that the existing room will safely withstand an explosion equivalent to 1,000 lb of TNT detonated at the rocket test stand 20 ft away. To survive the same accident, the new control room (to be constructed on top of the old one) should have 1-ft-thick walls (existing walls are 2 ft thick) with 0.33 percent reinforcement (Continued)

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(existing walls have 1.55 percent). Comparison of data with analysis indicates that an accidental explosion equivalent to approximately 1,800 lb of TNT will cause unacceptable damage to the control room. This analysis results in a much more economical design for the new control room than would have been achieved by constructing a new room identical to the old control room. Also, comparing results of this analysis procedure with data provided a good estimate of safe operating criteria and the maximum capacity for the control rooms.

PREFACE

The analysis and design summarized herein was sponsored by the National Aeronautics and Space Administration (NASA) Lewis Research Center, Facilities Engineering Division, Cleveland, Ohio.

This study was performed by personnel of the Structural Mechanics Division (SMD), Structures Laboratory (SL), US Army Engineer Waterways Experiment Station (WES), under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. James T. Ballard, Assistant Chief, SL, and under the direct supervision of Dr. Jimmy P. Balsara, Chief, SMD. Dr. Sam A. Kiger, SMD, was the project manager. This report was prepared by Mr. Richard C. Dove, SMD, and Dr. Kiger. Messrs. Mark K. McVay and David R. Coltharp, SMD, provided experimental data used in the verification of this analysis.

COL Allen F. Grum, USA, was Director of WES during the preparation and publication of this report. Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report may be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	metres
inches	2.54	centimetres
inches per foot	8.33	centimetres per metre
kips (force) per square inch	6.894757	megapascals
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.4535924	kilograms
square inches per foot	21.166667	square centimetres per metre

BLAST ANALYSIS AND DESIGN OF ROCKET ENGINE TEST FACILITY CONTROL ROOMS

INTRODUCTION:

In June 1985, the NASA Lewis Research Center began preliminary engineering design work on the expansion of their Rocket Engine Test Facility. One option for this expansion is the construction of an additional control room on top of the existing control room. Because of the proximity of the control rooms to potentially high-explosive materials, it was decided that the existing control room should be analyzed to determine its blast resistance. It was also decided that the proposed additional room be designed with a compatible blast resistance. NASA requested that the USAE Waterways Experiment Station (WES) support this effort by providing a blast response analysis of the existing control room and preliminary design recommendations for the proposed additional control room.

SCOPE:

An analysis of the existing control room was accomplished using the "Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs under Blast Loading" (CBARCS). This code was developed under the sponsorship of the Office, Chief of Engineers (OCE), US Army, as a part of the Computer-Aided Structural Engineering (CASE) Project, and is available at the National Technical Information Service, Springfield, VA (Reference 1). Only the wall directly facing the potential explosion position was analyzed, and since the penetrations in this wall were less than 5 percent of the wall area, they were ignored. Enhancement of the reflected blast loading due to the floor and walls of the test chamber adjacent to the control room was included in the analysis. The analysis determined the response of the wall under various amounts of high explosive (HE) (TNT equivalent).

To evaluate the safety of the existing control room, data from recent experimental concrete slabs loaded by explosives under conditions similar to the existing and proposed control-room walls were examined. These data formed a basis for judgment as to the conservatism of the analysis procedures used.

The design of the additional control room was also accomplished using the CBARCS program. Again, the wall facing the potential explosion position was considered the critical structural element. The CBARCS program optimization feature was used to iterate to a concrete thickness and a steel percentage which resulted in the most cost-effective structure. The explosion position was simplified by making the conservative assumption that the explosion took place at the elevation of the wall.

ANALYSIS OF EXISTING CONTROL ROOM:

The existing control-room wall was analyzed using the CBARCS program. This program uses yield line theory to analyze concrete slabs under high-explosive blast loads. The structure is idealized as a single-degree-of-freedom model. The program is consistent with the Army Technical Manual TM 5-1300, "Structures to Resist the Effects of Accidental Explosions" (Reference 2) and allows for the consideration of various slab edge conditions, penetrations, explosive types, explosive confinement, and reflection loading. It should be noted that this program is to be used for preliminary design and analysis only. Final design and analysis, including reinforcing details, should be in accordance with TM 5-1300.

Figure 1 shows the wall configuration and explosion position input into the CBARCS program for the existing control-room wall. The program output is shown in Appendix A. Results from different explosive weights indicate that a small increase in charge weight can result in a disproportionately greater increase in the corresponding wall deflection. Figure 2 shows this relationship and shows the charge weight which corresponds to various degrees of structural damage, i.e., in. of deflection.

TM 5-1300 indicates that a concrete slab without laced reinforcing is considered to fail at a 2-degree* support rotation to avoid buckling of compressive steel. According to the CBARCS program, this amount of rotation takes place under an explosive load of 900 lb of TNT and is equivalent to 0.70-in. deflection. However, TM 5-1300 also states in Chapter 6, Section 6-2, that a category-1 protection wall for personnel protection is allowed a support rotation of 5 degrees for laced reinforcement. Past experience at WES has shown that a concrete slab reinforced with conventional shear stirrups can sustain a support rotation of at least 5 degrees without failure. This does not prove that the control-room wall in question could rotate 5 degrees without failure, but it does point out the relative conservatism of the 2-degree rotation criteria.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 2.

COMPARISON OF ANALYSIS WITH EXPERIMENTAL DATA

The safety of the CBARCS analysis of the existing control-room wall can be evaluated by using data from a recent series of experiments conducted by Mr. Mark McVay at WES. The purpose of these tests was to evaluate different antispalling schemes for a concrete wall loaded by a cased TNT charge. Two of the experiments closely simulate the conditions of the existing control-room wall.

The first experiment was conducted at a scale of 1/2.8 of the control-room wall. This scales up to a 24-in.-thick wall loaded by a cased charge of 444 lb of TNT at a range of 14.12 ft (Figure 3). The flexural steel ratio was 0.25 percent with a steel strength of 60,000 psi and a concrete strength of 5,200 psi. Shear resistance was provided by 0.152 in. per linear ft of 60,000-psi shear steel. This is comparable to the control-room wall with a thickness of 24 in. and a steel ratio of 1.55 (considerably more than the 0.25 ratio in the test slab) with a steel strength of 40,000 psi and a concrete strength of 3,000 psi. Shear steel consisted of 0.40 sq in. per linear ft, 40,000-psi steel for the control room. To judge the conservatism of the CBARCS program, the program was used to analyze the experimental wall (Appendix B). This analysis will be directly compared to the experimental results.

The pressure history as measured at the bottom of the experimental wall is shown in Figure 4. The total effective impulse calculated by CBARCS was 792.64 psi-msec, while the scaled impulse from the experimental wall, measured at the position closest to the explosion, was 1,288 psi-msec. Because the control-room wall has a natural period of 30.4 msec, the wall is impulse sensitive; therefore, the loading by CBARCS is comparable to that of the experiment. It should be noted that the CBARCS program applies a uniform loading function over the entire surface of the wall. In the experimental case, the pressure was seen to attenuate substantially at increasing distances away from the source of the explosion. This indicates that CBARCS makes a conservative estimate of the loading function. The CBARCS structural response calculations are also shown to be conservative when the program predicts that the experimental wall should fail in flexure, with a support rotation of 2.3 degrees. The data from the experiment shows that there was essentially no damage to the wall (Figure 5).

The second experiment was conducted at a scale of 1/4.47 of the control-room wall. This scales up to a 24-in.-thick wall loaded by a charge of 1,755 lb of TNT at a range of 22.32 ft (Figure 6). The flexural steel ratio was 0.25 percent with a steel strength of 60,000 psi and a concrete strength of 4,000 psi. Shear steel consisted of 0.24 sq in. per linear ft, 60,000-psi steel. The CBARCS program was again used to analyze the experimental wall. This analysis showed that the wall collapsed with a support rotation of 12 degrees (Appendix C). The results of the experimental test were moderate damage and flexural response corresponding to approximately a 1.2-degree support rotation (Figure 7).

The final conclusion as to the capacity of the existing control-room wall is based on the CBARCS analysis and experimental data. The CBARCS program indicates that the control-room wall will withstand 900 lb of TNT before it will fail in flexure. However, when shear is checked as per TM 5-1300, the shear steel required is greater than that which exists in the wall. The experimental data indicate otherwise. In both experiments, the shear steel present was less than that in the control-room wall, yet diagonal shear failure did not occur. This supports a perception widely held by WES experimenters that the problem of shear failure is overestimated in TM 5-1300 and other similar blast-design manuals. Also, a comparison of the flexural response predicted by CBARCS for the experimental walls and the actual response of these walls shows the extreme conservatism present in the CBARCS program. Therefore, it is recommended that based on the experimental data the capacity of the existing control-room wall be considered to be 1,000 lb of TNT.

DESIGN OF ADDITIONAL CONTROL ROOM:

The design of the additional control room was simplified by considering only the wall facing the potential explosive (Figure 8). This wall was designed using the CBARCS program and TM 5-1300. The structural optimization feature of the CBARCS program was used to develop the least-cost wall to resist the given load. A detailed explanation of the optimization feature can be found in the CBARCS User's Guide (Reference 1). Briefly, the program takes an assumed cost for steel and concrete; sets up a cost function; and with an assumed starting point, increments the design variables until a minimum cost is obtained.

The CBARCS program's input and output can be seen in Appendix D. A concrete strength of 4,000 psi and a steel strength of 60,000 psi was used. No laced shear reinforcement was assumed; therefore, the 2-degree support rotation failure criteria was used. In th' first computer run, 1,000 lb of TNT was assumed to explode at the elevation of the wall with no floor or wall reflections. The wall was assumed to be fixed at all supports. This resulted in the computer iterating down to the minimum wall thickness of 12 in. and the minimum steel ratio allowed by the program and recommended by TM 5-1300.

With these results, it was decided that a more economical design may be possible. The preliminary design of the proposed control room assumed that the wall facing the explosion hazard was tied into a floor slab to be constructed on top of the existing control room. This would mean that the roof of the existing control room and the new slab would have a combined thickness of 3 ft of concrete. This is grossly overdesigned. If the existing roof could be used as the proposed floor, a cost savings would result. There is, however, no economical way to make a moment-transferring connection between the proposed wall and the existing control room. This means that the bottom of the proposed wall must be treated as a pinned connection or as a free edge, if we are going to do away with the floor slab.

The CBARCS design program was rerun, assuming that the bottom was a free edge (Appendix E). Again, the concrete strength was 4,000 psi, and a steel strength of 60,000 psi was used. This resulted in a design which required a 12-in.-thick wall with a vertical and horizontal flexural steel requirement of 0.33 percent on both sides. These are nearly the same requirements as for the fixed-edge case above. In the actual design, it is recommended that shear studs be provided to connect the proposed wall to the existing control room, providing a pinned connection at that point. These shear studs must be able to resist a shear of 13,100 lb per linear ft as per the shear present at the bottom support in the fixed-edge computer run. Shear stud requirements are dependent upon the stud layout and geometry chosen by the designers. However, examination of the literature shows that a reasonable shear stud design is possible for this loading. Diagonal shear reinforcement in the wall slab must be provided at 0.22 sq in. per linear ft in both directions, with a minimum spacing of 12 in. In this way, a safe design can be assured even though the actual pinned condition falls somewhere between the fixed- and free-edge conditions which were directly analyzed.

CONCLUSION:

The analysis of the existing control-room wall using the CBARCS program and TM 5-1300 resulted in a safe design load of 900 lb of TNT equivalent at a range of 20 ft. This is a conservative estimate due to the 2-degree support rotation requirement for unlaced concrete slabs and the conservatism of the CBARCS program. This conservatism is exemplified by a recent experiment where reinforced concrete walls under roughly comparable conditions showed no damage after testing. Also, reinforced concrete walls tested under much more severe conditions exhibited moderate damage and indicated a maximum allowable amount of explosive corresponding to about 1,800 lb of TNT at a range of 20 ft. The experiments in question did not model the enhancement of the blast loading due to reflection from adjacent walls; however, the moderate damage which resulted allows us to recommend that a load of 1,000 lb of TNT should be considered the capacity of the existing control-room wall.

Design calculations for the proposed additional control room using 1,000 lb of TNT equivalent indicated a required wall thickness of 12 in. with a flexural requirement of 0.33-percent steel vertically and horizontally on each side. The concrete strength was 4,000 psi, and the steel yield strength was 60,000 psi with 3 in. of cover concrete. Shear stirrups are required at 0.22 sq in. per linear ft with a minimum spacing of 12 in. Shear studs are required to tie the proposed control room into the existing concrete. The studs must resist a shear force of 13,100 lb per linear ft.

<u>REFERENCES</u>:

1. J. M. Ferritto, Robert M. Wamsley, and Paul K. Senter; "User's Guide: Computer Program for Optimum Nonlinear Dynamic Designs of Reinforced Concrete Slabs Under Blast Loading (CBARCS)" Instruction Report K-81-6, USAE Waterways Experiment Station, Vicksburg, MS, March 1981.

2. "Structures to Resist the Effects of Accidental Explosions" TM 5-1300, NAVFAC P-397, AFM 88-22, Department of the Army, Navy, and Air Force, June 1969.

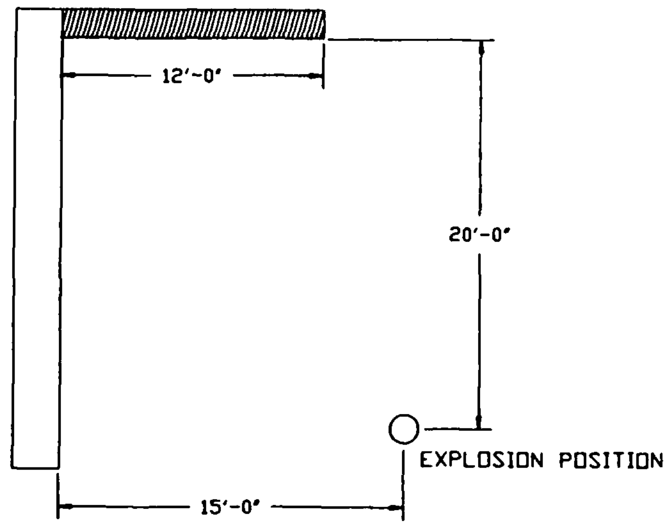

Figure 1. Wall and explosive position input into CBARCS for existing control-room wall.

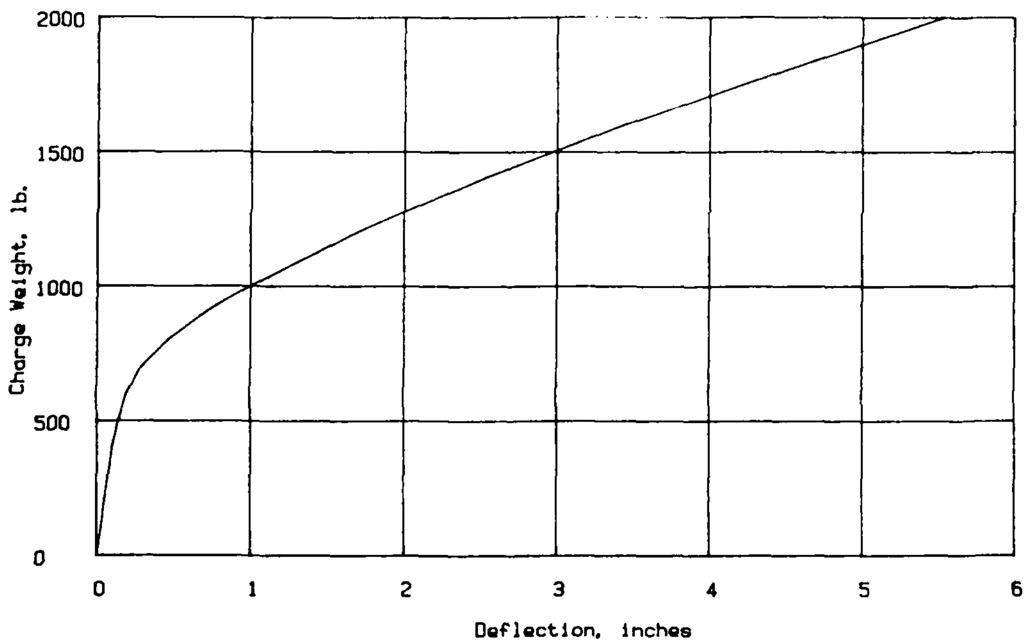

Figure 2. Charge weight versus CBARCS calculated deflection for existing control room.

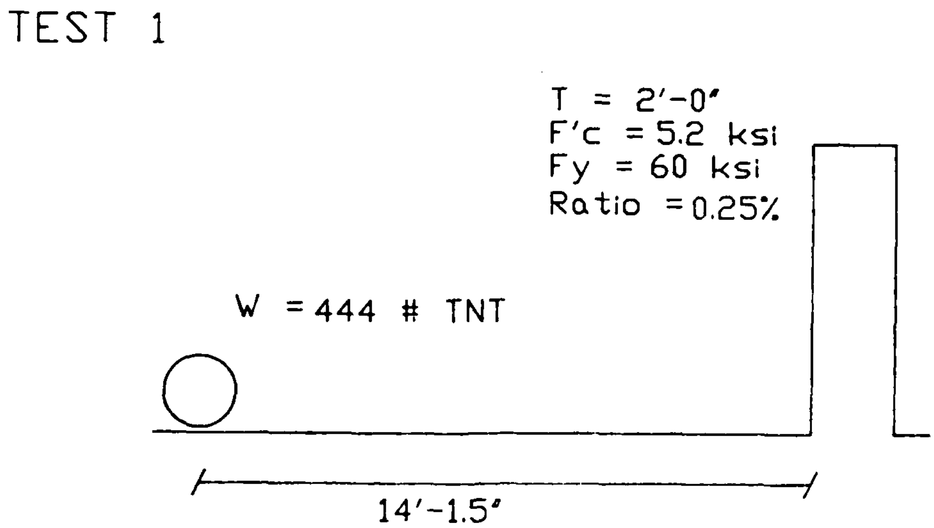

Figure 3. Layout of Experiment 1 scaled up for comparison with existing control room wall.

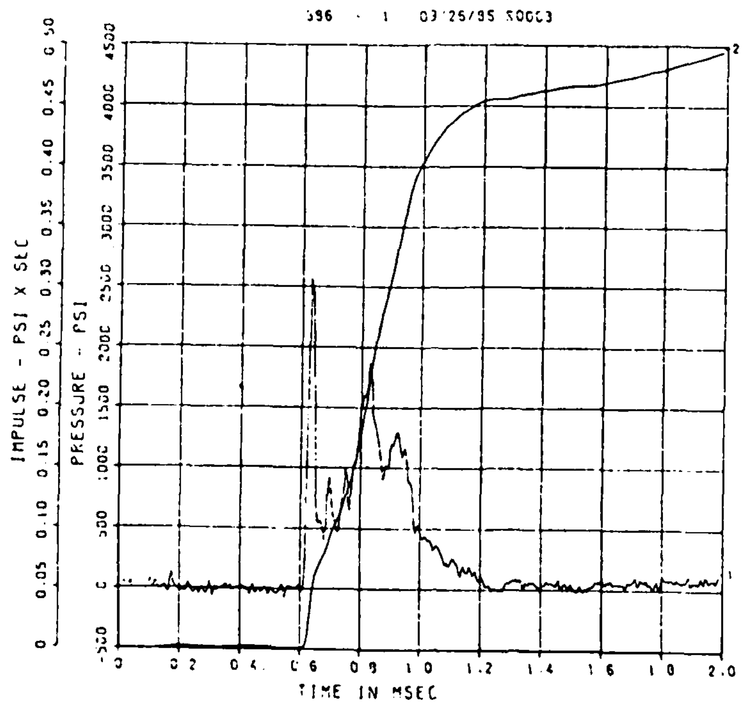

Figure 4. Pressure history for Experiment 1.

Figure 5. Posttest damage to inside of test wall, Experiment 1.

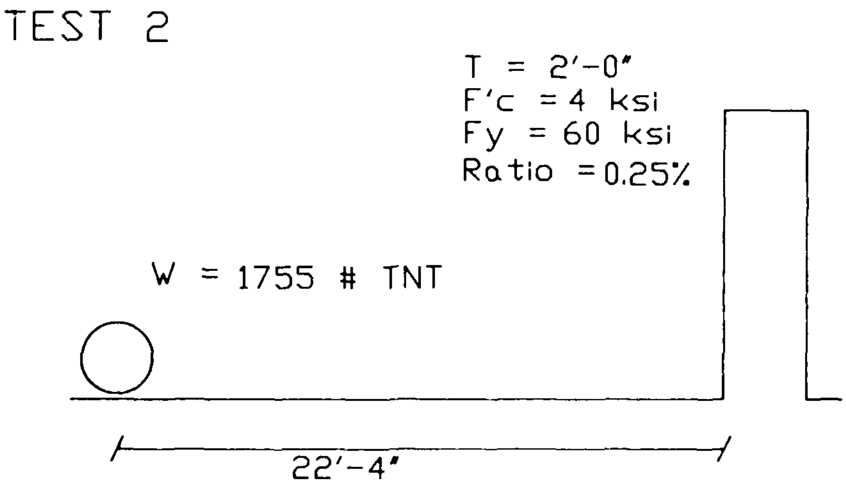

Figure 6. Layout of Experiment 2 scaled up for comparison with existing control-room wall.

Figure 7. Posttest damage to inside of test wall, Experiment 2.

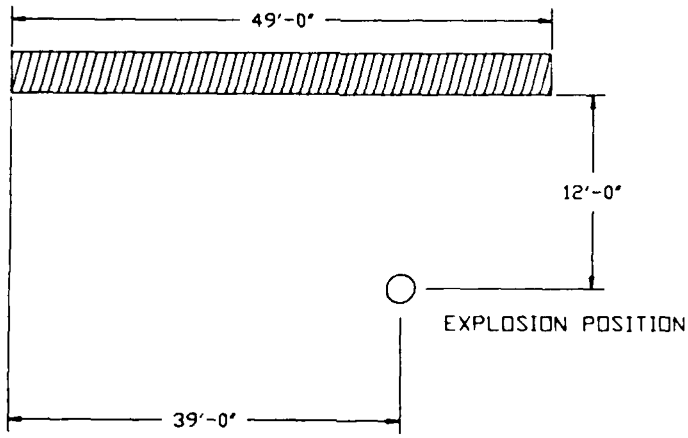

Figure 8. Wall and explosive position input into CBARCS for proposed control-room wall.

APPENDIX A

OUTPUT FOR EXISTING CONTROL ROOM

```
*****************************
* CORPS PROGRAM #   X0056   *
*       VERSION # 83/10/01  *
*****************************

          ********************** CAUTION **********************

          THIS PROGRAM SHOULD BE USED FOR PRELIMINARY DESIGN
          AND/OR ANALYSIS ONLY.  FINAL DESIGN AND/OR ANALYSIS
          INCLUDING REINFORCEMENT PLACING DETAILS SHOULD BE
          IN ACCORDANCE WITH DEPARTMENT OF THE ARMY TECHNICAL
          MANUAL TM 5-1300, 'STRUCTURES TO RESIST THE EFFECTS
          OF ACCIDENTAL EXPLOSIONS'.

          *****************************************************


INPUT NAME OF DATA FILE IN 7 CHARACTERS OR LESS.
HIT CARRIAGE RETURN IF DATA IS TO COME FROM TERMINAL.
 nasa:r


INPUT NAME OF FILE FOR OUTPUT TO BE WRITTEN TO.
HIT A CARRIAGE RETURN IF OUTPUT TO BE PRINTED AT TERMINAL
:




NASA
TNT

EXPLOSIVE PROPERTIES.  ...CHARGE WEIGHT(LB) =   900.0
NUMBER EQWT    EFORM EXPLOSIVE COMPOSITION BY WEIGHT
             KCAL/G      C      H      N      O     AL
   1   1.000 -0.078400 0.370 0.022 0.185 0.423 0.


PAMB(PSIA)=  14.69        TAMB(C)=   20.00

SHOCK WAVE CALCULATION

INPUT PARAMETERS                        CHARGE WEIGHT ADJUSTMENTS
CHARGE WEIGHT)LB)        =    900.0     ADJUSTED WT(LB TNT)  =    900.0
EXPLOSIVE NUMBER         =      1       HE ENERGY FACTOR     =    1.000
L/D RATIO                =   0.         CHARGE SHAPE FACTOR  =    1.000
CASE/CHARGE WT RATIO     =   0.         CASE WEIGHT FACTOR        1.000
CHAMBER PRESSURE(PSIA)=      14.69      PRESSURE SCALE FACTOR=    1.000
CHAMBER TEMP(C)          =    20.00     DISTANCE SCALE FACTOR   0.1036
ALTITUDE (KFT)           =   0.         TIME SCALE FACTOR    =  0.1045
                                        NORMAL REFL FACTOR   =    5.976


DISTANCE OF CHARGE FROM BLAST WALL         FT                  20.00
CHARGE WEIGHT                              LBS                900.00
```

BLAST WALL HEIGHT	FT.	8.67
BLAST WALL LENGTH	FT.	12.00
HEIGHT OF CHARGE ABOVE GROUND	FT.	0.
DIST BETWEEN CHARGE & LEFT BOUNDARY	FT	15.08
REFLECTION CODE		1 0 1 0

TOTAL IMPULSE	2617.21 PSI-MS
DURATION OF LOAD	7.08856 MSEC
FICTITIOUS PEAK PRESSURE	738.43209 PSI
EFFECTIVE IMPULSE	2617.21 PSI MS

HEIGHT 104.00 IN LENGTH 144.00 IN

DYNAMIC CONCRETE STRENGTH	3200.00
DYNAMIC STEEL STRESS	44000.00
THICKNESS CONCRETE INCHES	24.0000
THICKNESS OF SAND INCHES	0.
THETA ALLOWABLE DEGREES	2.0000

AREA VERT TOP STEEL/FT	4.0000	COVER	3.0000
AREA VERT BOT STEEL/FT	4.0000	COVER	3.0000
AREA HORIZ TOP STEEL/FT	0.3100	COVER	3.0000
AREA HORIZ BOT STEEL/FT	0.3100	COVER	3.0000

TYPE 1 CONSTRUCTION

CONCRETE MODULUS PSI	3218422
RATIO MOD STEEL/CONCRETE	9.01
GROSS MOMENT INERTIA	1152.00
AVE CRACKED MOM INERTIA	413.24
AVE MOMENT INERTIA	782.62
AVERAGE PERCENT STEEL	0.0086
D FACTOR MU 1/6	2590818668
D FACTOR MU 0.3	2767905403.

ALLOW SHEAR UNREINFORCED WEB	108.36 PSI	2275.61 LBS/IN WIDTH
ALLOW SHEAR AT SUPPORT	617.76 PSI	12972.96 LBS/IN WIDTH

UNREINFORCED CONCRETE THETA LE 2 DEG

POSITIVE VERTICAL MOMENT	275554.83
NEGATIVE VERTICAL MOMENT	275554.83
POSITIVE HORIZONTAL MOMENT	23675.13
NEGATIVE HORIZONTAL MOMENT	23675.13

SUPPORT ON 4 SIDES
YIELD LINE X FROM SIDE

LOCATION YIELD LINE LENGTH	71.60
LOCATION YIELD LINE HEIGHT	52.00
ULTIMATE LOAD CAPACITY RU	507.644
SHEAR LOAD AT VERTICAL SUPPORT	6577.75 LB/IN WIDTH
SHEAR LOAD AT HORIZONTAL SUPPORT	23620.30 LB/IN WIDTH
SHEAR AT DISTANCE FROM VERTICAL SUPPORT	7.20 PSI
SHEAR AT DISTANCE FROM HORIZONTAL SUPPORT	680.64 PSI

ALLOWABLE MAX DEFLECTION	0.7554

SHEAR CAPACITY(VC) EXCEEDED

LOAD MASS FACTOR	0.6536
MASS CONCRETE ONLY	3524.04

FIRST YIELD POINT AT PT2

ELASTIC LIMIT RE PSI	38.55
ELASTIC DEFLECTION XE	0.0036

SECOND YIELD AT PT 1

ELASTO PLASTIC LIMIT	110.44
ELASTO-PLASTIC DEFLECTION	0.0109
ULTIMATE RESISTANCE	507.64
PLASTIC DEFLECTION	0.1303

ULTIMATE RESISTANCE RU	507.64
ELASTIC DEFLECTION LIMIT XE	0.1129
STIFFNESS KE	4498.14

MASS	3524.037
LOAD	738.432
DURATION	7.089
RESISTANCE	507.644
STIFFNESS	4498.136

GAS PRESSURE	0.	DURATION	0.
NATURAL PERIOD			5.561391
MAXIMUM DEFLECTION			0.701770
TIME TO MAXIMUM DEFLECTION			5.669748
DURATION/NATURAL PERIOD			1.274602
LOAD/RESISTANCE			1.454625
ELASTIC DEFLECTION LIMIT			0.112857

MAX FRAGMENT SPALL VELOCITY FT/SEC 14.717872

APPENDIX B

OUTPUT FOR EXPERIMENTAL WALL NO. 1

```
****************************
* CORPS PROGRAM #  X0056    *
*        VERSION # 83/10/01 *
****************************

          ********************* CAUTION *********************

          THIS PROGRAM SHOULD BE USED FOR PRELIMINARY DESIGN
          AND/OR ANALYSIS ONLY.  FINAL DESIGN AND/OR ANALYSIS
          INCLUDING REINFORCEMENT PLACING DETAILS SHOULD BE
          IN ACCORDANCE WITH DEPARTMENT OF THE ARMY TECHNICAL
          MANUAL TM 5-1300, 'STRUCTURES TO RESIST THE EFFECTS
          OF ACCIDENTAL EXPLOSIONS'.

          ***************************************************

INPUT NAME OF DATA FILE IN 7 CHARACTERS OR LESS
HIT CARRIAGE RETURN IF DATA IS TO COME FROM TERMINAL
 EXP 1

INPUT NAME OF FILE FOR OUTPUT TO BE WRITTEN TO
HIT A CARRIAGE RETURN IF OUTPUT TO BE PRINTED AT TERMINAL

EXP 1
INT

EXPLOSIVE PROPERTIES       CHARGE WEIGHT(LB) =   444.0
NUMBER EQWT    EFORM EXPLOSIVE COMPOSITION BY WEIGHT
                 KCAL/G      C       H       N       O      AL
   1   1.000 0.078400 0.370 0.022 0.185 0.423 0

PAMB(PSIA)     14.69          TAMB(C)=   20.00

SHOCK WAVE CALCULATION

INPUT PARAMETERS                          CHARGE WEIGHT ADJUSTMENTS
CHARGE WEIGHT(LB)        =      444.0     ADJUSTED WEIGHT(LB TNT)       [illegible]
EXPLOSIVE NUMBER         =        1       HE ENERGY FACTOR              1.000
L/D RATIO                =      0         CHARGE SHAPE FACTOR           1.000
CASE/CHARGE WT RATIO     =      0         CASE WEIGHT FACTOR            1.000
CHAMBER PRESSURE(PSIA)   =     14.69      PRESSURE SCALE FACTOR         1.000
CHAMBER TEMP(C)          =     20.00      DISTANCE SCALE FACTOR        [illegible]
ALTITUDE (KFT)           =      0         TIME SCALE FACTOR            [illegible]
                                          NORMAL REFL FACTOR           [illegible]

DISTANCE OF CHARGE FROM BLAST WALL           FT                    [illegible]
CHARGE WEIGHT                                LBS                   444.00
```

BLAST WALL HEIGHT	FT	15 21
BLAST WALL LENGTH	FT	42 00
HEIGHT OF CHARGE ABOVE GROUND	FT	0
DIST BETWEEN CHARGE & LEFT BOUNDARY	FT	14 00
REFLECTION CODE		1 0 0 0

TOTAL IMPULSE	792.64 PSI-MS
DURATION OF LOAD	18.32496 MSEC
FICTITIOUS PEAK PRESSURE	86.50910 PSI
EFFECTIVE IMPULSE	792.64 PSI MS

HEIGHT 182.52 IN LENGTH 504 00 IN

DYNAMIC CONCRETE STRENGTH	5200 00
DYNAMIC STEEL STRESS	66000 00
THICKNESS CONCRETE INCHES	24.0000
THICKNESS OF SAND INCHES	0
THETA ALLOWABLE DEGREES	2.0000

AREA VERT TOP STEEL/FT	0 6720	COVER	3 3200
AREA VERT BOT STEEL/FT	0.6720	COVER	3 3200
AREA HORIZ TOP STEEL/FT	0 3050	COVER	2 4500
AREA HORIZ BOT STEEL/FT	0 3050	COVER	2 4500

TYPE 1 CONSTRUCTION

CONCRETE MODULUS PSI	3716314
RATIO MOD STEEL/CONCRETE	7.80
GROSS MOMENT INERTIA	1152.00
AVE CRACKED MOM INERTIA	142 89
AVE MOMENT INERTIA	647 45
AVERAGE PERCENT STEEL	0 0027
D FACTOR MU 1/6	247 [illegible]
D FACTOR MU 0 3	264[illegible]0805 14

ALLOW SHEAR UNREINFORCED WEB	109 [illegible] PSI	[illegible] LBS/IN WIDTH
ALLOW SHEAR AT SUPPORT	823 68 PSI	[illegible] LBS/IN WIDTH

UNREINFORCED CONCRETE THETA LE 2 DEG

POSITIVE VERTICAL MOMENT	74837 [illegible]
NEGATIVE VERTICAL MOMENT	74837 [illegible]
POSITIVE HORIZONTAL MOMENT	[illegible] 80
NEGATIVE HORIZONTAL MOMENT	[illegible]31 80

SIMPLY SUPPORTED BEAM

LOCATION YIELD LINE LENGTH	0
LOCATION YIELD LINE HEIGHT	21 [illegible]
ULTIMATE LOAD CAPACITY RU	17 [illegible]
SHEAR LOAD AT VERTICAL SUPPORT	0 LB/IN WIDTH
SHEAR LOAD AT HORIZONTAL SUPPORT	1[illegible] [illegible] LB/IN WIDTH
SHEAR AT DISTANCE FROM VERTICAL SUPPORT	0 PSI
SHEAR AT DISTANCE FROM HORIZONTAL SUPPORT	61 [illegible] PSI
ALLOWABLE MAX DEFLECTION	[illegible]

LOAD MASS FACTOR	0.7250
MASS CONCRETE ONLY	3909.20

ULTIMATE RESISTANCE RU	17.98
ELASTIC DEFLECTION LIMIT XE	0.1080
STIFFNESS KE	166.51

MASS	3909.200
LOAD	86.509
DURATION	18.325
RESISTANCE	17.984
STIFFNESS	166.503

GAS PRESSURE	0	DURATION	0
NATURAL PERIOD			30.444231
MAXIMUM DEFLECTION			3.641961
TIME TO MAXIMUM DEFLECTION			45.994932
DURATION/NATURAL PERIOD			0.601918
LOAD/RESISTANCE			4.810394
ELASTIC DEFLECTION LIMIT			0.108005
MAX FRAGMENT SPALL VELOCITY FT/SEC			11.381930

WALL COLLAPSES (THETA EXCEEDED)

AVERAGE SCAB VELOCITY	5.36
MAX SCAB VELOCITY	26.80

APPENDIX C

OUTPUT FOR EXPERIMENTAL WALL NO. 2

```
*****************************
* CORPS PROGRAM #  X0056    *
*        VERSION # 83/10/01 *
*****************************

          ********************** CAUTION *********************

          THIS PROGRAM SHOULD BE USED FOR PRELIMINARY DESIGN
          AND/OR ANALYSIS ONLY.  FINAL DESIGN AND/OR ANALYSIS
          INCLUDING REINFORCEMENT PLACING DETAILS SHOULD BE
          IN ACCORDANCE WITH DEPARTMENT OF THE ARMY TECHNICAL
          MANUAL TM 5-1300, 'STRUCTURES TO RESIST THE EFFECTS
          OF ACCIDENTAL EXPLOSIONS'.

          ****************************************************


INPUT NAME OF DATA FILE IN 7 CHARACTERS OR LESS.
HIT CARRIAGE RETURN IF DATA IS TO COME FROM TERMINAL
=EXP-2


INPUT NAME OF FILE FOR OUTPUT TO BE WRITTEN TO.
HIT A CARRIAGE RETURN IF OUTPUT TO BE PRINTED AT TERMINAL
=




EXP-2
TNT

EXPLOSIVE PROPERTIES.... CHARGE WEIGHT(LB) =  1755.
NUMBER EQWT    EFORM EXPLOSIVE COMPOSITION BY WEIGHT
             KCAL/G      C      H      N      O     AL
   1  1.000-0.078400 0.370 0.022 0.185 0.423 0.

PAMB(PSIA)=  14.69        TAMB(C)=  20.00

SHOCK WAVE CALCULATION

INPUT PARAMETERS                        CHARGE WEIGHT ADJUSTMENTS
CHARGE WEIGHT)LB)       =   1755.       ADJUSTED WT(LB TNT)      1755.
EXPLOSIVE NUMBER        =     1         HE ENERGY FACTOR     =   1.000
L/D RATIO               =  0            CHARGE SHAPE FACTOR  =   1.000
CASE/CHARGE WT RATIO    =  0            CASE WEIGHT FACTOR   =   1.000
CHAMBER PRESSURE(PSIA)  =   14.69       PRESSURE SCALE FACTOR=   1.000
CHAMBER TEMP(C)         =   20.00       DISTANCE SCALE FACTOR=  0.3289E 01
ALTITUDE (KFT)          =  0.           TIME SCALE FACTOR    =  0.3361E 01
                                        NORMAL REFL FACTOR   =   6.394


DISTANCE OF CHARGE FROM BLAST WALL          FT                 22.39
CHARGE WEIGHT                               LBS              1755.00
```

BLAST WALL HEIGHT	FT.	24.28
BLAST WALL LENGTH	FT.	67.05
HEIGHT OF CHARGE ABOVE GROUND	FT.	0.
DIST. BETWEEN CHARGE & LEFT BOUNDARY	FT	22.35
REFLECTION CODE		1 0 0 0

TOTAL IMPULSE	1271.26 PSI-MS
DURATION OF LOAD	29.33525 MSEC
FICTITIOUS PEAK PRESSURE	86.67140 PSI
EFFECTIVE IMPULSE	1271.26 PSI MS

HEIGHT 291.36 IN LENGTH 804.60 IN

DYNAMIC CONCRETE STRENGTH	4000.00
DYNAMIC STEEL STRESS	66000.00
THICKNESS CONCRETE INCHES	24.0000
THICKNESS OF SAND INCHES	0
THETA ALLOWABLE DEGREES	2.0000

AREA VERT TOP STEEL/FT	0.6500	COVER	4.7200
AREA VERT BOT STEEL/FT	0.6500	COVER	4.7200
AREA HORIZ TOP STEEL/FT	0.2980	COVER	3.7500
AREA HORIZ BOT STEEL/FT	0.2980	COVER	3.7500

TYPE 1 CONSTRUCTION

CONCRETE MODULUS PSI	3259423
RATIO MOD STEEL/CONCRETE	8.90
CROSS MOMENT INERTIA	1152.00
AVE CRACKED MOM INERTIA	134.05
AVE MOMENT INERTIA	643.03
AVERAGE PERCENT STEEL	0.0028
D FACTOR MU=176	2155830164
D FACTOR MU=0.3	2303184716

ALLOW SHEAR UNREINFORCED WEB	97.93 PSI	1876.49 LBS/IN WIDTH
ALLOW SHEAR AT SUPPORT	633.60 PSI	12615.81 LBS/IN WIDTH

UNREINFORCED CONCRETE THETA LE 2 DEG

POSITIVE VERTICAL MOMENT	67046.50
NEGATIVE VERTICAL MOMENT	67046.50
POSITIVE HORIZONTAL MOMENT	32794.70
NEGATIVE HORIZONTAL MOMENT	32794.70

SIMPLY SUPPORTED BEAM

LOCATION YIELD LINE LENGTH	0
LOCATION YIELD LINE HEIGHT	145.68
ULTIMATE LOAD CAPACITY RU	6.3199
SHEAR LOAD AT VERTICAL SUPPORT	0 LB/IN WIDTH
SHEAR LOAD AT HORIZONTAL SUPPORT	990.46 LB/IN WIDTH
SHEAR AT DISTANCE FROM VERTICAL SUPPORT	0 PSI
SHEAR AT DISTANCE FROM HORIZONTAL SUPPORT	41.42 PSI
ALLOWABLE MAX DEFLECTION	5.0958

```
LOAD MASS FACTOR                          0.7250
MASS CONCRETE ONLY                        3909.20


ULTIMATE RESISTANCE RU                          6.32
ELASTIC DEFLECTION LIMIT  XE              0 2829
STIFFNESS  KE                                  22.34


MASS            3909.200
LOAD              86.671
DURATION          29.335
RESISTANCE         6 318
STIFFNESS         22.336

GAS PRESSURE          0.          DURATION          0.
NATURAL PERIOD                                 83.122312
MAXIMUM DEFLECTION                             30.506442
TIME TO MAXIMUM DEFLECTION                    203.241966
DURATION/NATURAL PERIOD                         0.352917
LOAD/RESISTANCE                                13.717331
ELASTIC DEFLECTION LIMIT                        0.282875

MAX FRAGMENT SPALL VELOCITY FT/SEC             23 688421



WALL COLLAPSES(THETA EXCEEDED)
AVERAGE SCAB VELOCITY                     23.69
MAX SCAB VELOCITY                        118.44
```

*

APPENDIX D

OUTPUT FOR ADDITIONAL CONTROL ROOM

(FIXED EDGES ASSUMED)

```
*****************************
* CORPS PROGRAM #  X0056    *
*       VERSION # 83/10/01 *
*****************************

          ********************** CAUTION *********************

          THIS PROGRAM SHOULD BE USED FOR PRELIMINARY DESIGN
          AND/OR ANALYSIS ONLY.  FINAL DESIGN AND/OR ANALYSIS
          INCLUDING REINFORCEMENT PLACING DETAILS SHOULD BE
          IN ACCORDANCE WITH DEPARTMENT OF THE ARMY TECHNICAL
          MANUAL TM 5-1300, 'STRUCTURES TO RESIST THE EFFECTS
          OF ACCIDENTAL EXPLOSIONS'.

          ***************************************************


INPUT NAME OF DATA FILE IN 7 CHARACTERS OR LESS.
HIT CARRIAGE RETURN IF DATA IS TO COME FROM TERMINAL.
=nasa-o


INPUT NAME OF FILE FOR OUTPUT TO BE WRITTEN TO.
HIT A CARRIAGE RETURN IF OUTPUT TO BE PRINTED AT TERMINAL.
=



NASA-OPT
TNT

EXPLOSIVE PROPERTIES.....CHARGE WEIGHT(LB) =  1000.
NUMBER EQWT    EFORM EXPLOSIVE COMPOSITION BY WEIGHT
              KCAL/G     C       H       N      O      AL
   1   1.000-0.078400 0.370 0.022 0.185 0.423 0.


PAMB(PSIA)=  14.69         TAMB(C)=  20.00

SHOCK WAVE CALCULATION

INPUT PARAMETERS                        CHARGE WEIGHT ADJUSTMENTS
CHARGE WEIGHT(LB)       =   1000        ADJUSTED WT(LB TNT)    =    1000
EXPLOSIVE NUMBER        =     1         HE ENERGY FACTOR       =   1.000
L/D RATIO               =   0.          CHARGE SHAPE FACTOR    =   1.000
CASE/CHARGE WT RATIO    =   0.          CASE WEIGHT FACTOR     =   1.000
CHAMBER PRESSURE(PSIA)  =   14.69       PRESSURE SCALE FACTOR=   1.000
CHAMBER TEMP(C)         =   20.00       DISTANCE SCALE FACTOR=  0.9999E-01
ALTITUDE (KFT)          =   0.          TIME SCALE FACTOR      =  0.1008
                                        NORMAL REFL FACTOR     =   6.108


DISTANCE OF CHARGE FROM BLAST WALL          FT               20.00
CHARGE WEIGHT                               LBS.           1000.00
```

BLAST WALL HEIGHT	FT.	12.50
BLAST WALL LENGTH	FT.	47.00
HEIGHT OF CHARGE ABOVE GROUND	FT.	0
DIST. BETWEEN CHARGE & LEFT BOUNDARY	FT.	39.00
REFLECTION CODE		0 0 0 0

TOTAL IMPULSE	77.18 PSI-MS
DURATION OF LOAD	23.57221 MSEC
FICTITIOUS PEAK PRESSURE	6.54803 PSI
EFFECTIVE IMPULSE	77.18 PSI MS

HEIGHT 150.00 IN LENGTH 564.00 IN

DYNAMIC CONCRETE STRENGTH	4800.00
DYNAMIC STEEL STRESS	66000.00
THICKNESS CONCRETE INCHES	14.0000
THICKNESS OF SAND INCHES	0
THETA ALLOWABLE DEGREES	2.0000

AREA VERT TOP STEEL/FT	0.4000	COVER	3.0000
AREA VERT BOT STEEL/FT	0.4000	COVER	3.0000
AREA HORIZ TOP STEEL/FT	0.4000	COVER	3.0000
AREA HORIZ BOT STEEL/FT	0.4000	COVER	3.0000

TYPE 1 CONSTRUCTION

CONCRETE MODULUS PSI	3570519.
RATIO MOD STEEL/CONCRETE	8.12
GROSS MOMENT INERTIA	228.67
AVE CRACKED MOM INERTIA	24.66
AVE MOMENT INERTIA	126.66
AVERAGE PERCENT STEEL	0.0030
D FACTOR MU=1/6	465183272.
D FACTOR MU= 0.3	496979317.

ALLOW SHEAR UNREINFORCED WEB	106.52	PSI	1171.62 LBS/IN WIDTH
ALLOW SHEAR AT SUPPORT	760.32	PSI	2363.52 LBS/IN WIDTH

UNREINFORCED CONCRETE THETA LE 2 DEG

POSITIVE VERTICAL MOMENT	23606.86
NEGATIVE VERTICAL MOMENT	23606.86
POSITIVE HORIZONTAL MOMENT	23606.86
NEGATIVE HORIZONTAL MOMENT	23606.86

SUPPORT ON 3 SIDES
YIELD LINE X FROM SIDE

LOCATION YIELD LINE LENGTH	202.70
LOCATION YIELD LINE HEIGHT	150.00
ULTIMATE LOAD CAPACITY RU	5.7456
SHEAR LOAD AT VERTICAL SUPPORT	698.78 LB/IN WIDTH
SHEAR LOAD AT HORIZONTAL SUPPORT	627.25 LB/IN WIDTH
SHEAR AT DISTANCE FROM VERTICAL SUPPORT	59.40 PSI
SHEAR AT DISTANCE FROM HORIZONTAL SUPPORT	52.77 PSI

```
ALLOWABLE MAX DEFLECTION    .                    5.2469

LOAD MASS FACTOR                    0.6030
MASS CONCRETE ONLY                 1896.79


FIRST YIELD POINT AT PT2                .
ELASTIC  LIMIT  RE PSI                  2.03
ELASTIC DEFLECTION  XE                0.1704

SECOND YIELD AT PT 3
ELASTO PLASTIC LIMIT                    2.62
ELASTO-PLASTIC DEFLECTION             0.2328
ULTIMATE RESISTANCE                     5.75
PLASTIC DEFLECTION                    1.8318



ULTIMATE RESISTANCE RU                  5.75
ELASTIC DEFLECTION LIMIT  XE          1.2242
STIFFNESS  KE                           4.69


MASS          1896.790
LOAD             6.548
DURATION        23.572
RESISTANCE       5.746
STIFFNESS        4.693

GAS PRESSURE        0.        DURATION        0.
NATURAL PERIOD                          126.314047
MAXIMUM DEFLECTION                        0.784618
TIME TO MAXIMUM DEFLECTION               39.354967
DURATION/NATURAL PERIOD                   0.186616
LOAD/RESISTANCE                           1.139651
ELASTIC DEFLECTION LIMIT                  1.224233

MAX FRAGMENT SPALL VELOCITY FT/SEC      2.661582


        TOTAL COST      6739.16
        COUNT              1.00
INITIAL POINT VIOLATES A CONSTRAINT.  X)S ARE/  0.140000E 02 0 400000E 00 0 4000
00E 00

 G)S ARE
 0 446228E 01 0 471210E 02-0 200000E-01-0 200000E-01-0 200000E 01
-0 200000E 01 0.200000E 01 0 186000E 03 0.196000E 02
 0 196000E 02


TEMPORARY OBJECTIVE FUNCTION IS NEGATIVE OF VIOLATED CONSTRAINT NO    6  = 0 20
000E-01       FUDGE(I) =
0.           0              0.12000E 00 0 12000E 00 0 12000E 00
0.12000E 00 0               0              0.             0.
X)S ARE
```

```
 0.140000E 02 0.400000E 00 0.400000E 00

 G)S ARE
 0.446228E 01 0.471210E 02 0.100000E 00 0.100000E 00 0.100000E 00
0.100000E 00 0.200000E 01 0.186000E 03 0.196000E 02
 0.196000E 02


R = 0.48956325E-03
ITER =     0       P = 0.40000001E-01      OBJ = 0.20000000E-01
ITER =     1       P =-0.72161520E-02      OBJ =-0.21999999E-01

 G)S ARE
 0.427286E 01 0.477550E 02 0.142000E 00 0.142000E 00 0.142000E 00
0.142000E 00 0.600000E 00 0.187400E 03 0.196000E 02
 0.196000E 02
FUNCTION CALLS =      4


ALL CONSTRAINTS HAVE BEEN SATISFIED AND REAL OBJECTIVE FUNCTION WILL BE MINIMIZ
ED NEXT
X)S ARE
 0.126000E 02 0.400000E 00 0.400000E 00

 G)S ARE
 0.427286E 01 0.477550E 02 0.220000E-01 0.220000E-01 0.220000E-01
0.220000E-01 0.600000E 00 0.187400E 03 0.196000E 02
 0.196000E 02


R = 0.34531539E 02
ITER =     0       P = 0.12697054E 05      OBJ = 0.63485269E 04
ITER =    12       P = 0.74689290E 04      OBJ = 0.67630741E 04

 G)S ARE
 0.424584E 01 0.222557E 02 0.238858E 00 0.238858E 00 0.238271E 00
0.238271E 00 0.304410E 00 0.187696E 03 0.193920E 02
 0.193926E 02
FUNCTION CALLS =    164


R = 0.34531539E-01
ITER =     0       P = 0.67637800E 04      OBJ = 0.67630741E 04
ITER =     9       P = 0.61154845E 04      OBJ = 0.60935640E 04

 G)S ARE
 0.416843E 01 0.521713E 02 0.755730E-02 0.755730E-02 0.755720E-02
0.755720E-02 0.951225E-02 0.187990E 03 0.196322E 02
 0.196322E 02
FUNCTION CALLS =    135
XNEXT(I) =
 0.120002E 02 0.360242E 00 0.360267E 00


R = 0.34531539E-04
```

```
ITER =     0      P = 0.60730960E 04      OBJ = 0.60723626E 04
ITER =     3      P = 0.60730668E 04      OBJ = 0.60723797E 04

 G)S ARE
 0.416580E 01 0.531341E 02 0.239574E-03 0.239574E-03 0.242187E-03
0.242187E-03 0.303986E-03 0.188000E 03 0.196398E 02
 0.196397E 02
FUNCTION CALLS =    107
XNEXT(I) =
 0.120000E 02 0.360009E 00 0.360011E 00



R = 0.34531539E-07
ITER =     0      P = 0.60717273E 04      OBJ = 0.60717098E 04
ITER =     3      P = 0.60717257E 04      OBJ = 0.60717038E 04

 G)S ARE
 0.416571E 01 0.531650E 02 0.755325E-05 0.755325E-05 0.749465E-05
0.749465E-05 0.964972E-05 0.188000E 03 0.196400E 02
 0.196400E 02
FUNCTION CALLS =    106
XNEXT(I) =
 0.120000E 02 0.360000E 00 0.360000E 00
TOTAL FUNCTION CALLS =     516
ITER =,    0      PF =   0.6071726E 04      OBJ =   0.6071682E 04      X)S ARE
 0.120000E 02 0.360000E 00 0.360000E 00

 G)S ARE
 0.416571E 01 0.531660E 02 0.216122E-06 0.216122E-06 0.730378E-07
0.730378E-07 0.341992E-06 0.188000E 03 0.196400E 02
 0.196400E 02



       HEIGHT       150.00 IN     LENGTH       564.00 IN

    DYNAMIC CONCRETE STRENGTH       4800.00
    DYNAMIC STEEL STRESS           66000.00
    THICKNESS CONCRETE   INCHES      12.0000
    THICKNESS OF SAND    INCHES       0.
    THETA ALLOWABLE     DEGREES       2.0000

    AREA VERT TOP STEEL/FT           0.3600    COVER      3.0000
    AREA VERT BOT STEEL/FT           0.3600    COVER      3.0000
    AREA HORIZ TOP STEEL/FT          0.3600    COVER      3.0000
    AREA HORIZ BOT STEEL/FT          0.3600    COVER      3.0000

    CONCRETE MODULUS PSI                  3570519
    RATIO MOD STEEL/CONCRETE                 8.12
    GROSS MOMENT INERTIA                   144.00
    AVE CRACKED MOM INERTIA                 14.82
    AVE MOMENT INERTIA                      79.41
    AVERAGE PERCENT STEEL                  0.0033
    D FACTOR MU=.176                    291637288
    D FACTOR  MU= 0.3                   311571178
```

```
ALLOW SHEAR UNREINFORCED WEB      107.16   PSI             964.45 LBS/IN WIDTH
ALLOW SHEAR AT SUPPORT            760.32   PSI            6842.88 LBS/IN WIDTH
UNREINFORCED CONCRETE   THETA LE 2 DEG

POSITIVE VERTICAL MOMENT        17339.57
NEGATIVE VERTICAL MOMENT        17339.57
POSITIVE HORIZONTAL MOMENT      17339.56
NEGATIVE HORIZONTAL MOMENT      17339.56


SUPPORT ON  3 SIDES
YIELD LINE  X  FROM SIDE

LOCATION YIELD LINE LENGTH                        202.70
LOCATION YIELD LINE HEIGHT                        150.00
ULTIMATE LOAD CAPACITY  RU                        4.2203
SHEAR LOAD AT VERTICAL SUPPORT                    513.26 LB/IN WIDTH
SHEAR LOAD AT HORIZONTAL SUPPORT                  460 72 LB/IN WIDTH
SHEAR AT DISTANCE FROM VERTICAL SUPPORT            54 00 PSI
SHEAR AT DISTANCE FROM HORIZONTAL SUPPORT          48.07 PSI
ALLOWABLE MAX DEFLECTION                          5.2469


LOAD MASS FACTOR                  0.6030
MASS CONCRETE ONLY             1625.82


FIRST YIELD POINT AT PT2
ELASTIC  LIMIT  RE PSI                1.49
ELASTIC DEFLECTION  XE              0.1996

SECOND YIELD AT PT 3
ELASTO PLASTIC LIMIT                  1.93
ELASTO-PLASTIC DEFLECTION           0.2727
ULTIMATE RESISTANCE                   4.22
PLASTIC DEFLECTION                  2.1461


ULTIMATE RESISTANCE RU                4 22
ELASTIC DEFLECTION LIMIT   XE       1.4343
STIFFNESS  KE                         2.94


MASS           1625 820
LOAD              6.548
DURATION         23 572
RESISTANCE        4.220
STIFFNESS         2.942

GAS PRESSURE        0          DURATION        0.
NATURAL PERIOD                            147.696007
MAXIMUM DEFLECTION                          1.081181
TIME TO MAXIMUM DEFLECTION                 44.491406
DURATION/NATURAL PERIOD                     0.159599
LOAD/RESISTANCE                             1.551571
ELASTIC DEFLECTION LIMIT                    1 434316

MAX FRAGMENT SPALL VELOCITY FT/SEC          3.265566
```

APPENDIX E

OUTPUT FOR ADDITIONAL CONTROL ROOM
(ONE FREE EDGE ASSUMED)

```
****************************
* CORPS PROGRAM #  X0056   *
*       VERSION # 83/10/01 *
****************************

         ********************** CAUTION *********************

         THIS PROGRAM SHOULD BE USED FOR PRELIMINARY DESIGN
         AND/OR ANALYSIS ONLY.  FINAL DESIGN AND/OR ANALYSIS
         INCLUDING REINFORCEMENT PLACING DETAILS SHOULD BE
         IN ACCORDANCE WITH DEPARTMENT OF THE ARMY TECHNICAL
         MANUAL TM 5-1300, 'STRUCTURES TO RESIST THE EFFECTS
         OF ACCIDENTAL EXPLOSIONS'.

         ***************************************************


INPUT NAME OF DATA FILE IN 7 CHARACTERS OR LESS.
HIT CARRIAGE RETURN IF DATA IS TO COME FROM TERMINAL.
=nasa-o


INPUT NAME OF FILE FOR OUTPUT TO BE WRITTEN TO.
HIT A CARRIAGE RETURN IF OUTPUT TO BE PRINTED AT TERMINAL
=



NASA OPT
TNT

EXPLOSIVE PROPERTIES.     CHARGE WEIGHT(LB) =  1000.
NUMBER EQWT    EFORM EXPLOSIVE COMPOSITION BY WEIGHT
               KCAL/G      C      H      N      O      AL
   1   1.000-0.078400 0.370 0.022 0.185 0.423 0.

PAMB(PSIA)=  14.69        TAMB(C)=  20.00

SHOCK WAVE CALCULATION

INPUT PARAMETERS                          CHARGE WEIGHT ADJUSTMENTS
CHARGE WEIGHT)LB)       =    1000         ADJUSTED WT(LB TNT)    =   1000.
EXPLOSIVE NUMBER        =       1         HE ENERGY FACTOR       =   1.000
L/D RATIO               =   0.            CHARGE SHAPE FACTOR    =   1.000
CASE/CHARGE WT RATIO    =   0             CASE WEIGHT FACTOR     =   1.000
CHAMBER PRESSURE(PSIA)=     14.69         PRESSURE SCALE FACTOR=     1.000
CHAMBER TEMP(C)         =   20.00         DISTANCE SCALE FACTOR=   0.9999E-01
ALTITUDE (KFT)          =   0             TIME SCALE FACTOR      =  0.1008
                                          NORMAL REFL FACTOR     =   6.108

DISTANCE OF CHARGE FROM BLAST WALL           FT                20.00
CHARGE WEIGHT                                LBS.            1000.00
```

BLAST WALL HEIGHT	FT.	12.50
BLAST WALL LENGTH	FT.	47.00
HEIGHT OF CHARGE ABOVE GROUND	FT.	12.50
DIST. BETWEEN CHARGE & LEFT BOUNDARY	FT.	39.00
REFLECTION CODE		0 0 0 0

TOTAL IMPULSE	77.18 PSI-MS
DURATION OF LOAD	23.57221 MSEC
FICTITIOUS PEAK PRESSURE	6.54803 PSI
EFFECTIVE IMPULSE	77.18 PSI MS

HEIGHT 150.00 IN LENGTH 564.00 IN

DYNAMIC CONCRETE STRENGTH	4800.00
DYNAMIC STEEL STRESS	66000.00
THICKNESS CONCRETE INCHES	14.0000
THICKNESS OF SAND INCHES	0.
THETA ALLOWABLE DEGREES	2.0000

AREA VERT TOP STEEL/FT	0.4000	COVER	3.0000
AREA VERT BOT STEEL/FT	0.4000	COVER	3.0000
AREA HORIZ TOP STEEL/FT	0.4000	COVER	3.0000
AREA HORIZ BOT STEEL/FT	0.4000	COVER	3.0000

TYPE 1 CONSTRUCTION

CONCRETE MODULUS PSI	3570519
RATIO MOD STEEL/CONCRETE	8.12
GROSS MOMENT INERTIA	228.67
AVE CRACKED MOM INERTIA	24.66
AVE MOMENT INERTIA	126.66
AVERAGE PERCENT STEEL	0.0030
D FACTOR MU=1/6	465183272.
D FACTOR MU= 0.3	496979317.

ALLOW SHEAR UNREINFORCED WEB	106.52	PSI	1171.69 LBS/IN WIDTH
ALLOW SHEAR AT SUPPORT	760.32	PSI	8363.52 LBS/IN WIDTH

UNREINFORCED CONCRETE THETA LE 2 DEG

POSITIVE VERTICAL MOMENT	23606.86
NEGATIVE VERTICAL MOMENT	23606.86
POSITIVE HORIZONTAL MOMENT	23606.86
NEGATIVE HORIZONTAL MOMENT	23606.86

SUPPORT ON 3 SIDES
YIELD LINE X FROM SIDE

LOCATION YIELD LINE LENGTH	202.70
LOCATION YIELD LINE HEIGHT	150.00
ULTIMATE LOAD CAPACITY RU	5.7456
SHEAR LOAD AT VERTICAL SUPPORT	698.78 LB/IN WIDTH
SHEAR LOAD AT HORIZONTAL SUPPORT	627.25 LB/IN WIDTH
SHEAR AT DISTANCE FROM VERTICAL SUPPORT	59.40 PSI
SHEAR AT DISTANCE FROM HORIZONTAL SUPPORT	52.77 PSI

```
ALLOWABLE MAX DEFLECTION                            5.2469

LOAD MASS FACTOR                      0.6030
MASS CONCRETE ONLY                   1896.79

FIRST YIELD POINT AT PT2
ELASTIC  LIMIT  RE PSI                  2.03
ELASTIC DEFLECTION  XE                0.1704

SECOND YIELD AT PT 3
ELASTO PLASTIC LIMIT                    2.62
ELASTO-PLASTIC DEFLECTION             0.2328
ULTIMATE RESISTANCE                     5.75
PLASTIC DEFLECTION                    1.8318

ULTIMATE RESISTANCE RU                  5.75
ELASTIC DEFLECTION LIMIT  XE          1.2242
STIFFNESS  KE                           4.69

MASS            1896.790
LOAD               6.548
DURATION          23.572
RESISTANCE         5.746
STIFFNESS          4.693

GAS PRESSURE          0         DURATION         0.
NATURAL PERIOD                             126.314047
MAXIMUM DEFLECTION                           0.784618
TIME TO MAXIMUM DEFLECTION                  39.354967
DURATION/NATURAL PERIOD                      0.186616
LOAD/RESISTANCE                              1.139651
ELASTIC DEFLECTION LIMIT                     1.224233

MAX FRAGMENT SPALL VELOCITY FT/SEC      2.661582


         TOTAL COST      6739.16
         COUNT              1.00
INITIAL POINT VIOLATES A CONSTRAINT   X)S ARE/  0.140000E 02 0.400000E 00 0.4000
00E 00

 G)S ARE
 0.446228E 01 0.471210E 02-0.200000E-01-0.200000E-01-0.200000E-01
-0.200000E 01 0.200000E 01 0.186000E 03 0.196000E 02
 0.196000E 02


TEMPORARY OBJECTIVE FUNCTION IS NEGATIVE OF VIOLATED CONSTRAINT NO    6    0.20
000E-01      FUDGE(I) =
0.           0.          0.12000E 00 0.12000E 00 0.12000E 00
0.12000E 00 0           0            0            0.
X)S ARE
```

```
 0.140000E 02 0.400000E 00 0.400000E 00

 G)S ARE
 0.446228E 01 0.471210E 02 0.100000E 00 0.100000E 00 0.100000E 00
0.100000E 00 0.200000E 01 0.186000E 03 0.196000E 02
 0.196000E 02


R = 0.48956325E-03
ITER =     0      P = 0.40000001E-01      OBJ = 0.20000000E-01
ITER =     1      P =-0.72161520E-02      OBJ =-0.21999999E-01

 G)S ARE
 0.427286E 01 0.477550E 02 0.142000E 00 0.142000E 00 0.142000E 00
0.142000E 00 0.600000E 00 0.187400E 03 0.196000E 02
 0.196000E 02
FUNCTION CALLS =      4


ALL CONSTRAINTS HAVE BEEN SATISFIED AND REAL OBJECTIVE FUNCTION WILL BE MINIMIZ
ED NEXT
X)S ARE
 0.126000E 02 0.400000E 00 0.400000E 00

 G)S ARE
 0.427286E 01 0.477550E 02 0.220000E-01 0.220000E-01 0.220000E-01
0.220000E-01 0.600000E 00 0.187400E 03 0.196000E 02
 0.196000E 02


R = 0.34531539E 02
ITER =     0      P = 0.12697054E 05      OBJ = 0.63485269E 04
ITER =    12      P = 0.74689290E 04      OBJ = 0.67630741E 04

 G)S ARE
 0.424584E 01 0.222857E 02 0.238858E 00 0.238858E 00 0.238271E 00
0.238271E 00 0.304410E 00 0.187696E 03 0.193920E 02
 0.193926E 02
FUNCTION CALLS =   164


R = 0.34531539E-01
ITER =     0      P = 0.67637800E 04      OBJ = 0.67630741E 04
ITER =     9      P = 0.61154845E 04      OBJ = 0.60935643E 04

 G)S ARE
 0.416843E 01 0.521713E 02 0.755730E-02 0.755730E-02 0.755720E-02
0.755720E-02 0.951225E-02 0.187990E 03 0.196322E 02
 0.196322E 02
FUNCTION CALLS =   135
XNEXT(I) =
 0.120002E 02 0.360249E 00 0.360267E 00


R = 0.34531539E-04
```

```
ITER =     0      P = 0.60730960E 04      OBJ = 0.60723626E 04
ITER =     3      P = 0.60730668E 04      OBJ = 0.60723797E 04

 G)S ARE
 0.416580E 01 0.531341E 02 0.239574E-03 0.239574E-03 0.242187E-03
0.242187E-03 0.303986E-03 0.188000E 03 0.196398E 02
 0.196397E 02
FUNCTION CALLS =    107
XNEXT(I) =
 0.120000E 02 0.360009E 00 0.360011E 00


R = 0.34531539E-07
ITER =     0      P = 0.60717273E 04      OBJ = 0.60717098E 04
ITER =     3      P = 0.60717257E 04      OBJ = 0.60717038E 04

 G)S ARE
 0.416571E 01 0.531650E 02 0.755325E-05 0.755325E-05 0.749465E-05
0.749465E-05 0.964972E-05 0.188000E 03 0.196400E 02
 0.196400E 02
FUNCTION CALLS =    106
XNEXT(I) =
 0.120000E 02 0.360000E 00 0.360000E 00
TOTAL FUNCTION CALLS =    516
ITER =,    0      PF =   0.6071726E 04      OBJ =   0.6071682E 04      X)S ARE
 0.120000E 02 0.360000E 00 0.360000E 00

 G)S ARE
 0.416571E 01 0.531660E 02 0.216122E-06 0.216122E-06 0.730378E-07
0.730378E-07 0.341992E-06 0.188000E 03 0.196400E 02
 0.196400E 02


      HEIGHT      150.00 IN     LENGTH       564.00 IN

   DYNAMIC CONCRETE STRENGTH       4800.00
   DYNAMIC STEEL STRESS           66000.00
   THICKNESS CONCRETE   INCHES     12.0000
   THICKNESS OF SAND    INCHES      0.
   THETA ALLOWABLE      DEGREES     2.0000

   AREA VERT TOP STEEL/FT           0.3600   COVER     3.0000
   AREA VERT BOT STEEL/FT           0.3600   COVER     3.0000
   AREA HORIZ TOP STEEL/FT          0.3600   COVER     3.0000
   AREA HORIZ BOT STEEL/FT          0 3600   COVER     3.0000


   CONCRETE MODULUS PSI                3570519.
   RATIO MOD STEEL/CONCRETE                8.12
   GROSS MOMENT INERTIA                  144.00
   AVE CRACKED MOM INERTIA                14.82
   AVE MOMENT INERTIA                     79.41
   AVERAGE PERCENT STEEL                 0.0033
   D FACTOR MU=1/6                   291637288.
   D FACTOR  MU= 0.3                 311571178.
```

ALLOW SHEAR UNREINFORCED WEB	107.16 PSI		964.45 LBS/IN WIDTH
ALLOW SHEAR AT SUPPORT	760.32 PSI		6842.88 LBS/IN WIDTH

UNREINFORCED CONCRETE THETA LE 2 DEG

POSITIVE VERTICAL MOMENT	17339.57
NEGATIVE VERTICAL MOMENT	17339.57
POSITIVE HORIZONTAL MOMENT	17339.56
NEGATIVE HORIZONTAL MOMENT	17339.56

SUPPORT ON 3 SIDES
YIELD LINE X FROM SIDE

LOCATION YIELD LINE LENGTH	202.70
LOCATION YIELD LINE HEIGHT	150.00
ULTIMATE LOAD CAPACITY RU	4.2203
SHEAR LOAD AT VERTICAL SUPPORT	513.26 LB/IN WIDTH
SHEAR LOAD AT HORIZONTAL SUPPORT	460.72 LB/IN WIDTH
SHEAR AT DISTANCE FROM VERTICAL SUPPORT	54.00 PSI
SHEAR AT DISTANCE FROM HORIZONTAL SUPPORT	48.07 PSI
ALLOWABLE MAX DEFLECTION	5.2469

LOAD MASS FACTOR	0.6030
MASS CONCRETE ONLY	1625.82

FIRST YIELD POINT AT PT2

ELASTIC LIMIT RE PSI	1.49
ELASTIC DEFLECTION XE	0.1996

SECOND YIELD AT PT 3

ELASTO PLASTIC LIMIT	1.93
ELASTO-PLASTIC DEFLECTION	0.2727
ULTIMATE RESISTANCE	4.22
PLASTIC DEFLECTION	2.1461

ULTIMATE RESISTANCE RU	4.22
ELASTIC DEFLECTION LIMIT XE	1.4343
STIFFNESS KE	2.94

MASS	1625.820
LOAD	6.548
DURATION	23.572
RESISTANCE	4.220
STIFFNESS	2 942

GAS PRESSURE	0	DURATION	0.
NATURAL PERIOD			147 696007
MAXIMUM DEFLECTION			1 081181
TIME TO MAXIMUM DEFLECTION			44 491406
DURATION/NATURAL PERIOD			0 159599
LOAD/RESISTANCE			1 551571
ELASTIC DEFLECTION LIMIT			1 434316

MAX FRAGMENT SPALL VELOCITY FT/SEC 3 265566