Computer Automation for Structural Design of Domestic Nuclear Shelters

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Received: 27/8/2015 Accepted: 14/10/2015

ABSTRACT

The structural design of nuclear shelters is different according to the types of these shelters (domestic or public – aboveground or underground – shallow buried or deeply buried – reinforced concrete or glass reinforced plastic or thin metal sheets... etc.). UK and USA performed a calculation using a manual method to calculate the structural design for any domestic nuclear shelter, which may protect the people in it from air blast, thermal and nuclear radiation (gamma rays emanating from fall-out). The manual calculation method is very complex which is very difficult to use, in the present work, a simplified method is prepared, this involves a visual basic computer program to calculate the structural designs for the different domestic nuclear shelters. The program aims to provide the missing time in the calculation processes to calculate the structural design for any domestic shelter through entering specifications data for any domestic shelter. The program will calculate the structural design in a very short time which will save the effort and time in comparison with the manual calculation. Also, the computer program gives more accurate results than the manual method.

Key Words: Computer Automation / Structural Design / Domestic Nuclear Shelters.

INTRODUCTION

In addition to providing protection against thermal and nuclear radiation, purpose-built nuclear shelters should be designed to resist the air blast effects of nuclear explosions (1). Shelters are usually placed below ground so that the effects of blast are reduced, although comparable levels of blast (and fallout) protection can be obtained above ground by using thicker elements (2). Where structural elements are required to sustain relatively large direct blast loads they need to be of heavy ductile construction e.g. reinforced concrete. However, structures constructed of thin-walled materials such as glass reinforced plastic (GRP) or thin metal sheeting can also be used in shelters, but their ability to withstand blast loading depends on their shape, how carefully they have been manufactured and their interaction with the earth cover (3). Spheres or similar shapes are the most effective but special attention must be given to weak points such as joints and entrances. Thin walled lightweight structural shells obviously offer little protection against radiation, and need to be combined with dense cover to obtain radiation protection (4).

1. General Approach to Structural Design for Blast Resistance

The effects of blast loading are reduced significantly when shelters are deeply buried (i.e. when the earth cover is equal to or greater than about half the width of the shelter) as the overpressure is attenuated with depth and the soil acts as an arch above the shelter and takes parts of the vertical load (5).

The present research sets out guidelines for the structural design of surface or shallow buried rectangular domestic shelters constructed of reinforced concrete, or steel plate for overpressures up to

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3 atmospheres (315 kPa or 45 psi), and provides a simplified dynamic design method. Above this overpressure other factors will need to be taken into consideration (6).

The design rules in this research have been limited to the analysis of one- and two-way spanning slabs likely to be used in rectangular shelters as this shape is considered to be the most cost effective for materials such as reinforced concrete (7). The general principles of dynamic analysis covered can be used for shelters of other shapes e.g. cylinders, arches, spheres etc. The method of analysis presented is not mandatory and the design engineer can use other appropriate methods (8).

2. Simplified Dynamic Blast Design (9)

2.1 Basic Principles of Blast-Resistant Design of Ductile Structural Elements

The ultimate load capacity of a ductile structural element subjected to blast loading can be determined by considering its capability of sustaining external load by relatively large plastic deformations. The design rules in this research will limit the magnitude of the plastic deformations and thus the level of damage to the structural elements to a condition of moderate damage, where there will be considerable yielding of steel and cracking of concrete, but no significant impairment of the resistance to further loading.

2.2 Blast Loads

Blast loads F on surface and shallow buried shelters are presented in Fig. (1).

<table>
<thead>
<tr>
<th>Shallow buried</th>
<th>Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In dry ground</td>
</tr>
<tr>
<td>Roof + floors</td>
<td>Pso</td>
</tr>
<tr>
<td>Walls</td>
<td>0.5 Pso</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. (1): Blast loads on shallow buried and surface shelters.

Pso = overpressure

Dead loads, soil and water loads should be added to the blast loads given above.

A. Roof Elements

The roof should be designed for the full overpressure, plus the dead loads of the concrete and earth cover.

B. Wall Elements

Surface shelters require thicker walls than buried structures, as the blast wave is reflected and increased when it comes into contact with the face of the shelters. A value of 2.3 times the overpressure should be used for design.

Walls of shallow buried shelters are subjected to smaller loads than the above-ground case. For the purpose of these design notes a value of one-half the overpressure should be used, unless the shelter is constructed in ground with a high water table, where the full overpressure should be used. The earth and water pressure acting on the walls must also be added to the blast loading.

C. Floor Slabs

The floor slab should be designed for blast loading and the dead weight of the shelter. The design blast loading acting on the floor should be taken as that acting on the roof, the dead weight of
the entire shelter (with the exception of the floor slab) and any earth cover are to be included as permanent loads.

An approximate conservative analysis can be carried out assuming that these loads are uniformly distributed over the floor. In reality there will be a decrease in the calculated maximum bending moment as a result of the arching effect of the soil, but this will depend on the type of soil and position of the ground water level.

2.3 Dynamic Analysis of Shelter Elements

A rigorous dynamic design of a shelter will depend on the mass and stiffness of the shelter elements, and if a full dynamic design is considered applicable, the design engineer should refer to the many publications on dynamic design.

For ductile thick walled structures exposed to overpressure of up to 3 atmospheres from nuclear explosions, a safe solution can be obtained by assuming that the load duration is relatively long in relation to the period of inelastic response of the elements, and the following equation can be used:

\[
r_u = F \left( \frac{1}{1 - \frac{1}{2\mu}} \right)
\]

where required \( r_u \) = ultimate unit resistance

\( F = \) blast load (from Fig. 1)

\( \mu = \) ductility ratio = \( \frac{\text{permitted deflection}}{\text{deflection at the elastic limit}} \)

The amount of plastic deformation can be controlled by varying the value of \( \mu \). Below \( \mu = 1 \) the element will remain elastic and above \( \mu = 1 \) plastic deformation will take place. For moderate damage \( \mu \) should be taken as 3 and the equation becomes:

\[ r_u = 1.2 F \]

The expression \( \frac{1}{1 - \frac{1}{2\mu}} \) can be considered in terms of a partial safety factor for load \( \gamma_f \).

Thus for moderate damage \( \gamma_f = 1.2 \)
2.4 Design of Rectangular Reinforced Concrete Slabs for Blast Loading

2.4.1 Allowable Stresses

The behavior of structural elements subjected to blast loading depends on the ultimate strength and the ductility of its material. Reinforced concrete has sufficient ductility to allow dynamic increase factors (DIF) to be applied to the characteristic strengths of materials.

Dynamic increase factors for reinforced concrete are given in Fig. (2).

<table>
<thead>
<tr>
<th>Stresses</th>
<th>DIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel - bending</td>
<td>1.10</td>
</tr>
<tr>
<td>Concrete - compression</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Fig. (2): Dynamic increase factors (DIF).

2.4.2 Ultimate Unit Resistance

The ultimate resistance of an element varies with:

a. The distribution of applied loads.

b. The geometry of the element.

c. The percentage of reinforcement.

d. Type of support.

One-Way Elements:

For one-way elements the ultimate resistance is a function of the moment capacity at the first yield plus the moment capacity due to subsequent yielding at other critical sections.

Values of the ultimate unit resistance \( r_u \) for several one-way elements are shown in Fig. (3) where the following symbols are used:

\[ M_N = \text{ultimate unit negative moment capacity at the support.} \]

\[ M_P = \text{ultimate unit positive moment capacity at mid-span.} \]

\[ L = \text{span length.} \]
Edge condition & Ultimate unit resistance $r_u$  
---
Cantilever & $\frac{2MN}{L^2}$  
Simple supports & $\frac{8M_p}{L^2}$  
Fixed supports & $\frac{8}{L^2} (M_N + M_p)$  
Fixed simple support & $\frac{4}{L^2} (M_N + 2M_p)$

**Fig. (3):** Ultimate resistance of one-way elements.

**Two-Way Elements:**

Two-way elements can be analyzed using the yield line theory.

The value of the ultimate unit resistance $r_u$ for a two-way slab is given:

$$r_u = \frac{8 (M_N + M_p) (3L - x)}{H^2 (3L - 4x)}$$  (short span)

$$r_u = \frac{5 (M_N + M_p)}{X^2}$$  (long span)

**2.4.3 Ultimate Unit Moment Capacity**

The ultimate unit moment capacity of a reinforced concrete element subjected to blast loading can be found by using the following equations: safety factors for steel and concrete, $\gamma_{M}= 1$.

$$M_u = f_y \text{dynamic} \, A_{s} \, Z$$

$$M_u = 0.225 \, f_{cu} \text{dynamic} \, bd^2$$

$$Z = \left(1 - \frac{0.84 \, f_y \text{dynamic} \, A_{s}}{f_{cu} \, bd}\right) \, d \quad \text{but not greater than} \, .95 \, d$$

Where
\[ M_u = \text{ultimate resistance moment} \]
\[ f_{y \text{ dynamic}} = (\text{characteristic strength of reinforcement}) \times \text{(a dynamic increase factor)} \text{ from Fig. (2)} \]
\[ f_{cu \text{ dynamic}} = (\text{characteristic strength of concrete}) \times \text{(a dynamic increase factor)} \text{ from Fig. (2)} \]
\[ Z = \text{lever arm} \]
\[ A_s = \text{area tensile reinforcement} \]
\[ b = \text{width of section} \]
\[ d = \text{effective depth of section} \]

The ultimate resistance of the section may be taken as the lesser of the values obtained from the above equations.

### 2.4.4 Ultimate Shear Capacity

Slabs and walls should be designed without shear reinforcement. The ultimate shear stress in reinforced concrete should be limited to 0.04 \( f_{cu} \) where \( f_{cu} = \text{characteristic strength of concrete} \).

The ultimate shear stresses on one-way spanning elements are given in Fig. (4).

<table>
<thead>
<tr>
<th>Edge conditions</th>
<th>Ultimate shear stress on a section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantilever</td>
<td>[ M_u \frac{(L-d)}{d} ]</td>
</tr>
<tr>
<td>Fixed or pinned support</td>
<td>[ M_u \frac{(L/2-d)}{d} ]</td>
</tr>
</tbody>
</table>

**Fig. (4):** Ultimate shear on one-way spanning elements.

Where \( d = \text{effective depth of section} \).

### Minimum Area of Flexural Reinforcement

To ensure the proper structural behavior and also to prevent the excessive cracking or deformations, the minimum areas of flexural reinforcement given in Fig. 5 are recommended:

<table>
<thead>
<tr>
<th>Reinforcement</th>
<th>Mild steel</th>
<th>Hot rolled high tensile bars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main</td>
<td>0.25% ( bd )</td>
<td>0.20% ( bd )</td>
</tr>
<tr>
<td>Secondary</td>
<td>0.15% ( bd )</td>
<td>0.12% ( bd )</td>
</tr>
</tbody>
</table>

**Fig. (5):** Minimum area of flexural reinforcement.

where \( d = \text{effective depth of slab required to resist blast loading} \).

### 2.5 Design of Steel Plate Elements\(^{(10)}\)

#### 2.5.1 Allowable Stresses
A dynamic increase factor of 1.10 can be used for bending of steel.

### 2.5.2 Ultimate Unit Resistance

The ultimate unit resistance of steel plate elements can also be determined from the yield line theory and thus the table and equations in 2.4.2 can be used.

### 2.5.3 Plastic Moment Of Resistance

The greatest moment a steel member can sustain at full plasticity is the plastic moment of resistance:

\[ M_u = Z_p \times f_{y,\text{dynamic}} \]

where

\[ Z_p = \text{plastic modulus } = \frac{bd^2}{4} \text{ for a rectangular section, and} \]

\[ f_{y,\text{dynamic}} = \text{(yield stress of steel)} \times \text{(a dynamic increase factor)} \]

### 2.5.4 Shear

The dynamic shear stress for mild steel should not exceed 172 N/mm².

### 2.5.5 Connections

Bolts should be black bolts. High strength friction grip bolts should not be used.

The allowable dynamic stresses for bolts and welds are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Bolts: Tension</th>
<th>275 N/mm²</th>
<th>Welds: Tension or compression</th>
<th>275 N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear</td>
<td>170 N/mm²</td>
<td>170 N/mm²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bearing</td>
<td>410 N/mm²</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.6 Notes on Construction (11)

1. Materials and construction standards for reinforced concrete should generally comply with the British Standard Code of Practice CP 110 and BS 449 for structural steelwork.

2. Reinforcement is to be mild steel or hot rolled high tensile bars to BS 4449. Cold worked high yield bars must not be used.

3. Continuous reinforcement should be used wherever possible. Where it is necessary to have reinforcement laps the lap length must = 72 x diameter of bar.

4. All concrete must be thoroughly vibrated.

5. Construction joints should be kept to a minimum.

6. A 225 mm wall kicker should be cast with the floor slab.
7. No material should be applied to the inside walls or ceiling of the shelter that could become a hazard.

8. Sulphate resisting cement should be used in circumstances where soils contain sulphates to a dangerous degree. No other additives should be added to concrete.

9. A sump should be provided at the lowest level to enable any water that enters the shelter to be collected.

10. External elements of buried and shallow buried shelters should be protected by a water proof membrane.

2.7 Design Procedure

Step 1. Determine design stresses using dynamic increase factors from Fig. (2).

Step 2. Determine the external blast load for the element under consideration from Fig. (2).

Step 3. Calculate the ultimate resistance \( r_u \) required to sustain the design overpressure. For moderate damage:

\[ \gamma_f = 1.2 \]

\[ \therefore r_u = 1.2 F \]

where \( F \) = blast load from Fig. 2.

Add the dead and earth pressure loads to obtain the required \( r_u \).

Step 4. Calculate the magnitude of the ultimate moment capacity required to accommodate the required \( r_u \).

Step 5. Select a depth of member and a percentage of reinforcement to provide an adequate ultimate moment capacity.

Step 6. Check that the percentage of reinforcement provided exceeds the minimum values given in Fig. (5).

Step 7. Check shear.

Step 8. Check the radiation protective factor.
Examples of the Simplified Method of Design are:

**Example (1):** One atmosphere shallow buried domestic shelter. Reinforced concrete roof.

<table>
<thead>
<tr>
<th>Data</th>
<th>Calculation</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Given: 2440 mm clear span, one way spanning with fixed supports. 250 mm thick slab, with 50 mm cover to steel.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade 30 concrete ( f_{cu} = 30 \text{ N/mm}^2 )</td>
<td>( f_{cu} = 30 \text{ N/mm}^2 )</td>
<td></td>
</tr>
<tr>
<td>Mild steel ( f_y = 250 \text{ N/mm}^2 )</td>
<td>( f_y = 250 \text{ N/mm}^2 )</td>
<td></td>
</tr>
<tr>
<td>Consider 1 mm width of slab.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIFs from Fig. (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 1: Design stresses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_{cu \text{ dynamic}} = 1.25 \times 30 = 37.5 \text{ N/mm}^2 )</td>
<td>( f_{cu \text{ dynamic}} = 37.5 \text{ N/mm}^2 )</td>
<td></td>
</tr>
<tr>
<td>( f_{y \text{ dynamic}} = 1.1 \times 250 = 275 \text{ N/mm}^2 )</td>
<td>( f_{y \text{ dynamic}} = 275 \text{ N/mm}^2 )</td>
<td></td>
</tr>
<tr>
<td>Step 2: Blast load</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F = P_{so} = 1 \text{ atmos} = 0.1 \text{ N/mm}^2 ) (14.5 psi)</td>
<td>( F = 0.1 \text{ N/mm}^2 ) (14.5 psi)</td>
<td></td>
</tr>
<tr>
<td>For ( \mu = 3 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( r_u ) for blast = ( 1.2F = 1.2 \times 0.1 = .12 \text{ N/mm}^2 )</td>
<td>( \text{Req'd } r_u = 0.134 \text{ N/mm}^2 ) (19.48 psi)</td>
<td></td>
</tr>
<tr>
<td>Add dead load cone + soil = .014 ( = 0.134 \text{ N/mm}^2 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 3: Required ( M_u )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For square two way spanning slab ( M_u ) req'd = ( r_u \frac{L^2}{16} )</td>
<td>( M_u ) req'd = 49861 Nmm/mm</td>
<td></td>
</tr>
<tr>
<td>( = \frac{.134 \times 2440^2}{16} = 49861 \text{ Nmm/mm} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 4: Required ( M_u )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide same steel top and bottom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>250 mm slab ( A_s = 1.005 \text{ mm}^2/\text{mm} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( d = 250 - 58 = 192 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Z = (1 - \frac{0.84 f_{y \text{ dynamic}} A_s}{f_{cu} bd}) d )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( = 192 - \frac{0.84 \times 275 \times 1.005}{37.5} = 185.8 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or ( = 0.95 \times 192 = 182 \text{ mm} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Take ( Z = 182 \text{ mm} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M_u = f_{y \text{ dynamic}} A_s Z )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( = 275 \times 1.005 \times 182 = 50,300 \text{ Nmm/mm} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( &gt; 49861 \text{ Nmm/mm} )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Step 5: Reinforcement**

Try R16 @ 200 c/c

\[ Z = (1 - \frac{0.84 f_{y \text{ dynamic}} A_s}{f_{cu} bd}) d \]

or \( = 0.95 \times 192 = 182 \text{ mm} \)

Take \( Z = 182 \text{ mm} \)

\( \therefore M_u = f_{y \text{ dynamic}} A_s Z \)

\( = 275 \times 1.005 \times 182 = 50,300 \text{ Nmm/mm} \)

\( > 49861 \text{ Nmm/mm} \)

Use R16@ 200 c/c top and bottom in short span
### Step 6: Check min steel

Main = 0.25% x 1 x 192 = 0.48 mm²/mm

1.005 mm²/mm provided OK.

Other 0.15% x 1 x 192 = 0.29 mm²/mm

Provide R10 @ 200 c/c (0.392 mm²/mm)

Use R10 @ 200 c/c top and bottom sec steel

### Step 7: Check shear

\[
\text{Shear} = \frac{r_o \left( \frac{L}{2} - d \right)}{d} = \frac{134(1220 - 192)}{192} = 0.72 \text{ N/mm}^2
\]

<1.2 N/mm² OK

### Allowable shear

\[
= 0.04 f_{cu} \\
= 0.04 \times 30 \\
= 1.2 \text{ N/mm}^2
\]

### Summary of results

Slab thickness : 250 mm

Main steel: R16 @ 200 c/c top and bottom

Sec steel: R10 @ 200 c/c top and bottom
Example 2. One atmosphere shallow buried domestic shelter. Steel blast door.

<table>
<thead>
<tr>
<th>Data</th>
<th>Calculation</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Given:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear opening 600 mm x 1800 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild steel $f_y = 250$ N/mm$^2$</td>
<td></td>
<td>$f_y = 250$ N/mm$^2$</td>
</tr>
<tr>
<td><strong>Step 1: Design stresses</strong></td>
<td>$f_{y\text{, dynamic}} = 1.1 \times 250 = 275$ N/mm$^2$</td>
<td>$f_{y\text{, dynamic}} = 275$ N/mm$^2$</td>
</tr>
<tr>
<td><strong>Step 2: Blast load</strong></td>
<td>$F = 2.3 P_{uo} = 2.3 \times 0.1 = 0.23$ N/mm$^2$ (33.35 psi)</td>
<td>$F = 0.23$ N/mm$^2$ (33.35 psi)</td>
</tr>
<tr>
<td>For $\mu = 3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 3: Required $r_u$</strong></td>
<td>$r_u$ for blast = 1.2 $F = 1.2 \times .23 = 0.276$ N/mm$^2$</td>
<td>Req'd $r_u = .276$ N/mm$^2$ (40 psi)</td>
</tr>
<tr>
<td><strong>Step 4: Required $M_u$</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eff span = 650</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slab one way spanning, simply supported</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M_u\text{ req'd} = \frac{.276 \times 620^2}{8} = 13262$ Nmm/mm run</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Member size</strong> (consider 1 mm width)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Z_p = \frac{bd^2}{4} = 1 \times 15^2 = 56.26$ mm$^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M_u\text{ provided} = Z_p \times f_y$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$= 56.25 \times 275 = 15468$ Nmm/mm run</td>
<td></td>
<td>Use 15 mm mild steel plate</td>
</tr>
<tr>
<td>$&gt; 13262$ Nmm/mm run OK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note

Thickness of blast door may have to be increased for fallout protection against radiation, e.g. by steel/cone sandwich construction.
2.8 Suggested Reinforced Concrete Detailing

Suggested reinforced concrete detailing is shown in Figs. (6) and (7).

**Fig. (6):** Reinforced concrete simply supported elements.
3. A Computer Program for Structural Design of Domestic Nuclear Shelters

The steps of design procedure have been automated using Visual basic program \(^{13,14}\). The program consists of two directions: reinforced concrete roof and steel blast door, and the user can choose one of them. Then, the program begins to calculate the structural design of the domestic nuclear shelter according to equations and procedure mentioned in 2.7. If the user choose reinforced concrete roof button it opens another form which contains places for the user to enter the roof specifications, as shown in Fig. (8, 9). Then, the user press ok after he finishes and return back to the main form to choose entering specifications for steel blast door of the domestic nuclear shelter as shown in Fig. (11, 12). Finally, the program calculates the structural design after pressing "ok" button as shown in Fig. (10, 13). The computer calculation gives more accuracy and faster results.

The computer program architecture consists of three main modules: database module, user interface to enter the reinforced concrete roof specifications and the steel blast door specifications, and finally, the structural design results.
The user enters data through user interface and then the processor uses this data to get the required fields from database. Finally, the processor calculates the structural design according to the input data and database. The final result is introduced in the form of report for printing.

Fig. (8): Calculations of (Reinforced concrete roof of one atmosphere S. B. D. Shelter) User Interface.

Fig. (9): Fulfilling of Calculations of (Reinforced concrete roof of one atmosphere S. B. D. Shelter).
Fig. (10): Results of Calculations of (Reinforced concrete roof of one atmosphere S. B. D. Shelter).

Fig. (11): Calculations of (steel blast door of one atmosphere S. B. D. Shelter) User Interface.
Fig. (12): Fulfilling of Calculations of ( steel blast door of one atmosphere S. B. D. Shelter ).

Fig. (13): Results of Calculations of ( steel blast door of one atmosphere S.B. D. Shelter ).

RESULTS
In this research, the author chose a domestic nuclear shelter and calculated the structural design of reinforced concrete roof and the structural design of steel blast door using the manual calculation method and using the subjective program. The comparison of results of the two methods proved that the program gives more accurate and faster results than the manual method.

CONCLUSIONS

The manual calculations method of structural design for any domestic nuclear shelter is a very complex process which needs very long time to get the results as well as the possibility of more faults, but using the computer program the time and effort could be saved and also the accuracy increased with rare possibility for faults. So, the main goal from the research has been done.

RECOMMENDATIONS

It is recommended to use the subjective computer program for structural design of domestic nuclear shelters.

The design of shelters consists of lightweight flexible building material such as GRP or thin metal sheets and the design of deeply buried shelters are not covered in this research. It is recommended to conduct research on these types of domestic nuclear shelters.

It is recommended that the structural design and construction of shelters, designed for loading, should be supervised by a civil or architectural engineer experienced in structural design and practice.

ACKNOWLEDGEMENT

The author would like to thank Prof. Dr. Hisham El-Arabaty, Professor of Civil Engineering, Faculty of Engineering, Ain Shams University, for his kind support and his useful discussions.

The author wishes to express his thanks to A. Prof. Dr. Ahmed Hasan Madian, A. Professor of Computer Engineering, Radiation Engineering Department, NCRR, Atomic Energy Authority, for his kind support and his fruitful discussions.

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