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GUIDELINES FOR THE DESIGN OF PROTECTIVE STRUCTURES

G.J. de Ridder

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G J de Ridder
Pr. eng Ms (Calif)

Partner : Burger Pretorius & Partners cc
Kasteelstraat 61, Lynnwood, Pretoria

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A newly published design guide for the planning and structural design of protective buildings subjected to explosion blast loading is overviewed. This document was initiated by the Structures Division of SAICE. It is essential a literature reference survey but presents synoptic explanations on interpretation and application of a wide spectrum subjects mostly encountered in this specialised discipline of structural engineering.

Introduction

The physical protection of buildings is becoming increasingly of great concern to their owners and consequently to their designers. The two major contributing factors are expanding industry and escalating terrorism world wide.

Industrialization increases the risk of catastrophic accidents of explosion, for example at SAPPI-Ngodwana, Secunda and at Modderfontein not long ago.

Terrorism breeds aggressor tactics like the car bomb, incendiary bombs, hand-held rockets, limpet and other types of mines. Many examples can be cited where these instruments have severely or catastrophically damaged conventional buildings not to mention incalculable loss of life and hard assets.

A proper planning scheme for the protection of a building is generally divided into the Active and the Passive aspects. These apply for both existing and newly planned buildings.

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The Active aspects deals with operational countermeasures which require human intervention like guards, access control etcetera.

Passive countermeasures, which facilitate and enhance the active measures, are the responsibility of architects and engineers. Architects incorporate planning and functional security measures, while structural engineers design the structural elements to resist blast, fire and fragment effects. The latter discipline has become known as HARDENING of buildings.

The objective of the physical security design is to optimise the protection level within the design constraints of the project. Ideally, security issues should be addressed throughout the design process; not as an afterthought.

In the GUIDELINES FOR THE DESIGN OF PROTECTIVE STRUCTURES some fundamental principles of military facility design are applied in developing a rational approach to the hardening of civilian building structures.

STATE OF THE ART IN THE RSA

The application of protective design principles and hardening of buildings in the RSA is still in an developing stage, generally speaking.

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Individual examples exist, where the protective design is on par with the current international art. Due to security restrictions however, case studies of such have not been published locally but it is believed that exchange of experience and knowledge will become ever more available.

It is one of the most difficult but interesting subjects in structural engineering, requiring and relying heavily on empirical data and specialized test facilities. For this reason virtually all knowledge and data available in the RSA is "imported" from the USA, UK, Switzerland and some others where extensive data-bases exist. In some instances, verification of these is being undertaken in the RSA.

No formal educational course is offered by any teaching institution locally although specialized courses have been offered in the UK and it is believed being planned in the USA. However, considerable knowledge is available in the RSA through some private and institution libraries, enabling the proper design of protection.

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OVERVIEW OF GUIDELINES FOR THE DESIGN OF PROTECTIVE STRUCTURES

Some literature and a certain amount of knowledge on the subject of structural design for blast or impact loading on protective structures is available in South Africa. These sources of knowledge are not readily available to all engineers and different solutions can be achieved by using different sources, because one is dealing with an empirical, statistical based technical science which is continuously developing. Furthermore, the exchange and dissemination of state-of-the-art knowledge is not as free and unclassified as most other enigneering sciences in the international collegium. Protective design knowledge tend to be controlled by national interest criteria.

Most information is of American and Swiss origin, while British releases are becoming available now. Some South African institutions and individuals have compiled useful literature and experience. The need to consolidate and unify these have been recognised and set to task by the SAICE through the Committee on Protective Structures who started work in 1985.

The GUIDELINES discussed here-after is by no means completed, but the fundamental aspects are consolidated into a useful guide : Blast loading, quasi-dynamic analysis under blast loading, material characteristics and behaviour and miscellaneous design detail recommendations. Subjects not dealt with and which are under research for future revision of the Guidelines are : Fibrous material compositions, composite construction, schrapnel and secondary missile effects, safety glazing, industrial explosion effects and the methology whereby threat level or threat criteria can be established for a particular scenario.

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It is explicitly emphasized that this document should not be regarded as a Design stand-alone Code, or as a Handbook. The subject is far too vast and specialised; It is however presented as a literature survey Guide with synoptic explanations on the interpretation and useage of various sources for pertinent subjects which are most often encountered in the design process.

SUBJECT CONTENTS OF THE GUIDELINES

The subject material is arranged under 5 basic chapters.

1. Blast loading

2. Construction Materials

3. Analysis and Design

4. Design Detail

5. Miscellaneous Empirical Design Data

A brief summary of each chapter is discussed hereafter.

1. Blast Loading

This chapter presents a thorough theoretical discussion on the subject of blast phenomenology of an explosion in free air.

All salient blast parameters are defined and useful empirical data and scaling laws described.

The interaction of air blast with structures is discussed and a detailed example of a cantilever barricade subjected to an air blast, for example caused by a car bomb, is worked.

The case of confined explosion for example inside a building is also analysed.

The list of references on this subject is comprehensive and a comparison of some results using different sources of reference is presented.

2. Construction Materials

This chapter deals systematically with the dynamic mechanical properties of concrete, reinforcing steel, reinforced concrete, structural steel, soil and rock. Dynamic magnification factors is summarized for each material under blast loading, and the stress-strain behaviour explained.

With regard to foundation material, critical factors like soil penetrability, intact rock density and seismic velocity of soils and rocks is cited from verious literature sources.

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This chapter is very useful in that it summarizes all the relevant information without the reader having to procure the reference literature necessarily.

3. Analysis and Design

This chapter illustrates step-by-step mythology whereby a structure can be analized and designed once the blast loading and materials are known.

Although it primarily intends to summarize useful literature references, citing specific equations and graphical aids, the GUIDELINES goes further and recommends specific and essential items by way of verbatim quotation. It is thus possible for the reader to progress through a preliminary design without the need to revert to the references. For in-depth work and unusual case situation, reversion to the references will however be necessary.

The subject material deals with above-ground and underground box-like structures. Shock effects like acceleration and displacement due to near-miss explosions in surrounding soil is calculated. A design method is illustrated for protective layers against direct hit of missile or ballistics on a bunker. Alternative Swiss and American methods are compared.

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As the structural analysis of such structures is basically a dynamics problem of elasto-plastic response to impulsive loading, much attention is given to approximated procedures of dynamic analysis. Typically, a structure is discretised into beams, slabs and beam-columns for which accurate and simple dynamic solutions are available. The important subjects of Resistance-Function and Ductility-Ratio is surveyed clearly.

Design of tunnels and ducts exposed to internal blast loading is explained. Methods is illustrated whereby the size and configuration can be planned to control blast pressure propagated along escape or ventilation tunnels.

4. RECOMMENDED DESIGN DETAIL

This chapter deals with miscellaneous detailing of concrete and steel reinforcing akin to severe dynamic loading response and plastic deformation. Wall-to-wall, wall-to-floor etc. connection detail is given to optimise design and economy. The problem of pipe and cable penetrations under relative movement during shock is illustrated.

A section deals with planning and layout of typical bunkers, entrances, escape routes, airlocks and protective layer-construction.

5. EMPIRICAL DESIGN DATA

In contrast to the previous chapters, which contain theory-based, rigosistic-mathematical procedures, this chapter contains empirical data which has been compiled through practical field-blast tests by various international bodies.

Information of this kind is scarce and it's reliability often questionable. It is however included in the GUIDELINES for the reason that some information is more helpful than nothing.

Subjects addressed are for example the following:

Penetration times using certain tools on certain structures, for example a terrorist will require approximately 3 minutes using 11kg of explosive to effectively breach a 300mm reinforced concrete wall.

The destructive effect of various ballistic and shape charged weapons on typical barricades is given, while the thickness of concrete walling to resist mines and explosive devices like a car bomb can be graphically determined.

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CONCLUSION

The SA INSTITUTE OF CIVIL ENGINEERS has drafted a general guidelines and design aid on the subject which is intended to expose South African designers to state-of-the-art information and reference material. It is hoped that THE GUIDELINES FOR THE DESIGN OF PROTECTIVE STRUCTURES will serve as a useful aid on this subject of blast resistant structures.

REFERENCE

Committee on Protective Structures Structural Division SAICE, GUIDELINES FOR THE DESIGN OF PROTECTIVE STRUCTURES, Draft 2 June 1991.

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