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Mitigation of Blast Propagation in Undrground Spaces

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Abstract— "Protection against Terrorism" is an emerging factor which influences the urban planning process offering a new dimension to town planning.In urban settings; such public buildings may be underground at the heart of major cities, offering closed or semi-closed collective spaces. In such spaces, enhancement of the blast waves can occur by reflection and the structures will receive multiple shocks.

This paper presents the findings from a programme of research, which explores the opportunities offered by an effective town planning approach. Specifically it looks at the protection, which derives from using spatial forms to mitigate the effect of blast waves in underground spaces, as assessed with the AUTODYN simulation package 3D V3.0.07.

Index Terms— Architecture, Autodyn, Blast, Protection, Computation, mitigation, propagation, Terrorism, Underground,

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1 Introduction

In early civilizations, the main aims of establishing underground spaces were to provide protection against climate and to offer physical security.

Faced with the challenge of 21st century, the dominant threat to physical security is from terrorist attacks. In 1995, Japan suffered the world's first large-scale terrorist chemical gas attack in underground facilities, when a Japanese religious cult, Aum Shinrikyo or Aum Supreme Truth, attacked the Tokyo subway system, which is located underground, on March 20th. Five subway trains were simultaneously attacked, killing 12 people. About 5,500 people were sent to area hospitals for treatment from symptoms of chemical poisoning from sarin gas. Foreigners, including, one Swiss, one Irishman, two US citizens and two Australians, were among those who sought treatment for chemical exposure [1-3]. In early civilizations, the aims of establishing underground spaces were to provide protection against climate and to offer physical security.

The Urban Planner has a contribution to make in the enhancement of spatial survivability by optimising the town planning configuration (Space form, squares, landscape, street architecture… etc.) to provide a measure of protection without compromising appearance and utility.

Urban Planning is an integration process between the Urban Planning positive phase "The Structures" and the Urban planning negative phase "The Spaces" (streets, squares, public space … etc.). Each of them has measurements to reduce the effects of the threat to certain protection level. If both are combined, the effect of the threat will be reduced to a minimum

Focusing on the urban planning negative phase, the spaces, especially underground spaces, this paper describes the concept of using specific underground space forms to mitigate the effects of the blast wave values on the structures.

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2 Simulation Organization

2.1 Underground space classification

Underground Space can be categorized on the basis of the architectural design for the plan and section of the space, [4] as shown in figure 1, which identifies two categories of simulations:

- ***Group A (Closed space).***
- ***Group B (Connected space).***

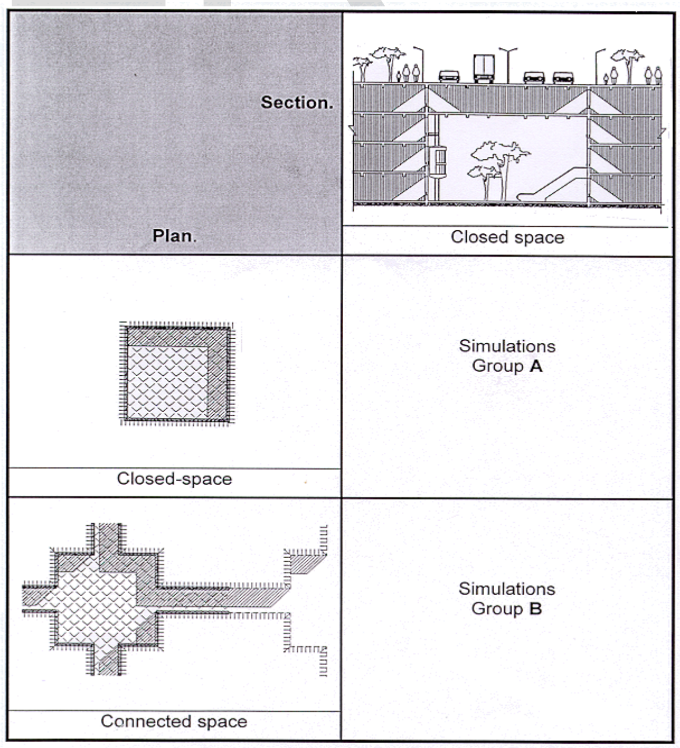


Fig. 1 Underground Space Classification

2.2 The spatial forms of underground space

Several scenarios were prepared to simulate a comprehensive range of spatial forms as shown in figure 2:

- Spaces with flat surfaces. [Triangular, cubic, pentagon, hexagon … etc.]
- Spaces with curved surfaces. [Cylindrical, concave plan, convex plan … etc.]

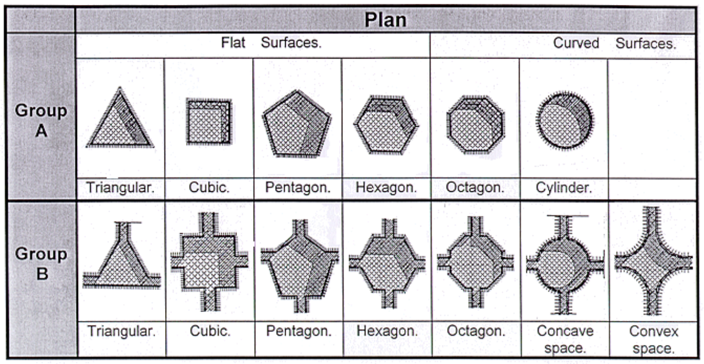


Fig. 2 The Spatial forms of underground space.

3 Reference Scenario

The Reference scenario, with which each group of simulations will be compared, is an explosion in the centre of the cylindrical underground space as shown in figure 3.

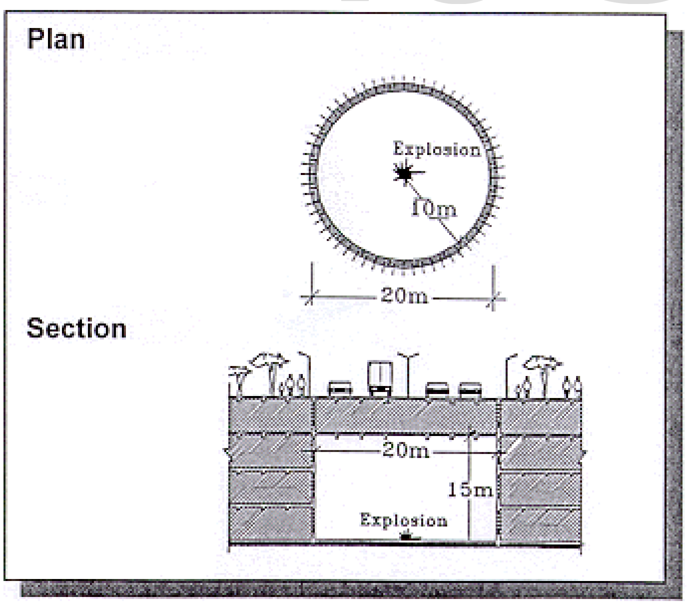


Fig. 3 Reference Scenario

The AUTODYN simulation package 3D V3.0.07,[5], was used to evaluate the impulse values on the structural elements, which enclose the space. Values obtained using the AUTODYN simulation package were validated using the ConWep programme [6]. This programme is based on measured impulse values from real events [Figure 4]. To aid comparison between simulations, all spaces were given the same dimensions, i.e. 10 m from centre of the space to any boundary, and 15 m in height

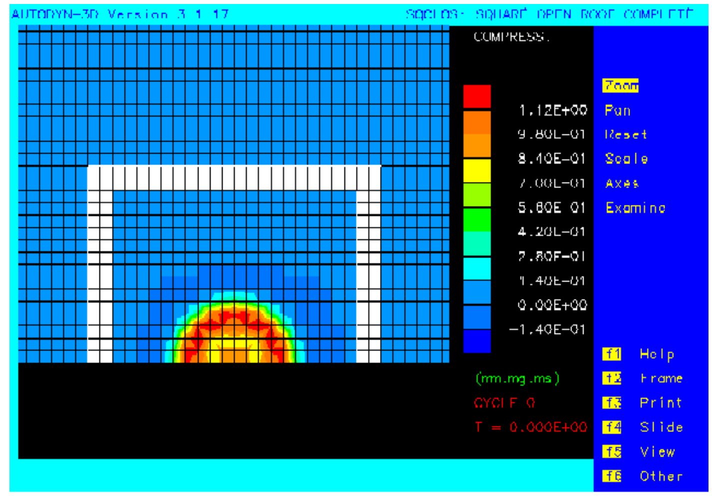


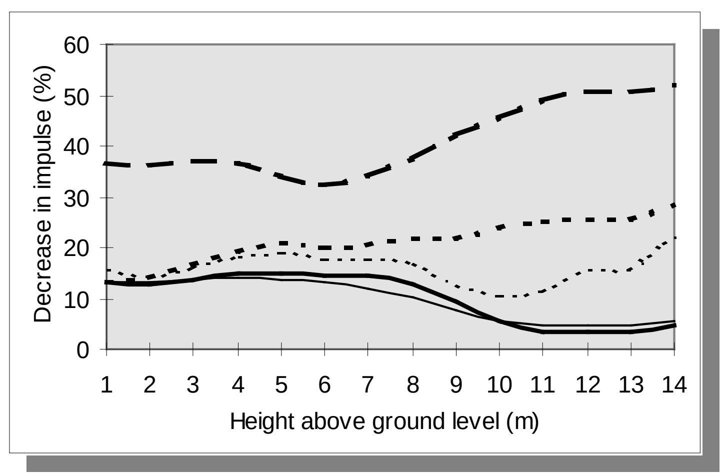
Fig. 4 Typical Reference scenario in Autodyn simulation with detonation after 7.923 ms

4 Results

The impulse values are presented for the mid-point of the sides, which form the spaces since: These are always at the same range from the explosion; also, they represent the most critical locations from a structural point of view.

4.1 Results of Group A

Figure 5 shows that the decrease in the impulse values, compared to the reference scenario, experienced by the walls of the enclosed space.



Triangular — — Square ······ Pentagon ———
Hexagon ▬▬ Octagon ———

Fig. 5 The decrease in impulse values (%), compared with the reference scenario, Vs Height (m) of group A.

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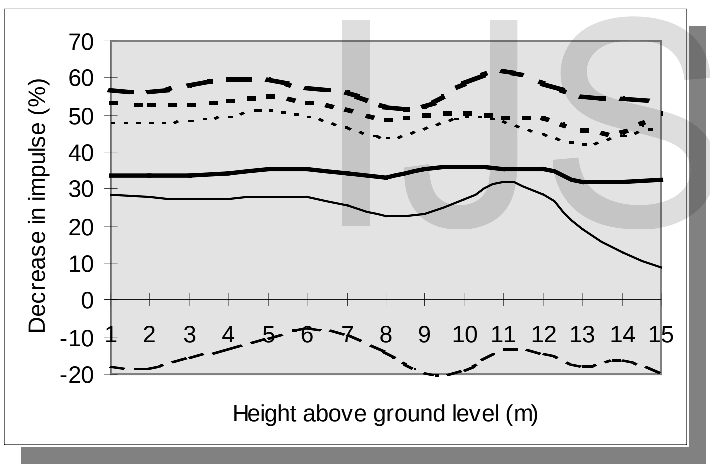
- *Triangular* plan of the spatial form, three sides, the impulse values were reduced by up to 51 % when compared with the initial case [the cylindrical spatial form].
- *Cubic* spatial forms, four sides, offered a reduction in the impulse values of up to 30% when compared with the initial case.
- *Pentagon* plan of the spatial form, five sides, the impulse values were reduced by up to 23 % when compared with the initial case.
- *Hexagon* and octagon plan of the spatial form, six and eight sides, the impulse values were approximately the same, and offered a reduction of up to 14 % when compared with the initial case.

4.2 Results of Group B

The connection openings between spaces offer evacuation routes for the blast waves. The reduction depends upon the number of openings and their dimensions. [For this paper, each underground spatial form has four openings with 4m width and 6m height]. Comparing fig. 6 with fig. 5 shows that spaces with connection openings show a greater reduction in impulse than the equivalent space without openings.



Triangular — — Square ...... Pentagon ——
Hexagon ▬▬ Octagon —— Convex space – – – –

Fig. 6 The decrease in impulse values (%), compared with the reference scenario, Vs Height (m) at mid-point of sides of group B

- The *triangular* plan of the spatial form with connection openings can offer reduction in the impulse values of up to 58% when compared with the initial case. [The cylindrical spatial form without openings].
- The *cubic* spatial form offered a reduction in the impulse values of up to 55 %, when compared with the initial case.
- The *pentagon* plan of the spatial form, the impulse values were reduced by up to 50 %, when compared with the initial case.
- The *hexagon* plan of the spatial form, the impulse values were reduced by up to 35 %, when compared with the initial case.
- The *octagon* plan of the spatial form, the impulse values were reduced by up to 28 %, when compared with the initial case.
- The *convex plan* of the space caused an increase in the effect of the blast waves inside the space of up to 20 %, when compared with the initial case.

5 Further Protection

Cylindrical, hemi-spherical, frustum and inverted frustum spaces are examples of the spatial forms, which can be used in the architectural design of underground space as shown in figure 7. The initial case, with which all simulations are compared, is the hemi-spherical space. The impulse values are taken at the midpoints of the sides, which form the space and all spaces

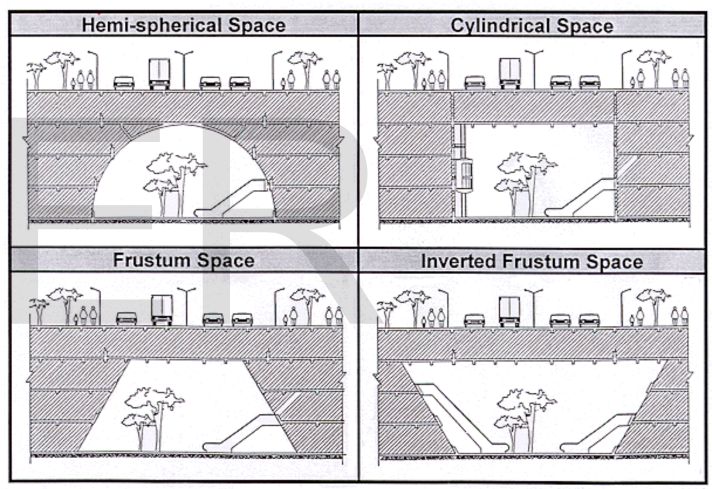
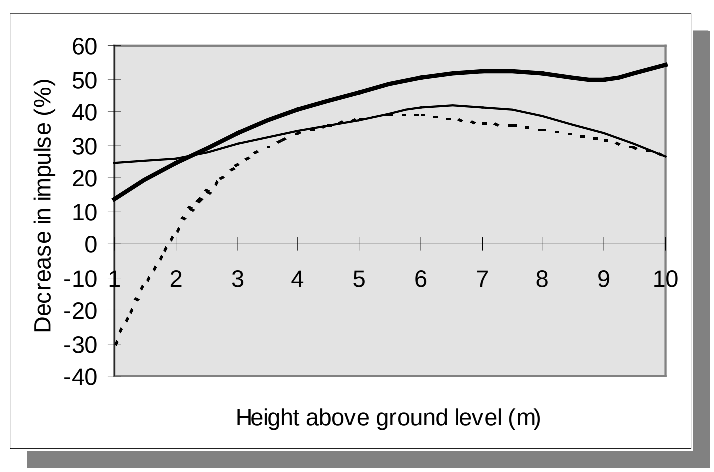


Fig. 7 Underground spatial forms



Cylindrical space ▬▬ Frustum space ——
Inverted Frustum space ——

Fig. 8 The decrease in impulse values (%), compared with hemi-spherical space Vs Height (m).

Figure 8 shows that the cylindrical spatial forms can offer reduction in the effects of the blast waves inside the space of up to 54%, when compared with a hemi-spherical spatial form, as an initial case.

The Frustum space can offer a reduction of up to 38%, when compared with the initial case, but increase of 30% at floors level. The Inverted frustum space can offer a reduction of up to 41%, when compared with the initial case.

6 Conclusion

1. Specific spatial forms can offer a significant reduction in the effects of blast waves inside underground space.
2. Cylindrical and inverted frustum geometries are better than a frustum and hemi-spherical geometries for reducing the effects of the blast waves
3. The results declare that each spatial form can offer a certain reduction in the effects of the blast waves.
4. The results declare that each spatial form can offer a certain reduction in the effects of the blast waves.
5. Connection openings between underground spaces can offer a reduction of blast waves through venting.
6. The technique of using specific spatial forms to reduce the effects of blast waves can be used without affecting the functionality of the space.
7. The Autodyn simulation package was found to be a convenient tool for measuring the effectiveness of using spatial forms in reducing the effects of the explosion.

References

[1] Scottish Development Department, the Welsh office report, " Roads in Urban Areas,"the Welsh office, 1993.

[2] I.Bently, A.Alcock, P.Murrain, S.McGlynn, and G. Smith, "Responsive Environments, architecture department and joint Centre for Urban Design," Oxford polytechnic, 1996.

[3l H. Kady, "The Architectural treatments for protecting structures," *M.Sc. thesis*, Military Technical Collage, Cairo, Egypt, 2003.

[4] E.H. Mahmoud,"Protection against Blast Waves," *3rd International Conference on SHOCK & IMPACT LOADS ON STRUCTURES*, Singapore, 2003.

[5] "Autodyn program V3.1.17," *Century Dynamics Limited*, 12 City Business Centre, Brighton Road, Horsham, USA, 2010.

[6] "ConWep Program," *U.S. Army Engineer Waterways Experiment Station*, 3909 Halls Ferry Road, Vicksburg, MS 39180, 2010.